[Note: Footnotes called out in text are given at the end of the relevant section.]

Best Practices Manual

The National Science Foundation-sponsored Engineering Research Centers (ERCs) are a group of engineering systems-focused, interdisciplinary centers located at universities all across the United States, each in close partnership with industry. Since the ERC Program was founded in 1985, the ERCs collectively have brought significant changes in the culture of academic engineering research and education. This Best Practices Manual was authored independently by staff of the ERCs and is updated by them periodically. It is not an NSF publication and does not necessarily reflect official NSF policy. The document is intended as a "how-to" manual for those involved in, or contemplating involvement in, the operation of an ERC or similar university-industry center. The chapters, presented as separate links below, are organized according to management roles and functional areas in an ERC.

Original Authoring Committee

ERC BEST PRACTICES MANUAL

A Collaborative Product of the NSF Engineering Research Centers

Prepared for

Engineering Research Centers Program
Engineering Education and Centers Division
Directorate for Engineering

National Science Foundation, Arlington, Virginia

NOTE

This Manual was originally authored by staff of the Engineering Research Centers in 1996. Subsequent chapters have been added and/or updated periodically by ERC staff in the intervening years. While the document was funded by the National Science Foundation, it is not an NSF publication and does not necessarily reflect official NSF policy.

AUTHORING COMMITTEE

The first edition of this Manual was authored by staff of the Engineering Research Centers in 1996. The committee was comprised of the leaders of six working groups; each working group in turn was comprised of ERC directors, faculty, and staff and was responsible for one chapter. A consultant served as Project Director and overall Editor of the Manual. The leaders (chairs and co-chairs) of those original working groups are listed here as Authors. The six working groups and their members are listed in Appendix A.

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Acknowledgements

The Engineering Research Centers (ERC) Program owes a great deal to the vision of the members of a distinguished panel of the National Academy of Engineering (NAE) for structuring the guiding goals and objectives for the Program.[1] These guidelines have stood the test of time well and produced a set of 26 highly productive and creative ERCs which have proven to be of significant value to their industrial partners.

As participants in the ERC Program, we are grateful to Erich Bloch, the former Director of the National Science Foundation (NSF), and Nam P. Suh, the former Assistant Director for Engineering, both of whom served in dual roles for the ERC Program--first, as creators of the concept while serving on the NAE Panel, and second, as "mentors" to the ERC Program while they served at NSF. Dr. Carl Hall, the Acting Assistant Director for Engineering at the time of initiation of the Program in 1984-85, led an NSF team in developing the first program announcement. He and Nam Suh laid down a pathway in the Foundation that would permit the interdisciplinary nature of the program to emerge and gave it the freedom to develop new methods and procedures to fulfill its goals. In 1984, Pete Mayfield and Lynn Preston were selected to initiate and manage the Program because of their experience in developing interdisciplinary research programs focused on important emerging technology areas. Mayfield and Preston together developed the defining characteristics of an ERC and spearheaded the development of the Program from

concept to reality. Mr. Mayfield led the ERC Program and the then-Engineering Centers Division[2] until his retirement in 1988; Ms. Preston was his deputy in both roles. Preston developed the NSF management systems as well as the post-award oversight and performance evaluation system for the Program. Upon Mayfield's retirement, she assumed the Program leadership role and Dr. Marshall Lih became Division Director. Under the leadership of Lih and Preston the ERC Program expanded significantly in budget and scope, deepened its partnership with industry, increased its emphasis on education within the centers, and developed strategies to encourage self-sufficiency of mature ERCs. The human resources development aspects of the Program were expanded in scope through the leadership of Dr. John White, Assistant Director for Engineering from 1990 to 1992. Dr. Joseph Bordogna, the present Assistant Director for Engineering, helped the Program develop its strategy for ensuring continued contributions in the next decade through a new generation of ERCs.

To the NSF ERC Program Directors we owe a debt of gratitude for taking on a complex and challenging role--a combination of mediator, arbitrator, and mentor--between NSF, industry, and academe; and for helping to guide and develop new ERCs and steer older ones toward self-sufficiency. The position is an exciting and demanding one, requiring interdisciplinary breadth, knowledge of management and technology transfer, and a commitment to integrating research and education. The ERC Program Directors would undoubtedly wish us also to thank, on their behalf, their colleagues in other divisions of NSF who have supported them in this role. (Appendix B at https://erc-assoc.org/best_practices/appendix-b-erc-program-officers-and-staff-1999 lists ERC Program officers and staff at the time the original Manual was placed online, in 1999.)

We must thank and also congratulate university administrators at more than thirty universities--from presidents to deans of engineering to department chairs--for accepting the risk that the ERCs represent, with their challenge to traditional academic practices, and for supporting the centers in their efforts to change the culture of academic engineering research and education. The Program would not be succeeding without their foresight in sharing its vision.

It should be noted that the challenges of the ERC Program have produced a new cadre of academic leaders at all levels. We have center directors who have grown in their capacity to lead faculty to fulfill a shared vision; a cohort of administrative managers who have developed a new culture of administrative and financial management on campuses across the country; a new group of industrial liaison specialists who serve as a bridge between academe and industry; and a group of highly dedicated education program coordinators who have a special devotion to mentoring and developing young engineers. As the older centers move on to self-sufficiency, a new generation of ERCs is now beginning the process of developing strong centers based on the experience of the first generation.

We extend our wholehearted appreciation to U.S. industry--to the more than 1,000 companies that have welcomed the ERC concept enthusiastically and joined in partnership with the centers. Their representatives to the ERCs have demonstrated great energy and commitment, working with faculty and in many cases with their industrial competitors to advance the technological strength and economic future of the Nation. In a very real sense, they too are pioneers of the ERC Program.

Finally, to our own colleagues--the members of all the ERC teams--we offer our gratitude and our congratulations. Together we have taken on the challenges of this novel program and achieved notable successes in the advancement of knowledge, the development of new technology, the education of a new breed of engineers, and the development of highly productive partnerships with industry. It has not been easy, and we have broken much new ground. This Manual attempts to capture much of the knowledge and experience inherent in that long effort, and again we thank you for participating so enthusiastically in its preparation.

NOTES

[1] NAE. 1984. Guidelines for Engineering Research Centers. NAE Panel on Engineering Research Centers. Washington, DC: National Academy Press.

[2] Now the Engineering Education and Centers Division.

Chapter 1: Introduction

1.1 About this Manual

1.1.1 Purpose and Intended Audience

This document is intended as a "how-to" manual for those involved in, or contemplating involvement in, the operation of a National Science Foundation-sponsored Engineering Research Center (ERC). Its purpose is to distill the existing knowledge and experience base regarding

ERC start-up, operation, and management into a resource tool for use by directors and other managers of prospective, new, and established ERCs.1

The Best Practices Manual is also unusual in having been conceived and written largely by those who do the jobs and have the experience-current ERC managers-employing not only their own experience but also the responses to extensive questionnaires sent to others in those positions across the ERCs. (As such, it should be noted, the manual is a publication of the collective body of ERCs themselves, and not of the National Science Foundation.) It was envisioned as a "living document" that would have immediate utility and direct relevance to users' needs and concerns. The manual is structured in a way that makes it accessible and easy to read, as well as easy to update periodically. It is available for viewing or download on a dedicated website at http://www.erc-assoc.org.

The authors wish to emphasize that this manual is not a "cookbook" or template for structuring and operating an ERC. As a resource tool, it is rich in ideas and experiences; but every ERC is different and exists in a different environment. Each of the existing ERCs reflects that uniqueness, and NSF expects that every prospective and new ERC also will be unique

1.1.2 Organizational Structure

The manual is organized by chapter according to management roles. A decimal numeric heading system has been used, with a separate Table of Contents for each chapter, to facilitate reader access to specific topics.

- Chapter 2 addresses the role of the ERC Director and other executives in providing leadership and strategic direction.
- Chapter 3 addresses the management, both long-term and day-to-day, of the center's research programs.
- Chapter 4 deals with the multifaceted education programs of an ERC.
- Chapter 5 describes the activities involved in industrial collaboration and technology transfer, focusing on the role of the Industrial Liaison Specialist.
- Chapter 6 describes the many vital tasks involved in the day-to-day administrative management of the center, including financial, personnel, and facilities management. The focus here is on the functions of the center Administrative Director.
- Chapter 7 deals with the complex issues associated with managing the NSF/ERC interface, both from the point of view of NSF and from the standpoint of the ERC.
- Chapter 7 deals with the efforts of the ERCs to increase the gender, racial, and thnic diversity of the center leadership, faculty, and students, and to establish a thriving culture of inclusion, in the interest of fairness as well as to gain the greatest possible breadth of input from the widest possible pool of engineering talent.
- Chapter 8 focuses on the Student Leadership Councils (SLC) that each ERC has, in which the students play an active role in the programs and even the strategic planning of the center.

- Chapter 9 addresses the special challenges of operating multi-institutional centers such as ERC, with a variety of academic partners.

The approach taken in each chapter is similar, in that there is, first, an overview of the functional area and its relation to the overall center operations. Key issues and concerns are then identified and addressed across the specific functions within each section. Where appropriate, an effort has been made to differentiate these issues in terms of the different phases in the life cycle of an ERC: start-up (Years 1-3), mid-term (Years 4-7), and maturity (Years 8-10). There is a strong reliance on actual events and case studies of successes and failures to derive "lessons learned" and "tips" for the practitioner. Attachments to some chapters amplify material dealt with in the text of the chapter.

In addition to the organizational similarities, the reader will also notice some differences in structure and style from chapter to chapter. These differences reflect the fact that different groups of ERC personnel wrote the chapters. Although the assembled document was edited throughout, the stylistic and organizational individualities of the chapters were in many cases retained as being reflective of, and pertinent to, the specific content and functions being addressed.

1.2 About the ERC Program

The ERC Program began in 1985 when the Nation was facing a strong emergence of highly competitive foreign firms fueled by government investment. There was a clear need to form partnerships that would strengthen the contribution of academic engineering to industrial competitiveness. The goal then was to address these challenges by developing 25 Engineering Research Centers, each of which (a) focused on a long-term vision important for industrial competitiveness, (b) integrated the traditional disciplines to address systems-level engineering research, and (c) formed university/industry partnerships in research and education.

A companion goal was to use the ERC concept as a catalyst to stimulate a broad-based change in the culture of academic engineering by integrating academic and industrial views, promoting the integration of research and education, involving undergraduates in research, and broadening the diversity of engineering graduates. The mechanism of centers was chosen as the means to accomplish those goals because centers can bring disciplines together. ERCs provide an integrated environment for academe and industry to focus on next-generation advances in complex engineered systems important for the Nation's future. Activity within ERCs lies at the interface between the discovery-driven culture of science and the innovation-driven culture of engineering, creating a synergy between science, engineering, and industrial practice. ERCs provide the intellectual foundation for industry to collaborate with faculty and students on resolving generic, long-range challenges to produce the knowledge base needed for steady advances in technology and their speedy transition to the marketplace.

ERCs also integrate engineering education and research and expose students to industrial views in order to build competence in engineering practice and to produce engineering graduates with the depth and breadth of education needed for success in technological innovation and leadership throughout their careers. The interface between research and education in an ERC is seamless at both the undergraduate and graduate levels, producing curriculum innovations derived from the systems focus of the ERC's strategic goals. ERCs can be a platform from which spring interdisciplinary, systems-oriented graduate degrees and options preparing students for careers in both industry and academe. Thus, graduates associated with ERCs enjoy the capacity to contribute to the Nation's global future through a rich spectrum of career paths at the cutting edge of technical progress and innovation. ERCs also emphasize outreach in research and education that allows faculty, college-level undergraduate and graduate students, and pre-college students and their teachers to be involved in the ERC.

ERCs are established by NSF as a result of peer-reviewed competitions generated by program announcements. They are supported by funds from NSF, industrial partners, the host academic institutions, and in some cases the home states and other governmental funding agencies. While NSF provides significant funds for each center, an ERC must identify and obtain substantial support from the other sources. This novel approach to funding a major research program is illustrated in Figure 1-1.

Figure 1-1: Primary Supporters of an ERC

NSF	INDUSTRY	UNIVERSITY
Catalyst/Integrator	Active Participant	Long-Term Commitment
• Base Funding • Management Guidance • Evaluation • Catalyst for Partnerships	• Advisor on Research, Education, and Testbeds • Funding Support • Collaborative Research Projects	• Research Facilities and Resources • Culture Change • Recognition for Tenure and Promotion

		• Nurturing of Students

In FY 2016, total annual funding provided directly to each ERC by NSF ranged from $2.48 to $11.09 million (for centers in their phase-down period prior to graduation from NSF support) to $3.25 to $8.38 million per year for ongoing centers. Roughly 60 percent of an ERC's annual budget comes from NSF and another 8% from industry; the remainder comes from other Federal agencies (22%), the host university (8%), and state and local and other sources (3%).

Currently (FY20), NSF supports 14 ERCs pursuing specific research foci in four broad areas, as listed below. (As of October 2021, 39 ERCs are self-sustaining after the conclusion of NSF support.)

For further details, see NSF's ERC Program homepage at https://beta.nsf.gov/funding/opportunities/gen-4-engineering-research-centers-erc

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Competition for new ERCs is now held periodically, usually every two years. ERCs receive NSF funding for up to 10 years, dependent upon renewal reviews conducted in the third and sixth years. At the end of their life-cycle as NSF-supported Engineering Research Centers, NSF expects ERCs to become self-sustaining with support from their members, universities, state governments, and other federal government agencies. Teams may emerge from parts of self-sufficient ERCs and enter competition for support as new ERCs. These ERCs recompete on an equal footing with all other applicants.

It is evident that the range of technology areas covered by the ERCs is quite broad. These centers are having a significant impact on U.S. industry through the transfer of knowledge and technology as well as through their graduates. More than 275 U.S. companies were members of one or more ERCs in FY 2018, of which about 46% were small businesses. Other ERC-supporting industrial organizations brought the total up to nearly 600. As of 2018, a total of 851 patents had been awarded to ERCs, 1,363 software licenses had been issued to companies, and 223 companies had been formed as spinoffs of ERC research, employing 1,414 people. Also as of 2018, the cumulative totals for degrees granted to ERC students were: 4,962 PhD, 4,238 MS, and 4,414 BS degrees. In recent years, roughly 1.5 percent of all engineering doctoral degrees granted annually in the United States are awarded to ERC students. Over the past 35 years, the ERC interdisciplinary, industry-oriented systems approach to engineering has spread rapidly throughout industry and academe. The ERCs continue to evolve and to fulfill NSF's expectation that they serve as change agents for academic engineering programs and the engineering community at large.

The participants in the ERC Program who have authored this manual hope that it will serve as a further vehicle for disseminating the ERC approach to engineering research and education, which we believe is highly beneficial and healthy for both academe and industry, throughout the American engineering enterprise.

NOTES

[1] Relevance of the manual to other research center programs (not only within NSF but also those of other federal or state agencies) was a secondary consideration. However, many of the principles presented herein are applicable to any government-sponsored university research center, especially one with industry involvement-not only in the United States but also abroad.

[2]An ERC jointly supported under a Memorandum of Understanding between NSF and the Semiconductor Research Corporation.

[3]The Earthquake Engineering Research Centers (EERCs) were established under a special program in 1997 to further knowledge and technology for earthquake hazard mitigation.

Chapter 2: Center Leadership and Strategic Direction

(rev. March 2014)

2.10 Life After NSF

2.1 Introduction and Approach

2.1.1 Directing an ERC: Basic Principles

Directing an ERC requires considerable technical and managerial leadership talent. First, the Director is responsible for the vision and center-level strategic planning that determines the direction of each center and inspires loyalty to its objectives. Second, he/she is responsible for taking the lead in organizing and structuring the center, which includes selecting the executive and administrative management team; organizing the principle research thrust areas; structuring the center's educational, outreach, and industrial liaison efforts; and deciding on what to delegate and to whom. Delegation and staffing during the life cycle of an ERC is an issue of fundamental importance to the success of the center; and the center's structure will directly influence the center's success in research, education, and industrial participation.

In addition, there is clearly no single absolute and "correct" way to direct an ERC. There are, however, a series of choices that must be made as the process is undertaken, and each choice necessarily leads to a set of consequences. The cumulative experience of the people who have directed ERCs for varying lengths of time in the center's life cycle has shown that every committee that is set up, and every administrative structure that is developed, will affect the center in ways that can be anticipated, at least in general terms. There are certainly many research centers in American universities, but the objectives, key features, and funding pattern of the ERC Program through the cooperative agreement with NSF make these centers unique in several important ways. The directorship of an individual ERC is, therefore, a unique responsibility in the academic framework of the universities within which these centers are placed.

All the ERCs owe a debt of gratitude to the pioneering Directors of the early "classes" of ERCs, who paved the way for the Directors of the later classes to refine the ERC concept. Building on the experience of these first-generation ERC Directors, a second generation of Directors expanded upon the ERC concept to position their centers for success in the 21st century. The third generation of ERCs (Gen-3), beginning with proposals in 2008, have additional responsibilities to address decreased student interest in science and engineering and an increasingly global economy. Thus, in addition to the goals of preceding ERCs, Gen-3 ERCs were commissioned to educate students to be more creative, adaptable, and entrepreneurial, as well as to understand the value of teamwork and their place in a globally competitive workforce. Gen-3 ERCs are also expected to reduce the time from discovery to innovation through adoption of an "innovation ecosystem." Additionally, Gen-3 ERCs have expanded educational and outreach missions to show impact over the life of the ERC on place-based activities at targeted K-12 schools that serve underrepresented and economically disadvantaged youth, to encourage interest and careers in the STEM fields.

Just as there is no absolute and “correct” way to direct an ERC, there is no “model” of the ideal ERC Director. There are, however, a range of characteristics that are likely success factors and any given individual will be stronger in some of these than in others. In addition, the "ideal" profile will vary across different fields, universities, and industry bases.
The Director normally would be a tenured professor with a PhD degree in a relevant field of engineering or science and some management experience. He/she would have achieved widespread recognition in his or her field for scholarly and intellectual attainments. If a Director comes to the university from industry to lead the ERC, it could be problematical if he/she expects to use a more "directive" style of management at the university than the academic culture normally accepts.

In terms of leadership ability, five very important traits can be identified: 1) the ability to articulate a vision for the ERC that is shared with industry and the faculty and that is flexible enough to evolve over time with the developments of the ERC and the field; 2) a clear perception of the current status of the field and a vision of future advancements and a strategy to achieve them; 3) the ability to think at the systems level and integrate research from different fields to achieve a systems-level goal; 4) the ability to recognize intellectual needs and identify needed talents, both internal and external to the university faculty, and to form and sustain a cross-disciplinary team over time; and 5) the ability to lead without coercion. A Director will probably be someone who prefers to deal with the big picture, rather than with details, and who knows how to hire and delegate the detailed tasks. It is also quite useful if the individual is a skilled “salesman” in representing the center's needs and capabilities to potential sponsors in industry and government, as well as within the university. Again, the ability to articulate the vision of the ERC and energize people to share in the vision for the ERC and its development is critical.

To that end, interpersonal skills that involve team building are valuable. Management in an academic environment is often a delicate operation, so it is strongly advisable that the Director be diplomatic, tactful, and empathetic as well as perceptive, alert, and determined. Given the enormous demands of the job and the personal self-sacrifices it entails, the ability to make a total commitment to the center is vital.

The prospective Director must have gathered together a group of colleagues and junior faculty in relevant fields who are willing to form the core of the ERC faculty team. It is also very important to have an industrial support base (or at least strong contacts) established through consulting, participation in a previous center, industry employment, etc. It is useful if the individual has good relations with the university and departmental administrators, although these relationships can be built after the center is established. Also valuable are other federal, state, and private support bases (e.g., foundations) beyond NSF.

The Director should understand the opportunity the ERC provides to change the educational/research culture of the engineering efforts of the university and the potential to impact the university beyond engineering. H/she should be interested in integrating the results of the ERC’s systems perspective into the curriculum in new and innovative ways.
Finally, in terms of attitudes and personal orientation, an ERC Director should be a team-oriented coalition-builder who welcomes change, since technological and "cultural" change are what the ERCs are all about. The person's attitude toward the encouragement of women and

underrepresented minorities to pursue engineering education and research must be genuinely positive. He/she should be oriented toward focused basic research that integrates science and engineering with long-term benefits for industry, because this is the fundamental rationale for the ERC Program. Finally, the Director should be oriented always toward achieving a center in which the integrated whole is greater than the sum of its individual parts.

In directing an ERC, a statement made by Professor Greg Carman, Director of the Center for Translational Applications of Multiferroic Systems (TANMS), based at UCLA, might be helpful advice to remember: *"I have always believed that life is more about the individual than the organization. If an organization is good, everyone contributes to the organization but no one is indispensable. Also the world does not fall apart if a member of the organization leaves; it is simply a natural occurrence that should represent an opportunity to make the organization stronger. In my world, the key is to make sure people enjoy what they are doing and to give them opportunities for growth. Furthermore, make sure that your employees have all the opportunities available to them and if there is a better position for them outside the organization, support them in getting this position—i.e., do not try to impede individual growth for the sake of the organization. I think this philosophy comes from managing students where they are not permanent employees but just staying long enough to learn a skill set and grow into more productive researchers outside. That is, if you want the best people you have to be prepared that* *some jobs in your organization are simply stepping-stones to where the individual will eventually be in their career."*

Because the success of an ERC must be measured in terms of the extent to which it has fulfilled the mandate set for these centers by NSF at their inception, it is useful to review their stated purposes. The primary goal of ERCs is to conduct innovative, cutting edge research to enhance the global competitiveness of American industry. Very direct and effective integration with industry is implicit in the charter of the ERCs; and the centers are to have a systems focus and to emphasize cross-disciplinary research and education. Consequently, an important change is envisioned in the education of young engineers—ERCs are to act as catalysts for the transformation of fundamental academic research in engineering into innovative technologies that industry can bring to commercial realization. That is, they will be centers that establish world leadership in emerging and important areas of research, in industrial relevance, and in cross-disciplinary education.

This chapter was prepared by a team of current and former ERC Directors (see Appendix A to this chapter). It is hoped that the suggestions made herein, although by no means absolute prescriptions, will provide new or prospective Center Directors with a greater sense of confidence in their decisions.

2.1.2 Chapter Organization and Objective

In an attempt to avoid duplication with other chapters of the ERC Best Practices Manual, this Center Leadership and Strategic Direction chapter will address the conception of an ERC, the daunting task of building and directing an ERC, and the set of decisions and actions that a new Director and Deputy Director must take, roughly in the sequence that they must make them. In doing so, it touches on subjects that are covered in much more detail in other chapters, such as Research Management (Chapter 3), Education Programs (Chapter 4); Industrial Collaboration and Innovation (Chapter 5), and Administrative Management (Chapter 6),

Early in the life of an ERC the Director must establish the ERCs vision and strategic direction, decide to what extent s/he will delegate responsibility for specific aspects of the center's operations, and must then hire or assign employees or faculty members to fulfill these functions. The initial management team and management structure is, by necessity, defined in the proposal and refined in the full proposal. Because not even the most heavily endowed universities can have all the high-caliber faculty in the right areas that are necessary to execute the strategic plan of a good ERC, faculty recruitment is the most potent weapon that the Director has in hand to shape the center. One of the Director's main contributions to the center will, therefore, often be in the area of faculty recruitment and replacement, both externally and on campus. This contribution will extend throughout the life of the center and will depend heavily on the relationships that s/he has built with contributing departments and with the university administration.

2.2 Vision and Center-Level Strategic Planning

2.2.1 Creating the Vision

How are the themes and vision for a prospective new ERC developed? It begins with a challenging and timely problem of great societal importance for which no single institution or discipline can overcome the technical, social, and economic barriers to achieve workable solutions. Every investigation or research agenda is based on a "genealogy," or cumulative body of knowledge or thought, upon which the researchers base their current understanding of a field and from which they draw a vision of how the current state of knowledge might be advanced.

Based on the historical developments in the field, each center creates a vision of what can be accomplished within 5- and 10-year horizons. Such a research vision should be based on realistic resources and the need for bringing various aspects of a particular field together to create the needed critical mass of interdisciplinary effort. The vision must be unique, or it will not strike a responsive chord in the NSF site review team that makes the initial recommendation for approval. The uniqueness of the vision will have educational ramifications both for the ERC and for achieving breakthroughs of sufficient intellectual weight to alter basic concepts in the field in which it originated, which will lead to educating a new type of graduate. However, the vision must also be industrially related and of sufficient practical importance to favorably affect the competitiveness of this country, if it is to gain the imprimatur of the ERC Program.

Since the main mission of the ERC Program is to make a positive impact on the U.S.' competitiveness in the global marketplace, it is important to understand and articulate the potential commercial impact of an ERC, if it is to be successful in achieving its goals. One way to make a case for the significance of the impact is to start with an extensive market analysis showing the size (current or potential) of the industry affected. If successful, will it impact systems integration and new ways of doing business? Will it help address the social dimensions of change? Will it create a major new industry? Is there an existing major industry in which the ERC expects to stimulate technical advancement and growth? Will the role of this ERC be central in the future of that industry? These are all elements of the center's vision.

Here the research thrust area[1]* leaders, center associate directors, and key industrial representatives usually have input into the development of the vision and achieve consensus regarding it. Although the broadest possible "buy-in" to the vision is considered essential, it is difficult to involve more than this group of key individuals in these discussions. In many cases an incoming Director will have formed very strong working relations with a few key individuals. These persons believe passionately in the vision on which the center is based, and in the objectives of the ERC Program. This group must forsake the security of the successful, well-funded Principal Investigator (PI) format of traditional research grants.

A consensus vision statement is now prepared that is shared with center faculty, students, the university hierarchy, and industrial representatives. Each vision statement should identify the overall goals of the center, not only in research but also in education and industrial interaction. Among the most challenging tasks is to build a sense of “community” among ERC researchers, who are spread among different campuses and different universities.

As the originator and/or custodian of the vision of the ERC, the Director must be prepared to articulate this vision, in verbal and written form, to a wide variety of audiences ranging in sophistication from local agencies to an NSF site review team. The Director is responsible for "tracking" the vision of the ERC and working with the Deputy Director in its evolution and execution to guarantee that the center is always at the cutting edge in research and at the forefront in the articulation of the perceptions that form the vision. The Director ultimately will be held responsible if the ERC is ever eclipsed or surpassed in any major component of the vision on which it is based. Consequently, a Director must maintain continuously a clear perception of the linkages between the vision of the center and its research, education, and industrial activities and progress within them.

Since it is essential that all participants in an ERC buy in to the vision once it is articulated, it is useful to examine the sub-elements of the vision in the form of the strategic plan and thrust area research plans at regular intervals so that the faculty, students, and industrial members of an ERC community have the opportunity to become engaged with the vision and subscribe to it. In ERCs that are narrowly based on specific, fast-changing technologies, it may actually be imperative that the basic vision of the center be examined periodically, in cooperation with industry, and altered to suit the advancing state-of-the-art. However, most ERCs are based on much broader visions, and here the role of the Director is pivotal. Strategic plans are just that—strategies. The thrust areas of the ERC can assume a life of their own and begin to consume their leaders' scientific and engineering passions, but thrust areas are only more valuable than the sum of the efforts of individual PIs if they contribute to achieving the center's vision. It is the task of each Director to ensure that the vision is clearly seen and well served by the center through integrated research and education. In fact, it is a requirement of the ERC Program that the integrated whole of the center be greater than the sum of its individual parts.

2.2.2 Pursuing the Vision: The Strategic Plan

The ERC now must develop a broad strategy for achieving its vision. How can a cross-disciplinary center take advantage of the opportunity envisioned? This is its mission. Is it realistic? Does the ERC have the necessary intellectual horsepower to achieve success in this area?

One way to answer these questions is to form a "blue ribbon" panel of objective outside experts to evaluate the plans and personnel of a proposed ERC. If the answers are encouraging, then the next step is to develop a strategic research plan to achieve the vision and mission. In this chapter we will focus on the overall strategic plan for a new center. Chapter 3, "Research Management," describes the process for development and updating of the strategic research plan.

In contrast to the process of originating the center's vision, the process of strategic planning is more democratic. In some centers the initial planning is done by an executive committee consisting of the Directorate (including associate directors, if any), thrust leaders and/or senior faculty, and key staff such as the education and outreach directors. A smaller group allows faster convergence on the initial plan. But in most centers the process involves, either at the outset or subsequently, discussion and input from all faculty members and research staff. (At one center the plan is posted electronically for criticism by all center participants; commentary is circulated via e-mail until all issues are resolved.) Usually the plan is reviewed and discussed at least annually by the Industrial Advisory Board (or equivalent). It can be tricky to avoid the natural tendency of industry to direct the details of the plan toward areas of short-term interest; the Director must be vigilant to filter out such influences and absorb them in the higher aims of the plan.

However, as with all proposals, once the center looks like it will be funded the faculty will ask "what's my role and funding?" This is especially challenging for ERCs, because typically a small, dedicated core of faculty may have actually written much of the proposal and the research thrusts and themes are usually written around teams, not individuals. Thus, the individual roles of faculty and students may not be well defined. For this reason, a center-wide retreat very early in the life of ERC is important—perhaps even prior to the actual funding start date—to develop a coherent vision and remind all participants about the various components of a viable ERC.

The first kick-off meeting would be the starting point for the review of the strategic plan for the ERC. Later on, it will also provide a benchmark for assessing the progress of the center and the value added to the field by its activities. No strategic plan is static, and prior to each annual report the plan should re-visited and refined. Often some topics that seemed important at the proposal stage will seem less critical as new ones emerge and the ERC team begins to pursue its research and outreach agenda. It is unwise to conduct a wholesale revision of the strategic plan. Rather, it's more like mid-course adaptations to experiences and "boots on the ground" realities, and responding to initiatives that may evolve from close collaboration with IAB members.

The Director, with key leaders of the ERC, may engage in "thought pieces" in influential feature articles or editorials about the domain in which they work. This will help articulate where the field is going and, by implication, how the strategic activities of the ERC map onto this comprehensive view.

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[1]A cluster of research projects managed as an integrated group to achieve one component of the center's overall strategic plan.

2.3 Structuring the Center for Success

Delegation and staffing during the life cycle of an ERC is an issue of fundamental importance. The related questions of how much to delegate, what management and operations functions to delegate, and how best to accomplish this distribution of responsibilities should be addressed in the planning stages of the ERC and on into the initial stages of funding and implementation of the ERC proposal. The center's structure will directly influence the center success on research, education, and industrial participation.

2.3.1 Deciding How Much to Delegate

When an ERC is funded by NSF it is probable that there will have been a personal prime-moving force who has initiated the application and gathered the research team. It is equally probable that the initiator will have a large and well-funded research group, or it is unlikely that the application would have been successful. But it is apparent that the duties of the Director of an ERC are sufficiently challenging that they are very difficult to combine with those of a successful and busy PI or research group leader unless the person concerned is adept at delegation. For this reason the first, and one of the most important, choices that a founding Director will make will be the extent to which s/he delegates responsibilities within the center as it begins its progress towards its first date with destiny at mid-Year3. If the Director delegates too little, s/he risks eventual "burn-out" and the loss of his/her own research program and even the center itself. If s/he delegates too much, s/he is likely to lose control of the center and jeopardize its ultimate success. The founding Director should assess the importance of all the potential roles within the center and decide which to delegate and which to retain. Three major factors that influence the Director's choice are: 1) the peculiar strengths of his/her center team, 2) the overall interests of the center and, finally, 3) the meshing of his/her own research interests with the welfare of the center. In any case, the Director's research must fit integrally within the scope of the center's research or it may be seen as a conflict of interest and a threat to the cohesiveness of the center. Such conflicts are viewed as serious by NSF, and must be resolved quickly.

If the Director chooses to retain control of administrative and routine personnel matters, s/he will drown in details as the center grows to encompass about 100 people. If the Director retains direct, personal control of financial matters, s/he can use this control to steer the center in detail, but s/he will be held responsible for every fiduciary ripple and s/he will encounter resentment when support is withheld or withdrawn. Experience teaches that, given the efficiency of sole autocratic command, a researcher can control and steer a research group of about 40 with some help from experienced staff and postdoctoral fellows. Therefore it is critical that the Director rely on and distribute responsibilities amongst her/his leadership team, beginning with the Deputy Director and Administrative Director. One approach is to have all of the administrative staff report through another designated individual (Deputy Director, Executive Director, or Administrative Director).

Sometimes just as important as the degree to which the Director delegates responsibility within the center are the mechanism(s) of delegation. This delegation should be done very carefully because its consequences for the smooth operation of the center are likely to be quite significant. Everyone involved in an ERC must realize that the whole exercise is driven by the center's vision and strategic plan. The administrative function is only an "engine" (albeit an essential one) to facilitate the realization of the vision and, as such, it will always be secondary to the program activities of the center.

There is general agreement among ERC Directors that the following responsibilities should <u>not</u> be delegated.

- Major resource allocation and budget decisions, including fiscal oversight
- Major realignment of center administrative and research structure
- Final decision on hiring (and termination of) faculty and key staff
- Final selection of companies to recruit as members
- Formal contacts with NSF to address major issues

- Policy interactions with department heads, college deans, and university top administrators
- Negotiations with lead university administrators for commitments of resources
- Integration of the ERC's annual report to NSF
- Responsibility for the integrity of the ERC's reporting systems.

2.3.2 Staffing the Center

2.3.2.1 The Executive Team

An important early decision must be the type of supervision and reporting to utilize for management of the center. There is clearly a limit, which is dependent on the personality and policies of the Center Director, to the number of center employees who can take detailed direction from this one source. The ERC Director can be aided in the complex center leadership role by selecting a Deputy Director who is capable of sharing the leadership and management responsibilities in the ERC. Some centers also have the Deputy Director share in overseeing many of the operational aspects of the center, such as directing specific research areas, accessing new facilities, allocating resources, negotiating with university administrative personnel, spearheading industrial interaction and technology transfer, and supervising administrative activities. It is also common for the Deputy Director to assist the Director in organizing and preparing the center’s NSF annual report and site visit.

In most centers, the Director and Deputy Director(s) are assisted by an Administrative Director who is in charge of many of the day-to-date operation tasks (Section 2.3.2.3 and Chapter 6), an Industrial Liaison Officer responsible for the implementation of the industrial program (Section 2.3.2.5 and Chapter 5), and an Education Coordinator or Education Director who leads in the implementation of the education and outreach efforts (Section 2.3.2.4 and Chapter 4). In addition, some centers have Associate Directors who oversee specific areas of research (Section 2.3.2.2 and Chapter 3).

2.3.2.2 Research Management

Chapter 3 deals specifically and in detail with research management in an ERC. However, management of this activity is central to the overall management and direction of an ERC and impinges on the success of every other area of center activity. The discussion here addresses research management in this broad context.

An ERC is an excellent power base because it represents a large amount of research money, and it will attract those who are interested in wielding financial power. The Director of an ERC must make a choice as to whether s/he will become the sole power broker, the leader of a small and select coterie of power brokers, or the arbiter of power who balances the process for the good of the center. A lesson learned from the management of research centers is that even the most promising center, founded on the most talented team of researchers, needs a constant flux of new people and new ideas to keep its edge. All centers try to stay ahead of the curve by recruiting excellent graduate students and postdocs, but very few give newly recruited faculty members senior positions with real access to center resources (especially if they are from outside the university). For this reason, the Director of an ERC may resolve to build an effective faculty intake mechanism into the center, select the new team members with great care, and choose research management structures that allow the newcomers to share power and resources on an equal footing with all other participants. The intent here is to ensure that the ERC survives beyond the 10-year time horizon by accommodating growth and preventing stagnation.

Rather than making all research management decisions personally, an ERC Director may find it more useful to maintain the vitality of the center by making sure that all ideas that serve the vision have an equal chance of implementation. It is certainly not the intent of the ERC Program to provide 10 years of high-level funding to a Director and an unchanging group of researchers, however capable and even brilliant they may be. Thus, a new Director must decide whether s/he will retain complete personal control over research management, set up a closed system of research management involving a select group of insiders, or augment the closed system with strategic planning and revitalization mechanisms that involve the whole center. Perhaps there is no choice to be made by a new Director, in the initial stages of the organization of an ERC, that will affect the center more than this pivotal decision. It is, however, advisable that the important decisions on strategic planning and research goals are made with the support and agreement of the Deputy Director and the key research faculty.

Research in an ERC is inspired and directed by the center's vision, as articulated by the Director and Deputy Director and supported by its members. The practical vehicle for the realization of this vision is the strategic plan, and the mechanism for its execution is the structure of thrust areas and testbeds found in all ERCs. As was described in Section 2.2, the Directors of most ERCs maintain firm control of the center-level strategic planning process; most decisions in research management are made by these Directors with the advice of a small inner circle of senior center researchers who comprise an executive committee. In some cases, periodic retreats or cyber sessions for the input of ideas have been employed as a means of involving more center members, and these have been proven effective in facilitating the development of a "center" perspective. But generally the responsibility for the planning and management of research remains centralized.

The complex research tasks and the associated reporting requirements of the ERC Program review process virtually demand that each center must appoint a leader for each research thrust area and that someone, usually the Director—often with the aid of the Deputy Director—must combine these reports with those of the education and technology transfer programs to produce the annual report. These thrust area leaders also provide a necessary management interface between the Director and the rest of the center's executive team and the faculty researchers, with responsibility for the detailed planning of research within each thrust. It is important to begin with the right number of research thrust areas. The "right" number may differ from center to center and field to field, and may also change across time. However, in general the fewer the research thrust areas, the easier it is to manage the research program.

Several centers cite difficulties in terminating existing projects. Most report that they depend ultimately on the Director to make these hard decisions, but such ERCs have closed research management structures that may require that the research committee vote against one of its own members. A number of centers often receive input from the Industry Advisory Board (IAB) on the relevance/quality of projects heavily into account in deciding whether to continue them. Site visit recommendations are another source of input**.** It is easier to terminate unsuccessful lines of research if there is a detailed strategic plan with milestones; this makes it apparent when a project is going nowhere and/or no longer fits within the strategic plan. Open channels of communication, with emphasis on the ERC research as a team effort, help to soften the blow. Nonetheless, it is important at the outset of an ERC for the leadership team to articulate both the requirements for retaining financial support during the life of the ERC as well as the process to terminate, such that all involved perceive the process as fair. Many ERCs also provide support to the graduate student(s) involved for at least one semester after termination and try to accommodate them within other ongoing projects.

2.3.2.3 Administrative Management

Because an ERC with NSF funding and average industrial, state, and university support constitutes a roughly $10 million/year enterprise, a centralized and proficient administrative structure is mandatory for effective organizational and financial responsibility. Therefore, an important leadership role in the center is the Administrative Manager or Director (AD), who is responsible for general management of the day-to-day operations. The selection of a capable AD is one of the most important administrative decisions a center must make. This position is discussed in more detail in Chapter 6.

The Director and the AD typically work very closely together; the smaller the administrative staff, the more this tends to be the case. The position of AD requires a strong generalist, and selection of the right person is critical. These individuals play a key role in the overall success of the centers. It is essential that the AD understands fully the vision of the center, its ideals, and its intended impact, and that s/he be treated as an equal partner in bringing them to fruition. The AD accepts the responsibility of implementing the center's vision in a manner acceptable to the university's and NSF’s bureaucracy. Therefore, mutual respect must be present between the Director and AD, with the Director articulating the concepts and ensuring buy-in and the AD providing a reality check on what is possible and identifying ways to implement the concepts. (Again, see Chapter 6 for a full discussion of this function.)

It must be noted, however, that the Director is ultimately responsible for any administrative lapses that may occur; consequently, it is important to maintain supervisory oversight and control of office management functions. One potential problem is that major budgetary/accounting problems may arise in a center from a variety of causes. Therefore, it is advisable for the AD to have significant expertise in budget management/monitoring and databases. If this is not the case, an additional person with this critical expertise must be added to the team and must also work close with the Center Director, at the expense of adding administrative costs.

The decision to hire specialists for other functions will affect the center in various ways. If an assertive accountant is hired, the finances of the center will be well managed; but at an extreme, account management may not be as flexible as the Director needs. If the industrial interface is handled by administrative staff on a part-time basis, the Director will be the *de facto* salesman for the center. If, on the other hand (as in most centers), an aggressive Industrial Liaison Officer is hired, the industrial interface will burgeon and there will likely be a strong technical connection with industry through the PIs. If the details and the policy of interdisciplinary education in the center are managed by a part-time faculty member as Education Director, students will tend to be trained in their home departments and assembled in the center for occasional seminars and NSF site visits. But if experienced specialists are brought in to be responsible for University Education and Precollege Education (as currently required), these vital areas of the center's activities will be competently planned and carried out, engaging students at all levels integrally within the center, Therefore, care needs to be taken when hiring specialists to ensure that they are capable of and willing to work in a collaborative open environment and can avoid "turf" wars.

The administrative infrastructures of centers thus range from a few people gathered tightly around the Director to small armies of specialists working for the benefit of the center, and each choice that is made will affect the kind of center that will emerge at the critical third- and sixth-year review milestones. The choices made in setting up the infrastructure of the center are matters of policy, and not of financial expediency, because at least two of the key responsibilities (technology transfer and education) may become largely self-funding. The administrative structure of the center must be set up thoughtfully by the Director, who must ensure that all major policy matters remain firmly under the control of center leadership and are complementary to the primary objectives of the center.

2.3.2.4 Education and Outreach Program

One of the three pillars of the ERC Program, education is an element with which most centers feel that they have had great success. This success may reflect the national need for education of interdisciplinary team-oriented PhDs more than it does the effective policies and programs implemented by individual ERC Directors, but in any case it is a very fertile area that may come to dominate the future of individual ERCs and figure even larger in the priorities of ERC Program itself. In the past decade, the National Academies of Science and Engineering and NSF joined with other professional groups to rethink engineering education at all levels.[1]

Education at all levels is a lot like gardening, in that it is labor intensive and requires great patience and commitment. Hence, it is an area of responsibility which an ERC Director must delegate to one or more full-time professional Education Directors. This responsibility is shared in a wide variety of ways across different centers. There is often one Director responsible for University Education and one for Precollege Outreach; in other cases there is an overall Education Director (often a faculty member) assisted by one or more Education Coordinators. In an area such as education, in which the ERC can facilitate but not dictate, the Center Director must work with the Education Director in setting up the college program structures. The Education Outreach Director is usually responsible for leading programs that include outreach to undergraduates from other universities and community colleges, as well as outreach to secondary school teachers and K–12 students. At the precollege level, many center faculty and students become involved in local science fairs, both as mentors or judges, and in community events such as science museums.

An experienced Education Director should know the center's students well enough to flag cases in which the student is confused and/or troubled by conflicting demands of the center and of his/her home department, or by any of the myriad problems that beset the engineering acolyte today. Because a mature ERC may involve 40-60 undergraduate and 60-80 graduate students, the Education Director cannot involve himself in either their individual or collective supervision. For this reason it is advisable to appoint an education committee of faculty, whose chairperson works closely with the Education Director to liaise with the students. In this way each student knows that the center provides a professional and a faculty member that they can contact with any problems.

All contemporary ERCs develop mechanisms for evaluating and assessing their education programs. Several have professional staff dedicated to this effort, which is a specialized discipline in itself. For more details, see Chapter 4, Education Programs.

The ERC Program strongly emphasizes education and is proud of the accomplishments of the ERCs in education at all levels. Although sustaining education programs after graduation can be a challenge, as the ERC moves to self-sufficiency after 10 years individual ERCs may find a very successful interdisciplinary education program that is relevant to industry to be an asset in their continuity.

2.3.2.5 Industrial Liaison/Technology Transfer

Industrial associates in a number of ERCs contribute to the finances of an ERC in a myriad of ways. Membership in an ERC at various levels requires a fee ranging from $1,000 to over $100,000 per year. NSF values these industry contributions and often uses the amount of cash fees collected from industry by a center as a "thermometer" of the health of its industrial program. NSF also requires a significant portion of these industry fees to be unrestricted funds (as opposed to directed funds for a particular thrust or project). However, these funds are still considered program income and thus cannot be treated as "gift funds." Funds raised with these fees can be lumped into a common ERC pot, or some ERCs elect to keep industrial member fees separate from thrust area-related research. In addition, in most ERCs industry can directly support a specific research endeavor; but this activity will operate independently of the thrust area work and is dependent only on its own budget. In some cases, research activities with industry require utilizing ERC resources to leverage industrial participation.

When considering the center's funding profile, it is important to maintain balance. For example, if most of the center's funding is from NSF, then the relevance to industry is somewhat suspect. Within industry, it is best to develop a diversified portfolio of partners ranging, if possible, horizontally across various industries and vertically from raw materials producers to parts suppliers to system manufacturers. If all the outside funding is from one industry, then there is a certain vulnerability if that particular industry goes through a bad patch. A balance between state and various federal government agency and industry funding is desirable because no one sponsor or sector then has an undue influence over the activities of the ERC. Maybe more important than all of these is to ensure the industrial advisory board has a balanced representation between small businesses and large corporations. Small companies may represent an important source of revenue beyond the 10-year NSF time horizon.

Center Director support and buy-in to the industry program is essential to its success, especially in the case of Gen-3 ERCs, which have additional requirements to stimulate startups, entrepreneurial activity, and other "innovation ecosystem" drivers. In the past, there has been a wide range of performance across the ERCs in this program element, which was so pivotal in the original funding of this program by Congress and by NSF. But as ERCs, and their industry programs in particular, have matured, those industry programs and their best practices have come to be very effective in enabling technology transfer and providing critical feedback and guidance to the ERC program. It is, therefore, extremely important that the Center Director, working with the center's Industrial Liaison Officer or Innovation Director, takes advantage of the center's relationships with its Industrial Advisory Board and the many communication mechanisms available through those relationships. The industrial collaborations are one of the key features that will enable the ERC to live beyond its 10-year financial time horizon of NSF funding.

The Director also must motivate the center's PIs to participate in the process of selling the center's technology. Because the Director must be personally committed to the process of technology transfer, s/he should take a very active role in company recruitment (also vital to center funding), in interacting with the IAB members, and in developing opportunities for joint research with sponsoring companies. S/He will also hire an Industrial Liaison Officer or Director of Innovation from outside of the academic framework and will give this employee the freedom to build strong relationships on an ongoing basis with companies interested in the center's technology. It is important in all of these instances that the ERC director also facilitates interactions between the ILO and Intellectual Property offices and Contracts & Grants offices at each institution. The development of a working Industrial agreement as well as the transfer of IP is based on the interactions that occur among these three groups—i.e., the ILO, IP offices, and industries—and represents a critical path to future successes.

2.3.3 Developing and Maintaining a Diverse Team and a Climate of Success for All

Developing a diverse team of researchers and staff represents a formidable challenge for an ERC, given the demographic distribution that currently exists in academic engineering. It is an important topic because some of the metrics that the ERC reports on an annual basis are directly related to the diversity of the culture within the ERC. In the diversity area, it is important that a Director form an initial research team that is competent and represents a distribution of team members with different demographics and backgrounds. This distribution is important to infuse new/different ideas and thoughts into the research and developmental areas, rather than relying on a monolithic culture with a myopic research focus. Diversity within the ranks of the primary investigators also sets the tone for future students recruited into the center, helping to ensure that "success for all" is ingrained in the ERC culture. While this may be the first important diversity decision a director may make, the second is wisely choosing the Education Director(s) and, in many cases, a Diversity Program Director. In some centers the Education Directors, both University and Precollege, have improving diversity as an integral part of their education program responsibilities. Where both Education and Diversity positions exist, they collaborate in developing and pursuing the center's diversity goals.

Candidates for both these positions need to be chosen with several important attributes in mind. These include: understanding the challenges facing engineering students and faculty from diverse backgrounds; being willing to make bold changes to promote a heterogeneous environment; and having established relationships needed to "grow" a diverse program within the ERC. The Diversity Director (or Education Director responsible for diversity programs) will first be faced with issues of working with Principal Investigators (PIs) to increase diversity within the graduate and postdoctoral sectors. This is challenging because most PIs typically use a narrowly focused process for selecting graduate students and postdocs. The Diversity Director may find more willingness on the part of the PIs to begin increasing the diversity of the undergraduate student population within the ERC, since these students feed the pipeline for the graduate and postdoctoral programs.

Some ERCs have developed the view that overcompensating at the undergraduate level will help recruit more diverse students into the graduate curriculum of the ERC. This may be especially true for programs focused at the K-12 levels, with the drawback of a significantly long time horizon to have an impact on the ERC's diversity. Nonetheless, the K-12 student population may represent the most important impact an ERC can have on diversity. It is here where engineering has fallen short—i.e., not doing an adequate job of attracting a diverse population to engineering studies and careers. One ERC uses the concept that educating K-12 students about entrepreneurial concepts might encourage more diverse students to enter engineering studies. Here, it may be important to educate the K-12 students on the life-long career benefits an engineering degree offers. One fact that has been useful is that the number one degree of CEOs in S&P 500 companies is typically engineering, not business. Therefore, if you want to be a CEO, a pathway to that goal is through engineering. Second, engineering represents a truly enjoyable experience that has lifelong rewards, and YES, it is fun to be an engineer. For the latter, it is important for the Center Director working with the Diversity Director to develop a climate that is inclusive and enjoyable for all. To that end, it is not sufficient simply to conduct research but it is also necessary to develop a climate that supports an "engineering family" type of environment.

2.3.4 Managing Research at the Interface of Disciplines

One of the distinguishing features of the ERC Program, an area in which it was a pioneer in contemporary academe, is its emphasis on cross-disciplinary research. In most cases the complex systems nature of the research naturally requires the ERC to be highly multi-disciplinary. Individual ERCs have devised many ways to facilitate cross-disciplinary interactions among the faculty. In a number of centers an absolutist approach is taken: i.e., projects without cross-disciplinary interactions will not be funded through the center's resources, or else the evaluation criteria for project continuation will include cross-disciplinary collaboration. In other centers the requirement is not so absolute for all projects, although there is a strong preference for cross-disciplinarity, and a strong message is given that collaboration is necessary if the ERC is to be successful.

Other mechanisms that are employed to encourage and facilitate these interactions include:

- specific requests for collaborative research to meet an identified need;
- special center funds made available for cross-disciplinary projects and proposals;
- inviting researchers from a range of fields to center research meetings and retreats;
- structuring center research so that project teams cannot complete their assigned projects without obtaining assistance from other teams;
- developing a set of "end-to-end" demonstrations, within and between research clusters, that illustrate how the tools and methodologies work together; and
- engaging in design activities with center industrial affiliates (which commonly involve participants from more than one project or research thrust).

2.3.5 Acquiring Facilities

Operating a well-run ERC involves bringing together the necessary resources, including not only personnel but also facilities and funding. Facilities required to carry out the ERC's research mission include so-called "signature space" for housing the center administrative offices, conference room(s), and general space for center-supported activities such as a computer laboratory, student library, and lounge where faculty, students, and staff can gather to discuss their work. Distributed laboratory space is necessary for developing basic materials, device, and system-level competencies. Usually the Dean of the College of Engineering and the Chairs of the individual departments make the signature space available to the center. Individual laboratory space is usually made available to faculty on a have-need basis. Some centers have succeeded in obtaining new buildings or significant expansions to existing buildings. Space is perhaps best negotiated at the time the final proposal is submitted to the NSF.

2.3.6 Some General Guidelines for Center Management

The three pillars of the ERC Program are research, education, and technology transfer. However, it is clear that the first (research) is a *sine qua non*, in that the educational and/or technological advantages are derived from the research program. Also, all ERC Directors quickly come to understand that NSF site visit teams have been instructed by NSF to view research as the first preference "gate" when assessing the extent to which an individual ERC has succeeded in its mission. Thus, research project choices represent a key component of a successful ERC.

Investing center resources in specific research projects must be guided by the strategic plan in which the center is united. When that critical time of each year rolls around in which decisions have to be made about how resources should be allocated to the various thrust areas, the Director will find himself or herself in a situation that will be dictated by choices s/he has made at the outset. Either there will be a clearly stated strategic plan that makes the finance committee's job possible, or there will be a struggle for funds and the Director will have to make all of the final decisions. If there is a clearly stated strategic plan, the Director should be vigilant to discern the real authorship of key inputs to that plan. The strategic plan of a center can be manipulated by a small group of faculty with preconceived notions of what direction they want the center's research to take or, at an extreme, by a single strong personality, often the Director, who simply tells the troops that this is what s/he has decided. The smaller the coterie of influential insiders, the more NSF money there is for each individual in that group. But NSF Program Directors and site visitors can detect such a situation fairly easily and will not tolerate it. ERCs have failed to win renewal because their research program lost its cohesiveness and collapsed into a collection of loosely connected single-investigator projects. It is important to always have pathways back to the larger picture defined theoretically by the unified strategic plan, as visualized in the classic ERC 3-plane chart (see Figure 1).

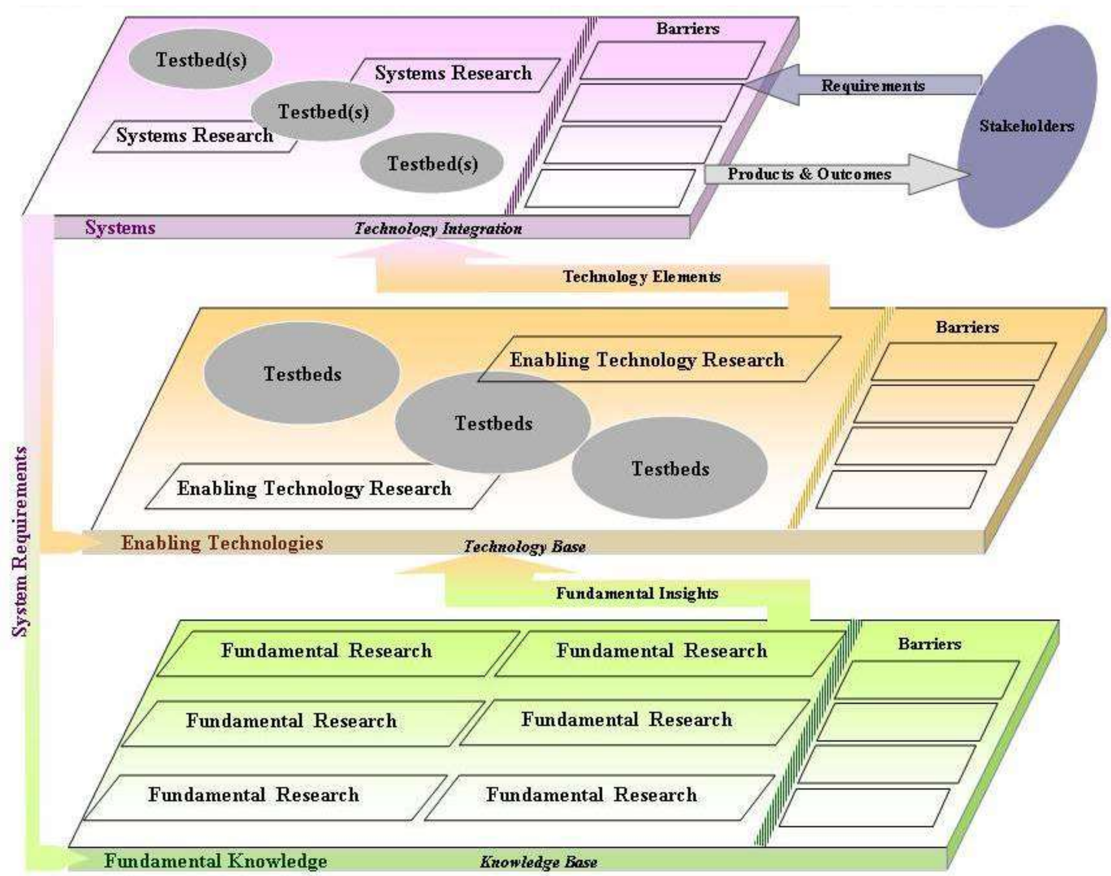

Figure 1. An ERC's strategic framework can be visualized via the 3-plane chart that connects the fundamental research, enabling technologies, and systems levels of the center's work.

There are many kinds of problems that can lead to failure for an ERC. Difficulties in leadership and management (including financial management), problems in research planning and execution (including disintegration and failure to address its vision), and failure to engage with industry positively and in the proper ways are all sources of serious trouble. However, some problems are less programmatic in nature and can be ameliorated to some extent by specific actions of the Director. One issue that nearly all ERC Directors cite as a serious problem is the heavy workload placed on the Director. Regardless of the extent to which responsibilities are delegated, the Director is still almost always subject to potential burnout. One Director describes the problem as "a major flaw in the ERC concept"; even after serving for the entire NSF-funded lifetime of a center as an ERC Director, he has found no real solution to the problem. The most prevalent approach to reducing the excessive burden on the Director issharing responsibilities with theDeputy Director. Delegation of the implementation of the ERC plan to carefully selected key staff members, including the Industrial Liaison Officer and the Education Director, also removes some pressure. Several Directors point to the enormous importance of having a highly capable Administrative Director who can handle many of the day-to-day operational tasks.

An ERC still represents a relatively new type of organization in academe, even though ERCs have now been around for more than 25 years. At each university where a new ERC is established, the members of the ERC faculty and staff generally have to feel their way along in forming a cohesive team because, typically, the university is not set up to service an ERC. Effective leadership from the Director is indispensable to this process. However, formal training in team-building and organizational interaction in this novel university setting can be highly effective in speeding the development of these skills.

Rewarding center participants for strong performance is an excellent morale-booster and an incentive for further success. Many kinds of reward are available for Center Directors to bestow. One of the most prevalent and effective is continued or increased research support, including seed funding; increased compensation is of course another mechanism. Additional travel funds for making presentations at conferences can be provided out of center unrestricted funds, as well as scholarships and fellowships. Increased visibility and support for making presentations at program reviews is appreciated as a career-enhancer. Success should also, of course, lead to promotion and tenure for junior faculty in the center. Several of the centers nominate their deserving staff for university awards and undergraduates for university-sponsored and professional society awards. (For Directors themselves, nomination to membership in the National Academy of Engineering is an appropriate form of recognition; several Directors have achieved NAE membership.) Some ERCs find it important to build a culture that actively pursues awards for its faculty across the board, i.e., from junior to senior. Recognition in the center newsletter and at annual meetings is an intangible but appreciated honor. Finally, nothing replaces the personal recognition and appreciation expressed by the Director and other center managers for a job well done.

2.3.7 Evolving or Restructuring the Management Team

One ticklish area of delegation that should be mentioned concerns perhaps the ultimate delegation, that of the directorship of the center. Succession is an issue that many ambitious executives, in academe as well as business, find difficult to address. If one is performing well and enjoying oneself as a Director, it is perhaps counter-instinctive to make plans to replace oneself. Nevertheless, several ERC Directors have stepped down over the years, and three have passed away, two of them suddenly. As a responsible manager with a major investment of energy and commitment in the center, it is only prudent to provide a viable contingency plan for one's succession and thereby minimize the turbulence that would ensue in the event of the Director's departure. Of those who have established a plan for continuity of leadership, most have appointed a Deputy Director or an Associate Director (often for Research), who will take over the leadership role until a search can be organized to select a new Director (who may or may not be the Deputy). NSF now requires every ERC to have the Deputy Director position.

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[1] See, for example: National Research Council. *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press, 2004.

2.4 Recruiting and Restructuring the Faculty Team

The Director's role in recruiting is pivotal to the center's success. This process starts with the formation of the team that assembles the initial ERC proposal and includes all subsequent new-faculty and on-campus recruiting, as well as the involvement of faculty from core-partner universities and other institutions on a project basis. Many of the university's faculty researchers will watch the center develop with interest, but far fewer are willing to do the hard work required to make the center successful. From the very beginning, the Director needs to define and disseminate the value proposition of being part of the ERC. In particular, s/he has to make it clear from the outset that, large as it may seem, an ERC budget gets sliced thinly, often to the extent that any given faculty member only sees the equivalent of an NSF single investigator grant. Faculty who are truly invested will be "in" for reasons besides the funding. Effective administration of any research enterprise calls for a careful balance between the superstars and the sometimes equally talented workhorses, and the new Director should carefully select those individuals who are committed to working toward the success of the center and not just toward the furtherance of their self-interest.

Further, it is up to the Director to form a cohesive team who will work well together. This is especially challenging with regards to faculty at the partner institutions, who the Director is unlikely to know well. S/he therefore has to depend on the leads at those institutions to serve as his/her emissary in recruiting. One model that works well is to recruit faculty who already have a history of collaboration with each other because they will have likely worked through/past interpersonal issues.

The Director must also hold to his/her vision and keep the objectives of the ERC Program in mind; and to do that, he or she must recruit faculty who can build a truly world-class research team. It is not essential that all center faculty be also talented in education and technology transfer, but they must—at minimum—acknowledge, respect, and support those equally important center activities. A particular hang-up can be the ERC's intellectual property policy, which in general will require the ERC to give members of its Industry/Practitioner Advisory Board some consideration even ahead of the inventors. Potential consequences include thwarting the inventors' ability to form a start-up company or open-sourcing their invention. Again, the Director needs to make that abundantly clear. (Some ERCs even require all participants to sign a form acknowledging that they understand the nuances of the ERC's intellectual property policy.)

Perhaps the best evaluation strategy the Director can apply throughout the process of recruiting, is to project his/her honest enthusiasm about all of the center's activities and listen very carefully for any signs of arrogance or superiority, both of which are attitudes that do not mesh well with the team culture of an ERC.

2.4.1 Recruiting for the Proposal Team

Experience has shown that the dedicated band of true believers that surround the prospective Director during the proposal stage does not always survive intact to form the nucleus of the funded center. This may actually be fortunate, because a diverse and evolving difference in attitudes, opinions, and approaches among the center's main contributors often helps to form the vision of a really exciting ERC. Such a group may also include people with different perspectives on the needs and best directions in the center's chosen field. For this reason, the faculty who constitute the university's critical mass in the chosen research area will serve as a good platform on which the prospective Director can begin to focus and define his/her vision of the embryonic ERC. The eventual interdisciplinary nature of the ERC will be determined largely by the strategic plan and the composition of the organizing group.

The prospective Director is well-advised to approach the respective Deans and Department Heads for their support and buy-in before recruiting faculty and graduate students from other departments. Doing so helps ensure that their considerations are understood and respected (and helps get them onboard for the long haul). Conversely, not doing so could lead to undesirable tensions between ERC and departmental goals and procedures. For example, at some universities, collaborations with other faculty members (as opposed to an investigator leading his/her own research) penalize young faculty working toward tenure; hence, participation in an ERC can actually constitute a threat to the career objectives of talented young people at those institutions.

2.4.2 Recruiting for the Initial Center Team

The first few years for the fledgling ERC are a critical time in its development. Faculty who were interested only in funding opportunities will begin to fall away, and the Director will need to rely on a significant commitment from his/her "recruits to the vision" for the process of delegation that will determine success or failure for the ERC. At least one, and preferably several, members of the successful organizing group should have a commitment to education and/or to technology transfer. NSF monitors these activities from Year 1 but, much more importantly, the full vision of the ERC Program cannot be expressed until pivotal ERC faculty embrace these parts of the vision. This is a period in which the Director must shape the initial team and aim it toward success at Year 3, but still keep his/her eye on the long-term vision for the center. This is also a time of exciting expansion and the Director should assess which disciplines need to be represented in the center in order for it to achieve world leadership, and make preliminary moves toward bringing the most effective proponents of those disciplines into the center .

To ensure that the allocation of research activities to affiliate institutions or PIs is successful and the activities are well-integrated with the center's educational and technology transfer protocol, it is also vital during these early years to have an established research alliance and a well-defined memorandum of understanding or equivalent binding inter-institutional agreement.

During the initial flush of the ERC's success, it is imperative that the new Director leverage the center's newly minted prestige to seed the long-term projects that, in his/her judgment, serve the center's vision. Conventional departments are looking for long-term center funding for new faculty, and the Director is now in a strong position in dealings with the university hierarchy to help achieve this. This is the time to staff the "long lines" of the Director's personal strategy for realizing the center's vision. This is the time to recruit, both from outside and from on campus, the people that the Director sees as being necessary for success at the third-year milestone as well as the people that he/she sees as being vital to the long-term vision of the center. Normally at this early stage of the center's development, these new recruits will be readily welcomed into the center.

Recruiting approaches can vary, depending on the ERC and its relationships with the departments involved, but some approaches are fairly standard. Usually one of the members of the Directors' executive committee is a member of the search committee in their respective departments. Center members attend the interview seminars, meet with the candidate in one-on-one discussions, and offer comments to the search committee based upon their experiences with the candidate. The decision about areas in which faculty should be hired usually remains with the individual department heads and their faculty. However, it is vital that the Center Director, as well as the participating faculty, be actively involved in the recruitment of faculty. The success of the center critically depends on the quality and interests of the faculty being recruited. Similarly, the Director and center faculty must work closely with the departments involved to ensure that the individuals recruited ultimately add value to both the center and to the department. This can be a major challenge. To make it easier, it is ideal if the center can be proactive in strategic planning with the departments with regard to mutual opportunities and responsibilities. The Director should try to meet regularly with Department Chairs in order to keep lines of communication open, and should make known the center's needs for faculty with particular qualifications. In some centers the ERC has taken the lead in recruiting a new faculty member.

ERCs can generally hire non-faculty research staff and other professionals devoted entirely to the center without a direct appointment in an academic department. Such individuals play an essential role in the management and operation of every ERC. Although this capability is valuable, it is important to realize that if the center’s strategic plan changes, these individuals may not fit into the new plan and may need to be reassigned or even terminated.

2.4.3 Restructuring for Years 3-6

The period between the third and the sixth year is the stage in the development of each ERC in which the Director must play an essential role in maintaining the center's vitality and renewing its vision. Because it is easier to write an internal justification for a portion of the existing ERC grant than it is to write a free-standing proposal to a granting agency, many center PIs will view with suspicion any new recruits who threaten their previous allocation of NSF money. The Director must control the funds that support recruiting at this and all stages of the center's development, and he/she must encourage the integration of new recruits through the systematic allocation of funds to these new faculty members, enabling them to hire and support graduate students. Established PIs, many of whom will have received substantial NSF support via the ERC, should now begin to decrease their reliance on center support, while new recruits now should be thoroughly integrated into center research teams with thrust area funding attached. Often some faculty who formed the initial nucleus start to drift away as the Center matures. This is natural and to be expected. As Director, remember that your principal task is to remain true to the Center’s vision, not to warp the vision as individual interests change.

Decisions that an ERC Director makes during this vital stage in the center's development will not only have a profound effect on success in Year 6 but, again more critically, will determine the structure that exists as the center faces the scale-down of NSF support following Year 8. If faculty are allowed to selfishly emphasize their own research interests or de-emphasis education or technology transfer opportunities, the Director may be forced to initiate measures to broaden the research and educational programs of the center and to lead to a shared vision, so that the center is revitalized as it tackles its greatest challenge, which is that of sustainability for several decades.

In the early part of this stage in the development of an ERC, it is essential that a certain attitude becomes embedded within the center. Conflicts and competitions will be inevitable as long as the center's research establishment sees the NSF grant as a source of funding from which each party hopes to receive a portion whose size is commensurate with his/her own perception of their talent and potential value to the center. The Director should reinforce the attitude that the center is in fact a consortium of talents in which participants can conduct a large and varied number of research and education activities, thereby satisfying their personal desires and fostering the growth of the center while serving the center's equal interests in education and technology transfer.

2.4.4 Restructuring for the Mature Center

A mature ERC represents a considerable investment of NSF funds that otherwise would probably have been used to initiate other centers. To be favorably evaluated at the critical sixth-year milestone, a mature ERC will need to have achieved world leadership in its chosen field of specialization. In most mature ERCs, the university, the state, and industry will have invested more than twice the NSF total of funds and all parties will have begun to see concrete accomplishments in education and technology transfer that will justify their enthusiasm and their confidence. It is at this time that the Director's recruitment activities will become both more important and more difficult.

New recruiting may become more difficult because the Director can only offer center support for tenure-track appointments in allied departments, and the research must be aligned with the center’s strategic plan. Few academics would accept a faculty appointment exclusive to an ERC at this stage with only two or three years of NSF funding remaining. The center may not hold together if it has become strictly a web of research alliances, but it certainly will find continuity if its technology transfer programs are valuable to member companies and if its faculty have learned to appreciate the power of collaborative research. As the center matures, the Director may choose to recruit a fresh cadre of faculty with specific interests and talents in the area of team-oriented, industrially related, interdisciplinary education; this transition, however, cannot be abrupt but must be implemented in a smooth and steady fashion.

It is clear that the Director of an ERC is the keeper of the center's vision and that recruiting is his/her most effective weapon in the realization of that vision. The Director will make pivotal decisions on center administrative and research management structures, but these structures are only as good as the people that the Director can call on to staff them and make them work. If the vision articulated by the Director of an ERC inspires and sustains interest within the engineering and scientific communities, many of his/her colleagues will be interested in affiliations with the center that may range from simple exploratory visits to total commitment. This interest facilitates recruitment strategies that include the recruitment of established research faculty from the university and its core-partner universities, and the well-orchestrated opening and filling of new faculty slots in areas that strengthen both the center and the affiliated departments. The Director may face a challenge from established center members, but the recruitment and integration of new center faculty is the key to the revitalization of the center and to the center's response to new opportunities in the field. Many centers report that an intellectual atherosclerosis results when the strategic direction of an ERC remains unchanged because of the personal research interests of established PIs, so recruitment of new participants is the Director's most effective weapon in preventing this natural aging process. As the center matures, cooperative and imaginative recruiting can form the basis of excellent relationships with allied departments because win-win recruiting aligns the Center Director's main weapon with a means for Deans and Department Heads to bring new life into their faculties or departments. Recruiting must strive for balance and it must serve the interests of the education and technology transfer programs that assume special importance as the center matures and plans for self-sufficiency.

2.5 Marketing and Fundraising

Although the NSF provides generous financial support for conducting core ERC program activities, most centers continuously pursue additional external funding opportunities. Many ERCs have been successful in leveraging the NSF investment by more than three-fold when associated activities are added. These additional funds are used to deliver greater services to students, the engineering community, and the center’s home institutions and to broaden their research activities, conduct enhanced education programs, and carry out additional innovation and translational research activities.

The NSF generally supports, and in fact encourages, these external funding activities, provided they complement the research mission of the center and raise the visibility of the core program. Centers must be mindful of their core competencies and not stray too far from their key strategic vision. The additional funding also helps centers lay the groundwork for sustainability and continued operations after Year 10. From the beginning, a center should promote an entrepreneurial culture and develop the processes and administrative infrastructure that allow faculty and key stakeholders to work to secure external funding.

Communicating the value of the center and its key strengths to external audiences is an important ongoing function of the center leadership. Outreach, engagement, and raising the visibility of the center and its programs is of the utmost importance. Most centers work to achieve recognition and awareness within the professional scientific community they are associated with, primarily for their scientific prowess. This is accomplished through a wide variety of actions, typically undertaken by staff at the lead institution. The benefits of actively marketing the center are many and include gleaning additional market sector insights, delivering and communicating value, setting the stage for long-term growth, and attracting new members and collaborators.

One strategy for motivating faculty to actively market the center is to appoint center "Ambassadors." These Ambassadors are typically senior faculty who travel widely and hold important committee positions in professional associations, standards organizations, governing bodies, government agencies, public policy making organizations, and other appropriate external organizations. As Ambassadors, their role within the organizations they are involved in is to represent the center, spread the message about the center's programs, and bring back important information to share within the center. These Ambassadors can be offered a small travel stipend for their services.

Industry members can also serve as important ambassadors of the center. Industry members that have forged close relationships with the center are often happy to promote the center and its programs to their professional network and stakeholders; and as "customers" of the center, their opinion carries weight. Some industry members will invite other companies to join the center based on their perception of value and history of positive experiences. Industry members who have a particularly wide reach in their domains or practice area can help spread valuable information to particular constituencies about the center and its programs.

Other marketing activities such as sponsoring booths at major conferences, supporting organizing committees for major industry events, and active, high-level participation in professional associations can help raise the visibility of the center. The value of marketing materials such as brochures, newsletters, and conference "swag" is often debated. There are many more electronic tools available now for disseminating a targeted message about the center that cost less and can arguably be more effective in educating different audiences. Social media and other information tools should be exploited to the greatest degree. The inexpensive logo giveaways and knick-knacks might not be the best investment of center resources.

The center's website is perhaps its most visible external image, with virtually unlimited variations and creative variations for conveying important information. A professional looking, easy to navigate, well organized website is a powerful marketing tool. Maintaining an up-to-date website and populating it with the appropriate information can be a fairly large burden for busy center staff; but it is vitally important as it is often the first introduction to the center that external stakeholders will see.

2.5.1 Potential Funding Sources

For most ERCs, their industrial partners are a primary source of funding to supplement the NSF award. This funding comes in the form of membership fees, sponsored research contracts, student stipend support, fellowships, in-kind donations, gifts, and intellectual property royalties. Membership fees for most centers typically range from $1,000 to over $250,000 per year, depending on the benefits and/or intellectual property (IP) received. When considering industrial financial support, it is critical for ERCs to maintain balance. Too little industrial funding could cause the NSF to question the center's relevance to industry. But an over-reliance on industrial funding, especially if it is from one industry, could create a vulnerability during distressed economic situations and increase the center's susceptibility to choosing short-term problem solving over longer-term basic research. Industrial financial support is discussed further in

Sections 2.3 and 2.6 as well as in Best Practices Chapter 5, Industrial Collaboration and Innovation.

There are a large number of competitive solicitations that are released by other federal agencies throughout the year, and many ERCs continuously apply for supplemental funding through this mechanism. The ERC and all that it conveys is generally viewed positively by other funding agencies and is seen as a stable, well supported platform for related R&D programs.

There are also a small number of NSF supplemental funding opportunities restricted to ERCs and other existing program participants, and centers which actively seek out these special solicitations can readily enhance their finances. Though very competitive, these are very attractive to centers because the pool of prospective applicants is relatively small, which increases the probability of success. The best known of these awards is the Small-business/ERC Collaborative Opportunity (SECO). The NSF programs aimed at accelerating commercialization of technology; such as Partnerships for Innovation–Accelerating Innovation Research (PFI-AIR) and similar grant opportunities are particularly well suited for Gen-3 ERCs; with their focus on commercialization. Similarly, the Research Grants in Engineering Education (RIGEE) and Catalyzing New International Collaborations (CNIC), or REU Site awards and similar NSF grants that can help to enhance an ERC's education and international engagement programs, are particularly attractive targets of opportunity.

Although the time horizon is long and it requires a considerable amount of up-front relationship building, centers can also pursue large, endowment-like support from corporate or private donors. It can take several years of meetings, discussions, and networking to lay the groundwork for soliciting this type of gift, but these large gifts can help to provide a modest but reliable source of operating funds for the center. Typically, approximately 4% of an endowment can be spent each year, while preserving the principal. The University development office, engineering foundation, or similar organization needs to be involved in this type of fundraising endeavor. Sometimes, a dedicated foundation or similar account is established for the center to receive this type of funding. There may be restrictions on the use of the funds and various University policies to comply with, but large gifts acquired from corporate foundations, high net worth alumni, and other similar donors are certainly worth pursuing. Naming rights for a lab, classroom, or test-bed facility can be part of the enticement to potential donors for these gifts.

2.5.2 The Director's Role

The role of the Director in marketing and fundraising activities is key. The Director creates the vision for the type of organization the center will be and must make the case that marketing and fundraising are important processes for achieving that vision. The Director must set goals, motivate staff, and guide staff in establishing the mechanisms and strategy for marketing and fundraising. The Director must work to create a culture where these activities are highly valued and where all center participants see their role in these activities. This can be a challenge, as scientists and engineers typically undervalue the importance of marketing, fundraising, and similar "soft" programmatic functions. The value of these activities in the life of the center and its sustainability and the potential benefit for all center participants that contribute to these activities must be conveyed.

It can be useful to establish annual targets for key metrics in marketing the center such as:

- Companies formally invited to join
- External corporate visits
- Proposals to be submitted
- Dollar value of proposals submitted
- Key conferences to participate in
- Others as appropriate.

The Director must also be an innovator in devising programs that keep the industry engaged and encourage higher membership levels. Thinking creatively and cultivating a good relationship with the University's Contracts and Grants and Sponsored Programs Office are essential if the center is to meet the evolving needs of its membership.

Working with the staff of the center, the Director must constantly reiterate and reinforce the value of marketing and fundraising activities. To have the greatest reach, partner universities must be fully involved in all facets of the center's marketing and fundraising programs. There should not be the perception that the lead University is the key actor and the partner universities are lesser participants. The center must be seen as a tightly knit, focused enterprise with a unified vision and programs.

2.5.3 Role of Center Staff

In addition to the Director, all Center staff also have a role to play in this important process. The most important of these is the role of the faculty, the Industrial Liaison Officer, and the Administrative Director.

The faculty make up the largest pool of talent within centers. In addition, they typically have large networks of professional associates as well as talents and experience in many of the skills that can contribute to effective fundraising and marketing. This typically applies to senior faculty, but junior faculty should be encouraged to contribute as well, as part of their professional development. The challenge is in helping faculty see the value of these activities and convincing them to take them seriously. To some degree, they should view the health of the center to be in their own self-interest. Faculty members at all campuses need to be involved, not just faculty members from the lead University. It can be a challenge to keep partner schools, particularly those with a small number of students and faculty and who may be receiving a somewhat modest amount of funds, involved in the center.

The Industrial Liaison Officer will typically be responsible for the marketing and fundraising activities directed at potential industry members. Although membership dues often provide a small percentage of total operating funds during the 10 years of NSF funding, the long-term sustainability of the center can be supported by industry membership and participation. The ILO will typically work with the Director to devise the specific objectives for the industry marketing program. The approach taken to meet these objectives will vary based on the target audience. Small businesses, big business, national labs, public organizations, and other types of groups each require a slightly different approach. In each case, the building of a long-term, mutually beneficial relationship with tangible and intangible positive outcomes is the ultimate objective.

Creation of brochures, video, PowerPoint presentations, a social media presence, and other marketing materials that target industry and highlight the strengths of the center is the responsibility of the ILO, in collaboration with a Communication Director (or equivalent), where one exists. Dissemination of these at conferences, company visits, or visits to the center, are the primary means of distribution. Prompt follow-up after the initial contact for more detailed discussion about the value of membership is key to securing new members. Equipment donations and other services and intangible support can also be sought.

The Administrative Director also has a key role in the marketing and fundraising of the center. In many instances the AD is the initial contact point from outside sources, as all inquiries to the center are monitored by the AD. The AD must communicate the information to other staff members for follow up and action through phone calls and/or emails. Once marketing projects and fundraising activities are underway, the primary responsibility of the AD is to manage the expenses and revenues and ensure that they are accounted for appropriately. Care must be taken to ensure that there is traceability for all monies expended and received. The source of funds for creation and dissemination of these marketing materials and expenses associated with their dissemination will likely be from different sources such as the industry membership pool or gift accounts. The AD is also responsible for being aware of the applicable university regulations around fundraising and financial management activities and advising the director and others with regard to compliance.

2.6 Partnership with Industry

2.6.1 Range of Interactions

ERCs interact with industry in multiple ways, and there is a spectrum of types of relationships between center personnel and the employees of the companies with which it interacts. Since ERCs are required to build multi-tiered industrial memberships, the most common mode of interaction is with companies who become members of the center. Typically, these member companies attend periodic Industrial Advisory Board (IAB) and technology review meetings where they receive information about ERC research progress, provide input about the direction of projects, and interact with center faculty and students. However, additional interaction modes within the context of the membership program are also possible and, in many cases, are highly desirable. These include member companies becoming actively involved in the ERC strategic planning process (discussed in the next subsection) or in the center’s research, education, business or membership development activities.

Participating in specific research projects, either as hands-on participants that perform some of the work required to advance the project or as mentors, generally involves member companies meeting periodically with ERC researchers to discuss the project progress and future directions. This mode of interaction can be formalized by inviting each member company to allocate a certain number of mentors to specific projects. Examples of participation in educational activities include industry providing guest lecturers, facilitating industrial internships for academic researchers, providing student stipend financial support, conducting workshops and short courses for both academic researchers and for representatives of other companies, supporting entrepreneurial education for ERC students and post docs, etc. Among these activities, a high-value opportunity that is rarely used is to request member companies to provide summer internships for young faculty. This mode of interaction is an excellent way to expand the training and the funding perspective of faculty, and is a fast way to accelerate the development of collaborative relationships between ERC faculty and member companies.

Member companies can also help support ERC industrial membership development by reaching out to other potential member companies and encouraging them to participate in the ERC and center business development activities, by helping ERC researchers evaluate the potential value of patentable ideas, and by helping to create and evaluate business plans for possible spin-off companies.

In addition to the modes of interaction just described, several other ways of interacting with industry are possible, many of which do not require a company to be a member. The most obvious of these is for companies to sponsor research activities at the ERC. In this mode of interaction, a company, or a group of companies, provide funding for specific research of interest to the company(-ies). Since these research projects often build upon ERC research, when such projects are of interest to companies that are not current ERC members, the opportunity to participate in this type of research projects provides an additional, very compelling argument for them to join as members, thus avoiding or minimizing IP conflicts between members and non-members.

Member companies also often sponsor research projects as a means to expand the scope of the ERC research in directions of interest. This creates opportunities for further leveraging research efforts. The first opportunity for leveraging is that a member company that provides additional support often becomes a demonstration site for ERC technologies, which can create a very compelling model for other ERC members to follow suit and also become more involved. Another is that, since ERC engineered systems often require the integration of multiple technologies, this kind of “associated project” also creates an opportunity to pursue projects funded by multiple ERC member companies, which can join into “mini-consortia” of shared interests (more details later).

Cooperative research contracts also allow the sponsoring company to see the center and its students in a very positive light and the company will offer hire center students, especially if they have been mentored by the company or placed in industrial internships. In fact, some centers report that member companies consider the ability to access and hire center students as being the best by-product of the center’s research program and a highly valued benefit of center membership.

An additional, very attractive mode of industrial interaction is when industry is actually a true partner in the development of technology. This can take multiple forms, such as when a company is interested in adopting an ERC technology and needs to customize it for its own specific requirements, which often include addressing the issues of safety, regulatory compliance, and marketing that typically fall outside the scope of ERC research. Another is when industry is capable of providing technology building blocks that expand the usefulness of the integrated system.

A useful way of promoting all of these interactions is to regard the ERC industrial membership as an ecosystem organized around a technology value chain. In this ecosystem, academic researchers provide the long-term fundamental research efforts required to conceive, integrate, and demonstrate new technologies. Industrial members engage in the value chain in multiple ways and play multiple roles. Some members are technology suppliers. They provide technology components that are needed for the technology to function. These can include equipment components, software, sensors, and control systems. Other members are technology integrators. Typically, these companies take components from other companies, and also from academic researchers, and build integrated systems. Suppliers of control systems are also often commercial integrators. Still other members are technology commercialization companies. They often take the responsibility for supplying the integrated system to end users. Another type of industrial member is the technology end-user. This type of member would use ERC technologies to make goods and/or to provide services to the marketplace. A final category of potential members are companies, non-government entities, and government agencies that engage in the management of technology operations. This includes companies that provide consulting services to other companies regarding the use of the technology (for example, environmental compliance experts), private foundations that are active in the promotion of certain technologies or are invested in proper uses of technology, and government agencies with direct regulatory responsibilities (i.e., EPA, FDA, DOE, FAA, etc.).

When the industrial membership program is regarded in this manner, the modes of interaction between academic researchers and industrial members become self-evident. As the role of each member company in the technology creation and commercialization process is clearly specified, then the company’s key interest is also made clear, and the optimum mode of engagement around ERC initiatives can be easily articulated

This ecosystem concept is also very useful in developing a strategy for attracting member companies. Typically, the end users of technology are everyone else’s customers. Thus, it is often useful to attract them first to the membership program. Once enough technology end users have joined the ERC, it is relatively easy to attract their suppliers. This concept is also useful in designing the multi-tiered structure of the ERC. It is relatively straightforward to understand the typical size of the different types of participants, and whether their corporate culture is favorable to supporting academic research programs, and if so, in which ways and at which level. For many ERCs, the top membership tiers are populated by technology end users, technology integrators, and large technology suppliers, while the lower tiers are often composed of small technology-component suppliers.

Finally, participation of government agencies with regulatory responsibilities needs to be carefully assessed. On the one hand, their participation can be attractive to companies interested in using the ERC as a forum for dialogue with the regulators, or who would like to engage the regulatory agency in the development or demonstration of a technology in order to facilitate the acceptance of the technology by the regulatory agency. These modes of interaction between academia, industry, and government can be very useful and can increase the relevance and the prestige of the ERC among industrial participants. On the other hand, companies could be concerned about exposure of their ideas and development plans in cases where compliance issues for the technology under development are not fully resolved. The best approach may be to engage in a frank and open dialogue with industrial members regarding the optimum way to engage the regulatory agency.

2.6.2 The IAB's Role in Strategic Planning

Meaningful involvement of the IAB in ERC strategic planning is usually beneficial for at least two reasons. First, it creates in the member companies a sense of "ownership," a stake in the success of the center. Second, it helps maintain the relevance and importance of technology development efforts. While the first of these two reasons is self-evident, the second one requires a bit more elaboration. Every ERC has a mission component that focuses on developing technology and transferring it to industry. Participation of the IAB in selection of technology development goals helps the academic leadership select the most critical targets, i.e., those that are of most tangible value to the companies that are the intended recipients of the technology. This is an important input that needs to be periodically updated, because the "most valuable technology" is a moving target. As time goes by and technology evolves, and as companies participate in ERC research, their technology platforms will evolve, and goals need to be periodically assessed and updated.

In practice, participation of the IAB in strategic planning can be implemented in a number of complementary ways. One very useful role for IAB members is to perform gap analysis. This involves answering questions, from an industrial perspective, such as: What are the most important unmet scientific and technological needs in your industry, and in your company? What would be the advances likely to have the largest impact, and why? What would enable your company to develop products faster, more reliably, and less expensively? Answers to these questions are both excellent guidance in selecting broad directions for ERC research and very good targets for industrially sponsored projects.

Another important strategic role for IAB members is to participate in "road mapping" discussions. ERC leadership teams should meet periodically to examine the relevance of center program components, assess their criticality and their potential contribution, identify program components that are missing or not sufficiently emphasized, and select potential changes to the research program that would help maintain its relevance and maximize its impact. These discussions are typically best implemented among a small group of committed participants. Involving a small group of senior industrial representatives in such discussions is often profitable, since it provides a broader perspective as well as a measure of objectiveness regarding the actual practicality and usefulness of proposed research efforts. Moreover, since most large companies are very familiar with road mapping as a standard practice of business development efforts, they can assist the academic leadership in the organization and the moderation of strategic planning workshops.

An additional good practice is for the ERC leadership to present proposed changes to the overall research program to the entire IAB during plenary meetings. This gives an opportunity to the small companies that typically belong to the lower membership tiers to provide their perspective and to help renew a sense of engagement in the long-term center strategy.

2.6.3 Agreements & Expectations

Each center is unique in terms of the industry to which it is connected. It is also commonly the case that the transformational vision established for a center brings together companies in a new value chain that did not previously exist. Therefore, the Director needs to determine how the center is positioned relative to their prospective industrial partners and what the technological value proposition for their center is. These aspects are important, as they dictate two components of establishing the center's relationship with industry, which are the membership and confidentiality agreements. Imbedded within the membership agreement is the intellectual property management plan for the center. The membership and confidentiality agreements are discussed in greater detail in the Industrial Collaboration and Innovation chapter of the Best Practices Manual (Ch. 5), with examples of each included, so the discussion here will focus more on the strategic implications of these agreements on the center, which the Director needs to consider.

Prior to establishment of a center—i.e., before the formal award—the center must recruit potential industrial members that agree to join the center when it begins. At this point of the relationship with potential industrial members, the Director should have the general outlines in mind for how the membership and confidentiality agreements and intellectual property will be managed so that the companies can begin to understand the nature and expectations of the relationship. These items will ultimately require review by the contracting personnel at the lead institution, partner institutions, and member companies. The review and iteration with all the parties will consume at least several months, so it should be initiated immediately at the inception of the center.

Creation of the industry membership and confidentiality agreements and intellectual property management plan need to be done very deliberatively and should incorporate input from the companies that agreed to be charter members of the center. With this input, the initial draft of the agreements will be composed by the lead institution, which will then be circulated to the company partners and partner institutions for their comments. The goal of the activity is to create robust agreements so that companies who join after the founding companies can find the documents acceptable without further edits.

2.6.3.1 Industry Membership and Confidentiality Agreements

The Industry Membership agreement establishes what the member companies receive in return for their membership fees and the Confidentiality Agreement establishes how confidential information will be handled between the lead institution, partner institutions, and member companies. In principle, these two agreements can be rolled into one, but it is not uncommon for industry to want them treated separately. These agreements will need to be signed by the lead institution, each partner institution, and each member company.

From a center leadership perspective, the membership and confidentiality agreements are strategically important, as they set the parameters for the interactions between the signing parties. The membership agreement will state what the lead and partner institutions are contractually obligated to provide to the member companies in exchange for the company membership fees, as well as laying out the structure of the membership fees. It is common to have a fee structure that is dependent upon the size of the company as well as the rights the member company is obtaining—e.g., whether or not the company is getting certain intellectual property rights. For instance, membership fees in some ERCs are as little as $1,000 per year, while others that provide free intellectual property licenses are as much as $250,000 annually with a three-year commitment. The agreement needs to also consider whether in-kind contributions from companies can be used in lieu of cash payments (generally in-kind payments are not a dollar-for-dollar equivalent to cash membership). If the center leadership team has decided that in-kind payments will be allowed, this should be clearly addressed in the membership agreement.

The confidentiality policy for the center needs to be either included in the membership agreement or be the subject of a separate agreement. It is important that the lead and partner institutions as well as the member companies understand and agree to the confidentiality policy, as the policy dictates how information can be exchanged. The policy needs to allow the academic institutions to freely exchange confidential information so the center can truly perform as a center. However, the confidentiality can be either a two-way or one-way agreement with the member companies. In either of these cases, the member companies need to agree to hold the center confidential information confidential within their organizations. However, companies might prefer not to provide the center with confidential information (a one-way agreement), so as to avoid contamination between the member companies. The choice of a one-way or two-way confidentiality agreement between the center and member companies should be made in conjunction with the founding member companies.

2.6.3.2 Intellectual Property

As mentioned above, how the intellectual property (IP) arising from the center will be handled must be addressed in the membership agreement. Importantly, the lead institution and all the partner institutions need to agree on how IP resulting from center-funded research (whether at the lead or partner institutions) will be handled vis-à-vis the member companies, and the center leadership needs to consider the strategic implications of the IP plan when it is established. Items to consider are: whether all member companies have the same IP rights (tied to membership fee structure); how long do member companies have to decide whether a specific piece of IP is of interest to them; and how are IP rights handled if more than one member company is interested. More details on IP, as it pertains to startup companies, can be found in Section 2.6.5.

Several relatively new considerations make the handling of IP even more critical for ERCs. First, patent law in the U.S. has shifted from first to invent to first to file. This situation needs to be managed by the center when sharing “in progress” confidential information with member companies. A second complicating feature is the Gen-3 expectation that the ERCs will spin-off startup companies as part of their innovation activities. While unique IP is generally the key underpinning of an ERC startup company spinoff, IP generated by base-award NSF funding to the ERC must be handled as prescribed in the membership agreement. Therefore, it usually is not possible to "sequester" ERC-generated IP for a targeted startup company. Instead, the eligible member companies must all first decline to pursue the IP. Given the complexity of the issues surrounding IP management in the center, the Director needs to be sure there is a clear understanding of how IP will be handled amongst the lead institution, partner institutions, and member companies.

The culture of the industry represented by the charter members of the center is another important consideration in developing an intellectual property management plan. The companies in many industries aggressively pursue patents in order to establish proprietary market positions and therefore prefer exclusive arrangements with center-developed technology. Companies in other industries, however, are sometimes mostly interested in ensuring that they are not excluded from using a technology development and are more accepting of universities' providing broad member access or even allowing public access to technology developments through publication.

Best Practices Chapter 5 includes a discussion of IP management and delivery in Section 5.3.2.

2.6.4 Meeting Industry's Needs and Expectations: How Far to Go?

ERCs must find a balance between the practical, hands-on activities that are of most immediate interest to industry, and the long-term, fundamental research goals that are needed to advance the scientific mission of the center. The need to balance these two perspectives is in fact an opportunity that helps maximize both the relevance of the long-term efforts and the scientific value of technology development activities.

One important observation is that a significant fraction of the "disagreement" between these two perspectives is often just a matter of semantics and interpretation. Most industrial members understand that technological advances are based on scientific progress. Likewise, many engineering academics enjoy and appreciate an opportunity to maximize the practical impact of their research. Thus, a relatively easy way of bridging the gap between the short-term perspective characteristic of industrial researchers and the longer (sometimes endless) time line of academics is to promote active discussion between both parties, preferably in the context of specific projects. In this respect, integration of project teams including both academic researchers and industrial mentors is a very useful approach for maximizing alignment of perspectives.

The preceding discussion notwithstanding, meeting industrial expectations is critical in order to maintain industrial interest. One way to accomplish this is to require every project to identify and spell out its technical and scientific deliverables, and to implement the practice of providing a timetable for completion of project milestones. This practice is standard in industry but is rarely implemented in academic research. Adoption of this and related practices, such as preparation of Gant charts and other project management practices can help create in industrial participants a sense of confidence that goals are being met and progress is being achieved, while at the same time giving the academic members the freedom to focus on the enabling scientific issues.

A more substantial way of meeting expectations and maintaining interest is to deliver what is promised, and to do so on a timely basis. This truism is not as easy to implement as one would hope. Specifically, when developing integrated technologies, research and development activities often must be carried out in a sequential fashion by different team members. Such coordination of activities is fairly common in industrial R&D efforts, but it is often outside the experience of academics, who tend to work in an entirely independent fashion. Once again, program management practices that are widely used in industry can be very helpful to academics who suddenly find themselves working interdependently.

2.6.5 Impact of Innovation Strategy on Member Companies

With the Gen-3 requirement that ERC innovation strategies will include technology transfer via startup companies, the Director will need to be able to explain how the center will handle startup companies relative to member companies. At first blush there would appear to be a clear conflict between the goal of translating technology to member companies versus translating technology to startup companies initiated by the center. Particularly worrying to companies is whether the center will hold back the "best" IP to be vested with startup companies. If the membership agreement has adequately addressed how center-generated IP will be handled, this concern should be alleviated.

Typically, any center-generated IP available for use in a startup company must first have been declined by the member companies. This progression needs to be considered if center personnel are hoping to initiate a startup company based on the IP in question. In reality, there will be many examples of center-generated IP that are still too early in the development cycle for member companies to be willing to license. For these cases, member companies are commonly supportive of the technology being further de-risked by a center-initiated startup company and may in fact want to establish some relationship with the startup. The advantage of moving funding for the technology translation work from base funding is the ability to explore additional funding opportunities with the startup company that are not available if the technology translation work only stays within the center. Additionally, moving the technology translation work into a startup company means that subsequent IP associated with the translational research is not convoluted with IP generated under the purview of the membership agreement.

The most complicated aspect of the center's innovation strategy with respect to the member companies is when a startup company formed by center personnel becomes a member company. If the startup company pays a membership fee that includes IP rights, they have the same IP rights as any other member company. The aspect that needs to be appropriately managed by the center is when a startup company is launched, relative to the IP becoming available to member companies. Even when a center is working to be completely transparent with their member companies, the center researchers will know about potential IP before the member companies do, so this situation must be considered when the center launches a new startup. The concern of appropriately handing IP relative to center startups will be mitigated by the fact that IP rights mean that member companies have the right to negotiate a license for the IP. Therefore, the ultimate disposition of the IP is in the hands of the IP office of the university having ownership of the IP and not in the hands of the center.

CASE STUDY:

The Data Storage Systems Center at Carnegie Mellon University (1990-2001), began as a totally industry-funded center with several million dollars in funding from US companies who were threatened by competition from foreign (mostly Japanese) companies. Initially, the industry was so delighted to have a university involved in this area that they put almost no restrictions on how the money was used. Later, as the DSSC became more sophisticated in its research and as profit margins for the industry declined, industry attached more and more "strings" on how the money was to be used. The Center's Director became a broker for industrial research projects for Center faculty, and although the research was cross-disciplinary and all the technologies involved in data storage systems were being addressed, because each company had different objectives there was no systems-oriented focus. The ERC award was then sought and won, and with the NSF funding, long-range, systems-oriented goals were defined and pursued.

In its 10th year as an ERC, the DSSC received $4.8M in funding from 50 industrial members, which accounted for 39% of its total revenue. Membership fees ranged from $60,000 per year for Affiliate Members to $250,000 per year for Associate Members who received royalty-free access to the Center's intellectually property. The ERC's research and education program involved 36 faculty, 14 postdocs and visiting researchers, 8 full-time research staff, 88 graduate students, and 23 undergraduate students.

Shortly after receiving ERC funding, the Center helped guide the industry into forming the National Storage Industry Consortium (NSIC), which helped to coordinate the long-term precompetitive research of the US Data Storage Industry as well as all the universities working in this area. In 1996, NSIC was involved in over $50 million in research. The DSSC did everything it could to support the consortium, even though a large part of NSIC funding went to other universities. For example, in 1998, the DSSC wrote a proposal and received funding for a Frontiers of Magnetic Recording Program that, over a three-year period, published over 192 papers and funded 87 students at 16 different universities. The NSF contributed $1.89 million to this program while NSIC contributed $3.37 million. The Director of the DSSC was also the Technical Director for this program. By 2002, the US Data Storage Industry was no longer severely threatened by foreign competition and NSIC was reincorporated as the Information Storage Industry Consortium (INSIC) and allowed foreign firms to become members, in order to better serve the worldwide information storage industry.

The DSSC has continued to thrive as a successful industry-funded center since graduating from NSF support in 2001. During its 25th anniversary celebration in 2008, the DSSC noted that during that period it had granted 132 masters and 200 PhD degrees, collaborated with 60 different industrial partners, spun off 6 companies with over 900 employees, and created 90 inventions and obtained 32 patents. In addition, the Center introduced 14 new and 60 modified courses into the Carnegie Mellon curriculum over those 25 years.

2.7 Relationships Among the Lead and Partner Universities

2.7.1 Leveraging University Resources

The establishment of an ERC constitutes a major commitment on the part of both the NSF and the host universities. Given the multi-institutional structure of Gen-3 ERCs and their mandate to achieve global impact and stature, it is essential for the universities to perceive the mutual win-win that is possible by providing adequate resources to ensure success. If the university is really committed to the objectives of the ERC Program, it will become a part of the university's own strategic plan at the highest levels. The university administrators will make specific long-term commitments to a new ERC in terms of both space and personnel. The university will also make significant changes in curriculum, and even in departmental structures, to nurture the center as a permanent part of its revitalized programs. Research alliances come and go, but a center can become a permanent part of a university if researchers stay together because of the value added by interdisciplinary research teams and by an education process predicated on cooperation between departments and in cooperation with industry. With this as a foundation, an ERC can innovate, translate, and create next-generation workforce leaders, thereby becoming a world-class resource to strengthen U.S. industrial competitiveness. Strong interplay among the ERC’s accomplishments and leveraging the university’s resources are the nucleus of sustainability beyond termination of NSF support.

2.7.1.1 Negotiating for Space and Facilities

Perhaps no decision that the Director of an ERC will make during his/her tenure is more important than the pivotal decision to press hard for contiguous space for the center. Especially if the center embraces several traditional disciplines, it is helpful for its faculty members, researchers, and students to be housed in contiguous space in order to develop the cohesiveness that is the life blood of an ERC. Proximity is a great facilitator; and the center will develop very differently in contiguous space. A technology-enabled and dedicated conference room for easy convening of *ad hoc* meetings, both local and virtual, is an essential ingredient. Faculty members will adopt a spectrum of arrangements that mirror the extent of their commitment to the center, in that some will have labs and offices in the center and work exclusively with center research teams, while others will retain offices and labs in their home departments and attend research team meetings and seminars in the center. Each lab should excel in its own area, while simultaneously promoting collective paradigm-shifting scientific advances and technological innovations. The key to this is that all center students will be housed in contiguous space, making the center their home on evenings and weekends, and integrating to form informal research teams and supportive friendships that will make them profoundly different from conventionally trained students. The ERC Program has been very effective in changing the pattern of graduate education in engineering and science in many universities. As a case in point, one current ERC has established a seamless offering of undergraduate and graduate (BS and MS) degree programs in bioengineering at a stand-alone facility, with graduate office spaces contiguous with the research labs.

For a new center, the advantages of contiguous space can occur in a couple of ways. It can happen through the allocation of a dedicated building, or through the repurposing and augmentation of an existing research facility, with the same end result. However, the chances of having that space allocated are directly proportional to the level of commitment of the university to the new ERC. That commitment is, in turn, influenced by the university's prior experience with research centers. If the university has built up relatively few centers, and really plans to build its research and education programs around these focused areas, it will certainly try hard to find contiguous space for an enterprise that will bring in significant extramural funding and positive global exposure to the university over the next decade. If the engineering faculty is highly research intensive, it may have developed a specialized building within which a number of research centers jockey for space in a pecking order that derives from their current and potential levels of funding. In such a situation, the new ERC should be able to find at least sufficient space for central administrative offices and lab space for specialized equipment that is central to its mission. However, engineering faculties in heavily endowed universities are commonly very short of space, so the new ERC may be forced to be a "virtual" center that exists in the common will of its participants and in the vision of its Director, but whose physical being is a distributed network of office, laboratories, and personnel connected by electronic linkages.

It should be noted, however, that the schedule and challenges in the creation of new research space and establishment of research infrastructure should not be allowed to impede timely progress on the center's overarching deliverables. Given that establishment of a fully functional new research space takes time, the ERC team, with the support of the university administrators, should be mindful of the negative impact if performance falls below the benchmark expectations of the NSF site reviewers in terms of Gen-3 ERCs.

It is essential to ensure that both the ERC faculty and students understand clearly the mission and goals of the center and how they relate to the way things are done in the center. Nothing is more deadly than the perception, by a site visit team or any other visitors, that the students have no idea what the center is all about. Real integration into interdisciplinary research teams occurs best in common lab space, and real bonding most often occurs when undergraduate and graduate students occupy contiguous space and develop a true *esprit de corps*. Hallways lined with center posters and echoing with spontaneous birthday parties for center students, group meals, poster sessions, and other social/academic gatherings are often the heart of a truly effective ERC education program. Most of the ERCs have a Student Leadership Council or comparable organization that facilitates interaction and a sense of common purpose among the students.

2.7.1.2 Direct Financial Support

A variable portion of the annual budget of ERCs comes from universities. Most ERCs have been able to obtain substantial financial commitments from their host universities, including annual support in addition to new faculty positions. For many ERCs, this annual support package includes equipment support, salary support for research staff as well as for new faculty positions in the center's field, operating costs including maintenance, and laboratory up-fitting costs. Further, core university partners often provide substantial cost-sharing support through the provision of administrative positions and student stipend, travel, and tuition costs.

University cost-sharing is often flexible in use and carries no indirect cost burden. Several of the ERCs have had new buildings constructed for the center, using funds provided partly by the university and in large part by the state. A dedicated building and/or state-of-the-art equipment and facilities make recruiting of faculty and graduate students easier, and also improve the attractiveness of the center to industry and funding agencies. A few ERCs have developed world-class experimental facilities for use by the center faculty and others; the funds have come from the university and the state government. The cost share serves as an indirect litmus test of the university’s faith in the positive impacts and outcomes expected of the ERC. Naturally, the university’s continuous commitment both during and after the center’s tenure is highly intertwined with its high performance and effective spinoff of innovative ideas.

2.7.2 Relationships with the University Administration(s)

In any university housing an ERC, the senior administration of a successful Engineering College is confronted almost daily with demands for support of specific programs by forceful proponents. The Director of a new ERC must present his/her vision of the center persuasively enough that the Engineering Dean and the university's Provost and Vice-President for Research, who are rarely both engineers or even scientists, buy into the vision to the exclusion of competing demands. The concept of the ERC is inherently exciting, and the objectives of an ERC are unique, but the center will not thrive if it does not capture the strong support and commitment of the university's senior administration.

To engender that support, it is imperative that the ERC be recognized throughout the university community as being on a plane of intellectual and scholastic excellence that equals or exceeds that of any other research unit at the university. Even 10 years after it is established, the center's accomplishments in fundamental and translational research, innovation, education and outreach should loom large in the university's own public assessment of its strengths. If the ERC does not dominate the internal priorities and self-image of the university, no amount of NSF planning and/or support will guarantee its continuity as an effective unit when it "graduates" from NSF support.

The Dean of Engineering must be willing to commit space and faculty slots to the nascent center. This individual in particular must be a dedicated supporter of the center. The Dean can be invaluable to the ERC and its Director as a facilitator, a "fixer," and an all-around strengthener of the center within the university. A few ERCs have had a Dean of Engineering as their Director; in other cases, ERC Directors have been promoted to positions in the Dean’s office, the Deanship, and beyond, including university President. The best relationship here is a close and supportive one. To that end, the Director should not hold her/himself aloof from such College functions as Parent's Day or alumni functions, because loyalties and goodwill are bidirectional.

The support of other senior administrators is also vital. The Provost must be willing to reinforce the College of Engineering with funding for new faculty slots and with approval for new programs, and s/he should see the center as an excellent model and an effective catalyst for interdisciplinary team research. The Provost and the Dean of Graduate Studies should be proactive in support of the acceptability of thesis work done on center research teams. The Vice-President for Research should help in the acquisition of contiguous space for the center, and s/he should support the center financially by helping to secure state funding and by returning a portion of the indirect costs (IDCs) on center grants.

Eventually, the Vice-President for Research should be so impressed by the center's success in team research, interdisciplinary education, and technology transfer that s/he will be willing to commit significant portions of her/his disposable funds to the establishment of additional *de facto* centers, even outside of engineering.

Given the Gen-3 emphasis on translational research as well as the multi-institutional configuration, the Office of Technology Transfer within the Division of Research has to work very closely with the ERC scientific team as well as with counterparts in the partner institutions. With the development of joint intellectual property across institutions, including potentially global institutions rising out of the Gen-3 structure, the role of the Vice-President for Research becomes even more critical. Meetings should routinely be scheduled among the ERC research team and these administrative units to tackle the problems arising out of these configurations well ahead of time.

The ERC Program can really benefit a university if its senior administrators become believers in the process, as they win and then run an ERC, so that the ERC ideas are "cloned" and expressed in other areas in which the institution has a critical mass of talent and experience. Public land-grant universities vastly outnumber heavily endowed private universities in the United States. For this reason, changes brought about as a result of ERCs in the public institutions may ramify to produce huge changes in national research and education policies, if the top university administrations capture the essential vision of the ERC Program.

2.7.3 Relationships with Academic Departments

The ERC's relationships with academic departments are critical for its impact and success during the NSF funding period as well as for sustainability upon graduation. Thus, the ideal would be to have associated departments, the center and the Dean operating as one team, and to effectively use that engine of innovation to pull the center and the school to achieve maximum impact across all their domains of research, translation, education, and outreach. Most of the time, an individual ERC may involve many different departments, and people from these different faculties may be among its participants. The Director of an ERC as well as participating faculty members must realize that the departments are the continuing administrative entities of the university. Most center faculty will hold tenured or tenure-track positions in conventional departments and virtually all graduate students will actually be registered in these departments. A center's impact and success is very closely tied with the support of the departments associated with it; a difficult relationship that must constantly be nurtured. In fact, as the center grows, it will become a two-way street, with the center leading cross-cutting, application-focused research and the department supporting associated education and outreach activities. The ERC Director must continuously persuade the power brokers of key departments that the center enlarges their research horizons and enhances their students' education—a win-win situation for all.. Most of the time, departmental support comes through the offering of center-specific courses, sharing in the cost of equipment, support for maintenance, travel expenses, ERC student tuition, fellowships, etc. This symbiotic relationship serves to enable Gen-3 ERCs to effectively deliver on their goals of developing the next-generation workforce and promoting broad thinking across research areas, disciplines, and groups.

Another factor of utmost criticality is the Dean's full understanding and strong support of the ERC's deliverables. The Dean as a connector with senior administration plays an important supportive role during the center's times of need, and also serves to make all parties involved understand that working in a positive manner with the center is in the best interest of the departments, college, and university itself. These acts can lead to recognition of the center, its Directors, and the members as a force to reckon with in the shaping of the school's own future direction. As a case in point, one ERC enabled the hiring of four new bioengineering faculty who have worked closely with faculty in other departments including mechanical engineering, industrial engineering, animal science, and education in creating innovations in biomedical research and education.

Many of the real problems that will challenge an ERC Director will involve affiliated departments directly, and the Director simply cannot afford to ignore this critical academic interface. Some departments will be only distantly related to the center, but normally few of these will be intimately involved. Divisive issues will include department faculty who "disappear" into the center and then expect recognition within the department for ERC-related accomplishments that most department faculty may not even know about. The worst scenario could be a faculty member getting credit for the ERC's accomplishments without actually having contributed much to the ERC, leading to unnecessary dissention within the ERC family itself. The lesson learned is that the operations need to be well laid out such that Director, Chairs, and Dean remain aware of the issues and stand together in all critical actions. ERCs are powerful in terms of funding and the inherent appeal of their vision. However, they can also engender resentment in the allied departments/schools that may surface and confront the unwary ERC Director when s/he least expects it.

These are potentially serious problems, but they can be avoided by a perceptive and personable ERC Director. Regular communication and information sharing with the heads of affiliated departments and the Dean can help the ERC as well as departmental/college administrators to "flag" faculty and student problems before they become too serious. Faculty slots that are allocated to the ERC should be filled in a way that benefits both the center and the department concerned. The Director should work with the departments to ensure that the filling of these slots not only benefits the center, but also contributes to the long-term interests of the department and the College /School. The ERC Director should apprise the department Chair of plans for increased research activity that will draw specific faculty away from teaching responsibilities, so that alternate plans can be made in a timely fashion. The ERC Director may submit a written assessment of the ERC-related performance of each faculty member to his/her department head, in ample time for its inclusion in the department's annual report.

The issue of promotion and tenure deserves special attention. Promotion and tenure decisions are made in the departments, and any animosity felt toward the ERC can easily be objectified in adverse promotion and tenure decisions that impact center junior faculty. In addition, the possible adverse evaluation of team research and multi-authored papers has been a point of uncertainty for many faculty and students considering participation in an ERC. However, a survey of ERC Directors showed no such experiences. In most cases, there is considerable collegial interaction on these matters between the departments and the center. Generally, the Director and/or senior center faculty provide departments with letters of assessment and/or support for candidates. In many cases, senior center faculty hold positions on the departmental review committees and college committees, where they have the same privileges as faculty from the departments. In certain instances, it is reported, the input of the Center Director has been the deciding factor in a positive promotion outcome. More than one Director related that participation in the center is viewed as favorable, not unfavorable, for promotion and tenure. Even in the few cases where the center has no direct influence on departmental and college review committees, the outcomes have been favorable for center-associated faculty.

Actually, this is not surprising, since the emphasis of ERCs on goal-oriented research, publication and interaction with other faculty, and excellence in teaching all mesh well with the concept of academic advancement. This will also lead to a culture change on campus by the university recognizing the importance of center-related cross-disciplinary research to serve a knowledge-based economy.

The ERC should cooperate with allied departments in the recruitment of graduate students, and the ERC Director along with the appropriate department chair should pay special attention to the composition of the advisory committee for center graduate students. In the simplest case, the student's thesis advisor will be a member of his/her host department and other members of the advisory committee will also belong to that department. In other cases, a graduate student may be supervised by an advisor from outside his/her home department and the advisory committee may be a smorgasbord. Especially in this latter case, it may be important to have the student give regular seminars in the home department, in addition to center seminars (they require no additional preparation), so that departmental people are not blind-sided by the final thesis. If the vision of the ERC is truly innovative and really addresses the cutting edge in the field, the student's thesis may well seem like fantasy or heresy to members of the home department, and departmental faculty should have adequate opportunity to get used to these new concepts.

In practice, this could also happen to young faculty members working in the center’s cutting-edge research while being part of a department having many senior faculty members engaged in traditional disciplinary research.

Good relationships with allied university departments should be effortless and natural, and they are vital in the solution of many of the problems noted by Directors (such as faculty recognition and student integration). For example, attending meetings of department heads called by the Dean may strike the new ERC Director as a waste of time, because many issues may not really involve the center. However, regular attendance builds good relationships and common interests and reassures the Dean and the department heads that the talented Director of this "hot" research unit, the ERC, views himself as just another member, like themselves, of the university leadership community.

2.7.4 Relationships with Center Faculty

Based on the experience of the ERC Program for the past 25 plus years, it has become clearly evident to NSF ERC Program Directors that certain characteristics of background, ability, and personality tend to be associated with success in directing a successful ERC. Of course there is NO one perfect model or behavior, but there are overwhelming indications of a true leadership pattern with “outside the box thinking” that leads to best performance. Certainly there is a range of leadership characteristics, and any given individual will be stronger in some areas than in others. In addition, the "ideal" profile will vary across different fields, universities, and industry bases. Finally, there are all the intangibles of team chemistry, timing, and luck that may play as significant a role as any other more objective factor in one's ability to lead an ERC effectively.

Interpersonal skills that involve team building are valuable whether you are a Center Director or a Thrust Leader. Given that the center involves activities with faculty members from different partner institutions, team efforts that give appropriate recognition to the key player(s) are of utmost importance. Management in an academic environment is often a delicate operation, so it is strongly advisable that the Director and faculty members be diplomatic, tactful, and empathetic as well as perceptive, alert, and determined. Given the enormous demands of the job and the personal sacrifices it entails, the ability to make a total commitment to the center is vital and the center should communicate that commitment as an important requirement for all those involved in the center.

In general, the prospective Director must have gathered together a group of colleagues and junior faculty, in relevant fields, who are willing to form the core of the ERC faculty team. It is also very important to have an industrial support base (or at least strong contacts) established through consulting, participation in a previous center, industry employment, etc. It is useful if the individual has good relations with the university and departmental administrators, although these relationships can be built after the center is established. Also valuable are other federal, state, and private support bases (e.g., foundations) beyond NSF.

The Director and the leaders of the ERC's research, education and outreach programs should understand the opportunity the ERC provides to change the engineering education/research culture of the university and the potential to have an impact beyond engineering. S/he should be interested in integrating the results of the ERC's systems perspective into the curriculum in new and innovative ways.

Finally, in terms of attitudes and personal orientation, an ERC Director should be a team-oriented coalition-builder who welcomes change, since technological and "cultural" change are what the ERCs are all about. The person's attitude toward the encouragement of women and underrepresented minorities to pursue engineering education and research must be genuinely positive. S/he should be oriented toward focused basic research that integrates science and engineering with long-term benefits for industry, because this is the fundamental rationale for the ERC Program. Finally, the Director should be oriented always toward achieving a center in which the integrated whole is greater than the sum of its individual parts, and not driven by the power nor the prestige of the position. It is critical that the Director through his/her actions makes the team players feel the ownership of the center and drive its deliverables because they believe in it.

A balance of research talent and commitment to the center's vision is essential; and interdisciplinary education and technology transfer will not reach their full potential unless the Director chooses his/her teams wisely. It is naive to expect that every center faculty member will excel in all center activities, but a subset must be capable of world-class work in each of the major areas of research, education, and technology transfer.

Within the university framework, an ERC Director must choose his/her style of interaction. A measure of persuasion and firmness may be necessary to obtain contiguous space, at the outset, and to take full advantage of the university's pledges of support for the center. As the center matures and begins to concentrate on the continuity of its research, education, and technology transfer programs, cooperative relationships with allied departments and the appropriate parts of the university hierarchy come to the fore. Mutually beneficial recruitment is the Director's most potent asset in this matter and a confrontational approach by a mature center may leave it surrounded by enemies at a time when it most needs friends. It is the stated intent of the ERC Program that the centers should make lasting changes in university education and also significantly improve the competitiveness of American industry; and most ERCs actually accomplish these objectives. Clever recruitment and excellent relationships within the university can extrapolate these changes by passing the center's vision to the university departments and faculties that constitute the operative research-education-technology transfer mechanism of our university system.

2.7.5 Inter-University Agreements

2.7.5.1 Intellectual Property

With the focus on multi-university collaboration (among each other and with industry) in a Gen-3 ERC's innovation ecosystem, effective domestic inter–university agreements are crucial to facilitate true symbiotic research and facilitate ground-breaking scientific and technical advances. Since the research as well as the membership of the research team is dynamic and interdisciplinary, it is to be expected that multiple partner universities will contribute to generating the intellectual strengths—and, often, IP—in connection with any given research topic. This necessitates that a clear process be in place amongst the universities when the collaborative research leads to joint IP and eventually a possible patentable process.

It is also important that the partner university economic development offices work together from Day One to get the necessary Memoranda of Understanding (MoUs) and other legal documents in place to facilitate joint IP development, patent prosecution, and revenue sharing to minimize potential disputes and concerns when reality kicks in and advances occur in the labs. The MoUs among the domestic partner universities must thus unambiguously encompass protocols for innovation disclosures and potential patent prosecution and revenue sharing issues.

In addition to focusing on domestic inter-university agreements, one also has to pay close attention to the foreign university partner/s due to the requirement for Gen-3 ERCs to attain global leadership status. The following paragraphs from the Industrial Collaboration Best Practices chapter 5 (Section 5.1.1.3) discuss the ERC agreement with foreign universities in more detail.

> "One area that merits further discussion is the formulation and execution of international agreements with foreign university partners. This originally was a required component of a Gen-3 ERC, but because of the complexities outlined below, beginning in FY 2013 a Gen-3 ERC may enter into a focused partnership with a foreign university governed by a formal agreement with mutually protective IP policies, or faculty-to faculty collaborations. In either

case, the partnership/collaboration must allow for ERC students to spend at least 30 days working in the laboratory of the foreign partner/collaborator.

"The establishment of the ERC/foreign university partnership agreement can involve a steep learning curve, concentrated on the complexities of international law and the vast differences in scientific culture and legal environments, especially in intellectual property ownership and business law specific to the partnering university's home nation. The "harmonization" of the final international agreement can take a great deal of time and expense that an ERC has to bear. These agreements need to engage the highest levels of the administration on both sides (university presidents, university system officials) from a policy and legal standpoint.

"As exchanges occur and joint IP becomes an issue, the agreement needs to include some mechanism to capture that IP under mutually protective terms. Additionally, ITAR and export control restrictions, especially with the development of new materials, need to be addressed in terms of international agreements. This could impact the exchange of information, materials, samples, and prototypes. Faculty-to-faculty collaborations would operate under less formal terms, as is traditional in academic research. However, the ERC still needs to be mindful to protect ERC-funded IP."

CASE STUDY:

A partnership was formed between the Revolutionizing Metallic Biomaterials ERC (RMB) based at North Carolina Agricultural and Technical State University and the University of Hannover Medical School in Hannover Germany. North Carolina A&T, as the host university on behalf of the ERC, negotiated a fixed fee with a local law firm with international business and IP law expertise to interpret German law and to draft a harmonized agreement. The German Inventors law differs from the Bayh-Dole Act in that, rather than assigning intellectual property rights to the University, German scientists and engineers retain rights to their inventions. German Law allows for a period of time in which a German employer (University) may secure rights to an invention in return for fair compensation to the inventor at the time of transfer of rights. If this option is not exercised in a timely manner, IP rights remain with the inventor. This arrangement tends to limit the nature of the global interaction between Hannover and the ERC to student and technical exchanges, as the ERC cannot ensure that IP obligations under Bayh-Dole will be met in cases of joint inventorship between an ERC investigator and a German investigator. It may be possible to address this concern. Opportunities for the ERC to participate in the option discussions between the University and the German inventor are being explored.

2.7.5.2 Industry Members

As might be expected, the IP sharing process can get further complicated when the ERC partner universities also collaborate on joint IP with industry and/or innovation partners. As always, a thoroughly thought-out agreement and plans for foreseeable contingencies will greatly facilitate the process. This subject is discussed in more detail in Section 2.6 of this chapter.

One of the first lessons that a new Director, along with the Industrial Liaison Officer (ILO), learns as s/he begins to get involved in technology transfer, is that there is a spectrum of different forms of potential interaction between any company and any academic entity. Some ERCs allow industrial members to license IP at reduced royalties; some agree to collaborate with their industrial partners in filing for joint IP when both are inventors; and some provide royalty-free IP to specific membership levels.

As was outlined in an earlier section, creation of the industry membership and confidentiality agreements and intellectual property management plan need to be done very carefully in the multi-institutional environment of an ERC. The initial draft of the agreements will be composed by the lead institution, with input from the partner institutions, before circulating the documents to the company partners and partner institutions for their comments.

CASE STUDY:

During the recession, while many companies were trimming employees or just holding steady, molecular detection and imaging solutions company "Daylight Solutions" was growing rapidly and, in 2011, relocated to a larger (35,000 square foot) facility in San Diego. The company is commercializing an advanced technology, quantum-cascade laser (QCL) systems, developed by a partnership with the NSF-funded Engineering Research Center (ERC) Mid-InfraRed Technologies for Health and the Environment (MIRTHE).

Daylight Solutions uses modular designs, meaning that any commercially available QCL chips can be deployed inside its systems. The lasers are based, for the most part, on InGaAs/InP material systems. Different vendors may be better at different parameters (e.g. wavelength selection, power, efficiency, etc), and allows the company to have a great deal of flexibility when designing their laser systems for a variety of customers and applications.

The growth of Daylight Solutions is in response to the growth of important commercial applications for QCL systems. Chemical imaging, such as cancer detection, pharmaceutical quality control, and materials inspection can use QCL technology. Others applications include alcohol breath detection and glucose sensing, marine stack emissions monitoring, atmospheric monitoring, and homeland security.

MIRTHE, like other NSF-funded ERCs, is a multi-institutional Center that brings together universities and industries with the goal of advancing technologies developed in the lab to a point where they can be commercialized by industry—in the case of MIRTHE's technologies, this means reduced to compact, easy-to-use devices that are inexpensive enough to be widely deployed. MIRTHE is headquartered at Princeton University, with partners City College New York, Johns Hopkins University, Rice, Texas A&M, and the University of Maryland Baltimore County. The Center encompasses a world-class team of engineers, chemists, physicists, environmental and bio-engineers, and clinicians. MIRTHE specializes in developing mid-infrared (3-30 µm wavelength) optical precision trace gas sensing systems based on new technologies such as quantum-cascade lasers or quartz-enhanced photo-acoustic spectroscopy, with the ability to detect minute amounts of chemicals found in the environment or atmosphere, emitted from spills, combustion, natural sources, or exhaled. The partnership between MIRTHE and Daylight Solutions is a perfect example of how world-class engineering research can be brought to bear on tackling big problems *while fostering economic growth at the same time. Dr. Timothy Day, CEO and CTO of the company, is a member of the ERC's Industrial Advisory Board.*

2.7.5.3 Articulation for Curriculum Sharing

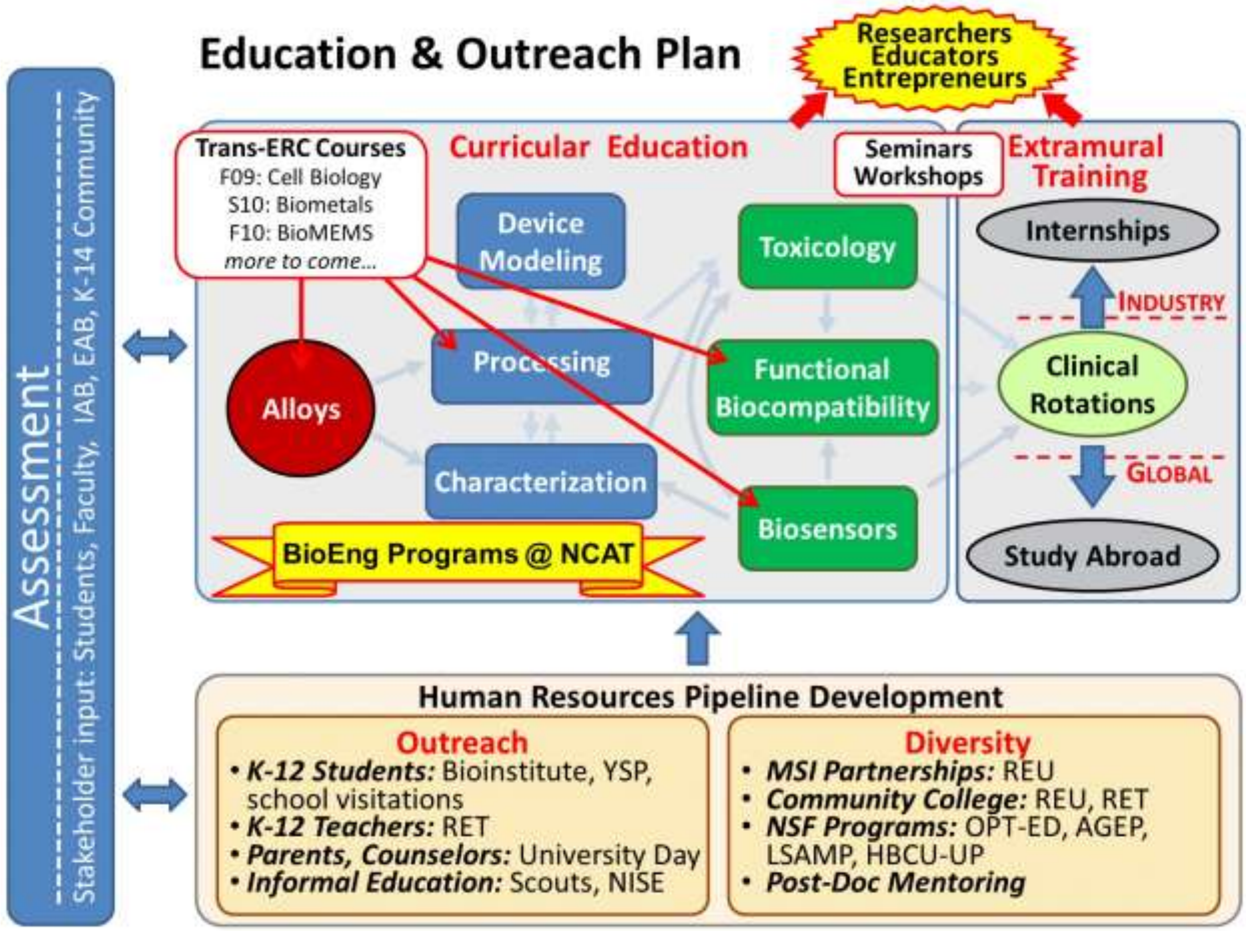
With the proper focus, articulation for curriculum sharing can become a great asset in connecting the partner universities, industries, innovators, and even the advisory board members in an ERC. This will subliminally facilitate the entire ERC student body and the members to become one ERC team. The intellectual depth envisioned by the ERC's three-plane chart and its research operational strategic plan can be smoothly connected with the ERC's educational and outreach strategic plan (as an example, the Center for Revolutionizing Metallic Biomaterials' plan is shown in the following case study) through this articulation for curriculum sharing. ERC-wide, using this plan, researchers and educators can work effectively towards the goal of educating creative, adaptive, and innovative engineers who are also well-grounded in the underlying science and engineering principles of the ERC's engineering domain.

Implementing a coordinated curriculum-sharing education plan among all core partner universities in an ERC promotes knowledge exchange, identification of best practices, and effective ERC-wide availability of limited or unique human and/or infrastructural resources. Such a plan would provide for the offering of key courses, workshops, and training that might not normally be available at partner institutions or those that add considerable value to the student researchers' knowledge and skills in relation to the ERC's specific mission. Such articulation in education and training also promotes true multidisciplinarity at a multi-institutional level, enabling the ERC to achieve greater things than the sum of its parts. Typically, shared courses would be taught by key thrust leaders or advisory board members with related expertise. Thus, curriculum-sharing articulation among the ERC partner universities moves them towards the fulfillment of the Gen-3 ERC mission as envisioned by NSF.

<u>CASE STUDY:</u>

The North Carolina A&T/Pitt/UC partnership via the ERC for Revolutionizing Metallic Biomaterials (RMB) has resulted in the development and offering of research-relevant graduate courses on a trans-ERC basis using the institutions' distance learning facilities and cyberinfrastructure. This articulation helped in the offering of at least three 'special topic' graduate courses shared among the partner institutions where ERC students participated.

Certain logistical issues must always be planned for to enable smooth articulation among institutions with differences in policies and operations. ERC-wide evaluation of the effectiveness of a shared curriculum requires its own set of institutional (IRB) clearances. As an example, one challenge encountered initially in the RMB trans-ERC course offerings was the mismatch in timings—North Carolina A&T and Pitt have always operated on a semester schedule, while UC used to operate on a quarter schedule, requiring allowances and adjustments at the start and end of courses. Assessment and evaluation have required the assessment lead at North Carolina A&T to coordinate with a local sponsor at the partner institution (for example, UC) to obtain IRB clearance of survey instruments shared among campuses to evaluate trans-ERC courses.



<u>CASE STUDY</u>

The Center for Biorenewable Chemicals (CBiRC), an NSF-funded Engineering Research Center (ERC) headquartered at Iowa State University (ISU), has embraced a very broad view of its role in stimulating multi-faceted dialog around ideas, innovations, and inventions. CBiRC now visualizes its role as operating in the front half of an open-innovation ecosystem, which flows and matures over time from concept generation to knowledge and patents, then to product research and development (R&D), and finally to commercialization.

Working with its industry members and startup companies, CBiRC narrows down the focus of incoming ideas and concepts to a subset of the most viable innovations. Sometimes (depicted by arrows in the figure) these come from outside; other times they are internal or flow outside or even between companies. The most advanced ideas flow to the project R&D stage and eventually broaden-out into the commercial realm. Also, from time to time there is an opportunity to incorporate early-stage ideas into a translational research opportunity.

What became clear from the multi-way discussion within CBiRC is that early-stage innovations still retain significant risk. In this form the ideas do not readily transfer to member companies and a different mechanism was needed. This led to formation of the CBiRC entrepreneurship course for graduate students, which has many similarities to the NSF I-Corps program. The *course acts as an idea incubator, creating a framework supporting the formation of multiple startup ideas and nurturing early-stage startups through technology-led entrepreneurship. One aspect of the course is that it provides explicit experience within the context of a bio-based economy. It emphasizes actual guiding of students through the steps required to found a startup company. Although run by CBiRC's Innovation Director, the course includes individual classes given by local CBiRC innovation Partners. The course culminates in a "Dragon's Den," in which course presenters become a panel of techno-commercial evaluators from whom students seek support and guidance regarding their technologies and readiness for startup funding. Students deliver presentations on company ideas and the panel responds with what the members like or dislike about the proposals. The best ideas from the course are offered further support if the sponsoring students are willing and interested.*

Initially, the course was within the Graduate Minor in Biorenewables, but it has now expanded to become a requirement of other ISU graduate programs called the "Biorenewable Resources and Technology Program," run by the ISU Bioeconomy Institute. The Graduate Minor allows students from a variety of allied disciplines to understand opportunities for developing bio-renewable chemicals via a combination of bio-catalytic and chemical catalysis steps. Students in the minor gain a background in the general issues related to the emerging bio-based industry, production, and processing of bio-renewable resources as well as exposure to the economic and environmental realities of the chemical industry. The course also delivers a process that allows students to visualize how technologies can lead to entrepreneurship, and it has led to identification of a need for greater support to nurture fledgling ideas. This need for support has evolved into the CBiRC Bio-based Innovation Startup Foundry.

Several startup entities have succeeded in gaining funding from translational research grants. For example, Glucan Biorenewables has a project funded under the 2010 ERC Translational Research Fund (10-617) as well as under the Grow Iowa Values Fund (GIVF); SusTerea and SolysTE have a project funded and one pending under the Iowa Innovation Green Fund (i6-Green); and OmegaChem gained funding from the NSF-I-Corps program.

2.7.6 Communication Among the Lead and Partner Institutions

It is unnecessary to belabor the importance of continuous, regular, and clear communication among the partner institutions in an ERC. This applies to all ERC deliverables—research, technology transfer, education, and outreach—and among all stakeholders: faculty, staff, and students. Given that most Gen-3 ERCs are composed of widely-dispersed institutions, it becomes essential to rely on telephones and the cyber infrastructure for active communications as well as asynchronous data access. Administrative leads play a key role in the scheduling of teleconferences and the generation of agendas and minutes and task item checklists. The commitment and regular participation of the ERC leadership provides direction and motivation for the rest of the ERC team to follow suit.

Communication techniques that provide the opportunity for face-to-face interaction include cross-ERC courses on topics of shared research interest that engage students from all partner institutions over a semester, or longer, and involve at least one faculty member at each campus in communications over the duration, in planning together for the success of their students.

Interactions of a shorter duration are cross-ERC seminars, internal conferences and jointly-organized symposia at national and international conferences. These are effective in allowing the sharing of interesting speakers and topics. Workshops, such as those focused on the ERC's specific topics targeting researchers/professionals from government, or those that engage all ERC students and deal with student leadership and ERC Biennial Meeting competition preparation, are also good tools for interaction and communication between institutions.

Regularly scheduled teleconferences and/or video conferences between the lead and partner institutions are effective in promoting the personal touch without the need for participants to travel. ERC directors, deputy directors, administrative leads, and industrial liaisons often find this technique useful for discussing administrative, leadership, and strategic direction issues. Teleconferences are also a good vehicle for promoting discussion on research issues between research thrust team members and on education issues among education and outreach team members. E-mails and the intranet are effective for providing offline discussion and within-ERC result-sharing and serve as valuable archives for report generation.

Leadership strategy planning meetings, pre-site visit preparation meetings and scientific, industrial, and educational advisory board meetings—whether face-to-face or through teleconferencing—are other valuable interactions between the lead and partner institutions. In addition, external dissemination venues provide further opportunity for partner institution collaboration and planning, which helps open up communication channels. These could include:

- joint journal and trade magazine publications;
- collaboration in maintenance of a unified cross-institution ERC website; and
- regular publication of student-generated SLC newsletters.

2.8 Other Collaborations and Outreach

2.8.1 Purposes and Mechanisms

In order for the U.S. to operate from a position of strength in research, innovation, translation, education, and economic impact, the mindset of the next-generation workforce is critical. To help address this need, a major goal of the ERC program is focused on producing graduates who will be creative U.S. innovators in a globally competitive economy. To that end, the ERC engineering workforce development program needs to include not only university-level education strategies but also strategies that attract precollege and non-traditional students to engineering careers, as well as strategies to involve a broad array of collaborations with government labs and innovation centers and foreign institutions. These involvements should include assessment to monitor progress and impacts over time and to improve the program as needed.

The role of Gen-3 ERCs is to strategize and impact the above through appropriate partnerships. Collaborations with and outreach to other institutions for research and education enable Gen-3

ERCs to disseminate more rapidly and widely the "ERC culture." This can be accomplished through a variety of mechanisms, including joint proposals, exchange of faculty and/or students, direct funding for specific research tasks, consulting activities, and other means. The goal is worthy, and in fact the results of these interactions have largely been worthwhile. This section of the chapter outlines generally followed operating principles, with some examples and lessons learned.

Experience has suggested that best practices for engineering workforce development partnerships include the following:

- This collaboration should be driven by a passion for engineering education and by strong leadership. Partnerships are successful and the results and impacts are profound when both parties are on the same wavelength, moving toward a common (and lofty) goal.
- Successful alliances can be established only when both parties benefit from the collaboration.
- It is necessary to identify those institutions that have capabilities and facilities that are complementary to the goals and mission of Gen-3 ERCs. In this way the interaction becomes a win-win collaboration that benefits both sides.
- For research collaboration, discussion among the ERC thrust area leaders should identify the appropriate individual(s) to contact at the other institution. The approach is then made and, if there is an interest, joint discussions are held to ensure that the outreach institution participant(s) have the same goals and are willing to follow the procedures used in the ERC. It is important to ensure that there is a strong intellectual match-up. Experience demonstrates that financial support alone is not a sufficient basis for a strong partnership.
- It must be realized that failures can occur. Therefore, it should be made clear at the outset that, if the interaction is not successful, the alliance will be terminated.

2.8.2 Academic Institutions

2.8.2.1 Non-partner Affiliated Universities and Colleges

NSF encourages the ERC, as it makes sense, to include as affiliated (non-partner) organizations one or more institutions participating in research and/or education programs, such as universities or colleges that are contributing affiliated faculty groups. To increase the impact of the ERC on the technical workforce, the ERC may partner with community colleges and or technical colleges.While the core configuration of an ERC allows up to four domestic partner universities in addition to the lead university, non-partner affiliated universities and colleges must be selected based on the value they add to the overall mission of the center. Often the success of the ERC does not depend on the number of partners so much as on the quality of the partnership, as far as the mission at hand is concerned. For example, the ERC-RMB, led by North Carolina Agricultural and Technical State University, includes only two domestic partner universities, the University of Pittsburgh (UP) and the University of Cincinnati (UC). The partnerships were initiated based only on inherent synergies and past track record. This gave the time and resources for judicious selection of non-partner colleges and universities, community colleges, and other institutions. In RMB’s case the non-partner affiliated 4-year institution is California State University–Los Angeles (CSULA) This approach is having a positive impact on many fronts, from multiple research proposals to graduates entering professional programs in medicine, to the students' winning of national-level recognition based on team research across the institutions.

Another type of ERC collaboration and outreach with non-partner universities and colleges is the Research Experiences for Undergraduates Program (REU), which is described in more detail in Section 2.3.2.4 of this chapter and in Best Practices Chapter 4, Education Programs. The REU program, for which supplemental NSF funding is available, allows leading undergraduates from other universities and colleges to experience hands-on ERC research opportunities that hopefully will encourage them to pursue graduate education in science and technology.

2.8.2.2 Precollege Partners and Community Colleges

The ERC's partnerships with community colleges and or technical colleges serve to increase the impact of the ERC on the technical workforce. Precollege educational institutions are included in order to bring engineering concepts to the classroom and stimulate student interest in enrolling in college-level engineering degree programs and in engineering careers. The partnerships also serve to strengthen the technical workforce and stimulate interest in careers in engineering.

The precollege education programs stimulate student interest in engineering careers and increase the diversity of domestic students studying engineering at the college level. This would include school districts and/or individual schools. A strong relationship with the above will create: (1) STEM teachers' involvement in ERC research and education programs, creation of educational modules for their school teaching activities, and integration into their curricula; (2) a strong impact on diversity and broadening participation of underrepresented groups, both teachers and students, into these engineering experiences; and (3) an infusing of creativity, innovation, and STEM leadership motivation among talented high school students through the Young Scholars program.

For example, some ERCs have formed partnerships with county school systems, middle schools, community colleges, and technical community colleges to provide outreach to secondary school teachers and K-12 and associate-degree level students. Some centers have also become involved in local science fairs, both as mentors or judges. This approach is creating a positive impact on many fronts: teachers and young scholars engaging in ERC research and pursuing national competitions, community graduates entering 4-year educational programs through a 2+2 articulation agreement, and organization of national education workshops.

2.8.2.3 Foreign Partners and Collaborators

Gen-3 ERC Programs aim to provide an opportunity for domestic students and faculty to collaborate in a globally connected university research and education environment. The collaborations established with researchers in foreign institutes should lead to the advancement of pre-competitive research. The judicious selection of foreign partners is just as crucial to the ERC's success as that of domestic partner and non-partner institutions. It should be based on the institution's position of global strength and leadership in the ERC research area; the passion and motivation of the global partnership coordinator in working with the ERC's leadership to advance common goals, leading to accomplishments such as the joint organization of workshops, conferences, and knowledge exchange—technical as well as cultural; and the opportunities for faculty-student exchanges. The foreign collaboration should add significant value to the research and also offer the ERC students the opportunity to work in a foreign laboratory for a mutually agreed period of time. Sufficient time in the foreign partner's laboratories enables the ERC student to have a meaningful international research experience that is relevant to the student's research in the ERC.

The foreign partner collaboration could be formalized through a Memorandum of Understanding (MOU) among the institutions, or less formal ERC-faculty-to-foreign faculty collaboration. The MOU approach is strongly recommended for future sustainability of the partnership. In both cases, there should be mutually protective Intellectual Property (IP) policies that could evolve over time to meet the requirements of the individual institutions. As an example, one of the current ERCs (ERC-RMB) had a global research partnership with Hannover Medical School (MHH) in Hannover, Germany, while the Indian Institute of Technology–Madras (IITM) provided additional global entrepreneurship and cultural knowledge. Passionate leadership from the coordinators involved has resulted, in addition to an exchange of students for research, the organization of international workshops in the biomedical field, including at the FDA, helping the ERC to become one of the trailblazers in this area of technology.

2.8.3 Federally Funded Research and Development Centers

As outlined in Section 2.5, there are a large number of competitive solicitations that are released by many other federal agencies throughout the year, and many ERCs apply often for supplemental funding and collaborative research through this mechanism. The ERC Program is generally viewed positively by other funding agencies and is seen as a stable, well-supported platform for related R&D programs.

There are also a small number of NSF supplemental funding opportunities restricted to ERCs and other existing Program participants, and centers which actively seek out these special solicitations can readily enhance their finances and opportunities for collaboration with other groups (see Section 2.5).

Among the different collaborators an ERC may develop, Federally Funded Research and Development Centers (FFRDCs), commonly known as National Laboratories, present some great opportunities while at the same time creating a number of difficult challenges. First, it is important to recognize that a National Lab is not a funding source, but rather a partner in building up the ERC's research programs. The ability to align research activities that meet a common vision and mission is critical for a strong collaboration. This is not necessarily a trivial matter, due to the nature of NSF and the National Labs. NSF has historically depended primarily on university-led efforts, which rely on graduate students at a relatively modest cost, and the research proceeds in an open-ended fashion. National Labs, on the other hand, depend primarily on career researchers and the research is driven programmatically by the funding agency requiring clear deliverables. Even if these deliverables cover long-term research goals, they usually address a very specific national need, such as cybersecurity for infrastructure. This has a myriad of implications in practice. For example, the National Labs tend to be very strong at creating new experimental infrastructure and building research capacity in a particular field. Still in recent years, they have put greater emphasis on involving students, including post-docs, and working more closely with universities as well as industry. NSF has moved more towards targeted research and innovation with research. So the two research models are moving closer together, reducing some of the barriers.

The natural division of labor between an ERC and a National Lab is for the ERC to focus on long-term research goals, while the National Lab leads experimental setups and provides firm deliverables that match programmatic needs. One way to enable this division is through post-doc assignments at the National Lab where the former student more fully explores ideas from their dissertation. This is not to say National Labs have no long-term research objectives. In fact, they may have on staff many mathematicians and physicists, and so on, who are accustomed to longer-term research goals than in engineering. Still, even in the pure science fields they are focused on clear program goals and demonstrations. ERCs will collaborate best if they understand those goals. It is worth noting the contrast of the multi-year budget cycle at NSF relative to the typically yearly funding decisions for the Labs. This research has to be managed so deliverable deadlines can be met.

As with most collaboration, long-term sustainability stems from developing personal relationships and actively working together on research problems. For some centers, this arises naturally from past collaborations and proximity. For example at the CURENT ERC at the University of Tennessee–Knoxville, many faculty and even some staff have joint appointments at Oak Ridge National Laboratory (ORNL), which is located within a short driving distance of the university. This is an obvious advantage in understanding the different environments. Even without proximity, many of the National Labs maintain strong relationships with several universities. It is important to have faculty on the ERC team who have fostered these relationships and understand the programmatic approach of the National Laboratories.

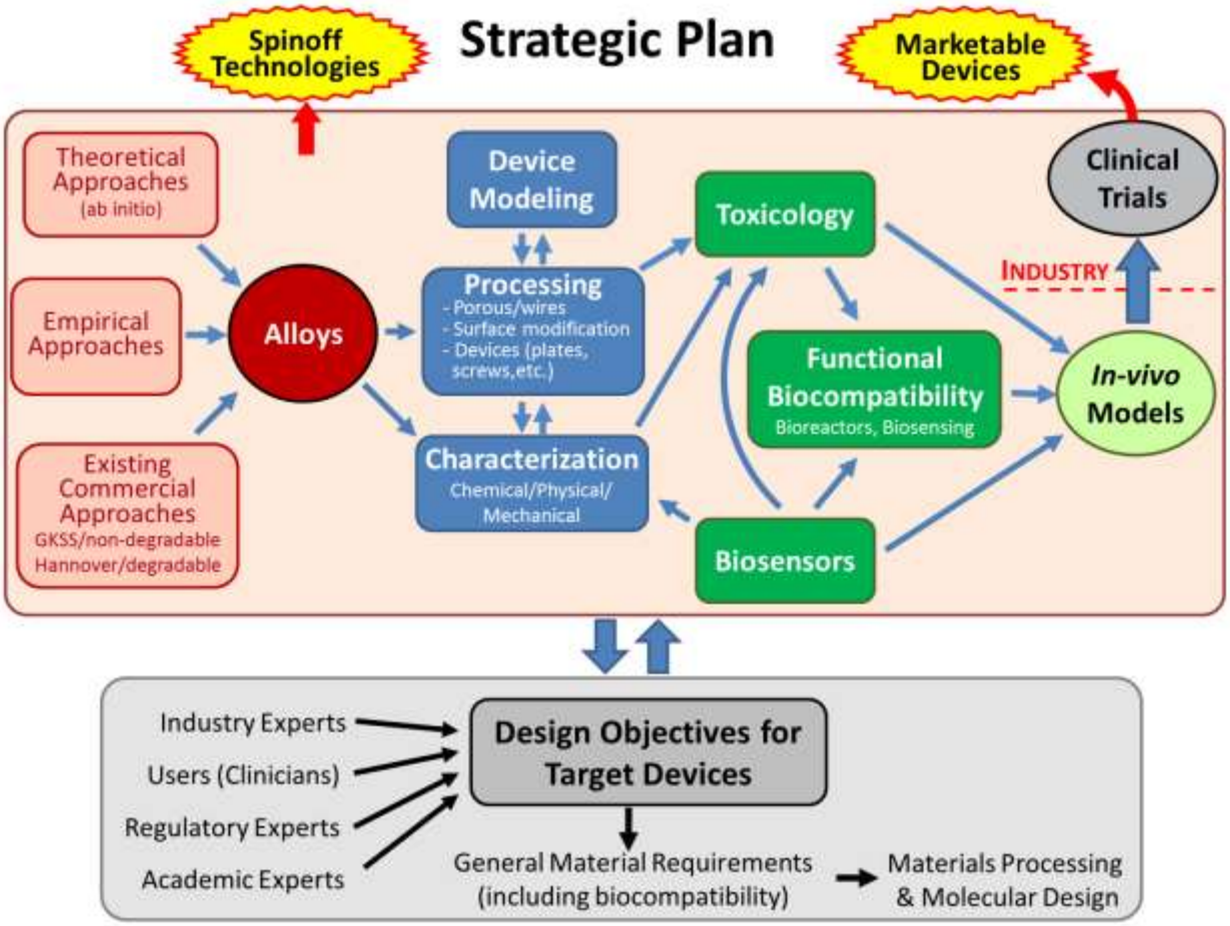
2.8.4 University, State/Local Government Organizations Devoted to Entrepreneurship and Innovation

Partnerships with state and local government and/or academic organizations devoted to entrepreneurship and innovation is an important aspect of Gen-3 ERCs. With needs for job creation serving as a driver, state and local governments are increasingly looking to find ways to support entrepreneurs, and are partnering with universities in this effort. Government agencies look to universities to provide technical support to entrepreneurial efforts, provide training in business basics, and train and develop the workforce required for new ventures to thrive. They also look to universities as the source for innovation from which entrepreneurial jobs may grow, and may have programs to provide some financial support for innovation in business areas targeted by the state for economic development. As such, it is important to engage representatives from these organizations in the ERC, preferably as innovation partners and advisors to the ERC leadership. The relationships built in this fashion will not only help to cement the center’s role in driving regional economic development, but help extent the center’s contacts, as these Government organizations are routinely sought out by entrepreneurs and are accordingly extremely well connected. While the exact nature of these organizations will vary from state to state, the State Department of Commerce is a good starting point for developing these relationships.

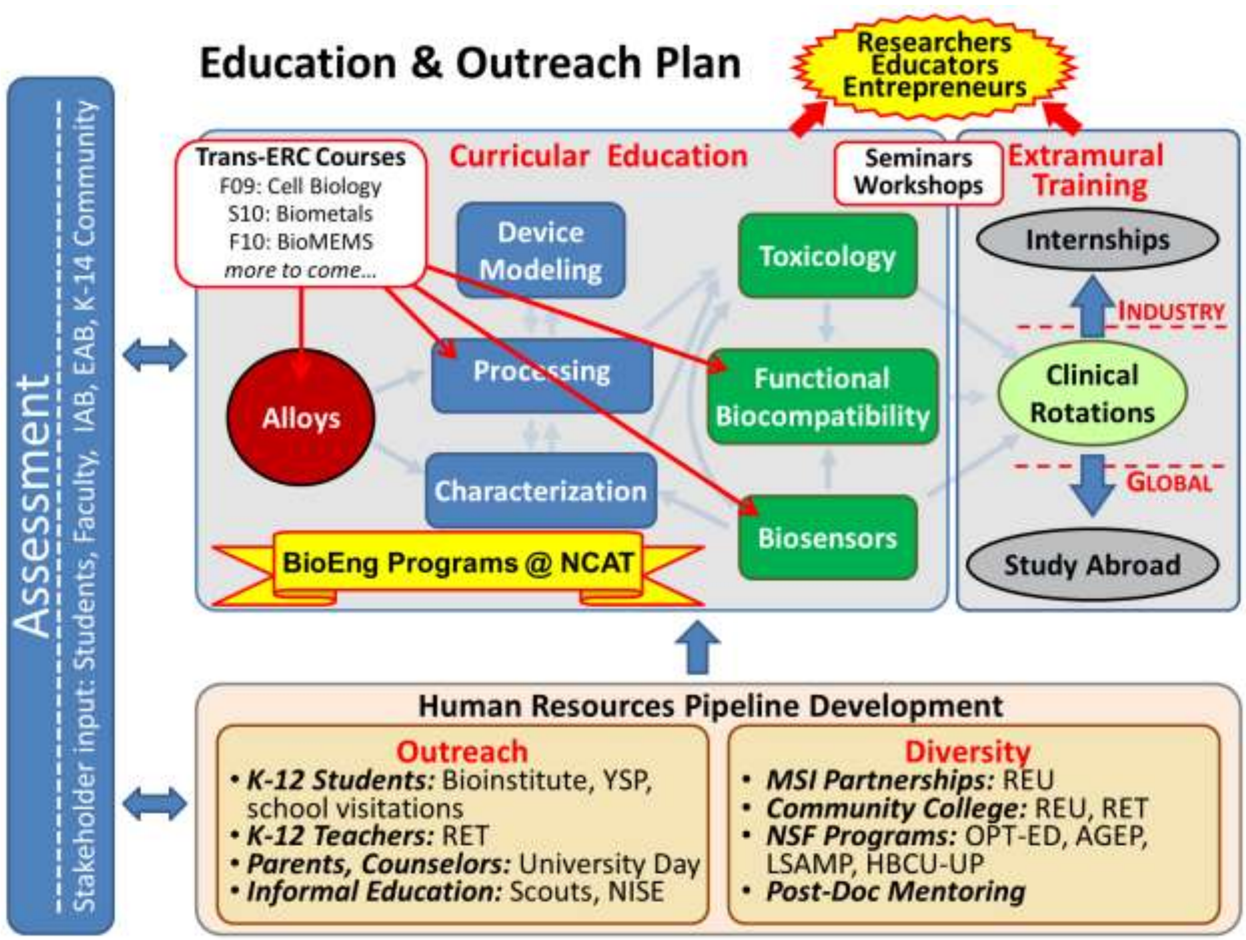
In addition to developing partnering opportunities, these organizations can help provide the ERC with resources needed to enhance entrepreneurship training for students. Many universities have established Centers for Entrepreneurship, and these groups should be formally engaged in the ERC's education and industrial affiliates programs. Similarly, staff and entrepreneurs at local business incubators can provide educational opportunities through seminars, workshops, and mentoring of students.

<u>CASE STUDY;</u>

The integrated research strategic planning and education and outreach strategic planning of the ERC for Revolutionizing Metallic Biomaterials at NC A&T State University (RMB) is one example of an ERC's approach to developing effective collaboration and outreach efforts. Both strategic plans have been carefully developed to be in support of each other, and both plans employ a uniform color coding scheme to demarcate thrusts and pathways and to track the impact of the vision and mission of Gen-3 ERCs from research to education to outreach. All partner (as well as non-partner) universities, colleges, community colleges, and other precollege partners, along with foreign partners/collaborators, federal labs, and academic/state/local government organizations devoted to entrepreneurship and innovation, are embedded seamlessly through these strategic plans, resulting in maximum impact.



ERC-RMB Research Strategic Plan



ERC-RMB Education and Outreach Strategic Plan

2.9 Working with the NSF

The ERC program directors (PDs) and ERC Program leadership at NSF provide an invaluable resource to ensure the success of an ERC. PDs guide each ERC through the annual approval process, which is tied to annual reporting and oversight. PDs also manage the site visit team. Since they often manage other ERCs as well as other grant portfolios at NSF, they can alert you to possible collaborators or competitors. They can be the ERC's best friend, but the ERC director and staff must be responsive to the numerous requests for information that often arise and frequently are urgent. Thus, both sides must commit to making the relationship work in order to succeed. The PD must balance this need with the requirement for objective oversight. The PD must follow the regulations governing the cooperative agreement, but can help the ERC director and staff understand and abide by the agreement.

2.9.1 Establishing a Mutually Supportive Relationship

At first glance, academe could perceive the NSF as simply a funding source for the ERC program, but it is really a partner. Through site visits, conferences, discussions, the ERC Best Practices Manual, and its program leader and program directors (PDs), the NSF is able to share its extensive experience in how the centers can effectively implement cross-disciplinary research programs, develop strategic-driven technology plans including testbed verification of its research, and prepare itself for long-term sustainability. And, the experienced NSF program directors and administrative staff provide a guiding hand as the center matures. Building and nurturing this relationship takes time and often starts before the ERC proposal is submitted.

NSF staff are open to discussing ideas for ERCs. This is a critical step for those aspiring to run an ERC: Go visit NSF at least a few months before the letter of intent is due. Bring a few high-level graphics showing the vision, the systems-level approach, and the team (including industry and education). At this meeting, the NSF staff can provide feedback on the vision, suggest possible partners, and critique, at a high level, the overall approach and strategy. This early feedback is essential to a successful proposal and, in case of success, initiates the relationship with NSF.

Contact with NSF staff during the proposal preparation and evaluation stage is allowed to some degree, but will usually be limited. They can answer some questions, but cannot provide detailed guidance on “what to put in the proposal?”. Obviously, the integrity and confidentiality of the review process cannot be violated. However, once reviews are made available, the NSF staff who were present for the review can often provide clarification of any ambiguous review comments. Such dialogue is extremely important when a pre-proposal has been invited for full proposal or when a full proposal has been selected for a site visit. Particularly for the proposal site visit, it will be important to already have established communication with NSF staff to facilitate site visit planning.

The NSF-ERC relationship that started in the proposal phase must expand and thrive for an ERC to have continued success. The PD is usually willing to work with the center director to help arrange for staff training. Since the ERC program and reporting requirements are unique and challenging, having trained staff from the beginning is important. Annual report data collection need not begin immediately, but should be scheduled as soon as possible. The NSF staff can help the ERC administrative staff understand the breadth and depth of information that needs to be collected and best practices for collecting the data. The NSF staff can also put center administrators in touch with counterparts at other ERCs, who can provide additional guidance. It is important in the first year for the admin staff to be in frequent contact with NSF.

Another critical program element that must be initiated immediately is the industry program. Again, the NSF staff should be considered a partner in making this happen by providing access to experienced industry program directors in other ERCs. In addition, NSF staff can alert center leadership to possible industry partners.

As an ERC nears the end of the 10-year funding cycle, NSF staff is critical in helping develop a sustainability plan. PDs can speak directly to university administration about the need for institutional commitment. PDs can also identify other funding mechanism, both within and outside of NSF, that can help sustain the activity of the center.

Just as it is important for NSF's experience to flow to the ERCs, it is equally important that information regarding the ERC's progress and successes flow effectively to the NSF staff. NSF's ability to demonstrate the value of the program is a critical element of the partnership. NSF will ask for assistance in a number of ways outside of the annual report. These will include production of "highlights," brief research updates on particularly compelling research within the ERC, which are included in the annual report but are also requested on an ongoing basis during the year. If the ERC produces press releases or is interviewed by the media regarding ERC research, it is important to acknowledge NSF support for the research. NSF may host research expositions to highlight particularly innovative projects. ERCs are often asked to contribute to such efforts. NSF may seek to have videos made which are used to promote NSF-funded activities. ERCs should fully support these efforts. Finally, PDs often need information ASAP when finalizing an annual report. They must present ERCs annually to an oversight board to approve the next year's funding and, based on their experience, must be ready to answer questions about the ERC's activities and progress.

2.9.2 The Oversight Process

NSF assesses the success and progress of ERCs in several ways. Annual reports and site visits are important components of this. As mentioned above, year-round communication with NSF program management is key to making both the annual report and the site visit go smoothly.

The annual reports demonstrate the strength of the ERC and the progress it is making in developing a creative and innovative research effort, a viable education program, and an effective outreach to and partnership with other institutions and industry. They also highlight the impact that the ERC has on the industry that is represented by its industrial partners. Other important aspects of the annual report are updates from prior year's criticisms and evidence of cross-disciplinary research within the center. NSF wants to see that the ERC investment is producing more than just a collection of projects that could simply be funded independently. Sections of the annual report can be dedicated to cross-cutting research or innovation to proactively address these issues.

The annual site visit is comprised of the NSF program director, selected staff, and a number of academic experts in areas of technology relevant to the ERCs mission who assess the center's progress and identify opportunities for future focus. It is important to have a good working relationship with the NSF PD, since they will be the conduit through which the ERC communicates with the site visit team. Site visitors will critique the ERC. Although they are not anonymous, the critique is anonymous. That is, the ERC does not know which site visitor authored a specific critique. The NSF PD can be the liaison to the particular site visitor, if more clarification is needed about a specific question. After the site visit report is finalized, the NSF PD is the one person who can provide guidance on how to address the concerns.

Years 3 and Year 6 are critical reviews in assessing the long-term viability of the ERC. The initial award is only for 5 years. If the site visit at Year 3 is unsatisfactory, then the NSF can phase down the ERC and end funding in Year 5. This is rare, but has happened and is extremely detrimental to both the ERC personnel and the NSF, since NSF erred in making the initial award in such a case. To ensure a successful Year 3 visit, it is important to invest in Years 1 and 2 to build credibility and to accept guidance from the site visit team. By demonstrating in Years 1 and 2 a willingness to produce a quality report, enthusiastically engage in the site visit, and respond to site visit criticism in a professional and constructive way, the ERC will set itself up for a strong Year 3 site visit.

The Year 6 review is even more critical because it determines whether the center is mature and adequately positioned for future success. To be favorably evaluated at the critical sixth-year milestone, a mature ERC will need to have achieved world leadership in its chosen field of specialization and must be able to demonstrate that it has effectively built upon its earlier years and that its long-term innovative research effort, education program, and outreach and partnership with other institutions and industry are in place, effective, viable, and sustainable.

2.10 Life After NSF

It is well known that the immediate success of a new or prospective ERC depends heavily on the extent to which the Director's vision engages the ERC's team, university, and industry and also satisfies the NSF Directorate and its site visitors. Likewise, the short-range continuity of an ERC depends heavily on the Director's success in continuously revitalizing the center through the integration of new faculty from within and outside the university. However, long-range success depends on the extent to which the center's continuing partners—the university and industry—value what the center has accomplished in interdisciplinary education and team-based research.

Therefore, it is important to start preparing early, securing support and money for permanent funding, while these stakeholders are still excited about the ERC. Ten years into the center's existence the mood may well shift. The end of NSF funding is not the time to ask for permanent funding for the ERC. The time to ask is much earlier than that, ideally in Years 4-6.

The chances of the center's survival are good. A 2010 survey of 31 graduated centers1[1] showed that more than 80 percent of them continue to be successful university research and education centers of excellence. Most graduated centers weathered the loss of NSF funding

1[1] Williams, J. & C. Lewis. Post-Graduation Status of National Science Foundation Engineering Research Centers—Report of a Survey of Graduated ERCs. SciTech Communications, January 2010.

reasonably well—albeit mostly with reduced funding and fewer faculty, staff, students, and industrial sponsors.

2.10.1 Graduation Planning

It was found in the above referenced survey that, as one would expect, one sustainability approach doesn't work for all centers. While the pieces of the puzzle are similar for all situations, no particular "hot buttons" correlate exclusively with success or failure, because the transition process is impacted by several factors.

Virtually all graduated centers report that the NSF ERC culture involving integration of research, education, and industrial interaction with a focus on cross-disciplinary, engineered systems research was extremely helpful in strengthening and sustaining the center before, during, and after graduation and should be a key element of the transition planning.

In planning for graduation, it is important for the center to define its stakeholders—faculty, staff, industrial partners and university administrators—and have as many of them as possible involved in creating the sustainability plan and making decisions about what stays and goes. The plan should reflect the interests of as many stakeholders as possible, and one effective planning technique that involves many of the stakeholders is to hold a sustainability retreat early in the center's life to create a roadmap for sustainability. This approach manifests a sense of "ownership" and commitment among stakeholders, making them part of the new, broader vision.

A realistic transition strategy builds on and enhances a center's strengths, including its position at the forefront of its discipline. The most successful of the current graduated centers focused on building on their previous successes, enhancing their existing areas of technology, and expanding their collaborations with industry and other federal agencies to obtain major grants in those technologies. This approach better defines the center's core technologies, makes necessary staffing changes, and increases focus on the present and future technologies relevant to industry and federal partners. These centers continue to build on what they are best at, much like successful companies that work at exploiting their core technologies and avoiding diversion into areas inconsistent with their strengths.

The vast majority of successful graduated centers reported changes in their overall field of research or industry since graduation, and most of them found the changes actually made the transition process easier. Changes cited included shifts from commodity to high-value-added materials that benefited graduated ERC testbeds and testing facilities, and the maturation of research areas into more diverse activities involving new strategic thrusts and basic research. Almost all of them have also instituted new research programs because of changes in their field of research; about half have experienced major thrust area changes, including expanding, narrowing, and becoming more strategic.

It is also important to remember during graduation planning that the graduated center will almost certainly undergo changes in overall funding that must be planned for—most likely reductions and the attendant reductions in the number of faculty and both undergraduate and graduate students involved. Successful graduated centers have had to deal with funding changes ranging from reductions of as much as 90 percent to increases as much as ten-fold.

Transition from NSF funding has broad ramifications, and the center programs that are most at risk are the same ones which NSF funding was likely used to put in place to begin with: basic research; programs and support for undergraduate students; STEM-related outreach programs for K-12, women, and minorities; and center infrastructure (including staff)—and it must be recognized in planning that they will be more vulnerable to reduced funding. Graduate education also can be affected. Key to the survival of these components is whether the lead university sufficiently values them.

Most successful graduated centers developed transitional plans that increased both the level and diversity of funding after graduation. Actions have included pursuing state and private foundation funding, increasing industrial collaboration, and increasing funding from federal agencies, as well as becoming more aggressive and active in submitting proposals and identifying funding opportunities.

2.10.2 Restructuring the Relationship with Industry

The center's relationship with industry is an important component of both its long-range continuity and its effectiveness in giving substance to its vision. Today's "leaner" companies believe they cannot afford large, esoteric, and unfocused research groups, any more than they can afford to send their people to yet another set of dry academic seminars. However, the fact remains that most of the groundbreaking research on which modern industries are based was and is conducted in universities.

The ERC that successfully makes the connection between university-based research and real industrial needs may outlive most of its faculty. A strong ERC can spin off companies with a real chance for survival and/or integrate itself into the planning process of companies to form functional strategic partnerships. Most of them have achieved an impressive body of advances in knowledge and technology and have been responsible for many major products and processes commercialized by industry. ERCs are usually highly valued by industry because they focus university research at a point where industry can grasp and exploit it, and because they produce a steady stream of uniquely cross-trained, team-oriented graduates who are likely to eclipse their peers in creativity and productivity. There is enough potential at the industrial interface to "power" a center indefinitely without NSF funding, but the director must harness the support of the university to preserve the essential strengths and distinctions of an ERC.

The foundation for a successful external relations strategy lies in building mutually beneficial, long-term relationships, which provide the basis for collaborations and partnerships. It is a nearly universal finding that personal interactions work best. In addition to the obvious approaches of pursuing increased industry funding, encouraging continued support by existing members, recruiting new members, and initiating industry-targeted precompetitive research projects, graduated centers have also developed programs and formalized methods that include industrial affiliates programs at several levels.

Some of the more successful approaches include research collaborations; visiting scholars (industry professionals working on campus for an extended period of time); seed-grant initiatives; industry-sponsored research; intellectual property licensing; teaming to win agency-sponsored programs; small state grants for local, small, and start-up companies; increased use of testbeds and fee-based testing services; increased emphasis on intellectual property development to spawn new start-ups, and increased industry input into new research projects; student internships and fellowships; and help with hiring students and negotiating the labyrinth of the university. Students spending time doing research at industry sites have fostered strong relationships with their industry hosts. Persuading industry personnel to visit an ERC even briefly (e.g., for one-day seminar visits) invariably brings surprised and highly positive reactions to what the center is accomplishing.

The center's research interests and programs will likely evolve during transition, with increased focus on short-term problems that satisfy the needs of its industrial partners and new, evolving, and tangential areas of research that did not exist when the ERC was founded.

A substantial majority of the graduated centers continue to receive guidance from an industrial advisory board and operate with a center-wide industrial membership and intellectual property agreement. Most of the advisory boards, however, have seen changes since graduation, including a transition from using a member-based model to a sponsored research or research area model, flexible membership fees based on research scope, expanded membership options, and increased focus on larger companies. Some graduated centers have changed their IAB strategies several times as the scope of their research areas has changed.

2.10.3 Positioning the Center Within the University

Most graduated ERCs reported that the program has had a long-term positive impact on the engineering research and education culture in their academic field and on their home institution. ERC status is considered a major contributor to the prestige and standing of universities, the academic departments involved, and the individual faculty members who are part of the ERC.

Therefore, it is not surprising that most of their university's policies have continued to be supportive of the ERC culture and have shown strong commitment to their survival during the transition process. The continued commitment of the university to the graduated centers is obviously key to the center's continued sustainability. Centers report that this support has ranged from (in most cases) a high level of continued financial assistance for a specified number of years to (for a few) an almost complete lack of interest in whether the center continued to exist at all.

It is crucial to begin building a case early for the center's graduation within the university. All participants in the center, not just the Director, should be involved. The industrial liaison specialist should become involved with the university's technology transfer people by sharing information, experience, and resources. There are many ways that the education director could share resources with the existing units on campus and make its value known. The AD continuously works as a liaison with the university's administrative network and, while often compromising to accomplish things, is able to air the center's perspective. The communications director is able to network with traditional departments, the college and university communications staff, and the outside world. If the center has found a better way to do something, share it. At every opportunity, center participants should get others within the university on their side so they would be missed if they weren't there. Everyone has a chance to make themselves indispensable by becoming actively involved in campus activities. Always think beyond the center!

There are several university-related issues that need to be resolved before an ERC graduates from NSF support to self-sufficiency. These include funding, space, and administrative position. Other potential casualties of reduced NSF funding are team orientation, the engineered-system focus, and interdepartmental collaboration.

Negotiating sufficient spacefor labs and testbeds and establishing synergistic relationships among the different academic departments required to implement new research thrusts is a challenge facing most graduated ERCs. In the best of cases, it may take a year or more to negotiate a permanent position for an ERC in the university structure. Since resources may be controlled by several different levels in the university (e.g., the Dean and upper administration), there are several negotiations that must successfully be navigated. In addition, chances are the initial agreement may have to be renegotiated more than once due to administrative turnover before a stable, long-term agreement is reached. The ERC requires a plan and positive leadership during this period to maintain high morale, with the Center faculty moving forward together. Whatever the agreement, it should be in writing, since verbal agreements are easily misunderstood.

Graduated centers typically receive transition funding and continued support from the university in the range of $50K to $1M per year. Financial assistance varies from direct cash contributions to equipment donations, to allocation of research facilities, to administration staff and seed funding support, to graduate student support through waivers and fellowships, to allowing the center to retain all or part of the indirect cost recovery associated with all or some of its research grants, to sharing income from technology licenses, to cost sharing on new proposals put out by the center. The ERC can directly influence the university's ability to create discretionary income by generating more contracts, banking more discretionary funds, admitting more students, and generating seed funding to start new ideas that can eventually mature into self-sustaining multidisciplinary research projects.

It is also important to establish where in the university hierarchy the newly-graduated ERC Director will report. This has a direct impact on strategic planning and promotion of center personnel. It is important that center personnel sit on both the faculty and administrative promotion committees to represent the unique perspective of multidisciplinary research. In addition, the ERC should be an integral part of the administrative strategic planning process, not only to ensure stability for the ERC but also to inject new perspectives into the strategic planning process.

<u>CASE STUDY:</u>

Adding the Systems Research Center (SRC) to the University of Maryland in 1985 brought prestige to the university and the A. James Clark School of Engineering. Because NSF chose the

Clark School to be the home of one of the first six ERCs, the college became recognized as a place of quality and excellence. It is difficult to imagine what a huge accomplishment this was at the time.

The university and its colleges benefitted from the association with the SRC in the key disciplines such as systems science and engineering, certainly, but also in electrical and computer engineering, mechanical engineering, and chemical engineering within the Clark School. The Robert H. Smith School of Business and the College of Computer, Mathematical and Physical Sciences also benefitted from the joint appointments.

The SRC, with its deliberate interdisciplinary focus, was the catalyst that jump-started interdisciplinary research at the university. Today this intellectual cross-fertilization is much more common. But in 1985 such concepts were quite new. There is no question that interdisciplinary research at the University of Maryland grew much faster because of the SRC's presence.

By the early 1990s, faculty were being drawn to the University of Maryland specifically to work in the SRC. Upon graduation, the SRC was renamed the Institute for Systems Research (ISR) and achieved line-item funding in the state budget—a major achievement. Today, faculty within the university still eagerly seek joint appointments or affiliations with the institute. The collegial atmosphere created by ISR among faculty from many different disciplines leads to collaborating on proposals for interdisciplinary research, with a high level of innovation.

Yet, ISR has found it difficult to maintain its share of state funding within the college and the greater university. It often disproportionately bears a greater burden of cutbacks than departments within the college. The shrinking number of ISR staff over the past decade is one indicator of this continual struggle. ISR's self-support model has become ever more entrepreneurial to maintain self-sufficiency.

It is a never-ending task to internally remind the university about the Institute and its worth. ISR has found through the years that it needs to heavily promote itself, its mission and its value to the university, not only to counteract assumptions and misconceptions, but simply to remain visible.

ISR has learned that universities are driven by impact, that long-term impact is far better than short-term impact, and that qualitative, transformational impact is far better than a just a list of statistics. The best metrics of impact for engineering are ISR graduates and what they achieve; industrial practice and creation of new sectors; patents and inventions that lead to innovations that change an industry sector or the way people work and live; seminal publications that change the knowledge base or the way people think; new courses, books, and ways to educate and train; and the international stature of faculty and programs.

[1] Williams, J. & C. Lewis. Post-Graduation Status of National Science Foundation Engineering Research Centers—Report of a Survey of Graduated ERCs. SciTech Communications, January 2010.

2.11 Summary Observations

As was noted at the beginning of this chapter, the job of directing an ERC is all about choices. No one should choose this powerful and prestigious position if s/he is not fully committed to the stated objectives of the ERC Program and to its values of team-oriented, industrially relevant, interdisciplinary research. The Director of a new ERC must choose the extent to which s/he will delegate and the areas over which s/he will retain effective control. Choices also are implicit in the assembly of the team that will apply for the ERC, and of the teams that will run the center at all stages of its development. A balance of research talent and commitment to the center's vision is essential, and interdisciplinary education and technology transfer will not reach their full potential unless the Director chooses his/her teams wisely. It is naive to expect that every center faculty member will excel in all center activities, but a subset must be capable of world-class work in each of the major areas of research, education, and technology transfer.

Within the university framework, an ERC Director must chose his/her style of interaction. A measure of persuasion and firmness may be necessary to obtain contiguous space at the outset, and to take full advantage of the university's pledges of support for the center. As the center matures and begins to concentrate on the continuity of its research, education, and technology transfer programs, cooperative relationships with allied departments and the appropriate parts of the university hierarchy come to the fore. Mutually beneficial recruitment is the Director's most potent asset in this matter and a confrontational approach by a mature center may leave it surrounded by enemies at a time when it most needs friends. It is the stated intent of the ERC Program that the centers should make lasting changes in university education and also sharply improve the competitiveness of American industry; and most ERCs actually accomplish these objectives. Clever recruitment and excellent relationships within the university can extrapolate these changes by passing the center's vision to the university departments and faculties that constitute the operative research-education-technology transfer mechanism of our university system.

In summary: Be faithful to your vision; articulate your vision to draw together a team of like-minded colleagues; and keep the dream fresh by adding new people who can move with the field.

Appendix A Contributors

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Chapter 3: Research Management

3.1 Introduction

3.1.1 Overview

This chapter addresses best practices for research thrust leaders, the research team leaders who are positioned on the Engineering Research Center (ERC) organizational chart between center directors and individual faculty researchers, with responsibility for one of several “thrust” areas within the center’s overall research program. Although aimed at ERC research thrust leaders, the chapter’s content may also be of value to other members of a center’s leadership teams (e.g., directors and deputy directors, faculty, testbed leaders, and industrial partners).

This section begins with background summarizing the quarter-century experience from which these best practices have emerged, followed by an explanation of the importance of research thrust leaders and the challenges they face. Perspectives on the types of best practices discussed in this chapter are then followed by a roadmap of the remaining sections.

3.1.2 Background

The National Science Foundation's ERC Program has, since the mid-1980s, supported centers to join universities and technology-based industries in focusing on next-generation advances in complex engineered systems (see Endnote 1). To enable a long-term collaboration, ERCs are funded for 10 years (11 years in the early days of the program). Of the more than 50 ERCs formed since the program began, 13 are currently being supported as of late 2010, with five more planned for initiation in early 2011; 29 of the 35 "graduated" centers are still in operation and self-sustaining (Endnote 2)

ERC activities are at the interface between the discovery-driven culture of science and the innovation-driven culture of engineering. ERCs have created synergies between science, engineering, and industrial practice while facilitating industry collaboration with faculty and students. Through ERCs, partnerships that strengthen academic contributions to U.S. industrial competitiveness have been formed, many undergraduates have become involved in focused research, and the knowledge and experiences of engineering graduates have been broadened.

Against the backdrop of an increasingly global economy in which U.S. competitive advantage rests heavily on innovation, five third-generation ERCs were established in 2008. These Gen-3 ERCs reflect the proven results of earlier ERCs but, with a greater emphasis on innovation, look to establishing more and stronger partnerships with small firms and startups, other entrepreneurial organizations, and foreign universities.

3.1.3 The Importance of Research Thrust Leaders

As the name implies, research and engineering are at the heart of ERCs. *Within the ERCs, research thrust leaders are at the heart of research management. They are the ones expected to lead a diverse group of researchers to deliver on ERC research and technology-translation goals in a timely manner and within a limited budget.*
Being a research thrust leader is challenging—a far cry from a simple research advisory role. It is the classic middle-management situation. Often research thrust leaders are:

- not in control of their research budgets;
- not involved in all decisions or interactions affecting their projects;
- not (in many cases) at the same location as the main lead institution; and are
- not provided additional compensation for time spent in their leadership role.

Despite these challenges, they are responsible for organizing a team of relatively independent investigators to deliver on a common thrust-level goal and are expected to lead the projects in their areas of responsibility to successful completion. The success of the ERCs in the overwhelming majority of the cases proves that they are able to accomplish this task.

3.1.4 Best Practices for Research Thrust Leaders

Many general management principles have proven useful over the years to guide research, development, and engineering endeavors and create competitive advantages (see, for example, Endnote 3). These principles include:

- Good top-level leadership with demonstrated commitment
- Strategic organizational vision and planning
- Adequate human capabilities and financial resources
- A customer focus
- Value creation
- An enduring focus on quality
- Good metrics for measuring inputs, outputs, and outcomes over time.

This chapter accepts such principles as valid bases for successfully managing highly technical efforts. However, it reaches beyond these layers of generality to describe the "how-to" methods that practicing ERC research thrust leaders have found to work in their real world. In other words, this chapter focuses on "best practices" gleaned from years of ERC experience.

The following list sets forth broad areas in which best practices are addressed in this chapter:

- Defining the roles and responsibilities of research thrust leaders in the context of developing strategic plans at ERCs
- Executing pragmatic approaches for strategic plans, such as sustaining buy-in of plans, enhancing communications up and down the ERC leadership chain and across the various thrusts, and developing and using metrics to assess ongoing projects
- Integrating the center's research efforts, both with the long-range needs of industry partners and with the education activities of partner universities.

Naturally, all of this has to recognize that ERCs vary in many ways. For instance, there are differences in numbers and locations of partnering universities and industries; internal organizations, policies, and procedures; heterogeneity in problem solving; and types and numbers of disciplines involved, as well as in the basic technology fields and industrial sectors on which the centers focus.

In other words, best practices for research thrust leaders at one ERC are not necessarily the best fit at another. So, *in considering the best practices that follow, research thrust leaders must adapt the concepts to the particulars of their own ERC.*

3.1.5 Chapter Roadmap

Sections 3.2 and 3.3 tackle two of the most important elements of good research management—development of a strategic plan and its execution. Section 3.4 deals with integrating the research and the industry partners. Section 3.5 addresses the integration of education and research. In each of these sections the emphasis is on best practices—solutions that have been found to work in real ERC situations. Practical examples or case studies are included in each section to illustrate the best practices. Recognizing the newness of Gen-3 ERCs, Section 3.6 looks into similarities and differences in best practices that might apply to these partnerships. This section also suggests ways to develop Gen-3-specific best practices.
Section 3.7 identifies the key contributors to this chapter, and Section 3.8 furnishes sources and references in the form of endnotes.

3.2 Best Practices for Strategic Planning

3.2.1 Strategic Planning is Important

Each ERC develops a top-level strategic plan for all of its operations using the ERC Program's 3-level strategic planning chart that depicts how engineered systems goals guide and motivate the center's fundamental research, enabling and systems technology research, and testbeds. The core of the plan contains the major elements involving research—a research strategy that reflects and supports the ERC vision plus a comprehensive plan that:

- Covers the three levels of ERC research (i.e., fundamental knowledge, enabling technologies, and engineered systems)
- Identifies clear barriers in the way of achieving the systems goals
- Identifies clear research goals derived from those barriers, by thrust and overall, as well as milestones for their achievement
- Contains adequate human and dollar resources
- Articulates metrics for measuring progress toward final completion of individual projects.

Amplifying these general guidelines, five strategic-planning best practices for research thrust leaders are described below.

3.2.2 Clearly Define Roles and Responsibilities

The strategic plan must define fully the roles and responsibilities of the thrust leader, each member of the team, and their relationship to the rest of the leadership team—

from the top to the bottom. Full definition encompasses three elements:
1) the reporting structure within the ERC;
2) how decisions are made on funding or discontinuing a project; and
3) an appropriate balance of industry interests against long-term research goals.
Aspects of the following best practices contain elaborations of these three elements. However, definition of roles and responsibilities has to include the added mandate that research thrust leaders must be delegated *authority* commensurate with their responsibilities. In other words, the thrust leaders cannot be held *responsible* for leading if they do not have sufficient authority to do so. This problem is generally avoided if thrust leaders are able to participate in early strategic research planning, are included in the ERC's leadership team, and can negotiate their role as members of that team to fulfill the thrust's/ERC's goals.

Management references often contain discussion of authority accompanying responsibility. For example, *"Typically, an employee is assigned authority commensurate with the task. ... When an employee has responsibility for the task outcome but little authority, accomplishing the job is possible but difficult. The subordinate without authority must rely on persuasion and luck to meet performance expectations."* (Endnote 4.)

3.2.3 Capture the Components of a Good Plan

A good strategic plan has many components. Inclusion of the following components is very important:

- An ERC has to establish a team culture versus the more traditional, individual-research culture, both intra- and inter-university;
- Ensure that the overall ERC vision and mission are articulated in the plan and shared by those in the research thrust leader's area of responsibility;
- Define resource and budget needs, given the goals;
- Lay the groundwork to take advantage of the best communication technology (e.g., to facilitate "brainstorming sessions" and other necessary interactions).
- Define succinct deliverables and outcomes on reasonable timelines.

3.2.4 Define a Structure for Adjusting the Plan

Research thrust leaders should never assume that, once a plan is completed, it will not need to be changed. In fact, change is more likely the norm. Therefore, at the outset a structure must be defined in which adjustments or corrections relating to the research plan can be made. Among other things, this type of structure would ensure that financial resources can be distributed or redistributed, both within and among universities.

To help measure progress and determine adjustments, metrics should be defined for successful research within an ERC. Proper metrics should not be just numbers of papers published or students graduated. Rather, they should:

- Measure each project's contribution to the thrust, such as advancing the testbed
- Exhibit an incentive to improve the thrust
- Consider additional funding from other non-ERC Program sources, attracted by the ERC's research
- Take account of industry funding obtained for the thrust.

3.2.5 Ensure the Research Tasks Can be Accomplished with the Resources Allocated

Despite the fact that budget reallocations will probably be needed at times, the initial plan should contain budget estimates that adequately cover the research tasks as well as the necessary administrative and management support. Don't volunteer to do too much for too little. Since budgets are likely allocated in the beginning from top levels of the ERC downward, be sure the plan contains commitments to do only what the budgeted resources will allow, and no more.

3.2.6 Create a Transparent Organizational Structure

A transparent organizational structure, preferably one that is "flat," should be created and set forth in the plan. This type of structure would succinctly identify the various interactions and dependencies that exist, both within individual thrusts and between thrusts.

3.2.7 Examples

The following excerpts are from the strategic research plans of three ERCs [1-Synthetic Biology Engineering Research Center (SynBERC, with overall objective: enabling technologies); 2-Mid-InfraRed Technologies for Health and the Environment (MIRTHE, with overall objective: enabling technologies); and 3-Collaborative Adaptive Sensing of the Atmosphere (CASA, with overall objective: specific system product). The excerpts furnish examples of the general strategic planning guidelines and best practices described in this Section 3.2.
Note that the objective statement for each ERC signifies the type of overall goal for the center. There is a difference in strategy when the goal is a very specific system versus breakthroughs in process or understanding that would make possible a variety of different system developments.

Referral to the planning details for the individual research thrusts contained in these and other ERC plans should further expose research thrust leaders to a range of strategic planning approaches. *Nevertheless, each thrust leader faced with developing strategic plans should try to ensure that the best practices outlined in Section 3.2 above are accommodated, regardless of past or current practices at any particular ERC.*

3.2.7.1 Addressing the Three Levels

ERC strategic plans normally display the standard "three-plane diagram" showing effort devoted to fundamental knowledge (bottom plane), enabling technologies (middle plane), and engineered systems (top plane). Although involved most heavily in the lower planes, research thrust leaders must recognize the great importance of their work to achieving success in the top plane.
To portray a variety of concepts, several three-plane diagrams appear below (see Exhibit 3.2.7.1(a-c)). The last (c) has text associated with it as an aid to understanding the diagram in subsection 3.2.7.2.

EXHIBIT 3.2.7.1 (a)

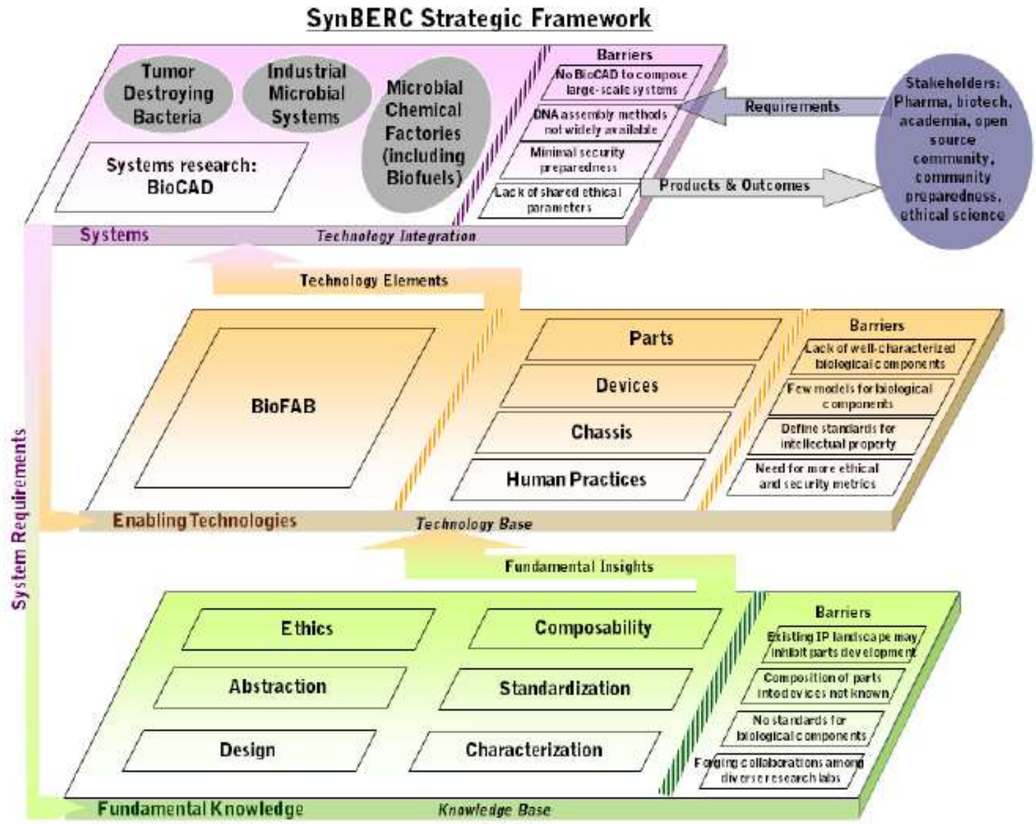
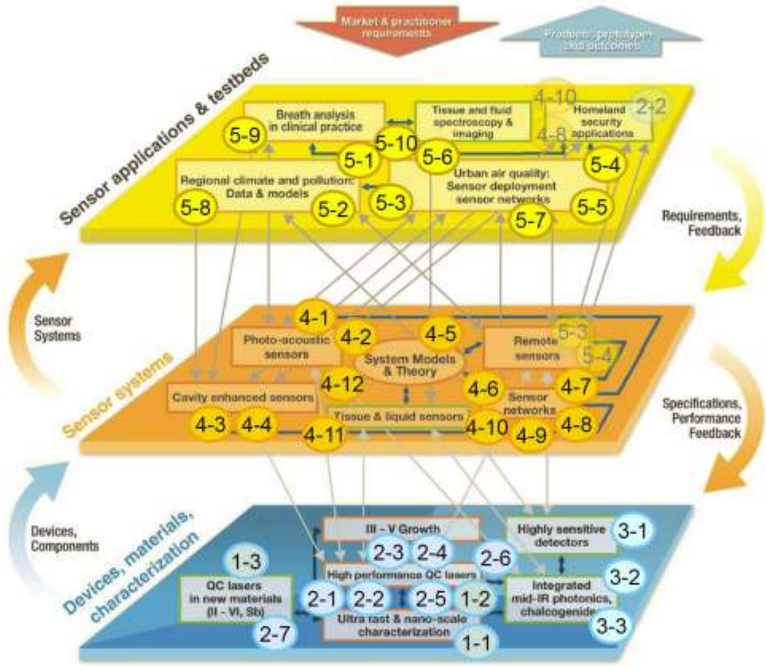


Figure 5.1-1. SynBERC three-plane strategic diagram. Last updated January 4, 2010.

EXHIBIT 3.2.7.1 (b)



Project assignment to MIRTHE's 3-level ERC strategic framework

Thrust –index	Project name …
5–1	Coupled Water, Carbon, and Nitrogen Cycles in Urban Environments
5–2	Coupled Water, Carbon, and Nitrogen Cycles in Urban Environments
5–3	Monitoring Trace Gas and Aerosol Properties in the Urban Environment
5–4	Monitoring Trace Gas and Aerosol Properties in the Urban Environment
5–5	Nitrous Oxide Instrument Development Using a Single Mode, Continuous Wave,…
5–6	Ultra Sensitive Ammonia Sensor for Urban Air Quality
5–7	Monitoring of Ammonia Mixing Ratios in Houston Using MIRTHE Technology
5–8	Gas Sensing Using Mid-Infrared Technology in Fish-Smoking Areas In …
5–9	Breath Ammonia in Humans, a Pilot Study
5–10	Development of Mid-Infrared Based Instrumentation for In Vitro Toxicity Testing

Thrust –index	Project name …
4–1	Development of Quartz Enhanced Photo-Acoustic Spectroscopy Based …
4–2	Development, Verification, and Validation of Three-Dimensional Models for …
4–3	Development of Trace Gas Sensor Platforms for Applications in Health , …
4–4	Development of External Cavity Quantum Cascade Lasers with High Speed, …
4–5	Develop Statistical and Deterministic Signal Processing Algorithms for …
4–6	Development of Ultra-Low Power, All-Digital-Signal-Processing Laser-Based …
4–7	Gas Sensing Wireless Networks
4–8	Optical Transmission and Signal Cancellation Techniques in Sensor …
4–9	Integrating MIRTHE Sensors into Wireless Meteorological Sensing Networks
4–10	Securing Sensor Networks
4–11	Mid-Infrared Cancer Detection and Monitoring
4–12	Confocal Microscopy Based on Quantum Cascade Laser and Single Hollow Core …

Thrust –index	Project name …
3–1	Novel Mid-Infrared Sources and Detectors Based on Resonant …
3–2	Photomodifiable Chalcogenide Glass Materials for Integrated …
3–3	Chalcogenide-on-Lithium Waveguides
2–1	High Performance (Threshold, Power, Efficiency) Quantum …
2–2	Spectrally High-Performance Quantum Cascade Lasers
2–3	3-5 µm Quantum Cascade Laser Gain Materials
2–4	Broadband Quantum Cascade Laser Gain …
2–5	Modelocking of Quantum Cascade Lasers
2–6	Integrated Tunable Quantum Cascade Lasers
2–7	Solid State Mid-Infrared Lasers Pumped by …
1–1	Nanoscale Characterization of Metal Organic Molecular Beam …
1–2	Mid-Infrared Ultrafast Diagnostic Instrumentation for Quantum Cascade …
1–3	Wide Bandgap II-VI Semiconductors for …

EXHIBIT 3.2.7.1 (c)

SECTION 2 - STRATEGIC RESEARCH PLAN AND OVERALL RESEARCH PROGRAM

2.1 STRATEGIC RESEARCH PLAN

The innovation being pursued in the CASA project is to supplement - or replace - the present national network of 150 large weather radars with thousands of small radars that can be deployed on cellular telephone towers, rooftops and other infrastructure. The closer spacing of the new radars will avoid the obstruction caused by Earth curvature and allow forecasters to directly view the lower atmosphere with high-resolution observations. This new dimension to weather observing leads to improved characterization and better forecasting of storms, resulting in improved warning and response to tornadoes and other hazards. In addition to the many engineering challenges associated with the radar network itself, software architectural problems to be solved include managing the system's many resources and data volume and designing an effective user interface. The central challenge is in designing and deploying a system that can sample the atmosphere where and when the user need is greatest to reliably issue alerts that the public trusts and responds to appropriately.

The solutions to the different problems posed by this project are to be found through CASA's working on three planes of engineering research as shown in figure 1. CASA's system focus (upper plane) is a real-time distributed system capable of focusing its resources onto particular sub-volumes of the atmosphere and delivering forecasts and other data that enable forecasters, emergency managers and the public to generate accurate alerts and make effective decisions when weather strikes occur. Realizing an effective and

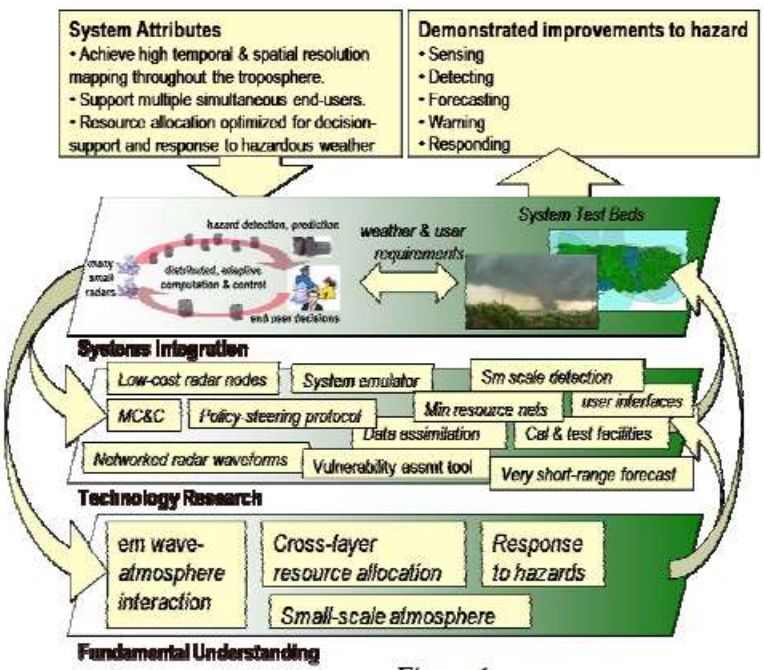


Figure 1.

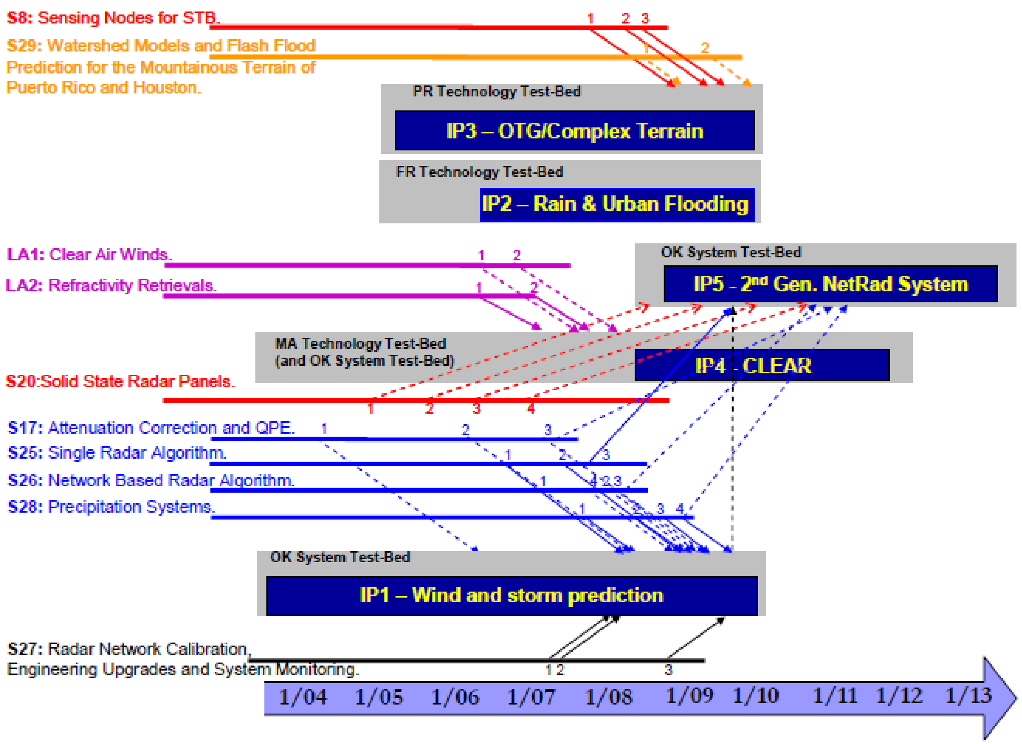
efficient system requires creating a number of new enabling technologies (middle plane) and conducting fundamental research to create new knowledge (bottom plane). Multi-disciplinary research in the lowest plane spans several disciplines, from electrical engineering investigations of how electromagnetic waves interact with the atmosphere, to atmospheric science investigations related to detecting and forecasting storm cells at high resolution, to computer science investigations related to resource optimization, to sociological and decision-theoretic studies about how individuals and organizations respond to severe weather hazards, utilize warnings and ultimately take protective action. Whereas the lowest plane tends to be the "comfort zone" of academic faculties, CASA's strategic concept is an interdisciplinary orchestration of work in all planes, from the definition of the system in the upper left, through targeted technology and fundamental

3.2.7.2 Identifying Clear Goals and Milestones

The CASA thrust-level example below (Exhibit 3.2.7.2) amplifies the general guideline of identifying clear goals and milestones by emphasizing the best practice of *defining succinct deliverables and outcomes on reasonable timelines*. This project-level milestone chart extends the CASA three-plane diagram shown in Exhibit 3.2.7.1 (c) above.

EXHIBIT 3.2.7.2

The milestone and deliverable chart for the Sensing thrust are shown in Figure (17). Sensing hardware (S27) and algorithms (S17, S25, S26, S28, and LA2) were extensively tested, evaluated, and improved through the successful operation of IP1 radar network. Other significant completed milestones include development and installation of sensing nodes (S8, S20), system calibration for IP1 operation (S27), system planning of test beds (S8, LA1), and application development (S17, S28, S29, LA2). The sensing system design of DCAS systems progresses through the IP1 test bed and the IP3 test beds, following system engineering approaches and CASA's strategic plan, and then progresses into the design of the IP5 test bed. The exploration of new processing algorithms and network based system models is on going with actual radar observations of the IP1 system level test bed.



S8.1 First OTG radar installation in Puerto Rico	05/09
S8.2 Second OTG radar installation in Puerto Rico	08/09
S8.3 Cross-validation of PR1 radar and OTG radars	12/09
S17.1 Operational attenuation correction algorithm	04/06
S17.2 Development of IP1 rainfall estimation system	07/08
S17.3 Development of IP1 hydrometeor type classification	07/09
S20.1 Antenna and TR module performance review	04/08

S20.2 Antenna and TR module fabrication	05/09
S20.3 Radar system integration	03/10
S20.4 Field test at MA1 / CSU-CHILL	06/10
S25.1 Dynamic waveform selection and processing	06/08
S25.2 Digital waveform generator	04/09
S25.3 Integration of wideband waveform with solid-state transmitter	12/09
S26.1 Real-time implementation of network reflectivity retrieval	10/08
S26.2 Implementation of networked waveform system	07/09
S26.3 Statistics of rain attenuation in IP1 network	08/09
S26.4 Interface Q-function algorithm with MC&C	06/09
S27.1 Implement networked waveform structure	02/08
S27.2 Implement clear air mode	03/08
S27.3 Transition to IP5	12/09
S28.1 Real-time implementation of DARTS	06/08
S28.2 Including DARTS nowcasting in MC&C	04/09
S28.3 Scale analysis for nowcasting	10/09
S28.4 Evaluation of network resolution enhancement system	12/09
S29.1 Prototype real time flood alarm system	05/09
S29.2 Radar rainfall mapping in STB	03/10
LA1.1 Statistics of insect scattering	02/08
LA1.2 Analysis of scan strategy for insect scatters	06/08
LA2.1 Implement real time refractivity retrieval	10/07
LA2.2 Clear air scan for refractivity measurement	05/08

***Figure 17.** The milestones and roadmap for Sensing thrust research*

3.2.7.3 Adequate Human and Dollar Resources

Exhibit 3.2.7.3 (a) shows the range of human resources needed by one ERC for its research program. This diversity of participants underlines the importance of best practices that establish a group culture, share the overall ERC vision and mission, and make use of the best communication technologies.

Rather than providing examples showing dollar resources that are merely accumulations of pages of ERC cost estimates by research project, the second exhibit below (3.2.7.3 (b)) amplifies a part of the best practice of defining a structure for plan adjustments, which could include financial adjustments. The example suggests that the original resource estimates may have been a bit short, which highlights that a priority emphasis for strategic planning should be on ensuring that the research tasks can be accomplished within the originally allocated resources—

requests for later “adjustments” in the form of budget increases will not likely be received favorably.

Another example of adjusting the original strategic plan appears in subsection 3.3.8.1.

EXHIBIT 3.2.7.3 (a)

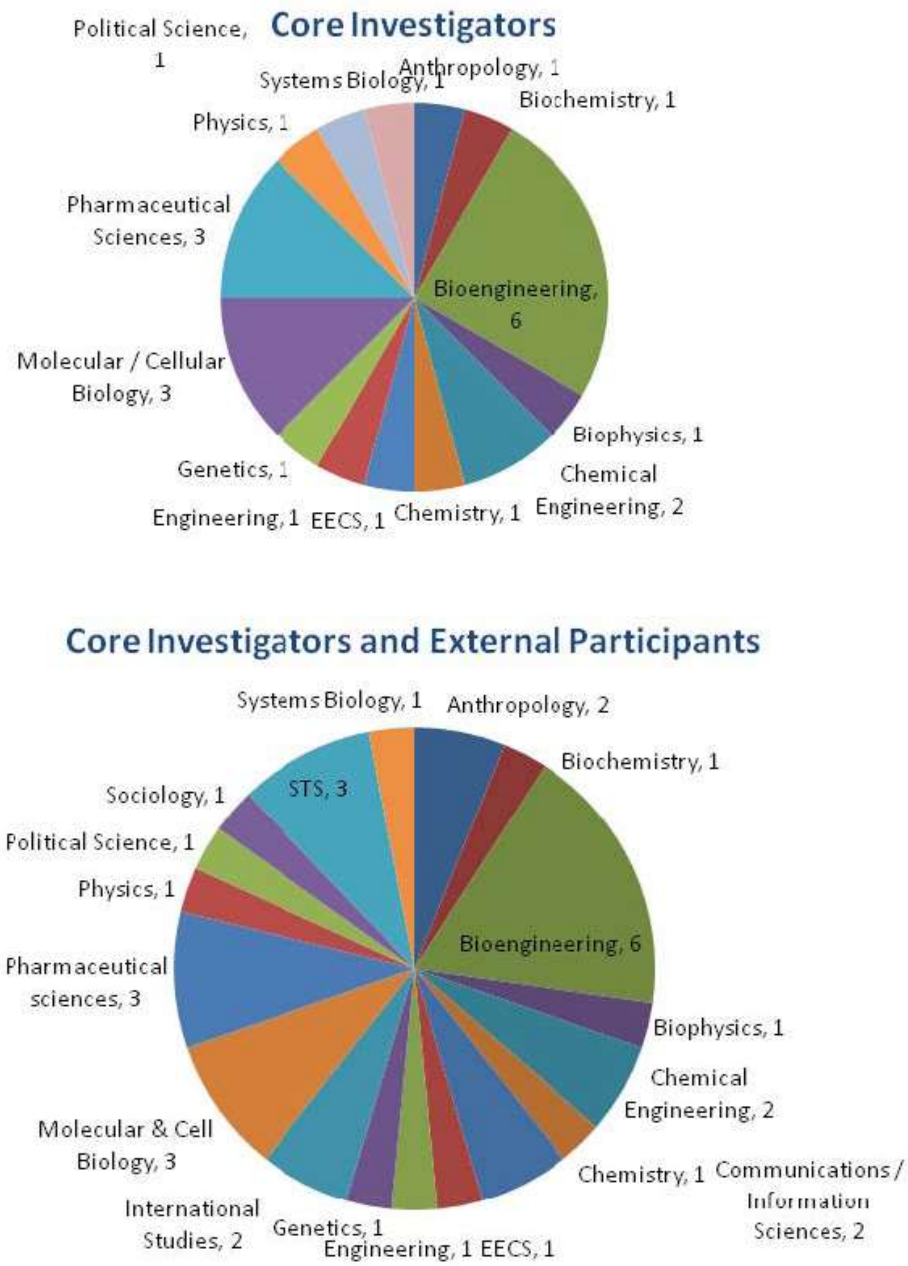


Figure 5.1-5. Research project investigators by discipline

EXHIBIT 3.2.7.3 (b)

2.1.8 Changes in MIRTHE's Budget

MIRTHE is still in the budgetary ramping up phase, and requests an additional $250k of NSF core funds in year 5, after which the budget is expected to be flat. These additional $250k are being used to support MIRTHE's ongoing research program, off-setting inflationary costs, and strengthening or supporting new programs with special attention to:

(i) Supporting MIRTHE's junior faculty;
(ii) Instituting a new mini-grant competition for post-doctoral researchers;
(iii) Supporting the speed up of the wireless sensor network projects;
(iv) Supporting student internships at industry/practitioner sites; and
(v) Providing more opportunities for direct student–industry interaction.

Overall, no major funding shifts are anticipated in the short term.

3.2.7.4

Articulating Metrics

The importance of good metrics cannot be over-emphasized. Several examples of metrics appear below (note the emphasis on "user-defined" metrics). See Exhibit 3.2.7.4.

EXHIBIT 3.2.7.4

Apart from storm motion and temporal correlation, in collaboration with the predicting thrust we will also produce Very Short-Range Forecast (VSRF), directly serving the end-user groups. This product will be initially built upon the current operational nowcast system in IP1. Currently, the nowcast product is used to predict the storm locations in a short-term. The performance will be quantitatively evaluated by Critical Success Index (CSI), as well as POD and false alarm rates. In IP5, the VSRF product will be also used to impact the "siren blows". The impact on the use by the end user group (emergency managers) will be the primary metric used in the operation process. We will work with the End-user thrust to define additional quantitative metrics to evaluate the performance, where the missed detection needs to be emphasized and the location of interest needs to be subjectively selected. A simple but significant example of the impact of VSRF on the end user group is spotter deployment (Collaborative System Goal). This collaborative system goal spans into three stages of development namely, a) demonstrate real-time detection, analysis, and VSRF products to Emergency Managers, b) demonstrate optimum MC&C protocol to maximize VSRF skill and c) demonstrate optimum MC&C protocol to maximize spotter deployment decision support. The metrics of effective spotter deployment are different from the direct metrics for VSRF such as CSI. For example the spotters may want to be located in a region, close to escape routes (good roads), as well as good vantage points with better visibility as well as the potential to get ahead of the storm. These needs will be mapped, via the MC&C into the scanning strategy to

…

Goal #1 Plans: In years 7 -10, we will begin to implement more objective measures for determining user needs and socioeconomic benefits to allocate system resources.

- *Users Needs* – We will develop user-defined metrics for data quality for response based goals such as emergency manager deployment of spotters. Metrics include FAR, POD, spatial and temporal requirements, and display considerations. This information will be determined as part of the EUI thrust's on-going decision modeling of user groups.

…

- *Weights* - Evolve from static trade-off coefficients to dynamic coefficients, based first on optimizing forecast skill and detections based on performance metrics developed by the scientific community, then based on user defined metrics for data quality, and ultimately based on higher level socio-economic goals.
- *Scan quality* – Quality is defined as obtaining the best data for users based on the user defined-metrics, or for the VSRF products. The user will no longer define scanning strategies, rather the spatial, temporal and physical properties of the phenomena of interest and the capabilities of the radar network determine the scanning.

…

Infrastructure Goal #2: Deploy 2 escan radars in the IP5 domain by 1/12; Infrastructure Goal #3: Deploy a 2nd generation MC&C by 1/11. In Version 4 of User Rules/MC&C, users state their preference for scanning frequency and coverage. The addition of escan radars creates a hybrid network containing radars with distinctly different scanning capabilities. Escan radars have agile beams that can be repositioned many times more quickly than mechanical radars. In addition, the user community is not familiar with the capabilities of escan radars. Therefore, as part of the deployment of escan radars and a second generation MC&C, the End User group will collaborate with the Distributing and sensing thrust to evolve a new set of user rules, multi-attribute utilities, and trade-off coefficients based on user-defined performance metrics for CASA products and decision goals. (See System Goal #1 for milestones related to user-defined performance metrics) In addition the EUI will collaborate to create the following system features for MC&C:

- Flexible data formats to enable visualization of base moments and new CASA products through existing software packages, such as AWIPS, the operational data platform used by NWS Forecasters, OKFirst, the operational platform used by emergency managers, a mobile platform for Blackberries and Iphone, and 3D multi-radar programs such as GR2 Analyst.
- Interfaces for dynamic user input into the system by weather spotters and by the NWS.

…

5.2.1.5 Challenges to the thrust

A remaining problem is to appropriately and systematically characterize part behavior, including the development of standardized metrics (e.g., promoter output in units of polymerases per second) and ways to assess composability and generalizabiliy in multiple contexts, as well as experimental protocols for their measure. Systematic characterization in many contexts is often beyond the scope of a typical student or post-doc-driven project, although much progress has been made in this respect with the first "datasheet" for an engineered device [33] and work to characterize promoter activity using an *in vivo* reference standard [34]. The development of the BioFAB will drive progress in part characterization, both by providing data on generalizability and interoperability of components, as well as by development of measurement standards that can be used in the individual SynBERC-funded projects.

…

- Standardized experimental protocols and metrics for measuring characteristics including:
  - part specifications;
  - part composability;
  - part compatibility;
  - part interoperability.

…

These features can be standardized with weighted metrics to indicate the usefulness of any chassis that contain all or a subset of such features. Chasses are then compared to one another based on these weighted metrics so as to determine the most appropriate one for a specific application. For example, a chassis with natural competency and high recombinogenicity may be best suited for genomic manipulations while ones with stable genomes and robust growth may be appropriate for metabolite production. Chassis characteristics are quantified and indexed in a database; an optimization search algorithm can be used to determine the most appropriate chassis within the database for use. Currently, chassis features are being characterized and quantified to determine the most effective implementation of such chassis standardization.

3.3 Best Practices for Executing the Strategic Plan

3.3.1 Executing the Strategic Plan is Vital

A research thrust leader's work doesn't stop when the strategic plan is formulated; that's only the beginning, a prelude to the real effort. Constant follow-up is necessary (e.g., continually checking progress and resource expenditures against the plan). Also, as noted earlier, research thrust leaders have to be willing to make adjustments to the plan if necessary—especially with respect to budgets, resource allocations, and schedules.

"Many [businesses] have plans; few execute them well. In fact, intensive research out of Harvard University indicates at least 85 percent of businesses do not execute their strategies effectively." (Endnote 5.)

Below (sections 3.3.2–3.3.6) are five pragmatic approaches and one important open issue (section 3.3.7) for research thrust leaders charged with executing their strategic plans.

3.3.2 Create and Sustain Buy-In

The goal here is to show how a particular thrust fits into the overall strategic plan of the ERC and to convince thrust members of the importance of their roles in fulfilling the center's larger vision and mission. To an extent, some buy-in may have occurred during preparation of the strategic plan. However, that buy-in may only be transitory as the real work gets underway and the relevance of a particular project to a distant vision or mission dims in the minds of participants. Accordingly, the research thrust leader must constantly reinforce the relevance to the ERC's goals and the consequent need for buy-in as the projects continue.

Budget and resource allocation issues must be part of this best practice (e.g., what dollar and human resources will be allocated, and when?). Ideally, research thrust leaders should participate in the center-level budget and resource-allocation processes and have a clear understanding of budgetary and resource-allocation responsibilities and authorities, from the top of the ERC downward. However, the extent to which this is possible depends on the ERC and university leadership. In any event, research thrust leaders must communicate clearly and often with the ERC director, colleagues, and subordinates about budgets and resource allocations.

3.3.3 Identify and Optimize Critical Paths

Critical path chains should be optimized to achieve the most efficient timelines, bearing in mind that some fundamental challenges may take time to resolve. Further, although interactions among team members are to be encouraged, extraneous interaction should be avoided so as to not complicate each critical path with unimportant connections. The project goals can be accomplished without all players in the thrust being engaged with every aspect of the work.

In addition, the thrust leader should ensure there is no overlap in deliverables, such as two research efforts producing the same results. Coordination of deliverables between thrusts is also important.

When necessary, research thrust leaders should support changes within the center to clarify the critical paths. Rationale for such changes could include achieving more realistic schedules, attaining better balance of budgets and resources along the paths, or implementing successful "workarounds."

To illustrate the last point, there might be a situation in which a research thrust leader has to decide how to keep a research team productive when waiting for a deliverable from another thrust. Alternatively, a thrust leader may be faced with developing workarounds when an outside deliverable fails to materialize. A best practice would be to request every project to have a Plan B if Plan A, which reflects input from another thrust, has a schedule slip or doesn't happen at all.

3.3.4 Establish Effective Communications Within Thrust and With Rest of Center

Continuous and effective communications, both up and down the chain of command, are essential. With respect to levels of management above the thrust leader, communications must be clear, convincing, and concise. For levels parallel or below, in some cases research thrust leaders may need to rely on persuasion. Direct orders to other thrust leaders or independent researchers are likely to be seen as abrasive and fail.

Best practices to overcome communication difficulties include the following:

- Define the goals and milestones as a team.
- Use video-conferencing and web-based communication systems.
- Establish regular schedules for meetings.
- Record minutes for key meetings and decisions.
- Develop a knowledge repository.
- Always communicate with principal investigators and project leaders.
- Don't forget the telephone or face-to-face communications—an e-mail can be misunderstood.
- Push to attend and interact at national meetings and professional society meetings (where ERC budgets permit).
- Schedule retreats for university students to show or present their work.

3.3.5 Monitor Progress and Deliverables

This topic addresses the following two aspects:

- Meetings and reports that illuminate various projects
- Metrics that measure progress and accomplishments.

Consideration here of meetings extends the preceding discussion of communications. Weekly or bi-weekly project meetings would be desirable, if possible, as would monthly meetings with center executives. However, a proper balance needs to be struck between meeting and doing. In other words, are the meetings worth the time spent? Meetings that involve thrusts across several universities are also challenging from travel and time standpoints.

On reports, research thrust leaders should establish and disseminate reporting schedules for interim progress, outcomes, and other deliverables. Monthly reports from individual researchers to thrust leaders along with quarterly reports from thrust leaders to higher levels of ERC management are probably sufficient. Caution should be taken to not overly burden the individual researchers who furnish inputs for such reports (i.e., they should not be too distracted from doing their projects). An online system might work well here.

Metrics for assessing performance are essential. As discussed in the previous section on strategic planning, the correct choice of metrics is very important. Much preferred are metrics that measure outputs and outcomes rather than inputs. It may not be possible to develop during strategic planning a complete set of worthwhile metrics, so research thrust leaders might be faced with this task during the execution phase. NSF's requirements for center metrics, in the context of both annual reporting and on-site reviews, must be taken into account here. The center's Administrative Director/Manager is likely to be the most cognizant staff member regarding these requirements, and should be consulted.

Developing metrics in collaboration with other members of the research team as well as with top ERC leaders is most desirable; that way everyone in the management chain will know what to expect in the assessments. Once established, the metrics should be reviewed in light of project realities, timely feedback should be provided to project leaders, and there should be willingness to adjust the metrics if a situation warrants. The project assessments would also be used to support recommendations for adjustments in budgets or resource allocations.

3.3.6 Adopt Effective Management Styles and Strategies

Several best practices regarding management styles are to:

- Use team-building approaches.
- Know and take account of backgrounds and capabilities of collaborators in the ERC.
- Develop and articulate a conflict-resolution strategy that everyone is likely to buy into.

Thrust leaders have to set research direction, so if people disagree on that direction an issue is raised on how to reach resolution. Depending on the issue, third party input (e.g., from some type of scientific advisory board or other technically savvy authority) can help resolve the matter. But clear articulation of the issue and what is done to reach agreement is important.

Note that possibly more contentious disagreements could arise on budgetary and resource allocations (see earlier discussion). Here the best practice would be to discuss the matter openly with participants in the team as well as other thrust leaders to gather information about various options for handling the situation. Then put it on an agenda for discussion with decision-makers in the ERC's leadership team. Finally, uncomfortable personality conflicts might emerge between individuals at various levels. If these cannot be worked out by face-to-face dialog, one suggestion is to consider bringing in a conflict-resolution expert. At a certain point, such conflicts become a matter for center leadership to address.

3.3.7 The Issue of Compensation for Thrust Leaders

Thrust leaders expend much time and energy on their leadership tasks. Other than an occasional "good-job" recognition from ERC management, their management work is not compensated. Should these leaders have some type of more tangible compensation for their important responsibilities? Several best practices are suggested below, but these are ultimately dependent on the ways individual ERCs and universities operate.

- Extra pay or vacation are at the top of the list of possible types of compensation for at least some of the considerable time and effort spent by thrust leaders to carry out their responsibilities associated with the ERC (e.g., through summer support or regular-year effort).
- Other forms of compensation could be making special training or professional-development opportunities available to thrust leaders; a variation could be a professional-development coach. (To help accomplish one or more of these possibilities, NSF's ERC Program office could be a resource to provide contact information concerning such opportunities.)

3.3.8 Examples of Adjustments to the Plan

It is useful to see examples of improvements that were made when strategic plans were being implemented. The first example below shows how fundamental elements of a strategic plan had to be modified based on lessons learned during implementation. (This experience also feeds back to Section 3.2, which contains a best practice of defining a structure that can accommodate adjustments.) The remaining examples, from ERC strategic plans described in subsection 3.2.7, show selected responses to various suggestions made by visiting reviewers after observing aspects of the implementation.

3.3.8.1 Changes to the Three-Plane Diagram

The example shown in Exhibit 3.3.8.1 starts with the original relationship between the planes of the diagram; it then explains why that relationship had to be changed. The example also illustrates this ERC's approach, after discussions with other ERCs, to achieving stronger faculty buy-in and team integration.

EXHIBIT 3.3.8.1

The Center uses a top-down, systems-vision approach in defining specifications and deliverables. The FREEDM system must be demonstrated with properly defined voltage and power levels for residential renewable energy generation and distribution. Research milestones and a quantitative matrix used to measure success will be defined by projected breakthroughs in three fundamental research areas: FREEDM system theory; post-silicon power devices; and advanced storage technology. To link the fundamental research results to the final system demonstration requires that several enabling technologies must be developed. Figure 2-2 shows the proposed sub-thrusts and their key relationships to the fundamental research, enabling technologies, and engineered systems planes. At the top plane, two subsystem test beds, IEM and IFM, are identified as integral parts of the ultimate 1 MW FREEDM System test bed. The new PHEV/PEV test bed is not shown. These test beds can only be developed by the integration of the five enabling technologies and by the synergistic team effort.

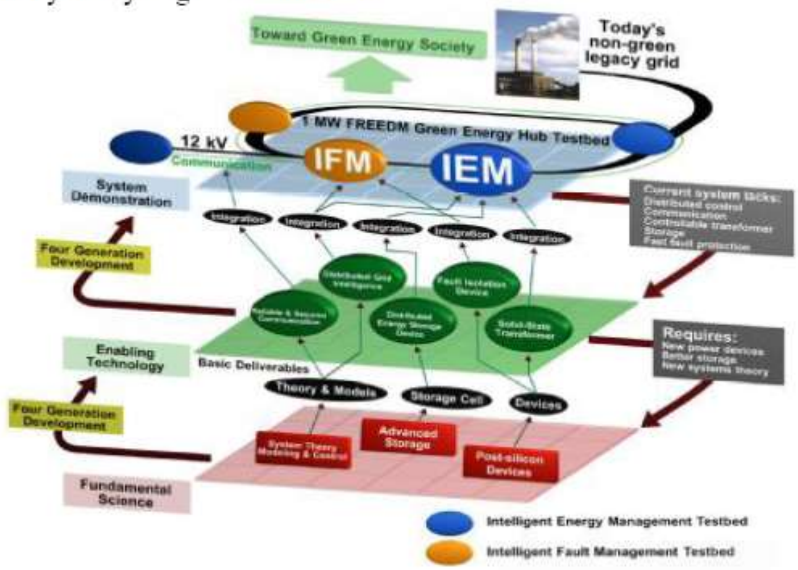


Figure 2-2. Original Center Research Area Strategic Plan

At the end of the first quarter of the Center's research program in December 2008, we started to notice that the center research program integration through three horizontal planes/thrusts in fundamental science, enabling technology, and demonstration is not effective. For example, PSD subthrust and AS subthrust are both part of the fundamental science thrust area. But these two subthrusts do not have much need for interaction due to their very different technical fields. On the other hand, they have a much stronger interaction with the enabling technology subthrusts they support, namely SST and FID for the PSD, and DESD for the AS. Therefore we have realized that it is much more natural to achieve research program integration through vertical plan integration. This is especially true for our center because the center's system vision (FREEDM System) strongly depends on the test beds, and these test beds can only be achieved through a strong integration of technologies in the vertical direction. The test bed needs determine the requirements of the fundamental and enabling technologies, and what can be achieved in the fundamental and enabling technologies in turn determines what can be demonstrated in the test beds.

At the December ERC conference in Washington, DC, we have also learned a lot from other ERCs on how to revise strategic plan of the center and on how to use this process to achieve stronger faculty buy-in and team integration. Therefore, in January and February 2009, the Center's executive committee met several times through teleconferences, and discussed how to reorganize the center's research program. The committee then recommended the following strategic plan changes in February 2009:

- Add a PHEV/PEV test bed to emphasize our integration from fundamental storage research (AS), to DESD enabling technology, to DESD application inside the vehicle (PHEV/PEV).
- Eliminate the three thrust leaders and the horizontal integration concept, instead, empowering the leadership of the three test beds. Dr. Mischa Steurer will serve as the IFM test bed leader. This test bed integrates vertically DGI, RSC, FID, PSD and SMC sub-thrusts. Mariesa Crow will serve as the IEM test bed leader and drive the vertical integration of DGI, SST, RSC, PSD and SMC sub-thrusts. The new PHEV/PEV test bed will be led by Ewan Pritchard, a well known pioneer in plug-in hybrid vehicle technology who recently joined the Center. This will allow vertical integration of AS, DESD, and PSD sub-thrusts.

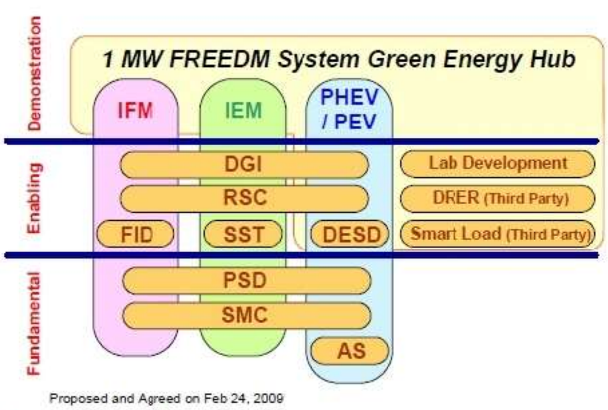


Figure 2-3, New Revised Center Research Area Strategic Plan

Figure 2-3 shows the revised three plane diagram, emphasizing the vertical integration among the various sub-thrusts.

The Center has recently further clarified the strategic relationship between the FREEDM Systems Center and NCSU's Advanced Transportation Energy Center (ATEC). ATEC was established in Feb 2008 by an investment from the state of North Carolina, Duke Energy and Progress Energy to facilitate the development of PHEV/PEV technologies. It has been agreed that ATEC activities will be considered core research projects of the ERC. The research activities in ATEC are mostly complementary to what are supported by the ERC, yet they both support a single strategic vision. ATEC will focus on advancement of PHEV/PEV hence will provide most of the funding in PHEV/PEV test bed. Additionally, ATEC's activities in motor drive and electric motor expand the center's activity into a very important area. A single industry membership will support both ERC and ATEC missions. A transportation working group will be formed under the FREEDM IAB to provide advice regarding ATEC specific activities. ATEC will remain as a Center of excellence at NCSU in order to develop technologies specifically for the transportation industry.

3.3.8.2 Communication and Interrelationships

The following example, responding to comments from a Site Visit Team (SVT) relates to best practices in the areas of communications and interactions that could identify commonalities.

EXHIBIT 3.3.8.2

5.1.2 Response to Site Visit Report – Strategic Research Plan

- **The SVT recognized the complexity and dynamics of this framework in the execution of the research plan. While the topology has proven to be quite useful, the SVT recognized that just as the components of the framework are dynamic and based on biological principles, so should the strategic execution of the framework. In this spirit, the SVT recommends that the communication among the leaders in the Center be frequent and include examination of the overall strategy as well as the day-to-day operations. The temporal frequency of looking at this strategy is important and leaving it solely to semi-annual retreats may not satisfy the dynamic nature of all of the moving components of this complex center.**

We readily acknowledge that examination of the overall strategy should occur on a regular basis. In fact, we held a PIs meeting specifically to discuss and refine our strategic vision in between the semi-annual retreats this year and we likely continue to hold such meetings as the Center progresses.

- **The SVT suggests that, as part of this frequent strategic analysis, the SynBERC team examine the inter-relationships of Parts, Devices, Chassis, frequently and look for where there is commonality in moving advances between different levels of biological complexity (as represented by bacterial, yeast, plant, or mammalian systems).**

This is a good suggestion. In addition to considering how our foundational engineering research ideas can be applied across the kingdoms of life, we also anticipate extending our work on engineered biological abstractions to still higher levels of biological organization, such as synergistic relationships among organisms, including tissues and ecosystems. For example, Radhika Nagpal of Harvard is being recruited onto our SAB; she is an expert on developing programming abstractions for controlling pattern formation in systems comprised of thousands of independent agents (e.g., cells).

3.3.8.3 Keeping the Entire ERC Team Coordinated

Here the example (Exhibit 3.3.8.3) illustrates the need to ensure that all elements of the team continue collaborating and working together in a coordinated fashion.

EXHIBIT 3.3.8.3

- **The SVT did not see sufficient evidence of integrated, coordinated activities. Human practices researchers have been working on IP, biosecurity, and health and safety issues; the IAB called for policies in these areas; and scientific/engineering researchers have been active in development of policies, for example, with Bio Bricks and the proposed IP policies presented at the site visit. These efforts seemed to be disconnected from one another. It was not clear how work in one area would be informed by, and inform those in another area. The SVT also could not see anyone who was responsible for assuring that there was active, ongoing collaboration in moving any of these issues forward. For example, someone to assure a policy is in place that is responsive to IAB concerns about security, or IP.**

It is true that we have many activities proceeding simultaneously and that these could be better coordinated. We have addressed many of the coordination issues in other sections of this report. With respect to the Human Practices Thrust, Rabinow is now the sole thrust leader. We hope that having one thrust leader, as opposed to two, will help to improve coordination in the Human Practices thrust. We have designed the Thrust 4 research cluster on safety, security, and preparedness as a conceptual strategy for integrating and coordinating efforts. Our proposed project on "Globalized Forms of Preparedness and Risk Management for Synthetic Biology" will extend and formalize this integrated approach. We have submitted an FTE request to conduct this project.

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- **The Human Practices Thrust seems to be treated in a different way from the other research Thrusts. The SVT didn't see evidence of an active, ongoing exchange of ideas between scientists/engineers and humanities/social scholars in the human practices arena comparable to the sharing of ideas/equipment/platforms associated with other research areas. Is there a real give and take between scientific/engineering and human practices researchers?**

We generally agree with this diagnosis, although it should be noted that in the very first line of the SVT's report, Human Practices was not listed as one of the Center's Thrusts. Further, as the SVT points out in the report "Science/engineering researchers do not seem to fully appreciate that there is an opportunity – of the same kind as in other technical areas – to provide world class leadership in an influential, emergent area of [human practices] research." In general, it is often difficult to engage scientists/engineers in human practices aspects of their work, maybe because they view it as a distraction. However, in general, we believe that SynBERC's investigators are more engaged in ethical issues of synthetic biology than other scientists have been in the ethical issues of their own scientific disciplines. Nonetheless, SynBERC needs to improve in this regard, and we intend to do so. Rabinow will propose to Keasling a structured formula to address these issues.

3.3.8.4 An Important Element of Research Not Being Addressed Adequately

In this example (Exhibit 3.3.8.4) it was learned that changes had to be made to include more attention and investment so that one important element of research (in this case, packaging) could be addressed adequately.

EXHIBIT 3.3.8.4

- **Packaging, a critical element to component integration, is not being adequately addressed.**

  We are aware that this critical element needs additional attention and investment. While much of the actual packaging research is in fact ongoing within MIRTHE's industrial partners, who have the requisite resources and incentive to optimize packaging, a smaller core of our industry members have approached MIRTHE to address packaging issues. When the opportunity arose to compete for ERC Innovation Awards in 2009, we proposed – and were awarded – a program termed "MIRTHE Industry Experts in Packaging." Through this program MIRTHE is able to retain a significant fraction of time and effort of two industry experts, who have long-standing experience in semiconductor device packaging (a more detailed description of the program can be found in Volume II). The program commenced January 2009, and new (used) packaging equipment has been ordered; the new packaging lab-building will proceed through the spring of 2010. With improved equipment, and – more importantly – industrial-level packaging expertise we expect to greatly enhance MIRTHE's packaging capabilities.

  Furthermore, MIRTHE's basic research in component integration in Thrust 3 has seen great progress through this reporting period; hence promising true packaging innovations originating from the center soon.

3.3.8.5 Monitoring Progress and Deliverables

This last example (Exhibit 3.3.8.5) reveals that a site visit team discovered that achieving the center's system-level goals would not be possible without further advances in component-level technologies. One element of the response was to continue bringing new faculty into the center to provide needed expertise. The earlier that monitoring of progress during implementation (a best practice) can identify shortfalls such as this, the earlier that corrective actions can be put into place.

EXHIBIT 3.3.8.5

- **System level goals are not possible without further advances in component level technologies, i.e. detectors, passive optics, integration, and thermal management;**

  We agree with the SVT's assessment of the need for advances in component level research; this is why an entire plane (the lowest one) of MIRTHE's strategic plan is dedicated to component development. We believe we have been able to demonstrate continued improvement in performance of our systems as individual component performance is enhanced. The QEPAS sensors are an example of an area where we are already making great strides towards our system level goals for medical and environmental applications. Nevertheless, it is clear there are fundamental technology barriers which must be overcome to achieve some of the particular proposed goals. One of our strategies to achieving this is continuing to bring new faculty into the center because of the need for expertise in specific areas (e.g. detectors) to meet system goals.

3.4 BEST PRACTICES TO INTEGRATE RESEARCH AND INDUSTRY

3.4.1 Why Integration with Industry?

The very nature of ERCs dictates continual involvement of industry (e.g., through strategic planning, by providing an industrial perspective on the research connected to specific projects, and with joint projects). The end objective is transferring tangible deliverables to industry, thus accomplishing a successful hand-off.
The subsections that follow discuss several aspects of this integration with industry in the context of the research thrust leader's role, best practices, and things to avoid. A case study for one second-generation (Gen-2) ERC is at the end.

Readers should be aware that some of the best practices delineated in this section received additional comments in late 2010 and early 2011 from persons very familiar with ERC interactions with industry. These comments were of two general types: (1) suggestions relating to Gen-2 ERCs that were intended to clarify relationships between the ERC Director, the Industrial Liaison Officer (ILO), and research thrust leaders with respect to their industry-focused responsibilities; and (2) comments most applicable to the newer third-generation (Gen-3) ERCs. Because Gen-3 ERCs are addressed in Section 3.6, comments most related to Gen-3 integration with industry appear there. Three comments that typify some of the interchange appear below:

"Excellent write-up … [but] written for decentralized management model and a product (not process) center ..." [Editorial Note: Gen-3 process center addressed in Section 3.6.]

"... this technical industry interface stuff is a force fit, whether you are Gen-2 or Gen-3. Some of it would be more appropriate if the Center has a testbed manager structure, but it should all be coordinated by the ILO."

"[Several] comments mainly refer to the role of the 'Industrial Collaboration and Innovation Director' and his/her interactions and relationships with other leadership members, in particular Thrust Leaders. The Industrial Collaboration and Innovation Director is a requirement of the Gen-3 Centers, and the functions and responsibilities are somewhat different [from] the ILO required in Gen-2."

3.4.2 Research Thrust Leader's Role in Integration with Industry

The research thrust leader is an important technical interface between an ERC and its industrial partners. Depending on the ERC, and recognizing that the Center Director is the top technical interface with industry, the Director may delegate to one or more research thrust leaders certain responsibilities. These responsibilities could include (a) helping to identify opportunities for effective collaborations between principal investigators in various thrusts and appropriate industrial partners, or (b) helping to manage the expectations of industrial partners. (Individual research faculty are also valuable in providing leads for the ILO to further develop.)
Roles of the thrust leader may include

- identifying critical bottlenecks that industry will encounter;
- developing strategies to lead and focus the thrust to find solutions to these bottlenecks; and
- aiding the Director as technical “co-gatekeeper,” which entails monitoring progress of industrial deliverables while ensuring the long-term scientific goals of the thrust are accomplished.

Finally, one of the most important functions of a research thrust leader lies in balancing the individual projects within a thrust and facilitating opportunities for coordinated interactions among an ERC's thrusts. With respect to industry, this function bears with it a responsibility of being aware of what industry currently requires and will require in the future as well as the expectations of various industrial partners relative to the research thrusts.

3.4.3. Best Practices Regarding Portfolio Balance, Communication, and Roadblocks

As part of a successful research thrust, there should be a mixture of both short- and long-term deliverables that are of interest to industrial partners. The portfolio should also be balanced within the thrust without compromising the ERC's scientific and engineering vision. Moreover, it is incumbent on the Center Director, aided appropriately by thrust leaders in concert with the ERC's industrial and scientific advisors, to establish a balance between more fundamental scientific work and work that will further the technological state of the art.

Based on technical insight into the capabilities of principle investigators working within the thrust, the research thrust leader can communicate with *senior technical* industry personnel to ensure that their needs—both short- and long-term—are being addressed. The ILO should be kept well apprised of such interactions to be effective in maintaining the overall engagement of industry members over the long term. From time to time, research thrust leaders can also organize meetings, panel discussions, and other mechanisms that involve both industry representatives and researchers. These "get-togethers" might, for example, address the needs of industry, explain research progress as well as the lack thereof, and reveal potential technical roadblocks that must be overcome.

3.4.4 Best Practices for Industrial Collaboration

The research thrust leader should foster a culture of collaboration between industry in general and the ERC. This type of collaboration will enable access to the latest technology advances made by the ERC, thus helping to ensure that industry is kept abreast of the current state-of-the-art and allowing efforts of the center to be focused on extending these advanced capabilities rather than reproducing them time after time for different segments of industry.

As an example of collaboration, an industrial mentorship program should be enabled. This would involve seeking appropriate mentors from the industrial partners who are well versed in the relevant technological and scientific disciplines of the university partners. These mentors would be available to students, preferably at regularly scheduled opportunities.

It is important to establish ERC-wide consistency with regard to industrial collaborations. To achieve this consistency, a common set of collaboration policies should be determined among the research thrust leaders within the ERC and in close consultation with the ILO.

3.4.5 Things to Avoid

To manage a research thrust effectively it is best for research thrust leaders to avoid intellectual-property issues, instead delegating those to the administrative and industrial liaison/legal staff of the center. Research thrust leaders should focus on the technical, not the legal, goals of the ERC and technology transfer. It must be noted that this type of delegation should not be interpreted as reducing the ILO to an administrative functionary. In most cases, intellectual-property issues requiring negotiations are conducted by the responsible academic partner, thus allowing the ILO to avoid appearing to be industry's adversary in technology-transfer engagements.
In addition, bilateral financial "deals" (e.g., involving commonly held ERC intellectual property) between individual ERC investigators and industry should be avoided. Such an outcome would threaten the sustained support of the ERC from NSF. Negotiating financial terms with potential member companies should only be done on behalf of the ERC as a whole by the appropriate ERC staff. In fact, a consistent umbrella of industry-ERC partnership rules should be adhered to. (It should be noted that this guidance could impact any Gen-2 ERC that elects to use "home-grown" start-ups as a mechanism for technology transition and commercialization.)

Conflicts between the desire to continue basic research versus the need to produce development products, which are usually under the purview of testbed managers, should be dealt with only through clear and mutually subscribed-to policies and procedures. Research thrust leaders should note that industry can sometimes serve a role in this situation by stepping in and helping to make sure that the research ideas get turned into desirable end products.

3.4.6 Case Study: Project Mentor Program at the Center for Structured Organic Particulate Systems (C-SOPS)

One instrument for promoting scientific collaboration and a better integration between academic and industrial colleagues is the establishment of a formal mentor program reaching all projects in the thrust. Such a program has been successfully implemented at the Rutgers-based C-SOPS, with a membership exceeding 30 companies. The mentor program is best described in terms of the roles and responsibilities of both the industrial and academic personnel.

3.4.6.1 Industrial Roles

Lead Project Mentor

- Is the primary contact with the academic project team
- Acts as chair of the mentor team composed of all projects' mentors
- Coordinates project evaluation on behalf of the center
- Working with the project leader, provides feedback to the Steering Committee and makes recommendations on any changes needed
- Attends the annual NSF site visit when required
- Acts as a center champion with NSF
- Provides input for technical reports as requested by the project leader.

Individual Project Mentors

- Participate in monthly project team teleconferences
- Assist lead mentor in project progress evaluations
- Provide an industrial perspective to center researchers
- Evaluate progress in project on behalf of their companies
- Help students (and faculty) gain an understanding of issues that are important in using center research findings in practical applications
- Facilitate incorporation of center findings into industrial practice
- Serve as project "champions," helping convey to their companies and the center executive committee a sense of the value delivered by the project

- Help center researchers gain additional resources (e.g., materials, equipment) from vendors and industrial contributors
- Provide other support in agreement with lead project mentor and project leader, including examples like:

  - o connecting to cutting-edge research relevant to the project;
  - o proposing or supporting advanced experimental approaches, design of experiments, or data analysis;
  - o providing tools, input, or support for capacity analysis, resource utilization, and project scope;
  - o conducting additional literature searches, such as using advanced search engines available to industry; and
  - o providing research technical expertise, where relevant.

3.4.6.2 Academic Roles

Project Leader

- Develops overall research plan for project
- Coordinates all project research activities with respect to participants, universities, and interrelated projects within and outside the thrusts
- Assures that all project participants are aware of the overall ERC strategic plan and their places within it
- Proposes and harmonizes deliverables with testbed leader
- Tracks and reports progress relative to thrust-level scientific goals and testbed deliverables (includes early communication of deviations from plan)
- Identifies and procures needed project resources (includes leveraging external funding)
- Organizes monthly project meeting for entire project team
- Maintains Social-Text (enterprise networking) workspace for project
- Prepares two technical reports annually and provides input to the thrust leaders in compilation of the project report and site-visit presentations in a timely manner
- Provides timely project-level input to the center-wide NSF annual reporting process.

Project Participants (Faculty)

- Propose research plans for allocated project tasks
- Participate in monthly project meetings and teleconferences
- Work with the project leader to ensure that all project-task participants are aware of the overall ERC strategic plan and their place within it

- Provide frequent updates on status to project leader
- Provide formal, written inputs to project leader in a timely fashion when project reports and presentations are due.

3.5 BEST PRACTICES TO INTEGRATE RESEARCH AND EDUCATION

3.5.1 Why Integration with Education?

Integrating research and education in the ERC curriculum is an effective way to bring undergraduate and graduate students together into the vision of the ERC and its connection to professional practice. The resulting courses can stimulate undergraduates to join research teams, provide a means to incorporate research findings into future curricula, and can change the engineering and science culture through interdisciplinary emphases. The projects for these classes can be inspired from the ERC's strategic plan – designing and building systems supporting the top two planes of the three-plane chart. In addition, these courses could select some of the fundamental technology on the first plane to incorporate into their system, thereby accelerating the readiness of the technology for use by others. The topics and case study below illustrate best practices to achieve the desired integration

3.5.2 Culture Change and Joint Responsibilities

One way in which ERCs have changed the traditional discipline-oriented culture of ERC-participating universities through education is by creating new interdisciplinary courses, including interdisciplinary ABET (Accreditation Board for Engineering and Technology)-accredited Engineering Capstone Design Courses, and even new interdisciplinary degree programs. An even more aggressive goal is to have the interdisciplinary courses recognized as fulfilling capstone design requirement in multiple engineering departments.

There are joint responsibilities between research thrust leaders and ERC education or outreach directors with respect to education at all levels, from K-12 to undergraduate to graduate. In addition, there are responsibilities with respect to faculty. In particular, this joint team has to resolve allocations, such as:

- receiving credit in home departments for developing and teaching ERC-related, multi-disciplinary courses;
- materiel costs (e.g., for system building);
- laboratory space; and

- intellectual-property issues.

3.5.3 Challenges

Research thrust leaders within each ERC must strive to develop innovative solutions and structures to secure adequate resources for curriculum development and other education-related activities. Resources may be obtained from multiple sources, including deans, department heads, industry, and research contracts, as well as the ERC budget. The situations in each ERC will be different, and indeed they may be different for each university member of a multi-university ERC.
Another challenge for geographically distributed ERCs is how to engage students in the overall research plan. To address this, one ERC holds a mandatory one week long summer workshop for the entire ERC. The venue rotates among the participating universities.

With the increased participation of foreign universities in third-generation ERCs, an additional challenge is maintaining balance in exchanges (e.g., of students or course-work) when the resources are unequal. (Section 3.6 on Gen-3 ERCs contains more discussion of challenges with respect to foreign universities.)

3.5.4 Opportunities

ERC integration with industry presents opportunities for education. To a great extent, industry focuses on shorter-term advanced development rather than longer-term research. This situation produces opportunities for student-led research teams to engage in industrial-inspired problems and gain access to hard-to-acquire data and support (e.g., equipment and money). Of course, associated challenges must be solved, such as industrial expectations of the robustness of results, intellectual-property ownership, and taking care that the student research is appropriate for education.

3.5.5 Case Study: Rapid Prototyping of Engineered Systems at the Quality-of-Life Technology (QoLT) ERC

With the advent of rapid-design methodologies and rapid-fabrication technologies, it is possible to construct fully customized engineered systems in a matter of months. Carnegie Mellon-based QoLT has developed a User-Centered Interdisciplinary Concurrent System-Design Methodology (UICSM) in which teams of electrical engineers, mechanical engineers, computer scientists, industrial designers, and human/computer-interaction students work with an end-user to generate a complete prototype system during a four-month-long course (see Endnotes 6 and 7).
The methodology defines intermediary design products that document the evolution of

the design. These products are posted on the Internet so that even remote designers and end-users can participate in the design activities. The methodology includes monitoring and evaluation of the design process by a dedicated faculty member and proceeds through three phases: (1) conceptual design, (2) detailed design, and (3) implementation.

End-users critique the design at each phase. In addition, simulated and real-application tasks provide further focus for design evaluation. Based on user interviews and observation of their operations, baseline scenarios are created for current practice. A visionary scenario is created to indicate how technology could improve the current practice and identify opportunities for technology injection. This scenario forms the basis from which the requirements for the design are derived as well as for evaluating design alternatives. Both types of scenarios are reviewed with the end-user.

A technology search generates candidates for meeting the design requirements. Several architectures are generated next, each appropriate to the various disciplines and involving:

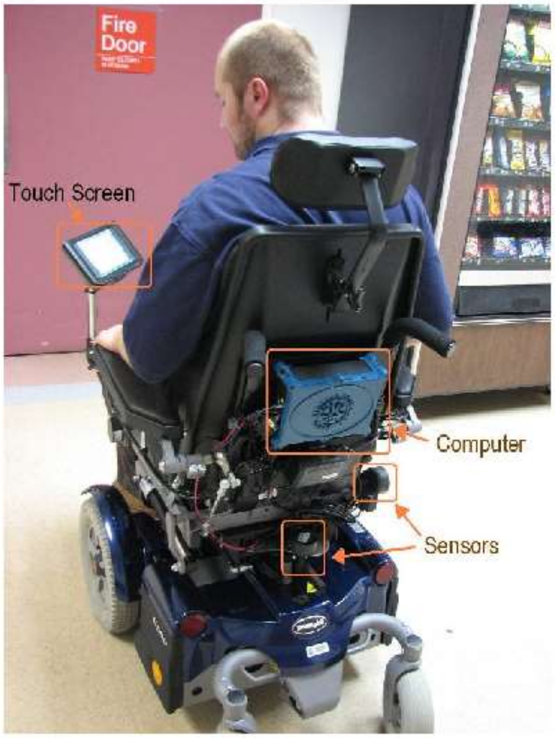
- Hardware
- Software
- Mechanical
- Shapes and materials
- Human-interaction modes.

User feedback on scenarios and storyboards becomes input to the detailed design phase. Designers alternate between the abstract and the concrete. Preliminary sketches are evaluated, new ideas emerge, and more precise drawings are generated. This iterative process continues with soft mock-ups, appearance sketches, as well as computer and machine-shop prototypes, until finally the product is fabricated.

Iterative evaluation by end-users throughout the design process yields the equivalent of a second-level (i.e., beta) prototype that is much closer to deployment than a prototype produced by a traditional design methodology. Further development through the Summer semester by selected students from the class yields a prototype suitable for pilot studies. Engagement of between 20 and 25 students from multiple disciplines (computer engineering, electrical engineering, mechanical engineering, computer science, industrial design, and human-and-computer interaction) yields 4,000 to 5,000 engineering hours devoted to an integrated-system prototype.

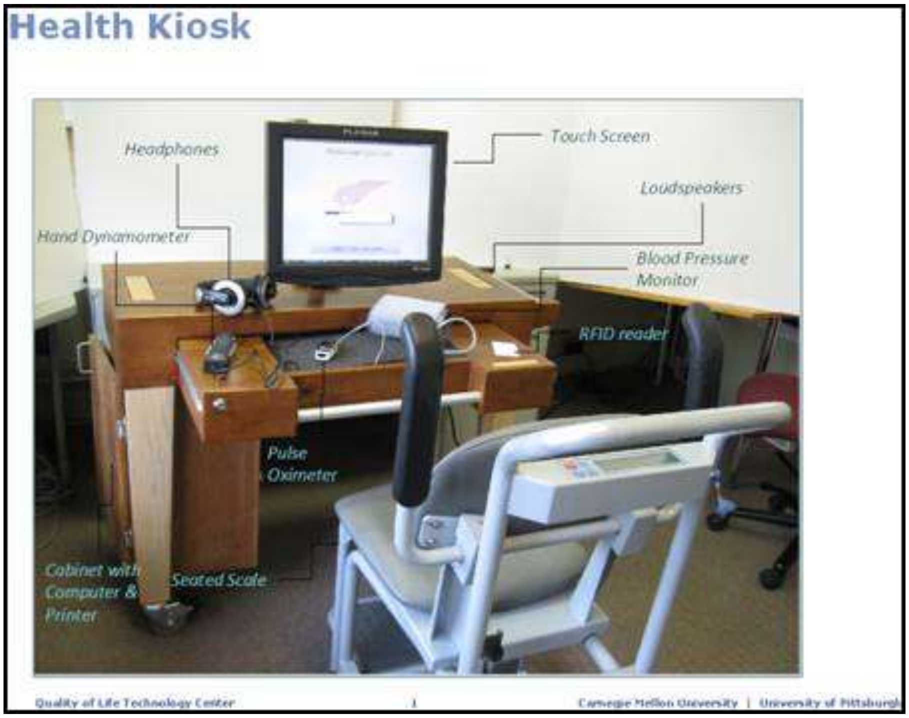
UICSM has been refined through more than 15 years of experience resulting in over two dozen mobile systems. Applications have included heavy-equipment maintenance (e.g., aircraft, airport people movers), Pennsylvania bridge inspectors, manufacturing, off-shore oil platforms, language translation for NATO troops, plus three example systems of QoLT-designed access technologies shown in Figure 3.5.1 (a-c).

Seating Coach

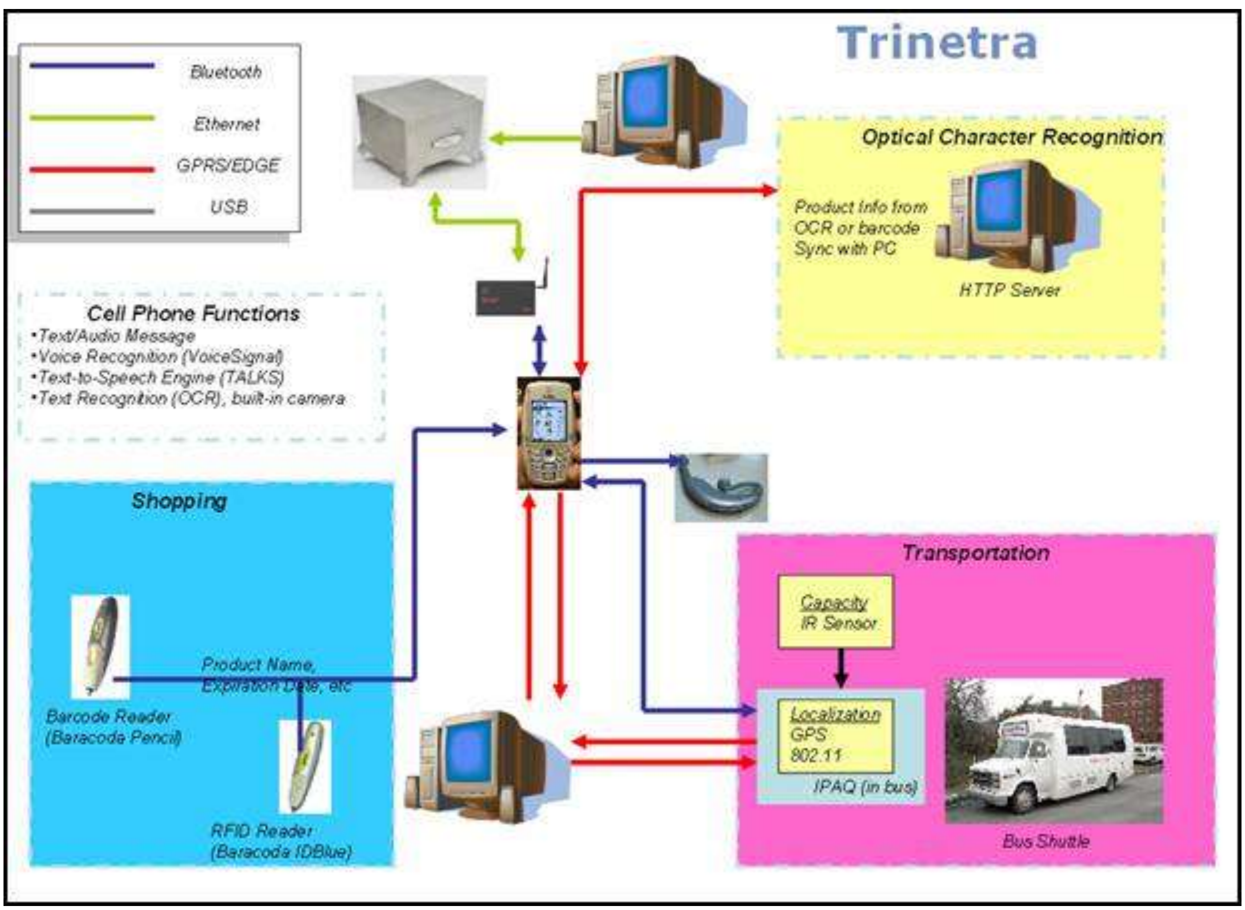


Virtual Seating Coach

(a) Power Wheelchair Virtual Coach



(b) Health Kiosk for Seniors Living in High-Rise Buildings



(c) Trinetra Transportation and Optical-Character Sign Recognition to Aid the Blind

Figure 3.5.1 (a-c) Three example systems of QoLT access technologies produced by the class using UICSM *(from Prof. Daniel P. Siewiorek; credit: Carnegie Mellon University)*.

3.6 GENERATION-3 ENGINEERING RESEARCH CENTERS

3.6.1 Gen-3 ERC Features

Driven primarily by the goal of actively stimulating technological innovation, NSF's new third-generation (Gen-3) ERCs are characterized by features including the following (see Endnote 1):

- Advancement of cross-disciplinary, transformational research and engineered systems through engagement with small firms
- Partnerships with member firms and organizations dedicated to stimulating entrepreneurship and speeding technological innovation
- Development of an engineering workforce that is innovative and globally competitive
- Partnerships with foreign universities to provide cross-cultural, global research and education experiences
- Long-term partnerships with middle schools and high schools to bring engineering concepts to the classroom, thereby increasing interest in future enrollment in college-level engineering programs.

Because these Gen-3 features rest on the core ERC construct common to all ERCs, many best practices for earlier ERCs will prove useful for Gen-3 centers. Nevertheless, some Gen-3 features—particularly funding small start-up firms for translational research from the ERC base budget, and partnerships with foreign universities and pre-college schools—could suggest substantial changes to past best practices. The paragraphs below illustrate several situations.

3.6.2 Some Gen-3 Situations that Might Require Change from Past Best Practices

Consider, for instance, the best practices associated with the major topics of this chapter: preparing and executing a strategic plan and integrating research with industry and with education. There may be little difference between Gen-3 ERCs and prior ERCs in which researchers are located at several geographically dispersed locations in the United States. However, when one includes foreign universities, that introduces a new dimension.
For example, communications involving foreign universities—even if by phone or "go-to-meeting" or sophisticated video teleconferencing—could be difficult because of the very

different time zones. But time-zone problems may be small compared to cultural and administrative differences between U.S. practices and those of foreign universities. For example, aspects of the following best practices for research thrust leaders could become substantially more complicated:

- Defining responsibilities and authorities for organizations and individuals
- Creating and sustaining buy-in
- Reaching decisions on budgets and resource allocations when the foreign component has to be funded by foreign sources of funds
- Deciding on deliverables and their schedules
- Establishing appropriate metrics
- Agreeing on financial terms and intellectual-property issues
- Resolving conflicts between research and industrial products
- Maintaining balance in education exchanges.

Similarly, dealing with pre-college schools could also complicate matters (the above section on integrating research and education recognizes K-12 affiliations). There is great interest within the United States on furthering STEM (science, technology, engineering, and math) education for young students. Nevertheless, preparing and executing strategic plans and integrating industrial firms (especially small ones) not only with U.S. and foreign educators but also with middle- and high-school teachers, is challenging for Gen-3 ERCs.

3.6.3 So What Is Needed?

It is apparent that some of the best practices delineated earlier in this chapter will need to be changed to accommodate certain Gen-3 features. Lessons learned from the early years of Gen-3 operations will shed light on just what changes are necessary. Therefore, a suggested best practice for start-up Gen-3 ERCs would be to document the kinds of best-practice changes they find necessary to accommodate the special features of Gen-3 operations.

However, there are other sources for best practices than ERCs themselves. At least two other groups come to mind.
First, many U.S. businesses operate on a global scale. They too prepare and execute strategic plans of global scope, and some also likely have ties of one kind or another to foreign universities. Several of these businesses should be good sources of best practices for the Gen-3 personnel (see Endnote 8).

Second, with all the U.S. interest in STEM education for pre-college students, several organizations could suggest best practices to the Gen-3 personnel. These organizations would include various entities in or associated with the Department of Defense (see Endnote 9) as well as the House of Representatives' STEM Caucus and STEM Caucus Steering Group.

When there is sufficient experience upon which to build a set of best practices for Gen-3 ERCs, revisions to this chapter and others in the Best Practices Manual will be developed and released.

3.6.4 Items of Particular Relevance

In late 2010 and early 2011, many additional comments relating to Gen-3 ERCs were received. This subsection summarizes those comments. To start, several important messages appear below. These are amplified in following paragraphs.

“... agree with the speculated differences and also with the approach of allowing real experiences to develop and be incorporated later.”

“[XXX University] will not allow us to enter into any export control licenses as these represent restrictions on academic freedoms. Instead we have had to find routes to basic research exemptions to export control. In a recent project in [YYY], we had to construct a locked structure to secure our testbed and hire a guard to monitor access to the prototype 24/7. Also, only US citizens were allowed to operate the equipment in [YYY] — except for one [YYY] student who had fortunately been trained on the equipment in [XXX University] during the prior year.”

“A major issue we have encountered to date is mentioned – how to work with the foreign collaborators when you cannot provide a direct fiscal incentive. We don't have it successfully solved yet, but are trying.”

Concerns exist regarding intellectual-property issues and research-versus-product conflicts.

Significant differences exist between Gen-3 and Gen-2 ERCs relative to integration with industry (see introductory comments in Section 3.4).

Export Controls. As noted above, Gen-3 ERCs need to pay particular attention to potential International Traffic in Arms Regulations (ITAR) and Export Control issues. Export Control restrictions are especially challenging when it comes to operating testbeds in foreign countries, even in countries that are considered friendly allies. Beyond the complexities of sending prototypes lacking U.S. security classifications, export controls restrict information flows as well. For example, foreign students might be trained on U.S.- based testbeds, but foreign students at a foreign partner institution might not be allowed to train on the exact same testbed outside the United States.

Working with Foreign Collaborators. With respect to creating and sustaining buy-in, experience suggests that foreign-partner involvement is usually developed because of a specific relationship between individual ERC faculty and a collaborator at a foreign partner. Leveraging that professional relationship tends to create the most functional interactions. With respect to the possibility of learning from U.S. businesses that operate on a global scale, management of export-control issues remains critical (see above). Industrial processes for managing global technology interactions may or may not be applicable in academic situations, which require preventing information flow between U.S. and foreign subsidiaries except through carefully structured legal agreements and joint-venture arrangements. Some U.S. universities have detailed guidelines, others don't. With respect to working with foreign educators, finding ways to leverage foreign STEM initiatives could be attractive to U.S. educators. One challenge with also integrating smaller firms is that they are typically very lean and don't have the band-width for these types of initiatives unless there is support from their investors (probably a better place to engage).

Intellectual Property Relative to Start-ups and Small Firms. Gen-3 ERCs are expected to have active start-up/innovation infrastructure, which may bring the ERC industry members' rights to intellectual property into conflict with fostering home-grown start-up firms, especially if exclusive intellectual-property rights are needed for start-up survival. One comment noted that, in a survey conducted last year, many of the Gen-3 ERCs did not have specific policies and procedures to navigate these "unchartered" waters, especially when the start-ups cannot afford to pay membership fees at a level comparable to existing member firms. Another comment indicated that, although the notion of an ERC playing an "angel" role in start-up funding is being considered, it is highly unlikely that the funding levels being considered would ever be large enough to have an impact on start-up viability. It needs to be recognized that small, high-technology firms are frequently unwilling to risk diluting their intellectual-property-generation capability by partnering with an ERC developing intellectual property in a space the small firms consider their own. This situation has been encountered with small firms looking at the ERC core (most transformational) programs.

Resolving Research-versus-Product Conflicts. Relative to resolving conflicts between research and industrial products, clear delineation between core ERC research and development (accessible by all ERC industrial members) and non-core, synergistic-sponsored (or more applications-specific) research is important. Synergistic research can also be sponsored in particular areas to speed technology innovation and transfer.

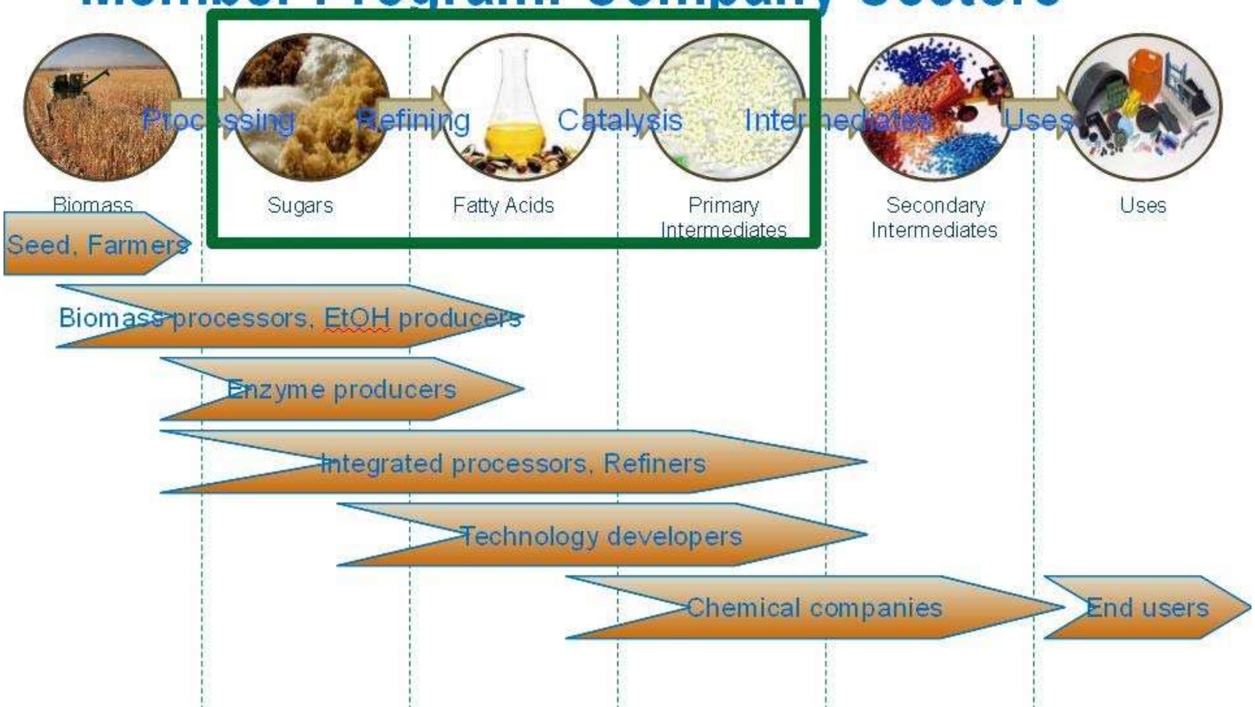
Gen-3 Integration with Industry. One person from a Gen-3 ERC contributed valuable comments by means of a slide presentation. The presentation was specifically oriented at Section 3.4, which addressed best practices for integrating research and industry. Because Gen-3 is the primary focus of Section 3.6, it was deemed best to include elements of that presentation here.

- Best practices for Gen-3 ERCs should explicitly recognize inclusion of innovation/venture partners in addition to industrial partners. Such partners can bring significant opportunities for early stage innovations to materialize (e.g., through start-ups).
- In light of the importance of innovation/venture partners, best practices for Gen-3 ERCs should also include recognition of the Industrial Collaboration and Innovation Director (ICID) as well as appropriate interactions between this Director and research thrust leaders (e.g., the Director manages and the thrust leaders assist).
- Depending on the Gen-3 ERC, some intellectual-property issues may be taken care of by the ICID.
- Regarding portfolio balance, communications, roadblocks, and industrial collaboration, there should be general sharing of best practices between the ICID (broader, across-ERC issues) and individual thrust leaders (primarily within-thrust issues).
- Perhaps a workshop day could be set up to acquaint industry employees at one end of a process spectrum to a basic overview of research and technology at the other end of the process spectrum.

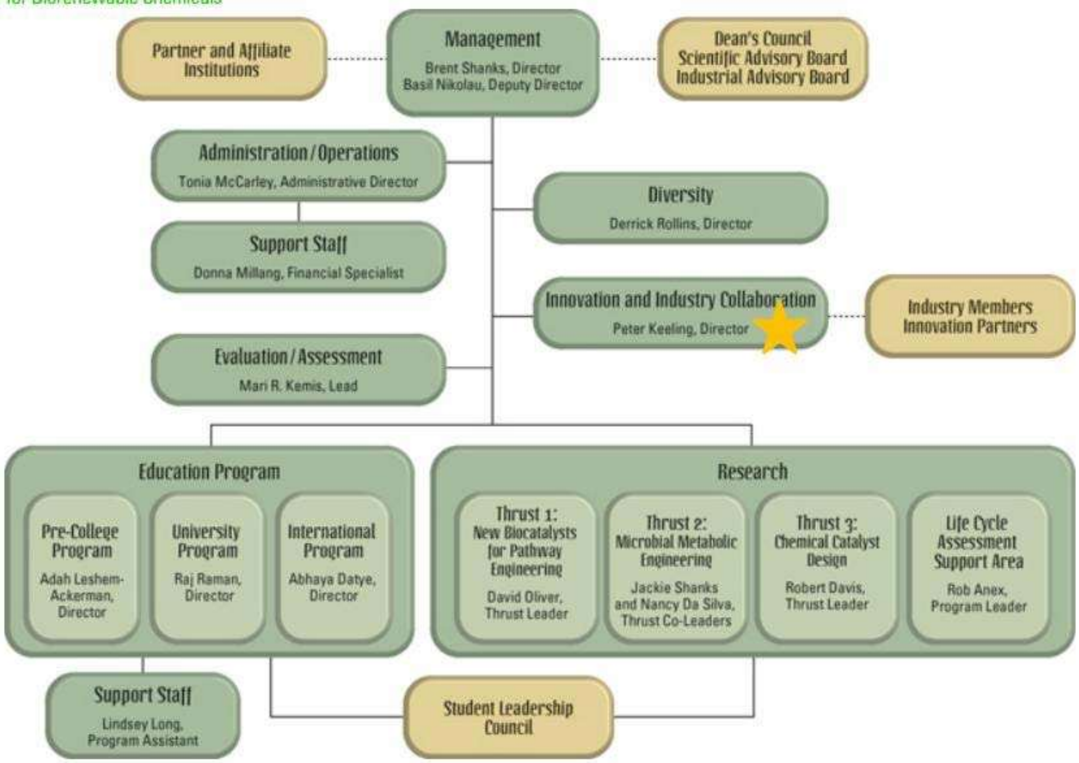
The three charts below furnish an overview of the ERC for Biorenewable Chemicals (CBiRC), the Gen-3 "process center" that was a basis for these suggestions. Note ICID (starred) in second chart.

CBiRC
NSF Engineering Research Center for Biorenewable Chemicals

Member Program: Company Sectors



CBiRC
NSF Engineering Research Center for Biorenewable Chemicals



CBiRC INDUSTRY MEMBERS AND PARTNERS

Industry Members: Allylix, Ashland, Chevron Phillips, Cibus, Danisco, DSM, Elevance Renewable Sciences, Genomatica, Grain Processing Corporation, Glycos Biotechnology, Novozymes, Poet Energy, Solazyme, The BioBusiness Alliance Minnesota

Innovation Partners: BioCentury Research Farm, Biomass Energy Conversion Facility, Center for Crops Utilization Research, Iowa Department of Economic Development, Iowa Values Fund, Iowa Demonstration Fund, Local Seed/Angel Funds, Pappajohn Center for Entrepreneurship, University Research Park, University Entrepreneurship Courses, University Offices of Intellectual Property, University/State Business Plan Competition

Venture Partners: Illinois Ventures, Khosla Ventures, Kleiner Perkins Caufield & Byers, Equity Dynamics, Mayfield Fund, Cimarron Capital

3.7 CONTRIBUTING AUTHORS

Norm Haller, a technical consultant working with SciTech Communications LLC, coordinated the contributions of a task group of ERC staff and wrote the chapter. **Court Lewis**, President of SciTech, organized and oversaw this effort. The ERC task group was led by **Wendell Lim**, Deputy Director of the Synthetic Biology Engineering Research Center (SynBERC), headquartered at UC-Berkeley, and **Henry Kapteyn**, a thrust leader at the ERC for Extreme Ultraviolet Science and Technology (EUV ERC), based at Colorado State University.*

The formative meeting for this work took place on December 2, 2009, as part of the National Science Foundation's ERC Program Annual Meeting in Bethesda, Maryland. Several teams met in an all-afternoon Research Thrust Leaders' Workshop to prepare a revised outline of Research Management Best Practices and develop some elements of the content. **Monika Ivantysynova,** Center for Compact and Efficient Fluid Power; University of Minnesota (CCEFP), was the team leader for Section 3.2. **Rich Schulz,** Quality of Life Technology ERC; Carnegie Mellon University (QoLT), led Section 3.3. **Alberto Cuitino,** ERC for Structured Organic Particulate Systems; Rutgers University, led Section 3.4. **Dan Siewiorek,** Quality of Life Technology ERC; Carnegie Mellon University (QoLT), led Section 3.5.

This chapter reflects the material developed there and subsequent reviews and additional inputs by workshop team members, as well as review by NSF ERC Program staff. In particular, in late 2010 and early 2011 additional comments relative to Sections 3.4, 3.5, and 3.6 were received by Court Lewis and Norm Haller. Some of these comments were from two original contributing members listed above (Alberto Cuitino and Dan Siewiorek). Other contributors were Joseph Montemarano, Executive Director, ERC on Mid-InfraRed Technologies for Health and the Environment (MIRTHE), Princeton University; Robert Karlicek, Center Director, ERC for Smart Lighting, Rensselaer Polytechnic Institute; Jacqueline Vanni Shanks, Thrust 2 Leader at the Center for Biorenewable Chemicals (CBiRC), Iowa State University; and William Wagner, Deputy Director, ERC for Revolutionizing Metallic Biomaterials (RMB), North Carolina A&T State University.

**Dr. Lim is on the faculty at the University of California at San Francisco, a SynBERC partner institution. Dr. Kapteyn is a faculty member at The University of Colorado-Boulder, an EUV ERC partner.*

3.8 SOURCES AND REFERENCES

Endnote 1. National Science Foundation. Fact Sheet, Engineering Research Centers. [http://www.nsf.gov/news/news_summ.jsp?cntn_id=114951].

Endnote 2. Williams, J.E., Jr., and Lewis, C.S. (2010). Post-Graduation Status of National Science Foundation Engineering Research Centers: Report of a Survey of Graduated ERCs. Prepared for Engineering Education & Centers Division,

Directorate for Engineering, National Science Foundation. Melbourne, Florida: SciTech Communications, January 2010. [http://erc-assoc.org/sites/default/files/topics/Grad_ERC_Report-Final.pdf]

Endnote 3. See the following source for discussion of the components of what a National Research Council committee judged to be mandatory considerations for a "world-class" research and development organization. (National Research Council. 1996. *World-Class Research and Development: Characteristics for an Army Research, Development, and Engineering Organization.* Washington, D.C.: National Academy Press).

Endnote 4. CliffNotes. Concepts of Organizing. Authority. Delegation. 2. Give team members the correct amount of authority to accomplish assignments. [https://www.cliffsnotes.com/study-guides/principles-of-management/creating-organizational-structure/concepts-of-organizing].

Endnote 5. Hal Johnson. Transition Issues: Create and execute a strategic plan for your company. Sacramento Business Journal. [http://sacramento.bizjournals.com/sacramento/stories/2003/12/01/smallb7.html].

Endnote 6. Siewiorek, D.P., Smailagic, A., and Lee, J.C. (1994). An interdisciplinary concurrent design methodology as applied to the Navigator wearable computer system. Journal of Computer and Software Engineering, Ablex Publishing Corporation, 2(3), 259-292.

Endnote 7. Smailagic, A., Siewiorek, D. P. et. al. (1995). Benchmarking an interdisciplinary concurrent design methodology for electronic/mechanical design. Proc. ACM / IEEE Design Automation Conference, 514-519.

Endnote 8. One source for the names of global companies who have disseminated best practices for their operations is Plant Success. [www.PlantSuccess.org]

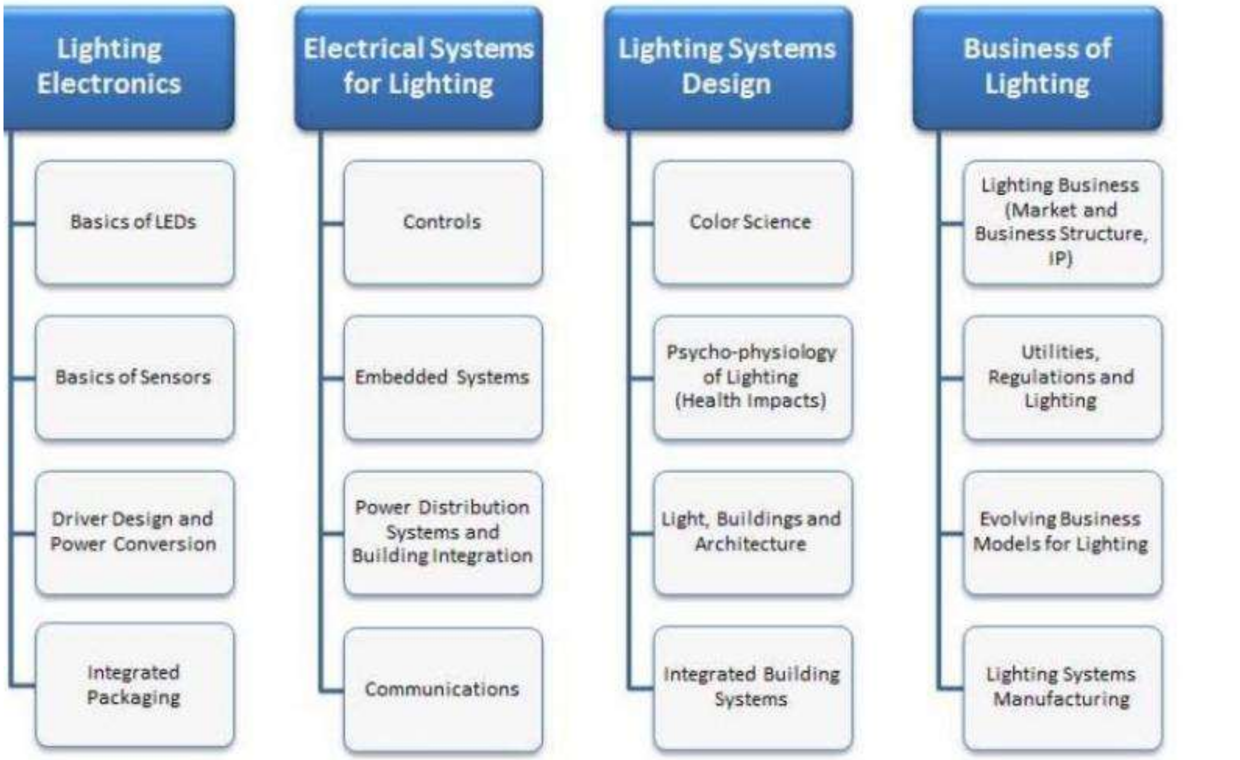
Endnote 9. Information on the nationwide STEM education program for youth, known as StarBase, is available from Ernie Gonzales, Office of the Secretary of Defense, Reserve Affairs. [Ernie.gonzales@osd.mil] Other sources for STEM information include the National Defense Industrial Association, the Air Force Association, and The National Academies.

Chapter 4: Education Programs

<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.0 Transitional//EN" "http://www.w3.org/TR/REC-html40/loose.dtd">

Appendix 4.3: Precollege and Community Engagement Examples

Image:



Appendix 4.4: Undergraduate Education Examples

Appendix 4.5: Graduate Education Examples

Appendix 4.6: Assessment and Evaluation examples

Appendix 4.7: Sustainability Examples

Section 4.1: Introduction

From the beginning of the Engineering Research Centers (ERC) program, ERCs have been focused on creating a culture that integrates research, education, and industrial practice to produce engineering graduates who are more effective in industrial practice, and to infuse new knowledge at the interface of disciplines into the engineering curricula. Third-generation (Gen-3) ERCs—that is, all ERCs established in FY 2008 and after—have an additional mandate, to increase the creativity of engineering graduates and expose them to innovation, entrepreneurship, and research practices in other countries and to produce graduates who will be creative U.S. innovators in a globally competitive economy." Each center is built on three pillars: research, education, and innovation through technology translation/transfer. All three of these components must be fully integrated in a successful center.

ERCs are motivated by an engineered systems vision and structured by a strategic plan that defines a research program to address barriers in the way of realizing the vision. The strategic research plan structures an integrated program of fundamental and applied research that feeds into proof-of-concept enabling and systems technology testbeds.

An ERC's education program is comprised of a university program and a precollege program. The university education mission of an ERC is to prepare students for effective practice in industry and to enhance their capacity for creative and innovative leadership throughout their careers. The precollege education mission rests on long-term partnerships with K-12 institutions to expose science, technology, engineering, and math (STEM) teachers to engineering and deliver engineering concepts and experiences to their classrooms to stimulate student interest in engineering careers. The interface of the research and educational culture of the ERC enriches the participating universities through the transfer of ERC-generated knowledge into engineering curricula.

A team of faculty, students of all levels, and staff who share the ERC's vision develop the ERC's culture. They come from different disciplines and perspectives of research, education, and technological innovation, and they include rich perspectives offered by diversity in gender, race, ethnicity, and other demographics.

According to the ERC Program culture and each center's specific education strategic plan, each center is expected to attract new students to engineering and to produce engineering graduates who will be highly effective in industrial practice and be the creative innovators of the global economy of the future. There are four main target audiences: graduate students, undergraduate students (including community college students and veterans), precollege students, and the general public.

Each ERC's engineering education program is expected to include:

- University undergraduate and graduate education programs strategically designed to produce graduates with the skill sets needed to be creative, adaptive, and innovative, well prepared for effective leadership in industry through knowledge about industrial practice,

technology advancement, entrepreneurship, and innovation. "Strategically designed" means that there should be an education strategic plan for the center, and it is especially important for Gen-3 ERCs since there is an expectation that the center develops and implements purposefully the education plan that will produce the type of students that the center is aiming to graduate.
- Advances in curricular materials derived from the ERC's interdisciplinary and systems-focused research;
- Long-term precollege partnerships aimed at exposing K-12 STEM teachers to engineering and to delivering engineering concepts and experiences to their classrooms (either directly or via the teachers) in order to stimulate student interest in engineering careers and increase enrollment in college-level engineering degree programs.
- General Outreach to involve precollege students in the ERC activities.
- Strategies to recruit and retain a diverse body of students who are involved in the education activities carried out by the ERC.

NSF provides guidance with respect to outcomes expected from a successful center education program. These outcomes are clearly articulated in the applicable solicitation and are reiterated below:

- The goals of the university education strategic plan will impart skill sets to undergraduate and graduate students so that they will be:
    - Effective in advancing technological innovation in industry
    - Adaptive and creative innovators
    - Effective in innovation in a globally connected, innovation-driven world.
- The strategic plan clearly specifies:
    - Desired characteristics and skill sets of graduate and undergraduate student researchers
    - Approaches to impart these skill sets to students via the education program
    - Measures to assess progress and impacts through longitudinal data
    - Mechanisms to incorporate assessment feedback to improve program content and delivery
    - Actionable plans to mentor students, post-doctoral researchers, and junior faculty.
- The education program will be integrated with the center's research with foreign collaborators so that students have the opportunity to carry out research relevant to the ERC's goals at foreign laboratories for a time sufficiently long to provide knowledge of foreign research practices, equipment, and other competencies.
- Effective plans are in place to integrate the ERC's cross-disciplinary and systems research into courseware and curricula and to disseminate outcomes and curriculum/outreach products to all ERC partners and for workforce training.
- The precollege education program will develop an effective long-term partnership with up to five precollege institutions (school districts or individual schools) nearby the lead and/or partner universities, to incorporate middle and high school teachers and students in ERC-related activities.

- If community college or technical college faculty and students are involved, the experience will add value to the educational capacity of the faculty and students as well as to the faculty and students of the ERC.
- Effective assessment tools are utilized to incorporate feedback from assessments/evaluations into the education programs to improve program content and deliver on program goals.

The development of an ERC education program requires strategic planning, a team of experts, and participation from all stakeholder groups. These teams can benefit from the collective experience of Education Program Directors at existing centers. This chapter has been assembled by these experts in ERCs across the country and is intended as guidance to those considering developing an ERC or ERC-like education program, as well as for new ERC education personnel who join an ongoing center.

It is important that new centers not interpret the contents of this chapter as a list of requirements for ERCs. Instead, it is a resource describing the collective wisdom of multiple ERC University Education and Precollege Education Directors. It can be used to identify programs and techniques that have worked in the past, being aware that each situation is different. ***Specific review criteria for each component of an ERC, by age of the ERC, are available at the ERC documents website*****.**[1]

Nonetheless, in addition to the prescribed goals above, the ERC must include a Research Experiences for Undergraduates (REU) Program, Research Experiences for Teachers (RET) Program, and Young Scholars (YS) Program (for Gen-3 ERCs only). However, NSF encourages centers to apply the same creativity and innovation that drive their research programs in determining how they develop and implement these education programs at their particular ERC. Additionally, latitude is given with respect to specific details and programming for other education and general public outreach programs that involve precollege students in ERC activities.

This chapter is divided into six sections: Program Planning, Precollege Education, Undergraduate Education, Graduate Education, Assessment and Evaluation, and Program Sustainability. Each has two parts. The first is a summary of the topic and includes suggestions and recommendations. The second part, a corresponding appendix, is a collection of center-specific program descriptions that offer an example of how that particular center has implemented a given program. These examples describe how a given program works in a specific center; together they illustrate the breadth of programs offered by centers as well as how centers have implemented required programs and developed new ones. Each example includes contact information, and readers who would like to import a given program are encouraged to contact ERC program personnel directly to learn additional details.

Current and prospective ERC Education Program Directors are urged to start with the planning section and follow the steps regarding identifying desired outcomes, identifying local programs that can be leveraged, identifying local opportunities for new programs, including assessment and evaluation in the process, and being mindful of opportunities for sustainability.

Each ERC Education program must support the mission of the center and each component must be consistent with the mission. Additionally, ERCs have historically been leaders in promoting diversity in all of their programs and all centers are expected to continue this tradition of including those who have been underrepresented in the Nation's science and engineering enterprise.

The following Exhibits provide data gathered by the NSF ERC Program from the ERCs in the portfolio. They give prospective and current ERC Education Directors information on the type of outcomes and investments made in Education by ERCs. The data was obtained from the NSF ERCWEB program database.

1 - https://www.erc-reports.org/public/library

Exhibit A. Current ERCs in FY2014 and Technology Clusters of the ERCs

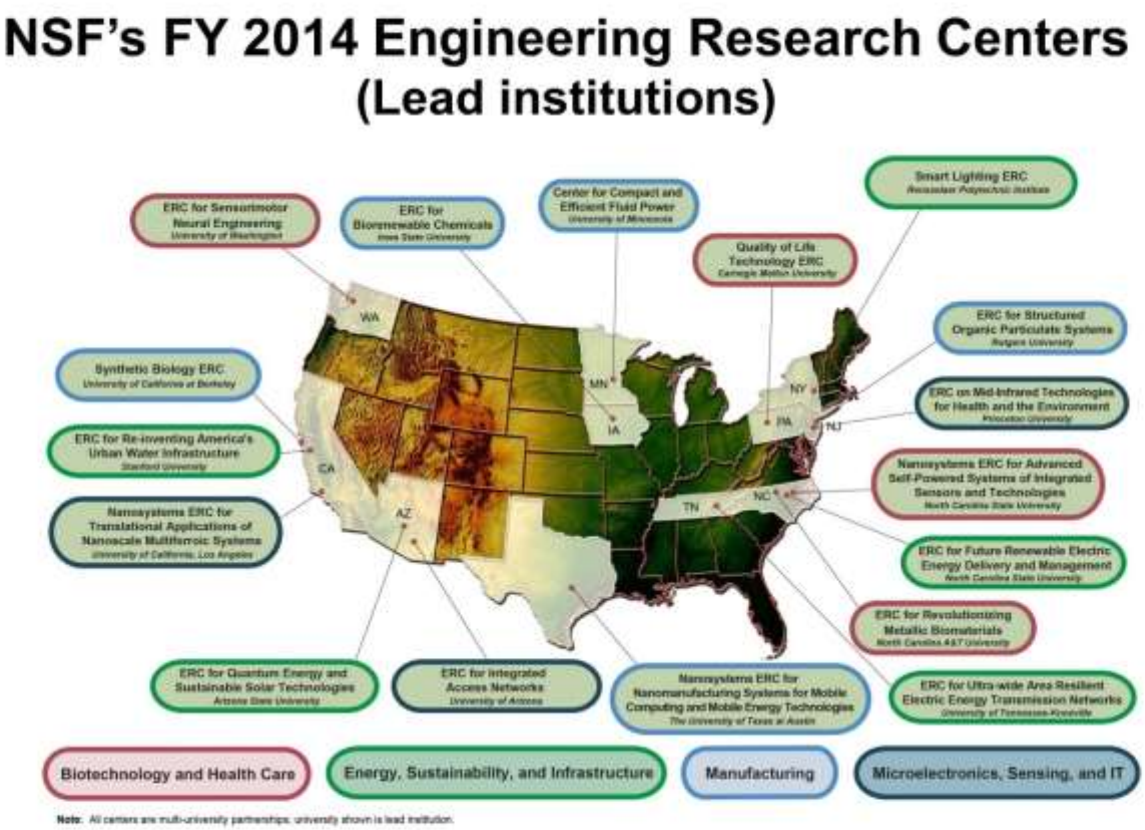


Exhibit B. ERC Influence on University Curriculum, Historical

ERC Influence on Curriculum, FY 1985–2013

	FY 2013 (20 ERCs)		FY 2008–2012 Annualized		FY 1985–2013 (58 ERCs)
Degrees	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
New Full-Degree Programs Based on ERC Research	2	< 1	3	< 1	42
New Degree Minors Based on ERC Research	2	< 1	3	< 1	30
New Certificate Programs Based on ERC Research	4	< 1	2	< 1	28
Courses	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
New Courses Based on ERC Research	63	3	46	3	864
Ongoing Courses With ERC Content	303	15	161	10	1,453
Course Modules Based on ERC Research	30	2	21	1	497
Textbooks	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
New Textbooks Based on ERC Research	10	1	3	< 1	152
New Textbook Chapters Based on ERC Research	13	1	7	< 1	52

Exhibit C. Curricular Impact of ERCs, FY 2007-2013

Curricular Impact of ERCs, FY 2007–2013

	FY 2013 (20 ERCs)		FY 2008–2012 Annualized		FY 2007–2013** (32 ERCs)
New and Ongoing Courses, Workshops, Short Courses, Webinars, and Textbooks Based on ERC Research	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
With Engineered-System Focus	335	17	208	13	1,470
With Multidisciplinary Content	280	14	208	13	1,396
Offered at Undergraduate Level	196	10	125	8	889
Offered at Graduate Level	313	16	176	11	1,264
Used at More Than One ERC Institution	40	2	43	3	267
Team Taught by Faculty in More Than One Department	78	4	52	3	373

Exhibit D. ERC Student Degrees, FY 1985-2013

ERC Student Degrees, FY 1985–2013

	FY 2013 (20 ERCs)		FY 2008–2012 Annualized		FY 1985–2013 (58 ERCs)
Degree Type	***Total***	***Per Center***	***Total***	***Per Center***	***Total***
Bachelor's	88	4	82	5	3,895
Master's	104	5	87	5	3,750
Doctoral	134	7	135	8	4,151
Total	***326***	***16***	***305***	***18***	***11,796***

Exhibit E. ERC Graduate Employment (20 centers) FY2013

ERC Graduate Employment (20 Centers), FY 2013

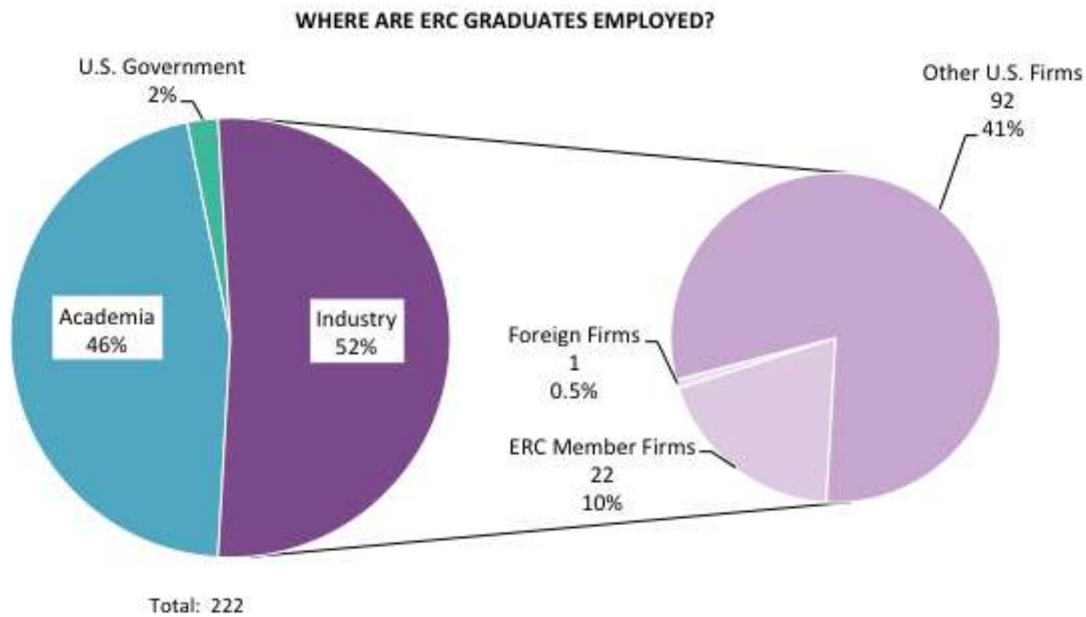
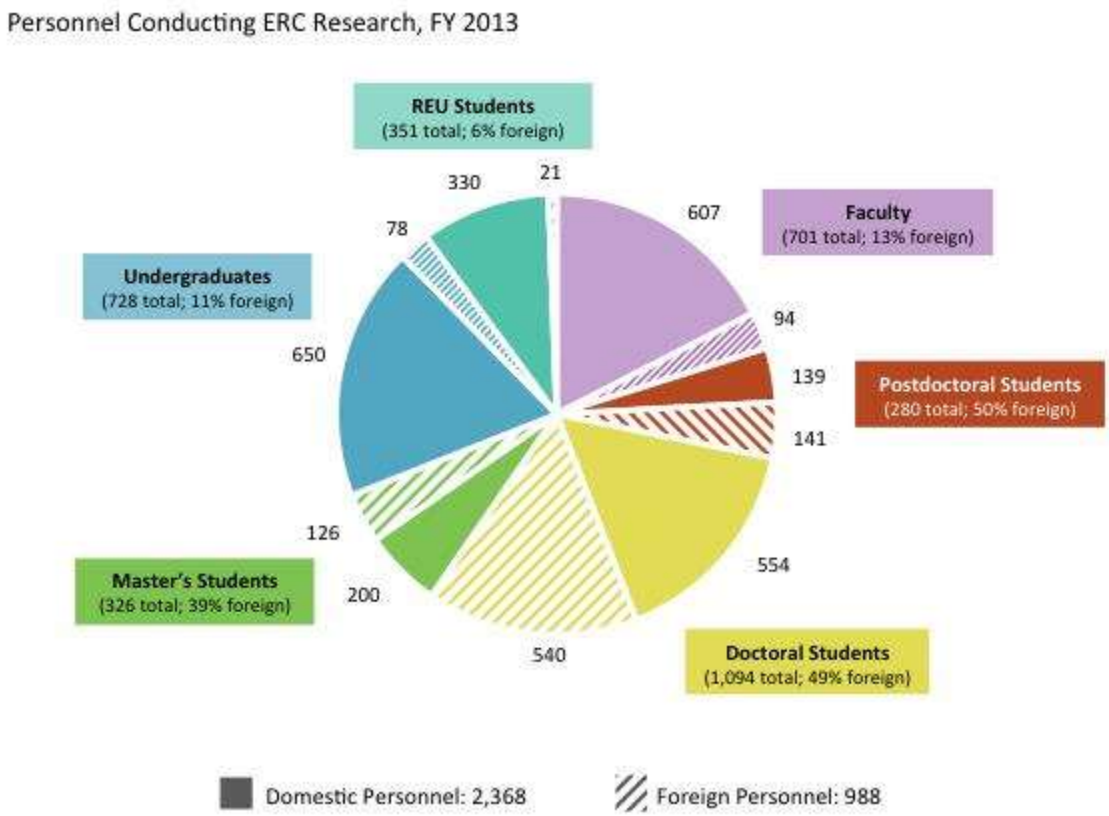


Exhibit F. Personnel Conducting ERC Research FY2013[1]



[1] The sum of the number of personnel for each category may exceed the total number of personnel because personnel may belong to multiple categories. Percentage of foreign personnel is calculated out of domestic and foreign personnel, excluding personnel who did not report citizenship.

Exhibit G. Education Program Expenditures from Unrestricted and Restricted Cash

All ERC Centers

Year	Average Education Total Per Center	Number of Centers	Education Total	Unrestricted Cash: Precollege Activities	University Education	Student Leadership Council	Young Scholars	REU	RET	Assessment	Community College Activities	Other
2002	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2003	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2004	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2005	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2006	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2007	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	[illegible]	$0	$0	$0	[illegible]
2008	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2009	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2010	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2011	[illegible]	[illegible]	[illegible]	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2012	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2013	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average All Years	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Year	Restricted Cash: Precollege Activities	University Education	Student Leadership Council	Young Scholars	REU	RET	Assessment	Community College Activities	Other
2002	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2003	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2004	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2005	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2006	$0	$0	$0	$0	$0	$0	$0	$0	[illegible]
2007	$0	$0	$0	$0	[illegible]	$0	$0	$0	[illegible]
2008	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2009	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2010	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2011	$0	$0	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2012	[illegible]	[illegible]	$0	$0	[illegible]	[illegible]	$0	$0	[illegible]
2013	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$0	$0	[illegible]
Average All Years	[illegible]	[illegible]	$960	[illegible]	[illegible]	[illegible]	$0	$0	[illegible]

* REU data was first collected in 2007, RET data was first collected in 2008, and Precollege Activities, University Education, Student Leadership Council, Young Scholars, Assessment and Community College Activities were first collected in 2012.

Section 4.2: Engineering Education Program Planning and Management

4.2.1 Introduction

The Engineering Education Program Planning and Management section of this chapter provides guidance for teams preparing new proposals, to newly awarded ERCs in their start-up phase, as well as to new Education personnel who join an established center. The section is organized into three main topic areas: (i) strategic planning, (ii) funding, and (iii) programs and Implementation. Specific programming suggestions and examples are detailed in later sections.

Planning the ERC's education programs must be conducted concurrently with the research and industrial/practitioner collaboration/innovation ecosystem components to insure maximum integration. All stakeholders should be included in the process, as education is a critical component of an ERC. Personnel qualified in collegiate and precollegiate education as well as education assessment and evaluation must be included at the beginning stages of the process. The Center Director, and representatives from each partner institution, as well as industry and practitioner representatives, must also be included in the process.

The primary objective of the comprehensive education programs at ERCs is to address the second goal of the ERC Program; that is, to produce graduates with deep knowledge of industrial practice and who will be creative U.S. innovators in a globally competitive economy. To that end, these programs include not only university-level education strategies but also strategies that attract precollege and non-traditional students to engineering careers. The programs will include assessment and evaluation to monitor progress and impacts over time and to improve the program as needed. All ERC education programs are tasked with improving the diversity of the engineering student body.

Each ERC has a strategically designed University Education Program focused on instilling in its undergraduate and graduate students the capacity for effective industrial practice, creativity, and innovation. The primary goal is to produce graduates who are technically prepared, able to integrate knowledge across disciplines to advance technology, knowledgeable of industrial practice, experienced in advancing technology, adept at working in highly functional teams, and effective communicators. An additional goal for Gen-3 ERCs is to deliver graduates who also are creative, innovative, and entrepreneurial and are experienced working in non-U.S. research cultures.

Given this guidance, the university education program must identify the key characteristics and skill sets its undergraduate and graduate students will possess upon graduation. The center should strategically design a set of programs, research training, and other experiences for their students to acquire these desired characteristics and skill sets. The ERC's foreign collaborations will serve as the basis for the overseas laboratory experiences for the students. The university education program impacts the curricula at the lead and partner universities. Based on the center's research, new courses and course modules/content for insertion in new and existing courses are developed. Although not required, the ERC may design and deliver a new degree program and/or certificate programs. If a Nanosystems ERC or an open topic ERC develops nanoscience and nanoengineering courses, course modules, lectures, etc., suitable for hosting on the cyber platform of the Network for Computational Nanotechnology[1] (NCN), those materials will be delivered to the NCN, where a broader community will have access to them in an open source mode for educational purposes.

The university education program will be carried out in collaboration with the ongoing education programs of the domestic partner universities. The program will be structured to involve ERC engineering and associated discipline students at the B.S., M.S. and Ph.D. levels and will be carried out in coordination with the center's Research Experiences for Undergraduates (REU) programs. The ERC may also coordinate university education programs with appropriate outreach to local community colleges and veterans groups for broader impact.

The goals of the ERC’s Precollege Education Program are to stimulate student interest in engineering careers and increase the diversity of domestic students studying engineering at the college level. The program will form long-term partnerships with up to five precollege institutions (i.e., school districts or individual schools). These institutions must be involved in the planning process to ensure that projects proposed will meet their students’ needs as well as to facilitate implementation and adoption. Opportunities for precollege institutions to work with the center include:

1. Involving their STEM teachers in structured ERC research and education programs;
2. Providing opportunities for research internship experiences for veterans who are teachers at the ERC;
3. Providing engineering learning and activity experiences for their students;
4. Integrating new course modules based on ERC research into precollege curriculum;
5. Developing strategies to involve underrepresented groups, both teachers and students, in engineering experiences with ERCs;
6. Developing general outreach programs to involve precollege students in the ERC’s activities; and
7. Enabling talented high school students to pursue research experiences in the ERC's laboratories through a Young Scholar program (Gen-3 requirement only).

Through innovative teaching methods and inquiry based-learning enabled by the ERC, these precollege teachers can inform precollege students about the excitement of engineering and technological innovation, and in turn, stimulate them to choose engineering degree programs in community colleges, colleges, and universities.

Although not required, community college and/or technical college faculty and students may be included in center activities to strengthen the skills of the technical workforce and stimulate some of these students to pursue B.S. degrees and beyond in engineering.

It is expected that the ERC's faculty and students will participate in the full scope of the precollege education program and that their mentoring efforts will be recognized and rewarded by their home institutions.

4.2.2 Strategic Planning

In planning an education program, the center's Leadership Team must take into account the following:

- *Center Mission Statement*. An ERC is a unique organizational team that has three mandates from NSF: (a) cutting-edge research, (b) technology transfer of the results of the research, and (c) preparation of the next generation of engineers and scientists. The mission statement should recognize the education component of the center that produces engineering graduates who will be highly effective in industrial practice and creative innovators in a global economy. The ERC’s culture evolves through a platform of transformational research and education programs in partnership with industry and other practitioners. It is essential to develop an Education Program Mission Statement as a component of the center's broader mission, to address NSF's mandates.

- *Education Program Goals.* Program goals must be specified at the beginning of the planning process. The Center Director, the Precollege Education Director, and University Education Director must develop the goals in conjunction with input from the center's Leadership Team. (*Please note*: All of these functions are known by different titles at different centers.) This step will ensure integration of research, technology transfer, and education (a hallmark of the ERC Program) and implementation of the program. These goals should be consistent with the center's mission statement and must address the scope of the program, the mechanisms for integrating center research and education, and mechanisms for industry-student interactions. The requirements for precollege educational outreach must be taken into account. Because ERCs have a particular mandate to ensure adequate representation of women and underrepresented minority students, recruiting measures to meet this mandate must be included. The goals will determine the scope and range of the ERC's education programs.
- *Organizational Considerations.* Initial planning must include the human resources that will be needed. The Director(s) of the Education program(s) should be a professional at the same level on the organizational chart as the research and technology transfer directors. It is recommended that a full-time professional be engaged at the outset and included in the planning stages of the program. While some centers rely on part-time faculty members to serve in this position, employing an individual with an education programming background will allow the center to implement a more complete and effective program.
- *The Actual Strategic Plan.* Given the limited lifespan of an ERC, the center's management must give strategic planning a high priority, beginning in the initial stages of a center's proposal. Strategic plans are dynamic documents that guide allocation of limited resources. They must be revisited annually to ensure that they are able to react to changes in the research and industrial environment and to allow for the exploitation of opportunities that arise during the year.
- *Budget.* The education program should include resources that match the proposed plan. While supplemental funding (e.g., from foundations, NSF, and industry) for particular programs may be available, center core funding resources should be earmarked to support the fundamental components that allow the center to meet its core educational goals. In FY2013, ERCs on average spent $488K each on their education programs (including restricted and unrestricted funds, see Exhibit G in the Introduction Section 4.1).
- *NSF/Center Interface.* NSF has an important guidance and support role to play in the development and growth of ERC education programs. NSF Program Directors and Staff are a resource to the ERC Education Directors in addition to their role in program oversight.

The strategic planning process for education is conducted in different ways at different centers, with a variety of participants, including the Education Director/Coordinator(s), the Center Director and Leadership Team, the center's Diversity Director, an Education Advisory Committee and/or the center administration, and possibly industrial stakeholder/partner or university involvement. See example 4.3.1.1 in Appendix 4.3 for a description of one ERC's planning process.

Some ERCs involve faculty from all of its departments of engineering or representatives from industry in the strategic planning process, as appropriate to the ERC's scope of research. Knowing the state of the art in your ERC research areas provides a base from which to modify and develop courses. Several ERCs use the activities of annual report planning and preparation as the time to review education program strategy and make changes. Some ERCs give the Education Director/Coordinator and staff leeway to make initial plans and decide on strategies, which are then reviewed by the Center Director and/or appropriate committee. Other ERCs form teams consisting of the Education Director/Coordinator, Center Director, some faculty members, and sometimes a graduate student representative. Another means of student input employed by centers is a Student Advisory Committee. Often the membership of such a committee is drawn from the center's Student Leadership Council. (See Best Practices Ch. 8[2] for information on these vital ERC student organizations.)

ERC Education Directors/Coordinators can consult their counterparts at other ERCs for ideas in constructing the initial plan, and they can meet with their Center Director, Industrial Liaison Officer/Industrial Partnership Coordinator, and senior center faculty to gather input on ERC education needs and issues. In addition, the Education Director/Coordinator must become familiar with the curricula at his or her particular school of engineering and other relevant departments within the university. Multi-university ERCs also must accommodate requirements of their affiliated universities' curricula.

The following is a general model of the process of developing a strategic plan:

Overall Goals/Objectives: The first step is to develop a statement of the overall goals/objectives of the education program, keeping in mind the center's vision (what you want the vision to be) and mission statement (what you do to implement the vision). Such a statement should include what you want to do, whom you want to affect, and how you intend to accomplish it. For example, an education goal/objective might be "to develop and deliver *innovative educational initiatives* to *prepare scientists and engineers* for the challenges of the emerging biology-based industries, *in order to produce a generation of engineers and scientists with a cross-disciplinary team perspective*." The strategy to accomplish this goal could include "a major outreach effort to middle and high school students and teachers."

Initiatives and Actions: Next, one must develop specific initiatives (specific, focused activities) and the actions for carrying them out. (Actions should be stated in measurable terms.) Initiatives might be planned in the areas of precollege outreach, undergraduates, graduate students, lifelong learning, and curriculum development. A few ERCs also include opportunities for elementary school students and teachers. For example, "K–12 initiatives will provide opportunities for middle and high school students and teachers to understand the center's research field and goals." This initiative might be supported by actions such as "Maintain a program of yearly demonstrations to X number of schools" and "Develop a web module."

The education strategic plan also should provide for developments over time. A plan appropriate for an ERC in its early years should change as the center matures, and will change even more as the center works towards self-sufficiency.

The center's program objectives and goals can assist to determine the scope of the program's offerings and to clearly identify projects and activities that consistently achieve ERC program objectives. Each project, activity, initiative or event should meet the following objectives:

1. Motivate diverse citizens to navigate the STEM pathway to expand and promote a talented STEM workforce.
2. Promote the awareness of <*specific area of research*>-- its technology, applications and career opportunities -- through positive, authentic experiences in informal precollege, undergraduate, graduate and industrial contexts.
3. Infuse <*specific area of research*> research and innovation into evaluated curricula and programs in informal precollege, undergraduate, graduate and practitioner offerings.
4. Create a culture that integrates research, education, and industrial practice for undergraduate and graduate students across the center.

The scope of the ERC's Education Programs is broad. It is useful to categorize programs by targeted specific audiences. Typically, as noted earlier, a center's Education Programs are divided into two main thrusts—University Education and Precollege Education—although a center may want to enhance its programs by providing public and professional/practitioner education programming.

Each program proposed under the two main thrusts should touch on one or more of the ERC Program's objectives. Specific programmatic elements of the Education Program portfolio include:

- Undergraduate research opportunities during the academic year in teams with graduate students
- Research Experiences for Undergraduates (REU)
- Research Experiences for Teachers (RET)
- Precollege outreach experiences for students in ERC activities
- Young Scholars research opportunities (Gen-3)
- Innovation and entrepreneurship experiences (Gen-3)
- Foreign laboratory experiences (Gen-3)
- New and modified curricula
- Research Experiences for Veterans/Teachers (NSF ENG/EEC Supplement opportunity)
- Other projects and programs.

Successfully meeting all of these expectations in the first year is not required; instead a focused effort in establishing the core program elements of the Program is recommended in the start-up phase. In fact, the site visit merit review criteria are phased depending upon the age of the center. (See the merit review criteria on this webpage.[3]) Following the first year, a phased approach works best. The University Education Program Director and the Precollege Education Program Director should strategically identify the respective programs that have the highest likelihood of success and sustainability and the appropriate timing of their implementation. A focused effort to design and implement the essential (required) elements of the program at the start-up phase is important. Shortly after the program is established and procedures and protocols, management, and organization are in place, the Education Leadership Team can begin to creatively design and implement programming specific to the needs of the center, its students, its stakeholders, and its researchers. The Education Leadership Team should assess components of the Education Program for risk and reward (success and sustainability) with anticipated timeframe and effort needed to coordinate, launch, and resolve. In the first year, a focused approach is recommended, rather than a shotgun approach. There are a variety of ways the Program could be phased and staged, and each center has unique resources, needs, and stakeholders. The Education Leadership Team should have a clearly devised strategy on how to phase the Program—its programming, its alignment with what's leveraged, and the needs of the center.

4.2.3 Planning for Sustainability

An important issue in strategic planning is the impact of the ERC's 10-year life cycle. Some program components are amenable to institutionalization, but others depend on supplemental funding that is not likely to be continued after ERC core funding ends. Courses that have been added to the curriculum by the center and any associated certificates, minors, and/or majors should be integrated in the university's curriculum prior to the end of the center, thereby becoming part of the continuing engineering education programming of the university.

As a center approaches the end of the NSF ERC Program funding cycle, these concerns come into sharper focus. NSF intends that the culture of ERC education will continue in the center; but without continuing support from the university, industry, or other programs at NSF, it is likely that most of the ERC's education programs will end. ***The center's Education Director/Coordinator should work with the center leadership to develop a self-sufficiency plan from the outset. This plan can include soliciting education funding from the university, foundations and the private sector (notably industry).*** It is recommended that programs and projects that have a high likelihood of sustained funding and/or support after the 10-year ERC Program funding cycle ends be identified in the initial phases of the ERC's development. It is visionary to consider who the long-term supporting stakeholders will be at the "graduation" of the ERC from ERC Program support, what programs may fulfill the future stakeholders' needs, and might those programs have a 10-year development phase in the ERC in order to provide value and justification to the future support of the center?

See section 4.7 for a more extensive discussion of sustainability of education programs.

The following are a few examples of best practices in the start-up phase that may help strategically align ERC education programs for long-term sustainability. The common theme for success is working to develop productive and lasting relationships from the very start of the center:

- Make the development of the engineering workforce through an ERC's education and research programs as critical to the center's mission as research, innovation, and entrepreneurship. This will create a sustainable education program that will be integrated within the research program, rather than a program independent of the center's research initiatives.

- Form meaningful, long-term relationships with K-12 schools. Over the lifetime of the ERC, outreach programs should become institutionalized at partner schools.
- Establish relationships and collaborations with other ERC Education Directors at the ERC Program's biennial meeting, during the monthly teleconference calls, and during special ERC Education Directors' retreats.
- Search out and build partnerships with existing entities on your campus that have permanent funding to leverage already existing and institutionalized programs.
- Ensure that multiple educational pathways are represented in the program (e.g., use K-12 programs to feed the undergraduate and graduate programs).
- Assess the needs of current and future stakeholders. Example questions include: "What are the needs of industry now and anticipated for the future?", "How can we can fulfill those needs?", and "What can we uniquely offer that answers to that need?"
- Institutionalize ERC education through new coursework, programs, and degrees. How can these be aligned across partner institutions? Understand curricular development and approval processes early for smoother integration and quicker implementation.
- Study what it takes to be successful in gaining site awards from the NSF REU and RET programs.

4.2.4 Understanding Needs, Context, Stakeholders, and Resources

Leverage Existing Infrastructure: In many cases, there are pre-existing programs, resources, and infrastructure at institutions associated with the ERC that can be leveraged to simplify the start-up process. Identifying and collaborating with these entities can save time and resources, allowing faster implementation of a variety of education programs, and facilitating the sustainability in the long run.

Identify Opportunities and Barriers: The assessment of opportunities for collaborating in education programs should be balanced with the needs of the center and any obstacles to success. While some programs offer the ease of "plugging in" to an existing infrastructure, it is important to ensure the student experience is unique and the educational content is tailored to the mission of the ERC.

Inventory Existing Resources: Some examples of resources that other ERCs have leveraged are listed below. These opportunities are highly dependent on resources available at each institution.

- Many outreach programs are extensions and specializations of prior existing programs. Also, ERC programs can be tied to existing programs by offering expertise and/or opportunities that were made possible through the ERC.
- Example partnerships include:

1. CalTeach, a UC-Berkeley teacher training/development program, provides professional development workshops to teachers in an RET program at the Synthetic Biology ERC (SynBERC).
2. The Transfer Alliance Program (TAP) at UC-Berkeley provides transfer advising services to Center community college REU students.

3. The California Institute for Quantitative Biosciences has co-partnered with SynBERC to develop and run Lab Bootcamps for Undergraduates, a traveling one-day symposium called "What You Can Be With a Ph.D", and a summer industry internship program for undergraduates;
4. A K–12 robotics camp was successfully integrated into the ERC K–12 program at the Quality of Life Technologies (QoLT) ERC; and
5. Aligning a center REU program with existing university-wide summer undergraduate research programs allowed the Biomimetic MicroElectronic Systems (BMES) ERC to leverage the many activities being provided to REUs by the University of Southern California, Viterbi School of Engineering, and encouraged students to become immersed in a large and diverse REU community. Many other centers, such as the ERC for Collaborative Adaptive Sensing of the Atmosphere (CASA), based at the University of Massachusetts-Amherst, the EUV ERC at Colorado State University, the Smart Lighting ERC at Rensselaer, and the FREEDM Systems ERC at North Carolina State University, have done the same thing.

4.2.5 Engaging Engineering Education Specialists and Evaluation and/or Program Assessment Experts as "Intellectual Partners"

From the start of the program it is good practice to either engage with, or have on staff, engineering education specialists and evaluation and/or program assessment experts. This communication will ensure that the education program's mission, vision, and program goals align well with the proposed programs and desired outcomes. These experts may also recommend surveying the current and future stakeholders to determine if the elements of the education program meet the needs of industry or other stakeholders.

Best Practices and examples of what others have done include:

- Approach education programs from a research perspective and aim to collect data suitable for publication.
- Utilize assessment experts who are familiar with NSF programs (such as REU and RET) and can bring expertise about what works and what doesn't to the table. This will save immeasurable time and money!
- Hire experienced education evaluators and researchers. For example, when putting the team of precollege leadership together, the BMES ERC put College of Education faculty on the leadership team. Similarly, the FREEDM Systems ERC works with other non-engineering faculty to conduct their precollege and college assessments. The ERC for Revolutionizing Metallic Biomaterials (ERC-RMB) at NCA&T State University has an evaluator who is on the faculty of the NCA&T School of Education. Her role is broad in scope, providing assessment overview for precollege education and outreach, as well as for shaping evaluation research in university education.

4.2.6 Role of Partner Institutions

Clearly defining the roles of partner institutions within the workforce development and education programs is a very important issue, one which has no prescriptive solution. There are many organizational schemes that have been successfully implemented in different centers. For example, the lead institution may centrally oversee the education program activities and manage the budget, with only a single faculty member at partner institutions to oversee progress. Alternatively, partner institutions may have individual education leaders and budgets to implement their own programs within the scope of the overall ERC education program mission and objectives. There is likely a range of solutions that lie between these two extremes. It is important, however, that all partner institutions be involved in these activities.

A few best practices and lessons learned from current and graduated ERCs include:

- The SynBERC ERC has an East Coast and West Coast hub, with one faculty member designed to oversee education program activities at campuses on either coast. All efforts are centrally coordinated at UC-Berkeley, but having faculty responsible for overseeing programs on each coast has been a great help.
- As you decide on the roles of individuals at partner institutions, be aware that it may be challenging to arrange Institutional Review Board Certifications (IRBs) across universities.
- The graduated Virginia Tech ERC, CPES, pioneered multi-university ERC partnership, developing cross-campus articulation agreements that enabled students from one partner campus to take a course at another campus and earn credit on the home campus.
- It is useful to form consortia within or across ERCs for large shared proposals, e.g., equipment.

4.2.7 Developing Partnerships Across the ERCs

Education leaders from other ERCs can be a key resource for centers in their first years. Partnering with other centers to leverage each other's pre-existing infrastructure, or simply seeking advice from someone with a few years of experience navigating the workforce development program landscape can be quite valuable.

Some examples of best practices in collaboration include:

- Attending conferences or seminars where education program representatives from all the existing ERCs will attend. This can be useful for collaboration and network building.
- Using other ERCs as a resource for recruiting teachers and undergraduates for RET and REU programs.
- Sharing a variety of programs, curricula, and assessment tools with partners at other ERCs.
- Partnering with other ERCs to co-sponsor a booth at recruitment conferences. This is an efficient use of resources.

4.2.8 Role of NSF

The Professionals of the Engineering Education and Centers Division are resources to serve the ERC Education Directors/Coordinators in developing and enhancing their education programs. They have the experience to provide guidance and to identify others who might serve as resources to assist in strengthening the education programs. NSF also provides publicity to industry and works through other NSF programs to support the centers.

NSF ERC core funds and supplemental funding based upon competitive proposals serve as a nucleus for developing strong education programs. Recognition of the importance of ERC education programs in the ERC biennial meetings and conferences and during site reviews help Education Directors/Coordinators strengthen their respective education programs. NSF support is philosophical as well as financial and is critical for developing strong ERC education programs and ensuring that education is an important aspect of the centers.

Some examples of NSF's support to ERC education programs include:

- Monthly teleconference calls among the University and Precollege Education Directors and NSF Program Directors responsible for ERC education efforts, hosted by NSF at ERC_E-O@LISTSERV.NSF.GOV.
- Continual emphasis by NSF Program Directors on the importance of education and educational programs in the ERC. In this way, NSF Program Directors emphasize to the leadership and faculty of the ERC the significance of these programs. This greatly helps the education endeavors at the centers.
- Providing opportunities for additional NSF sources of funding and publicizing these funding options to the centers.
- Emphasizing the significance of collaboration between centers and encouraging these collaborations verbally and through funding sources.
- Providing critical insight to centers through annual site visits that help improve center programming.
- Providing guidelines that define the programs, performance criteria that define excellent and poor performance, and reporting guidelines that document annual progress, as well as cumulative progress at renewal and at "graduation."
- Laying the groundwork for the development of education programs with a strong industrial element, by mandating an industrial component to the center's architecture. This component benefits both undergraduate and graduate students,
- Promoting innovative programs that allow cutting-edge technology to be developed to the point where it can be utilized by industry and benefit the general population, through funding of the ERCs. Center education programs are an essential vehicle for disseminating these new technologies into industry, by means of the center graduates and center outreach.

A strong relationship with the NSF ERC Program Leadership, and especially the NSF Program Director who is responsible for the oversight and review of your ERC, will enhance the development and implementation of an ERC education program.

4.2.9 Funding

Budget

The initial budget for education should include funding for start-up, advertising and recruiting, and other efforts to ensure a successful beginning for the program in addition to stipends for undergraduate students (e.g., for center research fellows, summer research programs, and other activities), research assistantships for graduate students, and appropriate staff support. Because ERC education programs must collect data and make extensive reports to NSF, data management and report writing capabilities must be planned for at the outset.

The initial budget may include some costs (such as travel) that support the development of relationships with the partner institutions and other undergraduate and minority institutions. Once these relationships have been developed, budgets may be partially reallocated to other purposes. Some centers use education budgets only for stipends and student support, with staff and travel budgeted in other center funds.

The education budget or the overall center budget must include funds for the leaders of the education programs to attend annually, either the ERC Program Education Retreat or the Biennial ERC Program Meeting.

As the center matures, NSF supplemental funding and leveraged support from other sources, as well as industrial funding, should increase. Ideally, after the first few years, it should not depend entirely on internal ERC core funds.

As the center approaches graduation, the most likely scenario for continuation of the education programs is through leveraged support via additional funds from the university, foundations, industry, and state programs as well as through NSF REU and RET site and other NSF education programs.

Education budget decisions allocating overall resources should be made by the center Leadership Team—including the Director, Deputy Director, Education Director/Coordinator, Thrust Leaders, and Industrial Liaison Officer. In some ERCs, Education Directors/Coordinators submit proposals for funding along with research thrust proposals, and all proposals are considered by an ERC funding committee. Some ERCs have a budget for program development, which includes scholarship/fellowship stipends and seminar and travel expenses. It is recommended that there be an amount, a set-aside for the education programs, that is respected by the other members of the leadership team, many of whom will have competing research proposals in line for funding.

The education program should include resources that match the proposed plan. While supplemental funding (from foundations, NSF, and industry) for particular programs is available, center core funding resources should be earmarked to support the fundamental components that allow the center to meet its core educational goals. In FY2013, ERCs on average spent $488K each on their education programs (including restricted and unrestricted funds, see Exhibit G in the Introduction Section 4.1). Items that should be in the education budget include:

- Administrative costs (e.g. faculty, staff, overhead, printing, and data collection/management)
- Graduate student support

- Support for Student Leadership Council (SLC) activities
- Funding to support the academic year undergraduate research program
- Funding for precollege outreach
- Programmatic funding needs
- Travel (for recruiting, dissemination, and annually to either the ERC Program Education Retreat or the Biennial ERC Annual Meeting)
- Assessment personnel and program
- NSF Requirements

- Minimum of $42,000 spent from the core ERC budget on the ERC's REU Program, regardless of whether or not there are REU site awards.
- Minimum of $42,000 (Classes of 2006-2012) or $87,000 (Class of 2015) spent from the core ERC budget on the ERC's RET program, regardless of whether or not there is a RET site award.

Other Funding Opportunities

Funding for educational activities may be derived from a number of sources. Specifically, there are occasional opportunities for competitive supplemental funding from the ERC Program, education/outreach awards from other divisions and directorates of NSF, RET and REU site awards, special grants from industry members of the center, funds from the university for diversity-promoting activities, education grants from philanthropic organizations, and possibly state sources. Opportunities should be pursued to leverage the funding received, using non-federal ERC funds for matching. Some centers have been quite successful in leveraging their education budgets with university, state, and other federal resources. External foundation (not NSF) funds may be used for matching funds with NSF-supported activities.

Opportunities from NSF include:

- ERC Program supplemental funds—these are provided for special initiatives, such as the Research Experiences for Undergraduates (REU), Veteran's Research Supplement Program[4], outreach to Historically Black Colleges and Universities (HBCUs), technical schools, and international programs, as well as other special supplemental funds. Such programs significantly strengthen ERC education programs. They provide a focus for center education activities and serve as a fulcrum for leveraging support from other sources, including industry.

- Division of Engineering Education and Centers Active Funding Opportunities
- Research Experiences for Undergraduates Site Award
- Research Experiences for Teachers (RET) Site Award

- Starting in FY2014, the EHR Directorate's Research Traineeship Program (NRT)

- Historically Black Colleges and Universities_Undergraduate Program (HBCU-U).

Industry: There are opportunities for supplemental funding from special grants from industry members of the center to sponsor outreach activities or events, capstone design projects, sponsored research under the center's Education and Outreach Programs. Industry associations are eager to support educational initiatives for the potential workforce.

Other Sources: Other creative routes in leveraging educational and outreach support include garnering investment from other local, state and federal governmental agencies committed to educational development. Examples include:

- U.S. Department of Education
- U.S. Department of Energy
- U.S. National Institutes of Health
- U.S. National Aeronautics and Space Administration
- Local school districts, associated initiatives, partnerships
- National student organizations and local student chapters

Fellowships: Assisting students to apply for fellowship support can greatly leverage the research funding for the ERC, and enhance the student's profile and prospects post-ERC.

Leveraging: Programs that allow for multiple purposes to be satisfied simultaneously are obviously desirable, which is highly dependent on pre-existing alignment, stakeholder needs, and funding. Alignment with other programs was discussed previously, and stakeholder needs should be part of the assessment regarding opportunities and barriers. Leveraging of funds can and should be conducted in the pre-proposal stage, by negotiating a percentage of the indirect costs, space, equipment funds - often as part of a cost-sharing arrangement.

4.2.10 Program Management

Initial planning must include the human resources that will be needed. Each component of the ERC's education programs, University Education and Precollege Education, should have an appointed faculty or senior administrator to direct the program. Cooperatively, the program should be led by a team ("Education Leadership Team" or "Education Task Force") consisting of the Education Director and administrative personnel, including those from the partnering institutions. The Education Leadership Team could consist of other representatives in the center, including the Center Director, faculty not appointed to the education program, the Industrial Liaison Officer, members of the Industry Advisory Board, the evaluation/assessment expert, Student Leadership Council (SLC) members, etc. It is critical to have many perspectives assisting to lead the ERC's education programs. The Directors of the University and Precollege education programs should be professionals at the same level on the organizational chart as the research thrust and Industrial Liaison Officer/technology transfer directors. It is recommended that full-time professionals be engaged for these roles at the outset and included in the planning stages of the program.

Personnel

The choice of Education Coordinator/Director, and the appropriate positioning of this person as a member of the center's Leadership Team, will determine the success of the center's education programs. Both the University Education Director and the Precollege Education Director should be part of the ERC's Leadership Team to demonstrate the importance of these programs to the center. NSF requires that the University Education Program be led by a faculty member to elicit the full respect and cooperation of faculty in programs that directly affect their students and the integration of their research into ERC curricula. This is especially important for curriculum development. The Precollege Education Program may be led by a staff person with expertise in this field and sufficient professional standing to also elicit full respect within the center. The primary focus should be on identifying an individual with an appropriate background to be responsible for the education activities of the center. His or her interest in interacting with students should also be a major selection factor. The University Education leader may be part-time but the Precollege leader should be full-time. Someone who is interested in mentoring students and working with REU students must be a member of this team.

Education Directors/Coordinators are responsible for writing up all aspects of their education programs for the ERC annual report and other documents. They also develop and write grant proposals of many types to expand their education programs. Therefore, strong communications skills and an ability to prepare successful proposals are important.

It is recommended that an Education Advisory Committee be established to give center faculty a mechanism to provide input into center education programs and to provide support for them. The composition of this group can include center faculty, external faculty, and industrial partners as is deemed appropriate.

A variety of organizational structures can lead to successful education programs. In some centers the Center Director monitors the Education Director/Coordinator, to provide oversight, input, and knowledge of the education programs. In other cases, the Education Director/Coordinator has more latitude to manage the education programs with limited oversight. The appropriate management style will vary from center to center.

The organizational structure of the entire education program may creatively reflect the unique arrangements between the lead and partner institutions of the ERC. Some centers operate from the center's headquarters and maintain all administrative and leadership functions of the education program at the lead institution, and distribute the programs, projects and activities across the partner institutions; but the coordinated effort is in one location. One disadvantage of this model is that the challenge of carrying out all education activities is a multi-campus effort, rather than being central to the lead institution. Other centers distribute their education program direction, leadership, and functions across multiple campuses.. However, this may pose a problem in cohesiveness and ensuring that the entire program drives impact by adhering to the education program objectives. Whatever structure is selected, all partnering institutions share equal responsibility for implementing the program.

Evaluation, Assessment, and Research Inquiry

Effective assessment tools are necessary to incorporate feedback from assessments and/or evaluations into the education programs to improve program content, ensure program sustainability, and deliver on program goals. Using an expert in program design, implementation, and effectiveness will ensure the program is meeting its goals and objectives and the center is accomplishing what it has been tasked to do. This expert in program evaluation can assist in mapping the ERC program objectives across all education program goals and will help to determine the success and potential for each project. In addition, plans are to be in place to disseminate outcomes and curriculum/outreach products of the college and precollege /community college programs to the participating partner and outreach institutions and beyond.

1 - http://nanohub.org

2 - http://erc-assoc.org/best_practices/chapter-8-student-leadership-councils

3 - https://www.erc-reports.org/public/library

4 - See Dear Colleague Letter No. NSF 13-047.

Section 4.3: Precollege and Community Engagement

4.3.1 Purposes and Goals

ERCs have a mandate to contribute to the precollegiate education system by introducing young students and their educators to the field of engineering and the technology impacted by the center's interdisciplinary research. The purpose is to bring knowledge of engineering to middle and high schools where the emphasis is on science education, with little understanding of the field of engineering. Additionally, there is a significant lag in textbook production, so an effort to integrate center research into classrooms brings cutting-edge engineering content to students in a timely manner. ERC K–12 programs are focused on helping to encourage students to consider careers in engineering. Given the limited ERC budget, when compared to the total precollegiate education system, ERCs and NSF recognize the limits of the impact they can have and that they cannot be all things to all constituencies. It is critical therefore that each ERC determine what precollege offerings work in the context of its specific strategic plan, resources, and community relationships.

Precollege education programs can increase student awareness of engineering careers and stimulate student interest in pursuing them. A key element to all ERC precollege programming is the recognition that it is in the national interest to encourage students who are traditionally underrepresented in engineering and technology careers to become involved. Focusing on underserved populations can contribute to efforts to increase the diversity of domestic students studying engineering at the college level.

ERC precollege programs cannot succeed without partnerships with local school districts and/or individual schools. A strong relationship with these partners will create (1) STEM teachers' involvement in ERC research and education programs; (2) creation of engineering-oriented educational modules for their school teaching activities and for integration into their curricula; and (3) strong impact on diversity and broadening participation of underrepresented groups, teachers, and students into these engineering experiences. See examples of such partnerships in appendix 4.3, section 4.3.7.

Some best practices for achieving successful precollege outreach are as follows:

- To make the best use of limited resources for ERCs' precollege outreach, many ERCs work in partnership with other education and outreach programs. For maximum impact, it is best to seek out established programs to which ERCs can add significant value, or to find promising new endeavors with which to partner. Partnerships may include university programs; school and school system organizations; and/or community resources, including informal science centers and public libraries.
- Another key feature of successful programs is the involvement of graduate and undergraduate students as well as the ERC's Student Leadership Councils (SLCs) in activities. These may include school visits and student tours, as teacher or student research mentors. Secondary school students often relate well to university students, who are closer to their own age. Engaging graduate students in outreach enhances their communication and leadership skills.
- To encourage program diversity, it is useful to partner with established campus multicultural programs; for example, ERCs have partnered with chapters of the National Society of Black Engineers (NSBE), the American Indian Science and Engineering Society (AISES), and the Society for Women Engineers (SWE). Additional partners include women in engineering programs and minority/multicultural engineering programs.
- Successful outreach programs are led by teams involving university educators and education faculty, precollege STEM teachers, as well as center engineers and researchers. Each group offers different talents and specialties that contribute to outstanding programs.
- It is best to have an educator with experience in K-12 education responsible for the pre-college program at each participating ERC location. Programs can be administered from a central location, but an on-site educational leader on each campus is desirable. Forming an Education Committee or Thrust with a representative from each campus can be valuable in accomplishing this goal.

The programs described below are for both K–12 students and their teachers. They include the two that are required for all centers, Young Scholar programs (Gen-3 only), and summer Research Experiences for Teachers (RET). In addition to these required programs, centers have developed other programs such as summer camps, courses, internships, science and engineering competitions, lab tours, school visits, lectures, and science and education fairs, some of which are conducted on-campus at the ERC and others on-site at the partnering school(s).

Given the creativity of center precollege personnel at developing innovative student opportunities, and the resulting variability of programs developed, the best way to understand the range of possible offerings is to review the examples that are found in Appendix 4.3 to this section. Contact information is provided and existing center administrators will be happy to share details about any programs that they have developed. All of these programs require significant time and resources to develop and administer. It is important for the center's strategic plan to include timetables that plan for the gradual phased implementation of Education programming over time rather than attempting to bring all these types of effort up to speed in year 1.

FEATURED EXAMPLE: *The BMES precollege program has developed a comprehensive and innovative education initiative designed to integrate science and engineering principles into the curriculum of inner city K-12 and community college students. The education program introduces and enhances experiential learning that promotes understanding of and enthusiasm for basic science, engineering, and technology—particularly among individuals who traditionally have been underrepresented in the science and engineering workforce. A guiding philosophy of BMES ERC outreach is that education is a community responsibility. The Center has developed a culture of connectivity in which biomedical engineering knowledge and the motivation to engage in scientific and engineering research transfers from BMES investigators to successive generations of pre-baccalaureate students and STEM educators. Formal and informal educational opportunities have been established to expand the scope and reach of the BMES outreach program beyond the classroom to a larger audience, including the extended family members of K-12 students. Through the education and outreach program since 2003, thousands of young children, their teachers, and families have interacted with and learned from BMES faculty (including the Center Director and Deputy Director), students, and staff. They now have a greater understanding of the role that science and engineering play in their daily lives, a first-hand acquaintance with people who are innovators, and a familiarity with the process of discovery. The outreach program recognizes and builds upon the fact that education is bidirectional between expert and novice. Like the K-12 teachers and students, the university community also benefits through their participation in precollege education and outreach activities. USC faculty and students gain a deeper understanding of the opportunities and challenges of urban education and the ways in which young people are motivated and learn. University personnel also increase their communication and managerial skill set, gain significant personal satisfaction, and have the opportunity to establish long-term mentoring relationships that are especially important for underrepresented and first-generation students who often lack role models for higher education.*

4.3.2 Required Precollege Student Engagement

Young Scholars Program (Gen-3 only)

Generation-3 ERCs are required to develop and to offer a Young Scholars (YS) Program to provide opportunities to exemplar high school-age students to participate in ERC summer research programs or internships. The purpose is to get students into research labs early in their careers, in order to excite and interest them in pursuing research and in engineering careers. These programs can require significant effort from administrative and research staff. They generally involve center graduate students who serve as mentors to the students. Please note:

there may be existing programs on campus that also serve these students that the ERC can leverage. (See example 4.3.4.1 and section 4.3.11 in Appendix 4.3.)

Student Competitions

Some ERCs sponsor student technology competitions or science fairs. Often, this is done by involving center researchers and graduate students as well as local partner organizations. The purpose is to involve students early on in their academic preparation in exciting engineering and science projects and research, or in fairs and exhibits displaying interesting and topical research.

FEATURED EXAMPLE: *The graduated ERC for Computer-Integrated Surgical Systems and Technology sponsors a semiannual robotics competition for local high school students. The CISSRS LEGO Robot Competition is a weekend-long competition giving high school students hands-on education and experience in engineering problem solving. The students, working in teams, design, build, and program a robot to perform a simulated surgical procedure.*

See example 4.4.6.1 in Appendix 4.4 for an international competition involving undergraduates as well as high school students. Example 4.3.4.5 describes ERC faculty involvement in a science fair that led to a high school student conducting research at the ERC.

Student Camps and Courses

Many ERCs have sponsored student camps and courses to involve K–12 students in fun, hands-on science and engineering experiences and thereby interest them in technology and careers inengineering. ERCs may also integrate center research into existing camps as a way to introduce broader audiences to engineering and science. See examples 4.3.4.2, 4.3.4.3, 4.3.4.4, 4.3.5.1, and 4.3.13.1 in appendix 4.3. Field trips and tours of ERC labs are another way to engage young students' interest. See 4.3.12.1, for an example.

In many cases, ERC students go to precollege schools, even at the middles school and elementary school level, to bring fun demonstrations to classes in order to engage young students in engineering concepts. See example 4.3.5.2 and 4.3.6.1.

4.3.3 Precollege Teacher Engagement

Research Experiences for Teachers (RET)

One of the fundamental components of ERC precollege education is the Research Experiences for Teachers (RET) program. The purpose of the RET program is to excite K-12 teachers about engineering by providing them with knowledge of cutting-edge research. Effective programs engage K-12 teachers in developing and modifying lessons to incorporate concepts learned during their research experiences. Graduate student researchers will need to be heavily involved, as they will serve as mentors to these participants. The most effective programs have students who accompany their teachers to campus during the summer and have outreach to the teachers' classrooms during the academic year by teams of faculty and students from the ERC.

See examples in appendix sections 4.3.2 and 4.3.3. Examples of precollege outreach programs that encourage greater diversity among engineering students are in appendix sec. 4.3.10.

Development of Instructional Materials

In addition to K-12 teacher-developed curricular materials, several ERCs have developed curricular materials for K-12 teachers that are based on the center's research. If it is determined that the production of classroom materials is part of the strategic plan, it will require a development team that includes members of the targeted school district, classroom teachers from the targeted grade level, and center personnel. Partnerships with Colleges of Education and the engagement of Education students may also extend these efforts. It is important that educational materials reflect all local, state and national standards and are developmentally appropriate. For example, some states require application of Next Generation Science Standards (NGSS) and the new engineering standards within them. Education Directors should consult the standards that apply in their area.

FEATURED EXAMPLE: *The NSF Nanosystems Engineering Research Center (NERC) for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) has partnered with professors of STEM education and engineers and has created nanoscale investigations that are correlated with science standards. The investigations are teacher-tested and reviewed by scientists and engineers as well as STEM researchers.*

For additional examples in the appendix, see 4.3.1.1, 4.3.4.3, 4.3.6.2, 4.3.8.1, 4.3.11.3, 4.3.11.5, 4.3.13.1, 4.3.14.1, and 4.3.14.2.

Conferences and Workshops

Some ERCs offer K-12 teacher professional development conferences and workshops. Professional development for teachers allows ERCs to multiply their efforts and to reach more K-12 students by increasing teacher interest and knowledge in science and engineering, particularly in exciting new research. Organizing these conferences can also require significant amounts of administrative and research staff effort. Participating in an existing conference requires less effort. For example, the NSF Nanosystems Engineering Research center (NERC) for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) provides professional development to K-12 teachers through on-site workshops as well as sessions for teachers at national and state teachers conferences.

FEATURED EXAMPLE: *The ASSIST NERC provides professional development to teachers through on site workshops as well as sessions for teachers at national and state teachers conferences.*

For additional examples, see appendix 4.3.3.1, 4.3.6.2, 4.3.7.3, and 4.3.14.1.

4.3.4 Community Engagement

Public events such as Science Cafés and science center presentations are effective ways to share research with adults and families in local communities. These types of outreach efforts build support for the ERC and for research. Such opportunities to participate in ongoing outreach efforts can be easy ways for ERCs to reach out to communities. See examples 4.3.6.2, 4.3.9.1, 4.3.9.2, 4.3.9.3, 4.3.9.4, 4.3.14.1, and 4.3.14.3 in Appendix 4.3.

To better engage veterans in engineering projects, NSF is now accepting requests from their active grantees for the Veterans Research Supplement (VRS)[1]. The proposed VRS will afford veteran students, veteran precollege teachers, or veteran community college faculty an opportunity to participate with active ERC grantees to conduct industrially relevant research in order to gain a deeper understanding of engineering.

4.3.5 Precollege Education Lessons Learned

To be effective, precollege outreach requires professional leadership and substantial resources. Furthermore, the outreach program should be included as a key component of the center and the Precollege Director should be included as part of the center's Leadership Team.

Center Directors should schedule regular times to meet with precollege personnel and promote inclusion of the precollege program in center activities.

In order to promote and sustain a more diverse engineering workforce, the center should strive to create an inclusive and supportive work environment for precollege teachers and students.

1 See Dear Colleague Letter Number NSF 13-047.

Section 4.4: Undergraduate Component (Core Students, REU, Community Colleges)

Although there are significant expectations for ERC education programs, there is a degree of local variation among centers. This variation arises naturally from the differences in center structure and composition. There are however, underlying similarities in what centers offer undergraduate students. This section will describe the similarities as well as the differences.

4.4.1 Core Students, Academic Year Research

Academic year core students are from the center's lead and core-partner universities. Integrating undergraduate students in the educational activities of ERCs is mandatory, and is perhaps the single most innovative aspect of the ERC145 education programs. While the research focus and educational vision of ERCs may differ, active involvement of the undergraduates in research has a major impact, not only on their education, but also on those around them. A special feature of the ERC Program is the emphasis on undergraduate participation in research. This is an excellent way to integrate center research into the undergraduate curriculum. Each of the ERCs has one or more programs through which undergraduates from the center's home institution(s) engage in research projects. See appendix section 4.4.2 for examples.

Including undergraduates in center research is the responsibility of all of the center's partner institutions. Undergraduates become part of a center research team and may be paid a stipend or enrolled in credit as determined by each center and institution. A minimum ratio of 1:2 undergraduates to graduate students is required. These core undergraduates are joined by ERC Research Experiences for Undergraduates (REU) visiting students in the summer. (See appendix sections 4.4.3, 4.4.4, and 4.4.5 for examples.) However, it is important to note that these two types of students conducting research are distinct groups for ERC reporting, assessment, and database purposes.

A critical component of the undergraduate research experience is the mentoring that the core undergraduates and REU students receive. Mentoring relationships for undergraduates involved in ERC research may involve faculty to undergraduate, staff to undergraduate, graduate to undergraduate, and undergraduate to Research Experience for Teachers (RET) participants and precollege Young Scholar (YS) students.

Mentors should be carefully identified, with plenty of time allowed for student assignment and mentor training. Being a successful mentor is not an innate characteristic. Therefore, training is imperative. Mentorship training should include everyone involved in the Undergraduate Education program (e.g. faculty, core graduate and undergraduate students, and staff). Training can take place through workshops, seminars, and via podcasts. Suggested topics could include "What is mentoring?," "Why is mentoring important?," "What are the different mentoring relationships in an ERC?," and "What constitutes a "good and bad" mentoring experience?" Importantly, specific "Do's and Don'ts'" related to each program should be clearly addressed. Undergraduate and REU mentor training should be done at the same time. Mentoring is a responsibility of all the partner institutions. See appendix sections 4.4.1.1, 4.4.2.3, and 4.4.3.1 for examples.

To create cohesion of the center's undergraduate researchers, they should be involved in the ERC's Student Leadership Council and should also participate in the NSF site visits and annual retreats.

4.4.2 Recruiting Methods

Undergraduates may be recruited through presentations at student organizations such as the student chapters of professional societies like the Institute of Electrical and Electronic Engineers (IEEE), the American Society of Mechanical Engineers (ASME), the American Society of Civil Engineers (ASCE), the American Institute of Chemical Engineers (AIChE), and through organizations like the Society of Women Engineers (SWE) and the National Society of Black Engineers (NSBE). Non-technical student organization groups may be approached to recruit for specific centers, depending on their mandates. They may also be recruited through announcements in the student newspaper, the ERC's website, printed flyers, and directly from classes and colleague's recommendations. Also, deans and departmental and other university offices may be helpful. Additional mechanisms such as Introduction to Engineering courses (cornerstone) and design courses (capstone) should be considered for recruitment. Participation in internal undergraduate research symposia and leveraging existing formal undergraduate research opportunity programs are also avenues of recruitment. Outeach by undergraduates to precollege schools, especially high school students, can be an important form of recruitment (see appendix section 4.4.11). Participation in contests and symposia relevant to the center's research is another option. See appendix example 4.4.6.1.

ERCs are national leaders in including students from underrepresented groups in engineering in their programming, so there is also a strong emphasis on recruiting undergraduate students from a diverse population, including women, members of underrepresented minority groups, those with disabilities, transfer or dual-degree students, and students from post-secondary technical schools and community colleges. These students may be from the engineering disciplines most prominently represented in the center, or may be studying other fields. Thus, undergraduates who are majoring in physics, chemistry, social sciences, education, and business can be valuable and productive participants. Please note, however, that packing the undergraduate population of an ERC with non-engineering students does not meet the ERC Program's goal of preparing undergraduates to pursue advanced engineering degrees or work as engineers in industry at the B.S. level.

centers should always monitor the diversity of the students who join the center. If the center's group of students is not meeting the center's diversity expectations, it is recommended that a survey of current underrepresented students at the center be conducted to see how they became involved with the center. This information may help the center to develop additional recruiting plans that will broaden the diversity of the undergraduate student group. See appendix section 4.4.10 for examples of programs to increase diversity. Example 4.4.8.1 describes a program aimed at recruiting students with disabilities.

4.4.3 Curriculum Development

Developing an ERC education program is a major undertaking, requiring substantial coordination of many faculty from different disciplines. The faculty involved in developing the ERC may already have a vision for new interdisciplinary courses or even a new degree program that can help achieve the Gen-3 ERC requirement to educate engineering students to be globally aware innovators and entrepreneurs. To that end, the ERC can help solidify the interactions that lead to course development and administration. The role of the ERC education program is that of a catalyst; the resources provided by NSF are small compared to those needed to develop and to maintain an entire academic program. Still, the catalyst serves an essential role, and there are examples of ERC education programs that have provided the necessary impetus for creation of new degree programs. (See appendix section 4.4.1.2, for example.) Degree programs may start as minor degrees, specializations, concentrations, or certificate programs and then evolve into new B.S. degree programs as the academic infrastructure grows through addition of resources from outside the ERC. The role the ERC plays in developing new degree programs at an institution depends strongly on how intellectually developed the field already is at the time the ERC is funded. If the area is new and just evolving, the ERC may lay the foundation for development of a program that comes to fruition in the latter years of the center, whereas if the ERC is funded in an area where faculty members are already offering interdisciplinary courses, a degree program may evolve more quickly.

New degree programs require substantial long-term institutional resources and commitment. Institutions have a responsibility to ensure that students are well prepared for life after the degree, and thus typically want extensive intellectual justification for how new programs will allow students to adapt to jobs in industry or academia. Before embarking on new degree programs, it is essential to arrive at a consensus of stakeholders as to what the expected outcomes of such a program would be. This process will facilitate the adoption of any new program developed. Appendix section 4.4.1.1 provides an overview of this process.

Courses (e.g., new courses, short courses, modules for ongoing courses, senior design)

A very important role of the ERCs is to enrich the core curricula in engineering through course modules for ongoing courses and new courses, particularly interdisciplinary and systems-focused courses. These courses will enrich the engineering curricula and also may provide the intellectual basis for a new degree program.

Developing new courses and/or materials for inclusion in existing courses is the first step toward integrating the ERC's research findings into the formal education process and is a key requirement for all ERCs. As a first priority, centers should look for opportunities to add modules, problem sets, and lectures to existing courses, to create relevant online content (non-course format), or to incorporate work in capstone design or similar courses to further integrate center research into the existing curriculum. This is an important means for ERCs to contribute to engineering education in a broader way, as insertion of new materials in ongoing courses does not require the levels of approval required for new courses. The bar is lower, the overall impact is higher, and center research advances can be leveraged more time-efficiently into the curriculum. The beta test approach is important here as well.

The philosophical and administrative aspects of new course development vary widely from institution to institution. At some institutions it may be possible for an ERC staff member to serve as the primary driver. At other institutions, faculty members serve in this role. Ultimately, the university is responsible for paying faculty to teach the course, and for providing additional infrastructure if the course is a lab subject. Thus, courses must fit the overall educational objectives of the degree programs at the institution.

ERC non-faculty staff, in developing undergraduate and graduate courses, should find the following tips helpful:

- Find an interested professor to be a champion for developing the new course.
- Pay the professor and a student helper to develop the course; or arrange with the professor's department chairperson to give the professor a teaching load reduction so that he/she can have protected time to develop the new course.
- Beta test course materials.
- Work on mechanisms to offer credit for students to take the course at the other ERC partner universities.

- Find a vehicle, such as a website or book, for wider distribution of course materials.

In institutions where ERC faculty have this responsibility, they can take advantage of these suggestions, which build on years of hands-on experience in many ERCs:

- Discuss your idea for a new course with your department head or undergraduate curriculum committee. If the new course is an elective in a hot field and you can demonstrate that students will flock to this course, the department will likely be supportive of your plans to develop it. For untenured faculty, development of a signature course can be a very positive factor in your promotion case.
- If preliminary discussions are positive, determine whether you will be provided with long-term support for teaching the subject. Developing a new course requires a great deal of work, so one should make sure it can be taught several times.
- Find a mechanism for supporting your time in developing the course, and for providing appropriate support, such as teaching assistants. If there is no textbook available (likely), course development requires a substantially greater investment of time than teaching an established course does. Foundation and government grants are available for new course development, and funding opportunities can be identified by asking colleagues. Reach out to an center for Teaching and Learning, if one exists at your institution.

Appendix section 4.4.1.3 provides an example of undergraduate course development.

Degree/Certificate Programs

Minor degrees or certificates give students the opportunity to develop depth in areas outside their major degrees. The rules for offering minors, as well as student participation in minor programs, vary widely from institution to institution. At some schools, interdisciplinary minors are a means to evolve the curriculum toward a new undergraduate major by providing a testbed for courses and for development of student professional societies. If the center is in a cutting-edge research area and students are excited about a minor degree in the area, chances are that it can develop a successful minor even if there are institutional barriers. The key is to build on student interest and enthusiasm. Here are some important considerations:

- Define the intellectual content of your minor first —What is essential for the students to learn, and how many subjects are required? Are there subjects already offered that could fit the minor, or do you need to develop several new courses?
- Determine which academic unit is the best home for the minor, whether it be a single department, a pair of departments, a school or college, or the whole university. An academic unit will be required to handle the administrative details if the minor appears as a degree designation, and the academic unit involved needs to be extremely supportive of the minor.
- The easiest minor to develop is for students from one's own school (e.g., engineering), because those students are likely to have taken the prerequisites (e.g., mathematics, programming skills, and biology) needed to take the more advanced courses in your

minor. Some academic institutions have firm requirements that any student should be able to complete any minor, and you must be cognizant of what your institution requires.

- If you develop a minor for a cross-disciplinary student audience (e.g., including both science and engineering majors), it is helpful to define a set of preparatory engineering subjects that provide the necessary background for non-engineering students. For example, non-engineering students may need to take Differential Equations and a mainstream sophomore-level engineering subject that uses differential equations to solve physicochemical engineering problems before they can enroll in the subjects in your minor. Alternatively, courses can be developed for non-majors, but this is usually a less attractive option over the long term. Engineering faculty are generally reluctant to develop a course for students who do not have engineering backgrounds, and cannot justify teaching such courses when teaching assignments are made.
- The minor should be well coordinated with the curricula of the major degrees. One must put appropriate advising in place to ensure that students are able to plan early in their academic careers to fit all the minor subjects into their schedules. It is helpful, for example, to write up a special advising document for freshmen and sophomores, to ensure they take appropriate background subjects early on. Conduct advising seminars once per term to get the word out to a broad audience.
- A minor degree curriculum, no matter how well planned, does eat into the unrestricted electives available to students. Some students may even overload on subjects in order to complete the minor. It is thus especially important to have good advising—students must appreciate that the minor is in some sense an Honors program if it requires substantial technical work. It is a choice the student makes. Students who are weaker academic performers might be encouraged to focus on their majors first.
- Create a curriculum committee that meets regularly to review the content and administration of the minor, and invite all the advisors for the minor to serve on the committee.
- Create a community of students involved in the minor by having lunches with students and faculty once per term.

<u>New bachelor's degree programs</u> must be developed with a different set of considerations in mind:

- The academic affairs office MUST be involved from the beginning when considering creating or modifying a new degree (minor or major) or anything that affects undergraduate student credits. They are responsible for shepherding the degrees through governance.
- Find out what new degree program in engineering or science was most recently approved at your institution, and use that program as a benchmark. Some institutions are conservative and develop new degree programs only once every few decades in response to new disciplines.
- The faculty who teach the courses and who will be responsible for the degree program after the center's NSF funding expires must be key drivers in developing the new degree program. Be sure to get the support of key faculty members, who can provide sustained efforts to convince the Chair, Provost, curricular committees, and other decision makers.

- Identify the constituencies for your program, and make sure you have enthusiastic buy-in. Equally important, identify any other academic programs that will be significantly affected (positively or negatively) and discuss your plans with the faculty involved. For example, if you are developing a program that depends on core science classes offered by another academic unit (such as chemistry, math, biology, or physics), they need to be involved, especially if their enrollments are likely to increase as a result of your plans.
- Make sure to contact your university's appropriate office (e.g., the Provost) to find out what approvals are required for a new undergraduate degree program. There is no point in developing an entire program if it will not pass this first hurdle.
- Work as closely as possible with the Chairperson of your school's curriculum review/approval committee, as well as your university's Undergraduate Curriculum Committee, before submitting all of the paperwork to those committees, to be sure that they buy into your new program. Doing so can save a lot of time in getting your new program approved, because these committees frequently deny or delay approval due to incomplete forms or unclear descriptions.
- Involve undergraduates in developing the new curriculum, to understand their interests and needs from the outset. This can be accomplished by presenting a proposed curriculum at a meeting of the professional society for the area related to the program. While some universities require participation by undergraduate students during the development and evaluation stages of your new program, it's a best practice to include undergraduates, whether it is a requirement or not. Neglecting undergraduate input can cause very long delays in getting the new program approved.
- Be sure that your program satisfies criteria of the Accreditation Board for Engineering and Technology (ABET), if one of your goals is to have an accredited program. Review and update this program on a regular basis.

4.4.4 Collaboration with Industry

Industry is involved in all aspects of the ERC's education programs. Industry representatives may serve as mentors to undergraduate, outreach, or graduate students. (See appendix section 4.5.3.1.) They may present lectures, course sections, or entire courses, provide input into the curriculum, or teach courses in partnership with ERC faculty members. Industry experts may serve on the student's masters or doctoral committee. Industry may sponsor undergraduate or graduate internships in industry (see appendix section 4.4.9.1 for an example), or sponsor students' undergraduate or graduate degrees in whole or in part. It is important to allow undergraduates to participate in Industrial Advisory Board (IAB) meetings and interact with industry through social media for networking opportunities. (See, for example appendix section 4.4.1.3.) These experiences provide them a window into industrial practice, and for those who wish to pursue industrial careers after obtaining the B.S. degree, involvement with industry often leads to job offers, due to the richness of the ERC experience. ERC Program-level evaluations have found that industrial supervisors of ERC alumni find them more effective in industrial practice than their single-investigator trained colleagues.[1]

ERC Best Practices Manual Chapter 5, "Industrial Collaboration and Innovation," has a section 5.3.5 on involvement of industry with the ERC education programs.

4.4.5 Evaluation and Assessment

The need and scope for program evaluation and assessment varies based on an ERC's education program objectives. It is suggested that a person with experience in program evaluation and assessment be identified and used.

An important component of ERC education program assessment is tracking graduates. Follow-up with former students extends the influence and value of the Undergraduate program and contributes to the participant's involvement in engineering careers and the continuation of their education toward advanced degrees. Former participants can be provided with guidance and assistance with applications for graduate school and for financial aid. Arrangements can be made with the center's industrial partners to assist participants with potential employment opportunities. Maintaining contact with graduates requires considerable effort, but it increases the likelihood that they will continue on to graduate engineering education. Learning of their accomplishments is also rewarding. Social media such as Facebook or LinkedIn can be useful in this effort.

4.4.6 Research Experiences for Undergraduates (REU) Program

ERCs are required to offer a Research Experiences for Undergraduates (REU) Program. This provides a mechanism to extend the integration of center research to students who would not otherwise have the opportunity to conduct this type of research on their home campus. An REU program also provides an opportunity to diversify their undergraduate student population, but cannot and should not be the only diverse group of students involved in center research. These programs can also serve as a fulcrum for leveraging support from other sources, including industry. The programs go considerably beyond the traditional research-focused mandate of university research centers. Indeed, they place a substantial demand on the administrative and financial resources of ERCs. For example, the ERC must allocate a minimum of $42K to its REU program from core funds and may seek an REU Site Award to supplement that effort. However, the center's REU Program is part and parcel of the broader mandate to develop a new and more industry-focused, product-focused culture for academic engineering and to spread that culture through education. In that sense, then, "outreach" to REU students is simply extended ERC education.

Appendix section 4.4.3 provides a number of examples of REU program planning and operation at several ERCs. Section 4.4.5 gives examples of REUs involving community college students.

REU Program Features

Students gain many benefits from their ERC REU experiences that are not normally available to their peers who are not involved in ERC education programs. REU students:

- Conduct individual or team research on ERC-related projects
- Develop teamwork skills through interaction with undergraduates, graduate students, and faculty
- Are encouraged to continue their education in graduate engineering programs

- Develop communication skills through written reports and oral presentations
- Participate in ethics and professionalism activities
- Interact with students from other universities
- Publish articles on research or give research presentations at national conferences
- Participate in industrial interactions
- Become involved in mentoring RET teachers and or Young Scholars
- Interact with a truly diverse group of students.

REU Program Structure

REU students may work as individuals or in teams, which may include the ERC's own summer undergraduate interns and even graduate students. The students' projects should include at least some elements of their own design and should be supervised by ERC faculty and graduate students. In many cases this environment provides first-hand knowledge of how industrial research teams operate. The total number of undergraduates involved in these summer projects from all sources at a given ERC can vary from as few as 4 or 5 to as many as 40 or 50. Some multi-site ERCs may have only a single REU program, so teaming with local students is vital. The mix of backgrounds, cultures, and approaches brought by students from different educational backgrounds is an important part of the REU experience. See appendix example 4.4.4.1. In addition to research projects, a well-rounded program of REU activities can include:

- Field trips to industrial sites
- Workshops on technical writing and public speaking
- Seminars in topics such as programming and engineering ethics
- Meetings with high school students visiting the campus
- Mentoring by graduate students and industrial residents
- Assistance with graduate school admissions applications and scholarship materials
- Exposure to an array of center publications
- A showcase to present the student's research project at the end of the summer program

Issues that require special planning include housing (prearranged and on campus in the same area), meal cards or subsidy for meals (to minimize the need for cash), on-campus transportation if needed, and access to institutional facilities. Careful scheduling of out-of-laboratory activities is also necessary to minimize research disruptions.

Recruitment Methods

Recruitment of REU participants can be challenging, since the main focus is on underrepresented populations, and the number of programs aimed at these populations has expanded, so there is keen competition for the best students. The ERC REU program has provided a critical outreach component to ERCs, giving them the opportunity to extend their work to many other institutions. Recruitment techniques that have proven successful include:

- Personal visits to other institutions

- Development of long-term relationships with Historically Black Colleges and Universities, Hispanic Serving Institutions, and other targeted underrepresented Minority-Serving Institutions
- Recruitment efforts by previous REU participants on their home campus
- Recruitment through national organizations (e.g. NSBE, AISES or SWE)
- Use of Women in Engineering (WIE), Minority Engineering Program (MEP) and offices that provide services for students with disabilities
- Participation in career fairs
- Internet postings
- Sharing of information about potential participants among ERC Education Directors/Coordinators across the ERC network.

As centers mature, they interact with other ERCs to help them recruit REU fellows for appropriate research areas. This exchange of applicants has been done on an individual basis, from Education Directors/Coordinators to Center Directors, and (in the past) via an e-mailed ERC Education Digest. Given the strong emphasis on recruiting REU students from a diverse population (i.e., women, members of underrepresented minority groups, students with disabilities, transfer or dual-degree students, first-generation students, and students from post-secondary technical schools), centers must develop/leverage connections with schools that serve these populations. Students may not be from the engineering disciplines most prominently represented in the center, and may not even be engineering majors. Undergraduates majoring in physics, chemistry, biology, social science, and business may be valuable and productive REU participants. Because of the burgeoning REU programs, the competition for top students obtained from traditional sources is intense. Broadening the applicant pool can help to achieve diversity while retaining high standards, thereby attracting a new pool of students to engineering. Diversity conferences such as SWE, Society for Hispanic Professional Engineers (SHPE), NSBE, and Society for Advancing Hispanics/Chicanos & Native Americans in Science (SACNAS) are effective mechanisms for recruitment. Centers have coordinated to co-host "ERC booths" at such conferences. This allows for greater visibility and leveraging of funds (i.e., doing so drastically lowers the cost for individual centers to participate).

REU programs may also benefit from linking with other internship programs on campus. This may allow for supplemental workshops, an expanded cohort, more diversity, and a comprehensive showcase of research projects at the end of the summer programs. One example transition program that uses research as a vehicle to introduce a diverse group of students to STEM is the ELeVATE program at the Quality of Life Technology ERC (see example 4.4.7.2). This program promotes military veterans' transition to campus by linking them with research projects and mentors to help them develop technical skills. Due to shared goals, the ELeVATE participants benefit from the REU program activities and *vice versa*. At the end of the summer, students from both programs can present their research in the same research showcase/forum. This is just one example of the type of program that a center could collaborate with across its campus.

A very effective recruitment strategy is to provide opportunities for Student Ambassadors (past summer interns) to recruit future participants at the target institutions:

• Set up information sessions and workshops

• Present research at information sessions and workshops

• Serve as guest speaker or panelists for information sessions and workshops

• Assist peers with application process

• Recommend peers for future summer internships.

Strategies for Funding

One of the best ways to leverage funding and to improve the efficient use of a center's resources is to join with others in setting up and implementing projects. Once the fixed costs have been met, additional participants bring down the cost per participant and provide cross-fertilization of expertise. A number of ERCs combine REU programs with other programs or funding sources. The availability of supplementary funding allows field trips and extended travel to be included in the students' experience. Many campuses host multiple REU programs and this provides opportunities to co-host ethics and communications workshops, social events, and seminars to the mutual benefit of all of the participants. Also, the considerable expense involved in long-distance relocation has been a barrier to some gifted students, and supplementary funding can be helpful. Again, the best sources of specific information about funding opportunities for attendees are the center websites, and the websites of universities and other centers provide opportunities for co-funding of programs. Providing an interesting research, cultural, and social program for the group requires planning and supervision, but the wide availability of campus facilities in the summer facilitates this process.

Mentoring

Mentoring is a strong component of the success of REU students within ERCs. Mentoring roles for REU programs may involve faculty to REU, staff to REU, graduate to REU, existing core undergraduate student to REU, and REU to RET and Young Scholar participants. Mentors should be carefully identified with plenty of time for student assignment and mentor training.

As was noted in section 4.4.1, being a successful mentor is not innate to all. Therefore, training is imperative. Mentorship training should include everyone involved in the REU program (e.g. faculty, graduate and core undergraduate students, staff).

Given the geographic distribution of the partners of most ERCs, special attention should be given to methods to connect student REU participants at multiple campuses represented within an individual ERC. It is recommended that no less than two students be located at a given institution, to avoid isolation. Additionally, web-meeting software can provide a mechanism to support weekly research discussions of the group. One face-to-face meeting of the group, either at the outset to introduce participants and facilitate web communications, or at an end-of the summer research poster session, is recommended.

Evaluation, Assessment, and Follow-up/Tracking

The comments made in section 4.4.5 apply both broadly and also specifically to REU programs. It is recommended to create REU cohort groups that allow messaging to the group and generating discussion among previous participants, allowing them to stay in touch with each other.

REU Lessons Learned

1. Use multiple methods to recruit diverse students into your programs.
2. Be highly inclusive – leverage resources at your university (e.g., other REUs, honors programs, etc.), and at partner universities.
3. Create strong two-way relationships with your industry membership.
4. Search for ways to create community – find a way to showcase undergraduate research results.
5. Mentoring is important; so train your mentors explicitly.
6. Assessment and evaluation are absolutely critical, and it is highly recommended that you partner with professional A&E teams (internal or external) to develop the A&E strategy for your center. You both need to establish the research questions, as well as ensure that the instruments and analyses will allow you to answer the questions (this includes getting human subjects clearance so that you can publish your results).
7. REUs must be U.S. citizens or green card holders

4.4.7 Community Colleges

The Nation's community colleges and technical institutes are valuable and often underused sources of technical workers. Community colleges serve a vast number and diverse population of students. Due to the flexible scheduling, modest cost, and other reasons, community colleges also attract large numbers of women and minority students. It is estimated that half of the Hispanic students attending college nationwide are at community colleges.[2]For these reasons, they are a fruitful and underutilized source of REU students (see appendix section 4.4.5).

In addition, many community colleges have historically close ties with industry. Industry-oriented or industry-sponsored certificate courses and technical training programs are often associated with community colleges rather than four-year colleges. The technicians and skilled workers of the technology industries are likely to be products of the community college systems.

For these reasons, ERC education programs should actively focus on creating links with community colleges. Again, Academic Affairs offices can help; they are resources to try to connect with and/or utilize any existing articulation agreements and partnerships. Strategies to develop such links may include:

- Provide speakers and guest lectures for community college classes, conferences, and events;

- Provide hands-on demonstrations and activities for community college classes, conferences, and events;
- Serve as an advisor or thought partner on STEM curriculum, proposals, transferring to 4-year institutions;
- Organize interested graduate students and postdocs to volunteer as judges for STEM activities and events at community colleges;
- Partner on grant proposals with community colleges, or provide letters of support for proposals submitted by community colleges; and
- Inform community colleges of STEM events at your campuses

Recruiting

A variety of methods are recommended for recruiting community college students. A starting point is to build a relationship with an academic leader (e.g., department head or program chair or senior faculty member) at target institutions. These people can provide invaluable advice on how best to reach their students.

Recruiting should be viewed as a year-round effort involving active, ongoing communication and interaction at target institutions. For example:

• Invite prospective students to STEM events at your campus;

• Attend conferences and other events that focus on the targeted population and follow up with community college representatives and students you meet;

• Host summer internship information sessions for students at community colleges;

• Host virtual information sessions and workshops through online webinars; and

• Send monthly emails to key staff/faculty contacts and student e-lists with opportunities, updates, and reminders.

Organizations or groups that can leverage your efforts include:

- MESA (Mathematics, Engineering, Science Achievement) is nationally recognized for engaging educationally disadvantaged students so they excel in math and science and graduate with STEM degrees. MESA partners with all segments of higher education as well as K-12 institutions. See appendix 4.4.10.1 for an example.
- Veteran's offices.
- Transitional programs (e.g., 2 + 2) are a powerful way of bringing community college students into 4-year research-oriented institutions. The maturity of such programs varies greatly state-by-state and therefore developing such opportunities will be highly variable amongst centers.
- Your campus' transfer office (if you have one).
- Advanced Technological Education (ATE) centers are NSF-funded centers that endeavor to strengthen the skills of technicians, whose work is vitally important to the nation's

prosperity and security. In ATE centers and projects, community colleges have a leadership role, and work in partnership with universities, secondary schools, business and industry, and government agencies, to design and carry out model workforce development initiatives. Given the complementarity of the ATE and the ERC mission, ATE centers may represent a viable location for outreach to community college communities by the ERCs. Please note: The location and subject matter for each ATE center varies by geographic location, so the opportunity for development of connections between ATE centers and ERCs will be highly variable.

Mentorship & Training

Community college students may require additional mentoring to ensure success when involved in summer-research programs populated primarily by students from research-intensive institutions. Take steps to ensure mentors are well trained, and consider doing “boot-camp” or similar orientation/immersion programs to help these students adjust. Community college students are likely best served by experiences within a cohort. Therefore, we discourage sending these students to partner sites where a cohort does not support them.

Other Activities

Community colleges offer extensive opportunities for ERC educational activities. For example, community college students—and possibly faculty members—can be participants in short-courses/workshops/RET programs/design competitions offered by the ERC. Community-college faculty/instructor participants could then become on-site recruiters for opportunities in the ERC, and student participants in short-courses can interact with center-faculty to build relationships. Community colleges may also be fertile grounds for ERC graduate student presentations and teaching.

Community College Lessons Learned

Don’t overlook campus outreach and recruiting professionals, who often have budgets and staff that have expertise in community college recruiting.

4.4.8 Veterans’ Opportunities for Engagement in the ERCs

NSF recognizes that veterans represent a potential underutilized workforce for the U.S. science and engineering research and industry communities. Many veterans are transitioning from active military service to civilian careers and exploring education options through the post-9/11 GI Bill. At a time when the U.S. is challenged with a science, technology, engineering, and mathematics (STEM) workforce shortage, NSF is exploring alternate pathways of veterans’ engagement into STEM fields.

To better engage veterans in engineering projects, NSF is soliciting requests from their active grantees for the Veterans Research Supplement (VRS)[3]. The proposed VRS will afford veteran students, veteran teachers, or veteran community college faculty an opportunity to participate with active ERC grantees to conduct industrially relevant research in order to gain a deeper understanding of engineering. See appendix section 4.4.7 for examples.

1 SRI (2004). The Impact on Industry of Interactions with Engineering Research Centers. (http://erc-assoc.org/sites/default/files/studies_reports/Impact%20on%20I...)

2 See http://www.highereducation.org/reports/pa_at/index.shtml

3 See Dear Colleague Letter Number NSF 13-047.

Section 4.5: Graduate Education Programs

There is a specific set of expected ERC-wide characteristics of graduate students who participate in any ERC. These are:

1. The ability to take a systems-level approach to problems;
2. Superior skills at working in teams;
3. Ability to apply an interdisciplinary problem solving approach;
4. Exceptional communication skills;
5. A solid grounding in the industrial perspective of their chosen area; and
6. The ability to contribute immediately and productively to jobs in industry.

In addition to the depth of training in their particular discipline, ERC students are also expected to have a breadth of knowledge that crosses disciplinary boundaries. These content-specific knowledge and skill sets will be specific to the particular ERC, and these desired skill sets should guide the development of the ERC's graduate education program. To assure that ERCs strategically address this challenge, Gen-3 ERCs are charged specifically with developing strategies to achieve those skill sets, and in addition, skill sets that will lead to greater creativity and innovation in a global economy.

Each center must first identify those skill sets using input from all their constituencies. While each center can select the mechanism for soliciting, distilling, and arriving at a consensus with respect to the desired outcomes, it is critical that this step be conducted in the first year of the center, to help focus the ERC's education strategy and its education program development. Several examples of how existing ERCs have accomplished this task are described in Appendix section 4.5.1. These include the CURENT ERC, which has identified skill sets and a program of activities that leads to certification of achievement related to the appropriate mastery of the items and traits that define the skill set. The FREEDM ERC has also organized the skill set acquisition into a portfolio program that serves as a guide as well as a mechanism for review of their graduate students' progression through the program.

4.5.1 Recruitment

The graduate program should contribute to the overall diversity goals of the center and actively recruit students. It is recognized that centers are not directly involved in admissions decisions and must be ever mindful of the relationship between the ERC and the associated departments, programs, or colleges. However, a center's presence on campus can be a key factor in attracting graduate students to apply to the institution. For this reason, center faculty can advise and monitor a potential recruit's application process and, once the student has been accepted in an academic unit, encourage them to join a center research group.

Tips for recruiting include:

1. Students and faculty traveling to conferences should be provided with brochures or fliers to spread information about the center.
2. Set up tables at conferences that offer the opportunity to meet with a diverse group of students, such as the NSF Louis Stokes Alliances for Minority Participation (LSAMP) regional meetings.
3. Faculty and staff should involve themselves in Departmental/College programs (such as the admissions committees) to guide decisions to be mindful of the ERC's needs and to be aware of newly available students.
4. Center personnel should keep a network of contacts in Departmental or College recruiting offices (particularly special offices for women or underrepresented groups) who have regular interaction with prospective students, and be sure that they have current information about what the center can offer new students.
5. A regularly updated website (particularly including opportunities for graduate students at the ERCs) is essential.

Other venues for recruiting on-campus include campus chapters of national organizations—and the annual national meetings of these organizations. ERCs often collaborate, through the activities of the ERC Education Directors, in securing a booth or a general presence at national meetings.

4.5.2 Student Financial Support

All ERC graduate students are supported financially by the center. Affiliated students are supported from other funding, often generated by the ERC or faculty involved in the ERC through funding from associated projects. ERCs are creative in covering the costs of graduate education through industry contracts, NSF grants, foundation or corporate scholarships, other federal and state agency sources of support, and industrial partner support for graduate students. It is recommended that new students be encouraged to apply for Graduate Research Fellowships from the NSF, DOE, and other competitive fellowship programs.

ERCs should also encourage graduate students to apply for professional society or industry scholarships, or in some cases to prepare proposals and perform contract research for funding to pay for conferences and research. Successful proposals allow graduate students to travel to conferences and companies, and give the students valuable experience in grant writing. Grant writing is yet another professional development opportunity offered to ERC students (see section 4.5.8, "Student-led Proposals," below).

In addition to the technical and research skills acquired, what distinguishes the graduate experience of an ERC student from a traditional program is the professional development components offered. In addition to the skill sets described above, ERC students also have the opportunity to develop leadership and mentoring skills through a variety of activities described below.

4.5.3 Role of the Student Leadership Council

The Student Leadership Council (SLC) is an integral part of the center leadership and management structure. It not only provides students with leadership skill development but also serves as a required liaison between the students and Center Director and center Leadership Team. Each council should include members from each partner institution that supports the graduate and undergraduate research efforts and should have a governing structure to coordinate the group. Interactions take place in face-to-face formats at regularly scheduled research meetings, such as the center's Industry Advisory Board meetings, NSF annual site visit, and the NSF ERC biennial meetings, as well as by social media and internet-friendly online formats.

An important function of the SLC is the annual SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis that they conduct of their center. This provides center management, the Industrial Advisory Board, and the NSF site visit teams with valuable feedback about center activities. The SLCs are charged with carrying out activities to address the weaknesses that are under their control and to communicate with the Center Director about significant weaknesses, opportunities and threats that the SLC feels threaten the success of the center. Other activities that may be coordinated by the SLC include mentoring of undergraduates, K-12 teachers, K-12 students, and managing the center seminars. It is important for center faculty to recognize that the SLC is a critical and required feature of an ERC, and to support their students as they take part in SLC activities.

As students come and go in their leadership roles of the SLC, it is important to have one person on the Education Leadership Team assigned to mentor the SLC to provide for continuity and support. In addition, each SLC should have a budget to support their activities. A few have research budgets and hold competitions for exploratory research projects relevant to the ERC's strategic plan.

4.5.4 Mentorship Training

Mentoring of undergraduate participants in the ERC's research program, as well as participants in the Research Experiences for Undergraduates (REU), Research Experiences for Teachers (RET), and Young Scholars (Gen-3 only) programs , often falls under the purview of a graduate student. Post-doctoral researchers and faculty are also involved, but direct interactions are typically mediated through advanced graduate students. Some programs have mentoring requirements built into the expected activities of the graduate students, especially for the supervision of summer REU Site participants. Please note: Mentorship training should be provided to all graduate students as part of their professional development activities, prior to allowing them to assume these responsibilities. See section 4.4.1 above.

4.5.5 Seminars

Presence and participation in seminar series are part of every graduate student's education. Often, the student's home department will have seminar series that require some attendance regimen. There are typically two types of center seminars. An ERC-wide seminar series is an important way to integrate the research teams and it is recommended to incorporate graduate student selection of topics and speakers in some meaningful way. Additionally, students often develop an independent seminar series that serves to connect research thrusts across departments as well as institutions. These series may be student-only forums that have a more informal feel. Both of these venues are important to connect often geographically dispersed students and help to instill a center identity.

4.5.6 Curriculum Development

One of the most lasting institutional changes an ERC can offer an institution(s) is by integrating center research into the curriculum. ERCs introduce curriculum changes in many different ways. Course revisions can take place at the undergraduate and graduate level based on the natural tendencies of ERC-affiliated faculty assigned to regular courses. New courses derived from the research program are expected outcomes of the ERC program. In some cases, new degrees are introduced. Here we focus on graduate-level curriculum development.

New Degree Programs, Masters/PhD level.

Many of these are described more fully in the examples in Appendix section 4.5.2.New master's programs are often the easiest to implement. They do, however, present challenges. Suggestions for developing one include:

1. M.S. or M.E. (Master of Engineering) programs that build upon an existing traditional M.S. degree, e.g., M.S. EE or M.S. ChE, may be developed by adding an area of emphasis to the existing program, perhaps leading to a certificate. They may also evolve into full-fledged programs. Departmental and/or graduate program buy-in from the beginning of the development process for this kind of new M.S. program is required, as is buy-in from all stakeholders.
2. Include opportunities for students to do some directed research with ERC faculty and to receive credit for it. The uniqueness of your ERC will permit students to do directed research in different ways with ERC faculty. This can be a valuable selling feature for the program.
3. Industry professionals can be valuable adjunct faculty.
4. New degree programs may take time to go through the approval processes that are specific to each institution.
5. New Ph.D. degree programs often require the longest lead times to get established. Before proposing a new Ph.D., the same process used to establish the center's expected skills set should be utilized to determine that all stakeholders view the center's field as one that should become a distinct degree or one that is an add-on to an existing degree program.

As an example, The Center for Structured Organic Particulate Systems (C-SOPS) has an emphasis in pharmaceutical manufacturing technologies. To better serve the needs of their graduate students, the partner institutions have various versions of a Pharmaceutical Engineering course sequence, leading to certificates or degrees at the Masters level. At Rutgers, the effort was directed at introduction of a new degree program (see example 4.5.2.4)

Another example is the Biomimetic MicroElectronic Systems (BMES) ERC at the University of Southern California. BMES has introduced several new graduate degree programs over the course of a decade. The programs are in response to training needs associated with new and novel medical devices. The training was best served by coordination between the School of Engineering at USC and their medical school as well as medical schools at other institutions. Specialized M.S. degrees and rigorous M.D./Ph.D. programs have also been introduced. See appendix example 4.5.2.3.

New Courses, Course Revisions, and Curriculum Coordination

The introduction and revision of courses based on the research findings of the center, as well as to introduce newer skill sets to graduates, are common in an ERC's curriculum development activities. Revision of courses has lowere barriers of approval and effort than the development of new courses, and thus in many cases provides greater return on investment. New course content and materials are often left to individual faculty to implement, but when the need for a coordinated curriculum is apparent, a broader effort is required. The Smart Lighting ERC has developed a curriculum matrix that facilitates the ability of students, as well as industry, to understand the relationships between the different requirements. Smart Lighting's *Illumineer* curriculum summarizes the desired background and skill set of graduates pursuing careers in smart lighting. See appendix example 4.5.2.5.

Course Articulation Between Partner Institutions

When partner institutions have course sequences or even entire degree programs already available, articulation agreements may be an efficient route to expanding their impact. The articulation usually emphasizes tuition payment/revenue agreements, but the inclusion of courses in the core or as electives in other programs should be carefully described as well. Students may be in residence at partner institutions and take courses for credit or they may participate by online delivery of the material between partner institutions. At the Collaborative Adaptive Sensing of the Atmosphere (CASA) ERC, students were able to enroll in coordinated Ph.D. programs that were otherwise not available to them through collaborative agreements. See appendix example 4.5.2.1.

Online Delivery

The acceptance of online formats for course delivery has been significantly elevated in recent years with the inclusion of free content from established institutions and recognized faculty experts. The major emphasis in the media has been associated with Massive Open Online Courses (MOOCs), but the standard course can also benefit from online formats. This is particularly useful when the partner institutions are sharing instructional expertise or have inter-institutional course requirements. It can be expected that a more widespread adoption of online, modular, or blended course formats will be prevalent in the near future.

Workshops

Almost all ERCs develop and run workshops to highlight recent advances in research, as well as to showcase new equipment or devices that are integral to their research thrusts. The workshops serve to bring together practitioners, outside experts, international teams and various vendors with graduate students in a concentrated learning environment. Workshops can be regularly scheduled or responsive to timely new innovations. Two examples are described in Appendix sections 4.5.1.4 and 4.5.3.2.

Innovation and Entrepreneurship

Gen-3 ERCs have additional requirements and a broader mandate to include training related to innovation, creativity, and entrepreneurship. While many ERCs infuse this training throughout their various programs, some have developed specific courses or modules/activities. The CITE workshop described in example 4.5.1.4 (Appendix 4.5) is one example. The ASSIST ERC has proposed a required set of activities associated with the specific skills and attributes particular to their graduates that includes this type of training. The identification of innovation and entrepreneurship training is a key component and the program is required as part of the completion of studies for students in the ASSIST ERC. See appendix example 4.5.1.2.

4.5.7 Industry Mentorship of Graduate Students

Industry plays a well-established central role in the guidance and relevance of ERC research thrusts and testbed activities. The degree of involvement of industry in the execution of research projects by graduate students can range from service on thesis committees to oversight of research on a regular basis. While it is difficult to ensure continuity of programs that have a very direct involvement of industry in a student's work, some coordinated mentoring can be very effective. The C-SOPS ERC has established a formal mentoring program for graduate students, as well as post-doctoral researchers, that connects students and post-docs to industry peers and experts. Regularly scheduled meetings with teams of academic and industry partners can also facilitate advancement of projects and make Industry Advisory Board meetings more focused. See appendix section 4.5.3.1.

4.5.8 Student-led Proposals

Opportunities for students to develop funding proposals can be a valuable experience that some ERCs have taken advantage of. Students recognize the value of coordinating a team to guide the proposed work and to interact with different groups associated with getting the project off the ground. In some cases, the funding for the project has come from the ERC and aligned with the testbeds identified for the technology development that was needed. For example, the CASA ERC nourished a student-led testbed (STB) in radar precipitation estimation that was well received by the research team and by the technology users. The project was funded through a diversity supplement as well as Louis Stokes Alliances for Minority Participation (LSAMP) and

Alliances for Graduate Education and the Professoriate (AGEP program funding. See appendix example 4.5.2.2.

Other opportunities for student-led funding include stipend and tuition support opportunities such the NSF and DoD Fellowships,[1] proposals to SBIR and STTR programs for development of innovative research ideas, and proposals to industry that may allow for company-specific testbed development or provide a service contract using the expertise of the students. Internships and part-time employment may also be beneficial if well-coordinated to the student's academic experiences.

4.5.9 International Experiences via Internships and Student Exchanges

Gen-3 ERCs have a mandate to provide opportunities for center students and faculty to collaborate in a globally connected university research and education environment. This is an opportunity for the ERC researchers to collaborate with "best researchers in the world" in areas where complementary expertise strengthens the efforts in the ERC while providing an opportunity for cultural and engineering practice experience for the students in global environment. This can be accomplished formally through a Memorandum of Understanding (MOU) or via faculty-to-foreign faculty collaborations. Gen-3 centers must ensure that the foreign collaboration adds value to the research and also offers the ERC students the opportunity to work in a foreign laboratory for a mutually specified period of time. It is essential that the student spend sufficient time in the foreign laboratory to have a meaningful international research experience that is relevant to the student's research in the ERC. In both cases, there should be mutually protective Intellectual Property (IP) policies. These collaborations are not expected to be in place in the proposal; rather they are expected to evolve over time as the research program evolves.

1 See, for example: http://www.nsfgrfp.org/ ;
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13646 ; and

http://www.onr.navy.mil/Education-Outreach/undergraduate-graduate/NDSEG-...

Section 4.6: Assessment and Evaluation

4.6.1 Rationale and Definitions for Assessment and Evaluation

NSF recognizes the importance of assessing the impact of all ERC University and Precollege Education programs and the General Outreach to involve precollege students in the ERC activities that it supports. Accordingly, in the 2015 ERC solicitation it was required that ERCs assess, evaluate, and track the impacts of educational and outreach programs on program participants; requirements in this area will be specified in each class' solicitation. Having an assessment and evaluation plan in place not only ensures that the center meets NSF requirements, but it is also key in determining which education programs are helping the center meets its mission and which should be modified or terminated. It is the best way to gather data that can direct the development of effective programs, and goes beyond the use of anecdotal information about program satisfaction towards a more data-driven approach for assessment and evaluation of impact.

As a starting point, it is important to define assessment and evaluation, because although often used interchangeably, the two terms define different processes. Contemporary definitions vary as a function of the context in which the assessment or evaluation occurs and in terms of the assessed content. In general, *evaluation* refers to a summative judgment of worth, merit, and value at the end of a project, while *assessment* is more formative (occurring as the project progresses) and guides improvement over time. Specific to the ERCs, assessment should guide continuous improvement of the ERC's University and Precollege Education programs and the General Outreach activities involving precollege students, while measuring the programs' impacts over time. NSF ERC Program-level evaluations of educational impact are carried out by the ERC Program.

Program evaluation and assessment are not just the evaluator's or assessment officer's responsibility. Education Directors also must understand the process, design, and content of program assessment and evaluation and how to present the results effectively to inform all involved. Additionally, the center's full Leadership Team should be included in assessment and evaluation efforts. Regular communication of efforts and results is recommended.

ERC impacts are most often related to college and career trajectories in engineering and related fields. ERCs contribute to both industry and academia via their precollege and university student alumni. Assessment is an important way to demonstrate this impact. In the sections that follow and in the appendix to this section, general guidelines, key features, processes, procedures, and examples are presented to guide ERC personnel in developing and implementing assessment and evaluation plans.

The structure of Gen-3 ERC education programs should inform this process—i.e., University Education (undergraduate and graduate), Precollege Education (RET and Young Scholar programs), and General Outreach designed to engage precollege students in the ERC's research area to stimulate interest in engineering careers. In addition, the University Education programs are designed so that the ERC graduates acquire skill sets needed to be effective in industry and creative and innovative in both academe and industry. This structure is often difficult for faculty to understand and the assessment/evaluation officer can be especially helpful in working with the ERC's Education Director in designing and assessing the impacts of this new approach.

4.6.2 General Guidelines

In order to develop an effective Assessment and Evaluation Plan, all stakeholders should be involved at the earliest stages of program development, including representatives from each partner institution. This will include Education Directors, assessment officers, program coordinators, and program evaluators. To ensure that all possess a clear understanding of the assessment purpose and planning process, the following steps are suggested:

- Assessment personnel and the related assessment plan should demonstrate an understanding of NSF requirements, including quantifiable outputs and the educational impact of study components.
- Assessment planning should co-occur with overall center programmatic planning and should be in place on the first day of center operation.
- Desired outcomes, perceptions, and expectations of the University and Precollege Education programs and the General Outreach to involve precollege students in the ERC activities, must be determined.
- Appropriate methodology and assessment tools must be selected for each activity.
- Timelines for each assessment component are a must.
- The center program Evaluation/Assessment Officer should be someone who is trained in qualitative (e.g., interview) and quantitative methodologies (survey design, psychometrics), and corresponding statistical and narrative analysis. Evaluators can be external or internal and each center must decide whether to have an external evaluator based upon discrete ERC needs. This person must understand the goals of the ERC program and the center in order to develop an appropriate design and instrumentation. Be mindful that many professionals trained in this field are accustomed to measuring learning outcomes, which is not a goal of ERC education programs, per se. Thus, precollege and university level programs will have different outcome goals that should be carefully determined using the ERC Program's performance assessment criteria and the center's own programs' goals.
- All projects must meet the Institutional Review Board (IRB) approval for not only the lead university, but also for the partnering universities and industry. Furthermore, it is a requirement that IRB approval be obtained before conducting any publishable research with human subjects.

One of the most challenging parts of the assessment process is determining appropriate expected outcomes. It is often the case that faculty tend to set unrealistic expectations and over-promise results. A common example is to list changes in state-wide standardized test scores as a result of a center program. Given the large number of variables that impact test scores, it is not reasonable to assume that a small-budget (in comparison to the total education budget that impacts test scores) intervention will have an impact on state-wide standardized test scores. It is therefore important that the assessment director work closely with research faculty to ensure that expected outcomes match the time, duration, and budget of the intervention.

Appendix section 4.6.1 provides several examples of program-wide education assessment and evaluation at different ERCs.

4.6.3 Assessment Design

There are multiple levels of information that can help guide the ERC education programs' development. Front-end evaluation is a useful tool, similar to market research. An example case where this would be useful is in the development of course materials that the ERC plans for adoption by a wide audience. Front-end evaluation would involve surveying the potential users (faculty) of the new materials about what topics they would like to see covered. Also, surveying potential students about what their existing level of knowledge about a topic is would uncover misconceptions that the developers could address. Incorporating end users into the design process results in better materials and facilitates adoption.

Many times, valuable information can be gleaned from informal quick studies with small numbers of participants. For example, prior to making a website or on-line unit public, it is always helpful to have small numbers of the intended audience beta test the site or materials. Problems with navigation and function can be easily corrected before “going public.” Also, quick, short surveys can help guide programming. For example, finding out how current students learned about the center can help recruiters identify useful recruiting avenues that should be continued, as well as identify less productive methods that should be abandoned.

Formal assessment will also be appropriate in many cases. Pre- and post-assessment of knowledge and skills utilizing objective instrumentation is an accepted way to measure student learning outcomes. Instrumentation typically includes items testing for specific content knowledge, and over time and with due diligence, instrumentation can be revised and modified to enhance validity and reliability (Drummond & Jones, 2010).

Both quantitative (e.g., scales, rankings, etc.) and qualitative (e.g., focus groups, interviews) methods are useful. Quantitative designs can fail to capture the richness of phenomenological experiences best offered up through personal narrative, so supplementing quantitative measures with qualitative methods can produce a more complete description of outcomes. Guided discussion can bring about descriptive data useful to the assessment process (Vacc & Juhnke, 1997). These mixed-method designs, when properly done, result in rich quantitative and qualitative data which are mutually supportive, thus enhancing design internal consistency and validity and increasing results generalizability (Hanson, Creswell, Plano Clark, Petska, & Creswell, 2005).

At a minimum, mixed-method assessment designs should include clearly articulated goals and student’s gaining skill sets. The essential goals are to determine whether the (i) mission statement is being properly addressed and (ii) students are gaining the desired skill sets. Content-specific instrumentation measuring teaching (i.e., educational activities) and learning (i.e., skill sets) is useful. Complementary case-by-case interviews or focus groups are also helpful.

There are useful frameworks to help organize the assessment and evaluation plan. One example is the Kellogg Logic model, which provides stakeholders with a visual template that connects activities to expected outcomes.[1]

4.6.4 Suggested Instrumentation

Instrumentation construction can often feel like a daunting task; however, the primary necessity for proper construction is time. Gen-3 ERCs are funded under cooperative agreements with an initial time line of five years and renewals can extend that to 10 years. Support is provided in annual increments. The first renewal review is during the third year, where NSF expects that the assessment program has been set up and is functioning effectively to guide practice. Three years is more than adequate to initialize and “study” instrumentation developed specifically for use within ERC education programs. Other requirements for instrumentation development include a good understanding of student learners, their backgrounds, and prior knowledge base, as well as the desired learning outcomes.

Table 4.1 provides suggested measures for assessing major education programs. Besides quantitative methods (e.g., survey), qualitative methods such as in-depth interviews are also useful to identify students' learning processes, outcomes and concerns. Initially, it is often a good idea to conduct a qualitative assessment due to the small sample size of most education programs.

Table 4.1: University and Precollege Assessment

Program	Example	Selected Measures
Undergraduate Program **(NSF requirement)**	• Academic-year Undergraduates Survey • Summer Research Experiences for Undergraduates (REU) Survey	• Career Path • Concept Inventory (e.g. Hestenes, Wells, & Swackhamer, 1992) • Research ability • Attitudes (Hilpert, J., Stump, G., Husman, J., & Kim, W., 2008). • Self-efficacy (Bandura, 2006) • Professional development (Rubric for evaluation of presentation, self-assessment of key professional skills) • Creativity • Descriptive metrics: publications, presentations, attending graduate school/ industry
Graduate student skill-sets defined by each center **(NSF Requirement)**	• Entry survey • Exit survey • Employee assessment	• Longitudinal tracking on the progress of graduate students' skill-sets defined by your center (e.g., creativity, innovation, analytical skills, problem solving, leadership, motivation, communication skills) before starting and after graduating from graduate school. • Employee assessment on students' skill-sets at workplace. • Quantitative metrics: participations of professional training, publications, internship, and awards. • Engineering Global Preparedness (EGPI: Ragusa 2010, 2011) • Engineering Creativity and Propensity for Innovation (ECPII; Ragusa, 2011)

Program	**Example**	**Selected Measures**
		• Course/program specific concept inventories
Precollege programs **(NSF requirement)**	• Young scholar program (YSP) survey • Research experience for teachers (RET) survey • Precollege partnerships • Portfolio assessment	• YSP: pre-and post-measurements on engineering knowledge, interest, research ability, attitudes, and future plan. Quantifiable metrics: publications, presentations, and persistence of interesting in studying in STEM. • RET: pre-and post-measurements on teaching efficacy , professional development, and engineering knowledge. • Quantitative metrics: impact of classroom curriculum development or research publications. • For students of RET Teachers: ○ Science literacy- specifically, science vocabulary, reading comprehension, science writing; (Ragusa, 2012) ○ Motivation for Science Questionnaire (Ragusa, 2012)
General outreach **(NSF Requirement)**	• Summer camps • Lab tours • Field trip • Community outreach	• Summer camps: pre and post measurement on engineering knowledge, interest in learning specific activity, self-efficacy in STEM, attitudes, & career/major preference. • Other outreach: post-measurement on interest in learning more, basic knowledge, and participant's feedback on overall programs.

Instrument sharing among ERCs is strongly encouraged. Granted, measurements will discretely vary according to ERC scientific and research orientation; nonetheless, assessment officers can talk among themselves to determine instrument-sharing advisability. The American Psychological Association recommends the following protocol for instrument sharing:[2]

1. Contact the instrument author to discuss instrument sharing.
2. Be mindful of copyright issues and obtain written permission from the instrument author prior to using the instrument.

As mentioned, instrumentation is generally discrete to each ERC research/scientific agenda. Thus, issues of fair use of copyrighted material must be considered. In short and when engaged in instrument sharing, the borrowing ERC, in collaboration with the instrument author, should discuss the likelihood of—or need for—instrument adaptation and discern the necessity for and ensuing transformative nature of those adaptations. A full explanation of fair use practices with copyrighted materials may be found at www.copyright.gov.

Overall, survey instruments should be carefully designed by the following steps:

1. Determine the evaluation goals or purpose of assessment;
2. Gather and study existing assessment reports from NSF (e.g., REU program, RET program, and YS program);
3. Use published (validated and reliable) scales from the fields of education, engineering education, sociology and psychology for specific measures you are interested in; and
4. Finalize the survey by pre-testing on a small pilot set of representative students.

Structured interviews are one methodology for discovery in the assessment process, particularly when the interview questions are predicated on a specific taxonomy for learning or criteria for assessment (Vacc and Juhnke, 1997). Case studies, phenomenological interviewing, or focus groups can be used for structured interviews. Once again, guiding questions derive from a good understanding of (i) student learning, (ii) learning outcomes or skill sets, and (iii) and mission statement concepts. To be effective, the person guiding interviews must be professionally qualified for individual interviewing and managing group dynamics.

Appendix section 4.6.2.1 gives an example of the development of an education program assessment instrument by an ERC.

4.6.5 Data Collection and Management

Creating a systematic and organized method of tracking all the education information and data through websites or other web tools (for example, Google Docs, or Survey Monkey[3]) across university partners is crucial. Data collection and management plans should be developed as part of the ERC proposal process.

Documenting photos, videos, and other form of evidence for each program is beneficial for writing the annual reports and renewal proposals. Cloud computing can be used to share photos across partner universities, if permitted by the institutions, although photo release forms and signed forms should always be stored with photos.

With quantitative designs, SAS, Mplus, SPSS, or Microsoft Excel can be utilized to analyze pre-/post- data. In raw form, these data should be housed in a locked office, on a password-protected desktop of the Assessment Officer. Once analyzed and ideally, aggregated, data should be (i) transferred to the ERC reporting database, (ii) reported at the annual conference, and (iii) reported in the engineering education literature.

Qualitative data such as interviews or focus groups' narratives can be audio-taped and, when possible, should be video-taped for data collection. Software also exists for analyzing and presenting qualitative data, (for example: http://provalisresearch.com/products/qualitative-data-analysis-software/). All data must be stored according to IRB requirements and retained for the time period required by each university.

4.6.6 Using Assessment Data

Assessment is intended not only to measure impacts on students and teaching efficacy but also to gauge programmatic effectiveness. Modifying and improving programs is best done through systematic data collection, management, and analysis.

NSF requires center reporting on an annual basis, and this includes Assessment and Evaluation activities and results. Assessment results may be used by the Site Visit Team to evaluate the effectiveness of the education programs. It is recommended that the center strive to exceed NSF expectations, highlighting signature programs by reporting data through graphics, tables, and longitudinal assessment; the ERC should focus upon the broader impact of educational and outreach activities specific to these signature programs.

Besides assessing participants' gains in learning, interest, attitudes, teaching efficacy, or future career goals, it is important to evaluate each education program as a whole in order to identify the weakness and strength of program design. Program evaluation will serve the purpose of improving logistics and program design.

4.6.7 Notes

Rationale and Definitions for Assessment and Evaluation

The National Academy of Engineering has recommended both best practices and attributes for engineering education in their *Engineers for 2020* report (NAE, 2005). Additionally, the Academy defined Discipline-Based Education Research (DBER) (National Research Council, 2012). The NAE together, with the National Research Council, identified "assessment best practices," (NRC, 2011) as an important component of DBERs. In 2006, the Educational Testing Service (ETS) published three issue papers describing a Culture of Evidence—or evidence-centered design—as a methodology for systematically assessing post-secondary education effectiveness across institutions of higher education. Evidence-centered designs link institutional or programmatic vision and mission with student learning outcomes, which in turn are aligned with discipline-specific professional standards, and measured by, or exemplified through, concrete evidence (Millett, Payne, Dwyer, Stickler, & Alexiou, 2008). See section 4.6.8 below for reference citations.

Framers of the ETS papers emphasized that "at the heart" of an evidence-centered design is the issue of validity, whereby evidences measure or exemplify that which they purport to measure or exemplify. Evidence could include (a) annual data collection with valid/reliable instrumentation; (b) pre-/post-test designs using instruments with multiple forms; (c) a variety of assessment formats, including asking questions; and (d) “peer group comparisons.” The goal of evidence-centered assessment is to produce valid and reliable data for decision-makers to determine higher education and programmatic effectiveness (Dwyer, Millett, & Payne, 2006; Millett et al., 2008; Millett, Stickler, Payne, & Dwyer, 2007).

Suggested Instrumentation

Resources for survey design and scale development from sociology and psychology disciplines:

Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method by Dillman, Smyth, and Christian.

Scale Development: Theory and Applications by DeVellis.

Reliability and Validity Assessment by Garmines and Zeller.

Psychometrics Theory by Nunnally and Bernstein

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1http://www.wkkf.org/resource-directory/resource/2006/02/wk-kellogg-found...

2http://www.apa.org/science/programs/testing/find-tests.aspx?item=4

3https://www.surveymonkey.com

Section 4.7: Graduation and Sustainability Strategies

4.7.1 What to Expect: The Big Picture

In the transition from an NSF-funded ERC to a graduated and self-sustaining ERC, the education programs undergo significant challenges and changes. Some program components are amenable to institutionalization, some gain support from their university administrations, but others depend on supplemental funding that is not likely to be continued after NSF funding ends.

As a center approaches the end of the 10-year NSF funding cycle, these concerns come into sharper focus. NSF intends that the culture of ERC education will continue in the center; but without continuing support from the university and industry, it is likely that many or most of the ERC's education programs will end. The center's Education Coordinator/Director should work with the center leadership to develop a self-sufficiency plan from the outset. This plan can include soliciting education funding from the university, foundations, and the private sector (notably industry or foundations).

When a center "graduates," or reaches its full term, NSF funding for educational activities may continue on a competitive basis for RET or REU Site awards, or other NSF education program awards. Depending on the Center Director’s commitment to education and the financial strength of the graduated center, some education programs may be cut back or ended. Areas that may be affected include the extensive involvement of undergraduates and underrepresented populations in education and research activities, RETs, as well as outreach programs. Given the importance of these areas, it is important to come up with a sustainability plan from the onset of the ERC. The continuation of a graduated center in some ERC-like form is essential to maintaining support for the associated education programs.

Preliminary data from earlier graduated centers suggest that:

- Research tends to become focused on applied, short-term projects that may not be suitable for dissertation level work.
- Undergraduate research and outreach program components (including programming for minorities and women students) decline.
- Student involvement, interdisciplinary focus, and team-based research decline.

- In most universities with graduated centers, the main lasting effect of the NSF ERC funding on education programs to date has been the development of multidisciplinary degrees, minors, and certificates that have helped shift engineering education away from the traditional disciplinary compartmentalization towards the interdisciplinary systems focus that is required to solve today's engineering challenges. As such, it is critical that courses that have been added to the curriculum by the center and any associated certificates, minors, and/or majors should be integrated in the university curriculum prior to the end of the center, thereby becoming part of the continuing programming of the university

Studies and a recent survey of graduated centers[1] have shown that successful continuation of education programming depends on several factors:

- Financial support (hard money) for a full-time person to coordinate activities, who is prepared to seek funding from grants and other sources;
- Strong institutional support , including support for the ERC education culture as well as significant cash or other direct financial assistance;
- Finding champions for the education and preparation of students, both in industry and at the university level;
- Engagement of faculty motivated to continue and the existence of institutional incentives that further this motivation;
- A strong, continuing commitment on the part of center leadership to the goals of an ERC education program;
- Successful securing of funding from governmental agencies and private foundations;
- Creative ways of packaging program elements that fit the type of activities industry is able and willing to support (i.e., lab training internships, design course support, graduate fellowships); and

- A strong, evolving research program.

Attention must be paid to all these characteristics from the outset. They must be nurtured and maintained throughout the life of the center in order to provide a platform for successful implementation of the strategic plan. Appendix 4.7 presents examples of sustainability planning for education programs of graduated ERCs.

4.7.2 Strategic Planning for Graduation

Impending graduation can seem overwhelming, but actually it is a wonderful opportunity to reexamine the education mission of the ERC and to further assess the programs (i.e., what worked, what didn't work, has the culture of academic engineering been changed?, etc.). " Based on this analysis, a new education vision can be established with a new mission statement, goals, objectives, organization, strategic planning, scope, range, initiatives and actions, budget, dissemination, delivery systems, and collaborations. It is important to communicate with industrial partners, education partners, and center faculty and staff to determine this new vision. It is also important to keep in mind the "products" of the education program and help create a strategic business model. This will help identify stakeholders and enable better communication about the benefits of the program for maximum leverage.

ERCs build considerable momentum in their education programs (both precollege and university) by the sixth year. They provide an educational environment for university students and K-12 access/support that is unmatched by other programs on campus. ERCs build an integrated cross-disciplinary culture in partnership with industry, where knowledge is transformed into real-world systems technology. The involvement with industry and the ability to see real-world results are strong motivators for undergraduates and even precollege students. These aspects are unique to the ERC environment and should be considered as valuable assets post-graduation. Considerable time and effort has been invested in creating programs that integrate research and education, collaboration, and a cross-disciplinary focus. The best strategy is to continue with an education vision that uses some of these programs, along with the "ERC" brand/status, and not to reinvent the wheel.

Timeline and Transition Plan Development

An important issue in strategic planning is the impact of the ERC's 10-year life cycle. Planning for center sustainability should begin in earnest no later than year 3 and, by year 5, a center should have a business plan for graduation. As funding is phased down overall in years 9 and 10 and the center graduates from NSF support, the education program's survival depends on institutional support (including cash), motivated faculty, commitment to the goals of the education program, and a strong, evolving research program. The continuation of a graduated center in some ERC-like form is essential to maintaining support for the associated education programs. As the center matures, the education budget should include increasing contributions from sources such as industry members, NSF education funding outside the ERC Program, and private foundations. Opportunities should be pursued to leverage the NSF funds using non-federal ERC funds for matching.

Key Participants

A strong relationship with the other members of the ERC's Leadership Team, and especially with the Center Director, will greatly enhance the center education program's prospects post-graduation. Organizational relationships that were created during the life of the center are key to the maintenance of most education programs, even programs that have been institutionalized. For example, partnerships with affiliated deans, department chairs, and other university leaders will affect the academic units and influence what a graduated center may anticipate in terms of its ability post-graduation to sustain delivery of classes, certificate programs, and new degree programs the ERC established. Sustained collaborations are the key to success, particularly for precollege programs. Working with local schools and universities is easier than working with partners who are farther afield. It also builds relationships with local partners that are potential sources of support and enables potential reforms in STEM education (and education writ large), it improves the diversity of the population drawn into STEM research, and it enriches the general scientific/engineering literacy. Therefore, as the center matures, it is beneficial to strategically focus precollege program support on efforts that resulted in strong local partnerships. However, the opportunity to act locally should not blind ERCs to their national and international opportunities, which reflect the technology and market scope of the industries they serve.

Industry. The value of the industry-education link to ERC success and ERC sustainability cannot be overemphasized. The link between industry and education is one of the determining factors in the success of an ERC, and the strength of this link is a crucial element in the longevity of the center. It can also provide a strong base for a successful sustainability plan, and this element should be incorporated into ERC strategic plans at an early stage of the center. Industry is involved in all aspects of the ERC education program. Industry representatives often serve as mentors to undergraduate, outreach, and/or graduate students and may serve on the students' masters or doctoral committee. Industry may sponsor undergraduate or graduate internships, or sponsor students' undergraduate or graduate degrees in whole or in part. Industry input helps shape the curriculum, develop original courses, and it influences the very nature and approach of the engineering curriculum of the future. Industry members may present lectures, course sections, or entire courses, or teach courses in partnership with ERC faculty members. Industrial representatives often serve on review panels evaluating and shaping the ERC education program. Industry interaction with ERCs may result in new employment and internship opportunities for students, and can even lead to the development of new research projects and thrusts for the ERC.

Many creative approaches have been developed to sustain the link between industry, faculty, and students in the center and to provide continued opportunities for industry mentorship of students post-graduation. At the most basic level, teams of students and faculty may continue to travel to companies for presentations, meetings, and tours. For more direct continued involvement, industry may design projects or suggest problems and provide funding for study by a team of faculty students in the graduated center. In general, industry will remain engaged if they feel working with the graduated center continues to help them hire students with the skills they need and address research critical to their marketplace success. Examples of success include:

- The Center for Biofilm Engineering (CBE) in Montana graduated in 2001. As of 2013, they are still doing well and just held a meeting with their companies—with 79 attendees.
- The Center for Power Electronics Systems (CPES) remains well funded and with increasing support from their Industry Consortium program at the level of more than $2M per year. The program alone supports about 30 graduate stipends. They are also well funded with sponsored research at a similar level.
- The University of Washington Engineered Biomaterials (UWEB) ERC continues to function after graduation, primarily as an Industry Consortium. Much of the research from the ERC has either been commercialized or is being successfully advanced with support from other grants (over $30 million).

Students. Students (undergraduate or graduate) should be involved in developing and evaluating post-graduation plans and implementing the new program. They are an important resource and will likely have a lot of energy, know what you are doing, and have good ideas for the future. Over ten years of NSF support, the center's reputation should have attracted students interested in working in an ERC culture; and future recruiting will benefit from the connections made by the center with departments, colleges, and the university during the life of the center. By demonstrating to others on campus the benefits of joint recruiting at professional meetings, specialized conferences (e.g., the Society for Advancing Hispanics/Chicanos & Native Americans in Science [SACNAS], the American Indian Science and Engineering Society [AISES], etc.), it is likely that other units on campus will cover the associated personnel and travel costs to facilitate continuation of these joint recruitment activities post-graduation. Centers should not be shy about promoting the "ERC" brand post-graduation to help with recruiting.

The Student Leadership Council has a strong role in education in a successful ERC and should be included in this strategic planning. It is also advisable that the SLC continue post-graduation, as it is a forum for student interaction and communication with the ERC's Director.

Budget

As the center approaches graduation, the most likely scenario for continuation of the education programs is through increased support via additional funds from the university, foundations, industry, or state programs as well as NSF education programs. Faculty attitudes toward center education programs differ with respect to funding. A research faculty member who is also coordinating an education program commented, "It is clear that faculty respond to rewards (primarily funding). If money is allocated primarily on the basis of research, then there is little incentive for faculty to devote significant effort to developing new or innovative educational activities." At many ERCs, however, faculty are enthusiastic about the education programs and even offer to support additional students from their research funds.

Continuing education programs such a short courses for industry can be self-supporting and/or generate funds if priced properly. Surveying the center's industrial partners will help determine if this is an option for a given center. Written educational materials developed for either practitioners or students can also be sold at cost to cover the production of the materials. Be sure to market the most successful education programs to universities, industrial stakeholders, and others. The resulting positive publicity may attract volunteers and other support or help recruit students. Publicity of center programs also promotes the concept of the ERC.

4.7.3 Retaining High Value ERC Educational Features

There are several features of the ERC education programs that are highly valued by a range of stakeholders. The following are critical post-graduation:

Education Director

One center has experienced not only no decline in programming after graduation, but an expanded education program. This center, the Center for Subsurface Sensing and Imaging Systems (CenSSIS), can serve as a model for others seeking to successfully transition to self-sufficiency. A large factor contributing towards their success is the integration of the ERC's Education Program Director into the college post-graduation. Funding for the position is now provided by the Dean's Office and is an indication of the degree of institutional support for the ERC vision, a key element identified by SciTech Communications[2] as a necessary condition for the maintenance of an ERC culture post-graduation. The previously ERC-focused education efforts have been disseminated into the college-wide programs that the ERC Education Program Director now manages. In addition, the graduated ERC at this location successfully seeded an Undergraduate Fellows Program that has been expanded to the College of Engineering as a whole. Similarly, the CenSSIS REU program has gone college-wide and pre-collegiate outreach activities have also expanded. These programs operate on an expanded budget derived from a combination of NSF grants, multiple foundation grants, School of Engineering funds and other non-industry sources.

University Education & Research Programs

A significant number of participants—more than for any other key feature—identified the education of university-level students as the single most significant strength of the ERC Program. The consensus viewpoint was that cross-disciplinary interactions are key to the unique value of an ERC-style education, and that all characteristics of this feature, such as the interaction with industry and the leadership experience gained through involvement in the ERC's SLC, are important and valuable. These programs are important because they provide: exposure to a cross-disciplinary systems view and opportunities, teamwork, exposure to the latest developments, innovation and entrepreneurship, leadership opportunities, direct involvement with industry, and communications training and opportunities.

These characteristics may be difficult to maintain post-ERC because of funding and cultural shifts. The following strategies can help overcome these barriers and help maintain these features:

- Establish a new ERC curriculum. This can be a challenging and complex task, but it can help maintain interdisciplinary research & education areas.
- New degree programs, in particular, will require substantial long-term institutional resources and commitment from the ERC and the parent university, but these will by their very nature be sustained past the life of NSF ERC funding.
- If your ERC is a multi-university center, establish long-term memoranda of understanding so that credit can be given to students taking the course at other partner universities.
- New degree programs must be especially well coordinated with the existing academic standards and structures of the university and build on student interest and enthusiasm; as such, they will also be sustained past the sunset of NSF funding.
- Professional certificate programs, if properly planned and delivered, can help meet the demand for continuing education in the ERC's associated industry and improve the reputation of the center. ERCs that offer such programs, however, must allow for enrollments that fluctuate with swings in the economy.
- Maintain and/or build new testbeds as a source of student research, interdisciplinary, and multi-campus research and education collaborations.

An example of College-wide adoption of ERC-developed courses follows:

- The graduated but still-active Packaging Research Center (PRC) at Georgia Tech had developed two "Design, Build, Operate" courses. Both of these courses were developed and initially fully supported by the PRC for about two years. After the trial period of two years the Center asked for them to be cross-listed and included as permanent senior-level courses in the curriculum of Mechanical and Materials Science and Engineering, in addition to Electrical Engineering. It took a little over a year for these courses to be approved by the departments and all was completed before the end of NSF ERC funding. These courses are now offered regularly every year. A graduate course that was developed by Center Director Rao Tummala, "Microelectronic System Packaging," is cross-listed among the other engineering departments (EE, ME, MSE and ChE) and continues to be offered regularly. Since the cross listing and approval process were completed before the end of NSF ERC funding, these courses became permanent courses in the curricula, which makes it easier to offer them every year without much support from the PRC.

Cross-institutional Collaboration

It is a significant challenge to maintain multi-campus cohesiveness and funding; all graduated ERCs have handled this differently, with varying levels of success. Cross-institutional collaborations can be preserved by continuing to share experiences and ideas through portfolios, workshops, and other mechanisms. Partner universities can continue to share recruitment activities by, for example, recruiting for one another, or by conducting joint recruitment events at partner universities for REU sites, Research Assistant (RA) positions, etc. In particular, both cross-campus research and education initiatives can be sustained, and new opportunities developed, by continuing to encourage cross-campus student exchanges (e.g., hosting REU students, cross-campus summer research exchanges for graduate students, and collaborative recruitment of graduate students from partner institutions). An important feature of most ERCs is the SLC, which gives students a collective voice in the center's affairs and fosters leadership skills. Continuing the SLC past graduation ensures continued communication between campuses. Examples of cross-collaboration success post-graduation include the following:

- When the Georgia Tech/Emory Center for the Engineering of Living Tissues (GTEC) graduated, Emory University and its partner Georgia Tech appointed a committee to make plans for the future. The ERC has been reconfigured and renamed, but continues to move forward with financial support from both institutions
- The Pacific Earthquake Engineering Research (PEER) Center operated as an NSF-funded Center from 1997 to 2008. The Center continues today, with more activity, research participants and funding than it had as an NSF center. PEER has added more core and affiliate institutions and investigators continue to write collaborative proposals and have more than 50 sponsors.
- The Gordon-CenSSIS ERC is still in operation. They competed for and won two major center-level awards as a multi-partner collaborative. These are the ALERT Center of Excellence, funded by the Homeland Security Agency, and the PROTECT Center of Excellence, funded by the NIH’s National Institute of Environmental Health Sciences. CenSSIS set up a plan on how to distribute external grants across the partner ERC universities to maintain those ties on new grants.
- The Particle Engineering Research Center (PERC) at the University of Florida is still continuing. Even though they were among the last of the single university-led ERCs, upon graduation in 2005/06 they joined hands with some of the faculty funded by PERC at other universities and have applied for joint research grants. With one of them they have established a joint NSF Industry/University Collaborative Research Center (I/UCRC).
- Following graduation the Offshore Technology Research Center (OTRC) partners (Texas A&M University and the University of Texas at Austin) successfully pursued a major 5-

year cooperative agreement with the Department of the Interior, which was subsequently renewed for another 5-year period, as well as several joint industry projects.

Opportunities for Diversity

The NSF funding and direct influence of the ERC to directly impact diversity will cease after graduation, but most graduated centers have found that the commitment to diversity has been institutionalized and that other sources on campus may be leveraged to provide support. During the center's lifespan, collaborating with NSF programs such as the Louis Stokes Alliances for Minority Participation (LSAMP), one of the Alliances for Graduate Education and the Professorship (AGEP), Bridge to the Doctorate, and other programs will create a network for fostering diversity that will continue beyond Year 10. Additionally, prior to graduation the center leadership should build relationships with the Deans of the Graduate School and Undergraduate Affairs, or their equivalent, at each partner campus to encourage and assist the University leadership to pursue diversity grants. Suggestions for sustaining the diversity culture of the ERC post-graduation include:

- ERCs should make special efforts to reach certain groups (including underrepresented minority groups, veterans, and at-risk youth). In this role, the ERC seeks to improve public awareness of technology, improve the skills and knowledge of potential science and engineering students, increase the diversity of the engineering student pool, and recruit those students to the ERC itself and/or its associated institution(s). Work with industry, university upper-level administrators, and other units on campus (for example, Civic Engagement and Service Learning units) to maintain these functions.
- Seek upper-level administration, industry partner, current NSF ERC, and other university organization support to continue recruiting events at diversity conferences (AISES/SACNAS, SWE, SHPE, NSBE, NOBCChE) and technical conferences (IEEE, AMS, ASCE, etc.).[3] Collaboration is necessary to both for research assistant stipends to recruit students and for booth/travel costs.
- Financial support for graduate students can be obtained from a wide variety of sources, including grants from NSF, private foundations, and federal and state agencies. Look to see if your university(-ies) has/have funding from or are a member of, the National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM) or have similar funding to help support new/continuing students past graduation.
- Determine which industry partners have a diversity agenda, and offer to help them with that agenda. Mutually beneficial activities may include: 1) seeking funding from industrial partners for student support on research projects of interest to them, at both the graduate and undergraduate level; and 2) helping industry recruit high-quality students for their co-op and internship opportunities.
- Work with campus administration to write new grants/initiatives to support diverse students (LSAMP; NSF Scholarships in Science, Technology, Engineering and Mathematics [S-STEM], NSF Improving Undergraduate STEM Education[4] and similar opportunities).
- Work with ERC faculty to write new grants/initiative to support diverse students, such as NSF Research Traineeship Program (NRT) in FY2014 or Partnerships for International Research and Education (PIRE) proposals.

- The emphasis on undergraduate participation in research is a special feature of the ERC Program, with an emphasis on recruiting from a diverse population (e.g., work with industry to pursue REU funding, work with your ERC faculty with aligned NSF grants to request supplemental funding for REU students, solicit university support for administration of REU programs from multiple departments within the university, write new REU site proposals around joint testbeds, etc.).
- Domestic and international collaborations are vital, since graduate students from external institutions can best be recruited by forming long-lived collaborations with the faculty and staff of those institutions.

Precollege & Community Outreach

ERC personnel agree that there is significant value for the Nation in K-12 outreach and the majority viewpoint is that this key feature should be retained. The center's educational mission includes educating the public on developments in science, engineering, and technology; retraining engineering and industrial workers in new technologies and research areas; and designing programs to reach new audiences with new engineering and technological innovations. However, these features are also possibly the single most vulnerable aspect of the ERC program post-graduation. The most vulnerable K-12 programs are those established because they were mandated, but not leveraged with existing campus resources or local community partnerships. ERCs generally do not have sufficient expertise to continue to design and deliver effective community K-12 outreach programs after graduation without such institutional partnerships.

With that said, there are sustainable options for an ERC to continue outreach to K-12 teachers and students, contribute to reforming science and math education at the precollege level, and expand the student pipeline for engineers. Suggestions for sustaining K-12 programs include:

- Conduct a needs analysis. Each ERC should determine what precollege offerings make sense in the context of its strategic plan, resources, and community relationships.
- Define a post-center focus by working with faculty and administration to identify elements that are of benefit to them, such as broader impacts for their research grants.
- Engaged faculty can help to maintain K-12 teacher and student workshops, competitions, lab tours, and school visits. Summer camps may be supported through student participation fees, and may generate enough revenue to provide scholarships for socially or economically disadvantaged students.
- Continue to “be present” in community events to encourage community college and K-12 students to pursue careers in engineering and undergrads to continue on to grad school.
- Design Challenge Workshops may be a means to engage the K-12 community, community college students, and others with university students, faculty, and industry partners in addressing center goals.
- Submit an RET Site proposal to NSF.
- ERCs should collaborate with successful, established non-ERC K-12 programs and/or with technical education specialists with K-12 expertise. ERCs can serve as a resource for positive experiences (e.g., via the RET program), and these partners can help sustain programs post-graduation.

- The goals of precollege and community programs should be defined early and revisited often in order to develop appropriate sustainability plans. Centers have defined a wide range of goals—from transforming K-12 technical education to simply providing an enrichment component—based on their strategic plan pre- and post-graduation.

See appendix sections 4.7.1.3 and 4.7.1.4 for examples of precollege program sustainability.

Partnerships with Industry

The value of the industry/education link to ERC success and ERC sustainability cannot be overemphasized. This link is one of the determining factors in the success of an ERC, and its strength is a crucial element in the longevity of the center. It can also provide a strong base for a successful sustainability plan, and this element should be incorporated into ERC strategic plans for graduation at an early stage of the center. Industry should be involved in all aspects of the ERC education program, as noted in section 4.7.2 above (Strategic Planning**)**.

Industry is also keen on maintaining relationships with the center. In a study conducted in 2004 by SRI International,[5] the five factors that were rated as "very important" or "extremely important" by the highest proportion of industry representatives (between 48 and 53 percent) were:

- The continuous existence of a strong ERC "champion" in the company unit;
- Management support of the ERC within the company;
- The closeness between the ERC's specific technical focus and theirs;
- Responsiveness of ERC faculty/researchers to their needs; and
- The ERC's efforts to communicate and stay in contact with sponsors.

In addition, the hiring of a center student or graduate was the most highly valued of all types of ERC partnership benefits. Approximately 40 percent of the member representatives reported that their unit had hired at least one ERC student or graduate as a summer or regular employee. About 12 percent had hired three or more ERC students or graduates. On a wide range of performance criteria, a large majority of ERC students or graduates hired were rated "somewhat better" or "much better" than comparable non-center hires. More than half of the student or graduate hires were rated as performing "much better" than comparable students in their breadth of technical knowledge (53 percent) and in their ability to work in interdisciplinary teams (55 percent). Fully 87 percent were regarded as performing better than comparable hires in their overall preparedness for working in industry.

Many creative approaches have been developed to strengthen the link between industry and students in the ERC program, to provide opportunities for industry to mentor students, and to build post-graduation sustainability plans. Suggestions on critical steps for developing sustained industry/education partnerships include:

- The ERC's Education Coordinator/Director should have a close relationship with its Industrial Liaison Officer (ILO), because the two activities overlap strongly and affect each other's results.

- Educational links to industry involve mutual learning, in which knowledge flows both ways. To help establish programs that fulfill this need and have high potential to be sustained, industrial contacts/partners for the education program should be identified as early as possible.
- Develop an interactive program with industry that brings industrial involvement at many levels.
- Engage graduate students in developing and implementing industry-education partnerships. They will bring a unique perspective for helping students to learn how industry operates and to understand industrial perspectives, so that they are prepared to contribute immediately on the job after graduation.
- Industrial internships are one of the most valuable mechanisms for industry-ERC educational interaction and are readily sustained post-graduation. They are mutually beneficial, providing vital technology transfer and educational experience for both undergraduate and graduate students while giving the industry partners a thorough look at students as potential employees.
- As the center matures, education programs should be reviewed with industry to help ensure industrially relevant education and industrial support in the later years of the ERC.
- Encourage teams of students and faculty to continue to travel to companies for presentations, meetings, and tours post-graduation. Continue to maximize student interaction with industry through poster sessions and presentations at industry meetings and workshops whenever possible.
- Industry also may continue to design projects or suggest problems for study by a team of students in the ERC, but they should be encouraged to directly fund these projects.

Delivery and Dissemination Systems

During NSF funding, the ERC should incorporate a variety of delivery and dissemination systems within its education portfolio. Graduated ERCs have found some systems to be effective mechanisms for continuing high-value education aspects post-graduation. Examples include:

- Short courses provide not only continuing education opportunities for industrial personnel but also technology transfer both to and from the center and can be supported through participant fees post-graduation.
- Seminars and workshops are among the quickest, most efficient, and most economical ways to promote industry-ERC interaction involving students and faculty. They can be video-recorded for future access.
- Some ERCs record courses and/or industry presentations for later viewing by students (including industrial personnel) at remote locations.
- ERCs have pioneered the development and use of many innovative educational technologies. Their impetus has included: the need to deliver nearly identical information to scattered locations (various affiliated universities and industry sites) on diverse schedules; larger class sizes; and a growing scarcity of faculty. Find a vehicle, such as website, online video, course module, or book that works for your particular center partners.

- Computer-based instruction—distributed through CDs, Dropbox files, and/or web access—offers convenient access to educational modules, workshop presentations, conference presentations, educational games, and other materials.
- Government and industry are developing standards for web-based learning systems,, but these standards remain immature and this may impact the longevity of such resources.
- New ERC-initiated web-based authoring and delivery systems are under development that should influence standards and ultimately improve the development and delivery of educational materials on the web.

Other Opportunities

We recognize that ERCs play a facilitative role in helping faculty think about commercial applications of their research. Therefore, involvement in an ERC facilitates "role transitions" for faculty members. Some ERCs facilitate these transitions better than others, and there are a number of best practices involving faculty role transitions. For example, several universities have internal entrepreneurship mentoring. Often, volunteer consultants are available in areas such as law, management, venture capital, and serial entrepreneurship. In many cases, the consultants are alumni of the ERC or university, and they coach academics on how to participate in the commercialization of their research discoveries. These consultants are also a source of referrals for finding capital and managerial talent. Other universities offer a great deal of support to potential faculty entrepreneurs in advancing their technology in a way that allows the faculty researcher to remain an academic researcher instead of trying to become a CEO. These models can be replicated in other places where the level of support is available from state, city, industry, and university sources. One interesting best practice involved creating a position titled "Industry Professorship." The ERC's ILO is a central figure in creating an innovation-friendly environment.

4.7.4 Sustainability Summary

Past studies and a recent survey of graduated centers (SciTech Communications, 2010) have shown that successful continuation of education programming depends on several factors. Attention must be paid to all these characteristics from the outset. They must be nurtured and maintained throughout the life of the center, to provide a platform for successful implementation of the strategic plan. Critical factors for successfully sustaining ERC education programs post-graduation include:

- A full-time (hard money) person to coordinate activities, who is prepared to seek funding from grants and other sources;
- Strong institutional support, including support for the ERC education culture as well as significant cash or other direct financial assistance (space, dedicated personnel, new department or unit, etc.);
- Champions of the education and preparation of students, both in industry and at the university level;
- Faculty and students motivated to continue and institutional incentives that further this motivation;

- A strong, continuing commitment on the part of center leadership to the goals of an ERC education program;
- Creative ways of packaging program elements that fit the type of activities that industry is able and willing to support (i.e., lab training internships, design course support, graduate fellowships);
- A strong, evolving research program;
- Successful securing of alternate funding for education programs, including other NSF and federal agencies, state, industry, foundation, university and community support;
- Research that is able to evolve to remain on the cutting edge;
- Dedicated/paid personnel in place to develop, coordinate and run the programs but also willing to seek funding from grants and other sources;
- Degree programs (minor, major, certificates) and courses that were established during the NSF-funded years;
- Effective transition strategy that builds on and enhances the center's strengths;
- Broad involvement of faculty, staff, industrial partners and university administration in transition planning;
- Institutional factors (e.g., degree of university commitment, whether the center is a prized asset, and whether policies are supportive of cross-disciplinary research and education);
- Active industrial support and continuation of industrial membership and Industrial Advisory Board guidance;
- Industry becoming involved in the cost of student training (i.e., funding a training laboratory, supporting short courses that are also used for industry, student fellowships, research assistantships, design course support, and awards);
- Effective implementation of a realistic transition strategy that builds on and enhances the center's strengths; and
- Quality of leadership of the ERC's management team and the education program directors.

4.7.5 Bibliography: Graduating ERCs and Education Program Sustainability

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1http://erc-assoc.org/topics/policies_studies/Grad%20ERC%20Report-Final.pdf

2 Williams, James E. & Courtland S. Lewis (2010). Post-Graduation Status of National Science Foundation Engineering Research centers: Report of a Survey of Graduated ERCs. SciTech Communications, Melbourne FL.

3 AISES/SACNAS: American Indian Science and Engineering Society /Society for Advancement of Chicanos and Native Americans in Science. SWE: Society of Women Engineers. SHPE: Society of Hispanic Professional Engineers. NSBE:188 National Society of Black Engineers. NOBCChE: The National Organization for the Professional Advancement of Black Chemists and Chemical Engineers. IEEE: Institute of Electrical and Electronics Engineers. AMS: American Mathematical Society. ASCE:,American Society of Civil Engineers,

4http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504976&org=DUE&from=home

5 SRI (2004). The Impact on Industry of Interactions with Engineering Research Centers. (http://erc-assoc.org/sites/default/files/studies_reports/Impact%20on%20I...)

Section 4.8: Strategies and Lessons Learned

There are several key features of a successful ERC Education Program. The program must be recognized as a critical part of the organization, and this should be reflected in the center organizational chart and budget. Personnel with the appropriate credentials and background must be recruited, and must also be considered part of the center Leadership Team and included in all leadership activities. There are prescribed components of every ERC (e.g. REU, RET, Young Scholars for Gen-3) but centers are encouraged to develop and to adapt these to meet their institutional requirements. Given the 10-year life span of a center under NSF funding, education programs should be dynamic. It is to be expected that NSF’s education priorities may shift as new opportunities become available during the lifetime of the center. Centers must be both flexible enough to meet new challenges, and also proactive in identifying new opportunities to make an impact.

ERC students need to go beyond the traditional engineering training by having opportunities for leadership and professional development (for example in innovation, creativity, and global awareness). Center faculty must buy into this and support student’s time in these value-added activities outside of lab/research time.

As the ERCs have evolved to date, education program developers and staff have devised a number of strategies and learned lessons that have benefited the centers' education programs. Many of these are summarized below.

4.8.1 Engineering Education Program Planning and Direction

- Funding for education should be consistent with its high priority among NSF ERC program goals. The explicit financial support of the Center Director is crucial.

- In planning an education program, the center must align its vision and goals with the center's strategic plan and objectives.
- The choice of an Education Coordinator/Director will determine the success of the education program. The University Education leader may be part-time but the Precollege leader should be full time. Someone who is interested in mentoring students and working with REU students must be a member of this team. The positions should be viewed as professional, with appropriate flexibility, autonomy, and status.
- An Education Advisory Committee should be established to give center faculty a mechanism to provide input into center education programs and to provide support for them.
- Adequate ERC core funding must be provided to the education program. A collection of supplemental grants alone does not make a coherent program, as not all funding opportunities will fit in the education strategic plan and only those that do fit should be pursued.
- It is prudent to develop an education program in phases that are implemented over several years, beginning with programs for graduate and undergraduate students in the center's home institution(s).
- Strategic planning for education must consider the impact of the 10-year ERC life cycle. As a center "graduates" from NSF support, the Education Program's continuation depends on institutional support (including cash), motivated faculty, commitment to the goals of the education program, and a strong, evolving research program.
- As the center matures, the education budget should include increasing contributions from sources such as industry members, NSF supplemental funding, and private foundations. Opportunities should be pursued to leverage the NSF funds using non-federal ERC funds for matching.
- A strong relationship with the personnel of the NSF ERC Program leadership, and especially with the center's Program Director, will greatly enhance a center's education program.

4.8.2 Students

- ERC faculty and staff should cooperate with the department and college in recruiting graduate students as broadly as possible (such as at professional meetings, by word of mouth with colleagues, and via the internet).
- Financial support for graduate students can be obtained from a wide variety of sources, including grants from NSF, industry, private foundations, and federal and state agencies.
- Outreach to graduate students at institutions that are not part of an ERC can best be obtained by forming collaborations with the faculty and staff of those institutions. Both domestic and international collaborations are vital.
- An important required feature of ERCs is the Student Leadership Council, which gives students a collective voice in the center's affairs and fosters leadership skills.
- Developing a feeling of “centerness” among students at geographically-distributed locations requires planning, regular opportunities to interact, and faculty support for time to do this.
- It is crucial to provide multiple and frequent avenues for students to interact with center industrial partners.

- Opportunities should be provided for students to gain an understanding of engineering in the global context.
- Centers have a mandate to provide students with specific training/experiences designed to help them become the creative innovators and technology leaders of the future.

4.8.3 Curriculum Development

- Establishing a new ERC curriculum is a challenging and complex task, involving coordinating many faculty members in an interdisciplinary research area.
- New degree programs, in particular, require substantial long-term institutional resources and commitment from all ERC partner universities.
- Inserting ERC-developed materials (modules, lectures, etc.) into existing courses is easier than developing new courses and over time can have greater impact.
- Find a vehicle, such as web delivery or a book, for wider distribution of course materials.
- A new minor degree program must be especially well coordinated with the existing academic standards and structures of the university. The key to successful development is to build on student interest and enthusiasm.
- Involve students (undergraduate and/or graduate) in evaluating plans and implementing the new program.

4.8.4 REU Lessons Learned

- Use multiple methods to recruit diverse students into your programs.
- Be highly inclusive—leverage resources at your university (e.g., other REUs, honors programs, etc.), and at partner universities.
- Create strong two-way relationships with your industry membership.
- Search for ways to create community—find a way to showcase undergraduate research results.
- Mentoring is important, so explicitly train your mentors.
- Assessment and evaluation are absolutely critical, and it is strongly advised that you consider partnering with professional A&E teams (internal or external) to develop this. You need to establish the research questions from the onset and ensure that the instruments and analyses you have chosen will allow you to answer your research questions (this includes getting human subjects clearance so that you can publish your results).
- Key point to keep in mind: REU's must be U.S. citizens or Permanent Residents (green card holders).

4.8.5 Precollege Programs

- Precollege engagement requires professional leadership and substantial resources in order to be effective.
- The precollege program should be included as a key component of the center and the Precollege Director should be included as part of the center Leadership Team.
- Center Directors should schedule regular times to meet with precollege personnel and promote inclusion of the precollege program in center activities.

- In order to promote and sustain a more diverse engineering workforce, the center should strive to create an inclusive and supportive work environment for precollege teachers and students.
- Sustained collaboration is the key to success in this part of the ERC's mission. By working directly with schools, other ERCs, academic institutions, and companies in collaborative partnerships, ERCs can propagate their successes through first-hand human contact, which is the most effective channel for transferring educational know-how or technology.
- Don’t overlook campus outreach and recruiting professionals who often have budgets and staff, as well as expertise in community college recruiting.
- ERCs' collaborations with K-12 teachers and students are an important contribution to reforming science and math education at the precollege level and expanding the students’ pathways for engineering. Each ERC should determine what precollege offerings make sense in the context of its strategic plan, resources, and community relationships.

4.8.6 Sustainability

Studies and a recent survey of graduated centers have shown that successful continuation of education programming depends on several factors. Attention must be paid to all these characteristics from the outset. They must be nurtured and maintained throughout the life of the center to provide a platform for successful implementation of the strategic plan. Critical factors for successfully sustaining education programs post-graduation include:

- A full time (hard money) person to coordinate activities, who is prepared to seek funding from grants and other sources;
- Strong institutional support, including support for the ERC education culture as well as significant cash or other direct financial assistance (space, dedicated personnel, new department or unit, etc.);
- Champions of the education and preparation of students, both in industry and at the university level;
- Faculty and students motivated to continue and institutional incentives that further this motivation;
- A strong, continuing commitment on the part of center leadership to the goals of an ERC education program;
- Creative ways of packaging program elements that fit the type of activities industry is able and willing to support (i.e., lab training internships, design course support, graduate fellowships);
- A strong, evolving research program;
- Successful securing of alternate funding for education programs, including other NSF and federal agencies, state, industry, foundation, university and community support;
- Research that is able to evolve to remain on the cutting edge;
- Dedicated and paid personnel in place to develop, coordinate, and run the programs but also willing to seek funding from grants and other sources;
- Degree programs (minor, major, certificates) and courses that were established during the NSF-funded years;
- An effective transition strategy that builds on and enhances the center’s strengths;

- Broad involvement of faculty, staff, industrial partners and university administration in transition planning;
- Institutional factors—degree of university commitment, whether the center is a prized asset and whether policies are supportive of cross-disciplinary research and education;
- Active industrial support and continuation of industrial membership and Industrial Advisory Board guidance;
- Industry becoming involved in the cost of student training (i.e., funding a training laboratory, supporting short courses that are also used for industry, student fellowships, research assistantships, design course support, and awards); and

- Effective implementation of a realistic transition strategy that builds on and enhances the center's strengths.

Chapter 5: Industrial Collaboration and Innovation

Jean Wylie COI Talk (50MB podcast)
COI Risk Analysis (Word doc)

Download: Chapter 5 PDF file

(rev. Jan. 2013)

5.0 Overview

This chapter discusses some of the most effective practices that existing ERCs have learned to use in conducting industrial collaboration and innovation programs. It addresses issues such as establishing a partnership with industry, building an industrial constituency, the benefits and difficulties of industrial interaction, building an "innovation ecosystem," and the role that the NSF plays. Case studies are used to illustrate some effective approaches. Abbreviations for ERCs that are referenced in these case studies are defined in Attachment 5-A. This chapter also defines the innovation ecosystem, along with the management and delivery of intellectual property from the perspective of ERC planners. It ends with a discussion of the role of the ILO within the ERC.

A central motive of the National Science Foundation (NSF) Engineering Research Centers (ERC) program is to form partnerships between academia, industry, and innovation-focused entities in systems-oriented research areas that are critical to the Nation's future economic strength. Each ERC collaborates with industry and other practitioner organizations from the early inception of its vision creation and subsequent strategic planning, and this collaboration extends to technology development and application. By thus expanding and accelerating technology translation, transfer, and eventual commercial use, this approach bridges the traditional innovation gap between the single university investigator and industrial adopters of academic research results. ERCs develop a group of members that includes firms of all sizes along the value chain of sectors important to the realization of the ERC's engineered systems vision.

By embracing industry and innovation throughout the entire cycle of technology creation, development, and implementation, the ERCs are distinctive among NSF research centers. Each second-generation (Gen-2, Class of 1994-2006) and Gen-3 (Class of 2008 and beyond) ERC is tasked to develop a membership program for industrial collaboration and technology transfer. In addition, each Gen-3 ERC is challenged to expand that program to include state and local government or university organizations devoted to stimulating entrepreneurship and innovation—the innovation facilitators. Both Gen-2 and Gen-3 ERCs are expected to stimulate technology transfer through member firms by means of information exchange, hiring of ERC graduates, member-funded sponsored research projects, and translational research with small firms when member firms fail to license new ERC-generated Intellectual Property (IP). Both Gen-2 and Gen-3 ERCs are charged with developing graduates who are better prepared for effective practice in industry and leadership in technological development. In addition, Gen-3 ERCs are charged with developing graduates who are more creative and innovative and better prepared for leading innovation in a global economy than their non-ERC counterparts are.

Thus, each ERC team envisions and plans transformational technology and education with its industrial/practitioner[1] partners from the outset. Each center's strategic plan, developed with industrial partners, helps identify areas for joint projects and experimental testbeds for validating research results in practical applications. NSF holds ERCs responsible for tracking their research results through commercial implementation.

ERCs are required to build large research programs with considerable financial support from industry. While some support may be in the form of contractual agreements with deliverables, in many centers an equivalent or greater sum consists of unrestricted industrial grants to the center. Special emphasis is often placed on attracting small and medium-sized companies to ERCs because of their more rapid acceptance of new technologies and rapid growth potential.

In 2012, ERCs reported corporate memberships ranging from 7 to 47 companies per center (averaging 23 per center). The distribution of membership among large, mid-size, and small companies depends somewhat on the industry involved, but most centers have members in all three size categories. Overall, small firms (<500 employees) and large firms (>1,000 employees) make up 43% and 48% of the members, respectively.

For established centers, industrial/practitioner member organizations provided 9.4% of the total ERC direct support in 2012 (5.4% unrestricted cash, 1% sponsored projects, and 3% in-kind contributions). Including support provided by organizations who were not members, this percentage rose to 11.7% of ERC direct support for 2012.

Equally impressive is the large number of technologies that have been invented by ERCs and implemented by their industrial partners. For example, as of fall 2012, a total of 676 patents had been awarded to 61 ERCs between 1985 and 2012; 1281 licenses had been issued to companies; and 146 companies had been formed as spin-offs of ERC research, with a total of 1,032 employees. In addition, hundreds of discrete innovations had made their way into use in industry. The ERC Program invested over $1.0B in ERCs between 1985 and 2010, with a return on investment in the 10s of billions of dollars[2].

While all ERCs are expected to plan, create, validate, and transfer new technologies, some of these activities inevitably receive greater emphasis at different stages in a center's life cycle. New centers (years 1-3) necessarily focus on strategic planning with industrial partners, attracting new members to their efforts, and developing forums for interaction. Mid-term centers (years 4-7) must focus on demonstrating successful industrial collaboration and technology transfer results, promising more to come beyond the sixth-year review, and beginning to prepare for self-sufficiency. Mature centers (years 8-10) are putting new technologies into play while attracting new companies and finding new ways of teaming with industry without NSF support, including generating industrial endowments. Successful centers initiate long-term sustainability planning jointly with their industrial partners well before the end of ERC Program funding, ideally as early as year 4, with significant progress by year 6.

Experience shows that the enthusiasm and appeal of a start-up center is very effective in attracting industry involvement; but as centers mature and sponsors become more demanding, industrial collaboration requires more work. On the other hand, age confers the advantages of experience and credibility. In the early stages, centers sometimes need to set modest membership fees, focus research on knowledge and technology development, and use industry as a partner in identifying problems. In later stages, in preparation for self-sufficiency, centers may begin to add sponsored projects funded by specific industry partners, where the research on these projects would include a focus on applications and firm-specific development based on the ERC knowledge generation and technology developments. Care should be taken to maintain a strong base level of support that enables discretionary funding of core projects and new and exploratory work. The ERC should be mindful not to turn the center into a "job shop" for industry or a collection of applied and often closely held sponsored projects as the time for self-sufficiency from NSF support comes into play.

The center's life cycle in the first few years is somewhat analogous to NSF being a venture capitalist, funding a build-up of infrastructure and providing substantial leverage to industrial support. But the venture capital analogy projects the wrong relationship between NSF and the ERCs because NSF is not looking for a direct monetary Return on Investment (ROI); rather NSF's expectation is that the Foundation's return on investment is in terms of high-quality research, impact on national economic development, etc. By year 6, the center has "gone public," establishing a certain amount of credibility with regard to its benefits to industry, and begins to face a new set of challenges. With the infrastructure in place, the center matures, and the issue of delivery becomes preeminent.

But industrial collaboration with ERCs extends beyond the development and transfer of technology. Industrial members are stakeholders in more than just strategic planning and collaborative research. They also have a vested interest in the ERC's educational activities because of the impact on their workforce development. Industrial members give practical experience to ERC faculty and students by hosting faculty sabbaticals, student internships, and on-site ERC seminars. Members also participate at the center in hands-on courses, seminars, and co-advising graduate students. The university and/or state and local government innovation partners in Gen-3 ERCs become more involved in stimulating entrepreneurship and promoting innovation.

Industrial involvement in the early stages of technology planning and development provides substantial payoffs when ERC students graduate. Many of the hiring companies have noted that ERC graduates, by virtue of their systems-oriented training, are more skilled at technological innovation and product/process development than their non-ERC counterparts. They also are capable of integrating knowledge across disciplines, working in teams, understanding industrial needs, and addressing problems from an engineering systems perspective. Industrial sponsors typically comment that ERC students "land on their feet running" and "do not require the usual 12 to 18 months to come up to speed." Many ERCs and their industrial members agree that students are the best and most lasting form of technology transfer. (See Section 5.2.4.1 for a more detailed discussion of the job performance of ERC graduates.)

The ERCs' relationships with companies and practitioner organizations are situation-specific to some degree. Each one is unique, depending on the nature of the research undertaking, the scope and type of the industries involved, the strategic direction of the center, and the personalities of the leadership team. Within this diversity there are common issues, which each center must resolve to create a functioning partnership with industry. The objective of an ERC should be to establish a very broad constituency of industry and government practitioner stakeholders. Emphasis on the dollar amounts of support should be balanced by a focus on the intellectual and economic potential of a collaborative effort.

Ultimately, the ERCs are testbeds for broader cultural change in university-industry collaborative research. They are pioneering new ways of bringing research results to market, breaking down many traditional barriers that have hindered cooperation between universities and industry. Every lesson they learn makes it easier for those who follow to work together productively, as the working partnership of university administrations and faculties with corporate researchers develops. This is perhaps even truer of the centers that have graduated from NSF support, since those centers operate without the NSF ERC award and therefore must justify their benefits to both their host universities and their industrial members.

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[1] Practitioner partners are organizations that will support the ERC's research as center members and will use the outcomes in the delivery of services; these include local government agencies, hospitals, etc. Industrial/practitioner partners will be referred to as industrial partners or industry members throughout the rest of this document.

[2] Engineering Research Centers: Innovations—ERC Generated Commercialized Products, Processes, and Startups, Courtland S. Lewis, February 2010. (http://www.erc-assoc.org/topics/policies_studies/ERC%20Innovations%202010-final.pdf)

5.1 Establishing An Industrial Affiliates Program

A critical initiation activity in any center is establishing buy-in for the vision and putting in place the infrastructure that is required for effective industrial collaboration and innovation programs, including agreements with stakeholders, marketing programs, and systems for tracking interactions with industry and innovation partners. The Center Director and senior leadership of the center typically form the vision and strategic plan for industrial interaction and innovation during the center's proposal development process. The infrastructure required to affect this vision and strategic plan must be developed and honed with post-NSF self-sufficiency in mind.

In the initial months of new ERC formation, it is important to work with the university and its technology transfer office to establish internal support and work out an ERC membership agreement for the program. NSF requires each ERC to develop its own generic membership agreement, governing the participation of industrial and practitioner members and specifying the forms of industrial cash and in-kind contributions that constitute membership in the center, as discussed in Section 5.1.2. It is important to remember that this must be an ERC-wide agreement that includes an ERC-wide IP policy, encompassing the lead and partner institutions.

In ERCs where university/industry research centers may already exist, it is essential to examine and compare the existing membership structures, fees, and terms and conditions and involve all key personnel at the universities from the start in drafting the new ERC agreement. Support for the ERC is generally high immediately after the awarding of the cooperative agreement, and the climate for negotiating long-term university support is strong. Be mindful that some universities may have Industry/University Cooperative Research Centers, where the agreements are different from ERC agreements and some university officials may not be aware that they are different.

Experience shows that while many ERCs may have one or two technical disciplines and therefore departments that dominate the ERC researcher and student populations, ERCs are by their nature cross-disciplinary and therefore will involve talent and infrastructure from multiple departments, and sometimes multiple colleges—although Colleges of Engineering should and do dominate, as one would expect. ERC Directors must report to the Dean of Engineering.

5.1.1 Foundational Agreements to Establish Industry Collaboration and Innovation

Establishment of an ERC requires certain foundational agreements to be expeditiously put in place in order to set the stage for success. It is critical that the ERC and host university complete these agreements as early as possible in the ERC's first 12 months in order to establish a sound working protocol with all ERC stakeholders.

5.1.1.1 ERC Agreement with Host University Regarding Overhead and IP Returns

One key element of structure is the development of an agreement in the early initiation of the ERC regarding overhead and technology licensing returns to the ERC cost center vs. other university cost centers such as the disciplinary departments. Clearly, overhead return discussions can become problematic if faculty are conflicted between submitting proposals (industry or federal agency funded) through their home department vs. the ERC.

Similarly, many university intellectual property policies provide technology licensing royalty, fee, and equity liquidation returns to various units (university research office, college, department, inventors) and sometimes include "centers" or "research units" if the invention was spawned in a separate unit. ERCs should get specific, early commitments on what overhead and royalty returns will flow to the center to avoid confusion and hard feelings downstream. If the center is not included initially in IP licensing returns, the director can approach the university administration or technology transfer office and negotiate a portion of future royalty returns to be earmarked for the center. Because there is no "money on the table" during these negotiations, it may be possible to secure a future revenue stream before the center even begins its research. Taking a long-term view toward self-sufficiency for the center, it is a good idea to participate in royalty and equity liquidation returns and set those policies in place early.

All centers work with their university intellectual property officers to comply with university standards on such matters. A good working relationship with the university IP administrators is important in developing a successful partnership with companies. Since centers span more than one university, clear agreement among the administrations of all the academic partners is essential. Procedures for notifying industrial partners of the existence of center-developed IP should be clarified between the center and the universities' intellectual property officers. In all cases, IP agreements should accord with regular NSF guidelines, as set forth in the effective NSF Grant Policy Manual.

5.1.1.2 ERC Host University Agreement with Domestic Partnering Universities

The ERC host university should work diligently in the initial year of the ERC to assure that agreements with partnering universities involving intellectual property management rights and responsibilities, reporting responsibilities, industrial partner benefits, etc., are consummated at the start of the Center's life. Of specific concern is to assure that the research review and intellectual property rights provided to industrial partners of the ERC through their industrial membership agreements accrue to them regardless of which partnering university faculty are inventors. This should include clear and unambiguous agreement as to industrial partner benefits from core research funded by membership fees, the ERC award, university cost sharing, and other funds provided to the ERC without restriction regarding use, as opposed to sponsored project research supported by industry or other sources. Industry membership agreements typically provide rights to core research of the ERC, with no mention as to the origin of inventions from that core research. Rights granted to industry partners must be consistent with inter-university agreements and ERCs must assure that this is codified in Inter-institutional Agreements or subcontracts at the time of engaging initial industry partners.

CASE STUDY: The issue of "royalty distribution" back to the ERC instead of the home department of the inventing investigator(s), for inventions arising from ERC research, is a sensitive one. University policies vary greatly, and the question of what is fair is valid. One example is the long-graduated Data Storage Systems Center (DSSC), at Carnegie Mellon University (CMU), which was an ERC from 1990 to 2001. This now self-supporting center produced some key technologies in data recording that continue to have an impact on the industry today. CMU's Intellectual Property policy is one of the most liberal in the country, in that it gives 50% of all royalties to the inventor(s) and 25% to the research unit (in this case, the DSSC), retaining only 25% for the university, which actually owns the patents. Most universities retain considerably more. One factor in CMU's decision to allocate the research unit's proportion of the royalties to the DSSC is that DSSC holds a considerable portfolio of patents, and the Center pays the cost of each of those patent applications. Royalty returns to both the Center and to individual faculty and even students have, at times, been substantial and have contributed significantly to the DSSC's success in maintaining self-sufficiency. Based on this history and that of other ERCs, the NSF ERC Program management believes that ERCs should negotiate with the host and partner universities a portion of licensing returns to the ERC (royalty, equity liquidation, and other forms of payment such as fees and litigation returns) for ERC-generated technology, as a unit of the university's research enterprise. The rationale for this is that it is the cross-disciplinary research program and the ERC's testbed culture that have generated the technology, not the investigator's laboratory alone. It is true that university administrations will likely be resistant to changing their royalty return policies; negotiations after the award is made might actually be easier than at the proposal stage. Although NSF recognizes that the high levels of return that DSSC enjoys are extremely rare (even anomalous), there are several other centers with this type of royalty distribution allocation, although at lower percentages. DSSC provides an example of the impact that this issue can have on ERC self-sufficiency.

5.1.1.3 ERC Agreement with Foreign University Partners

One area that merits further discussion is the formulation and execution of international agreements with foreign university partners. This originally was a required component of a Gen-3 ERC, but because of the complexities outlined below, beginning in FY 2013 a Gen-3 ERC may enter into a focused partnership with a foreign university governed by a formal agreement with mutually protective IP policies, or faculty-to faculty collaborations. In either case, the partnership/collaboration must allow for ERC students to spend at least 30 days working in the laboratory of the foreign partner/collaborator.

The establishment of the ERC/foreign university partnership agreement can involve a steep learning curve, concentrated on the complexities of international law and the vast differences in scientific culture and legal environments, especially in intellectual property ownership and business law specific to the partnering university's home nation. The "harmonization" of the final international agreement can take a great deal of time and expense that an ERC has to bear. These agreements need to engage the highest levels of the administration on both sides (university presidents, university system officials) from a policy and legal standpoint. The following is a case history of the IP issues involved in an exemplar ERC/foreign university partnership.

CASE STUDY: A partnership was formed between the Revolutionizing Metallic Biomaterials ERC (RMB) based at North Carolina Agricultural and Technical State University and the University of Hannover Medical School in Hannover Germany. North Carolina A&T, as the host university on behalf of the ERC, negotiated a fixed fee with a local law firm with international business and IP law expertise to interpret German law and to draft a harmonized agreement. The German Inventors law differs from the Bayh-Dole Act in that, rather than assigning intellectual property rights to the University, German scientists and engineers retain rights to their inventions. German Law allows for a period of time in which a German employer (University) may secure rights to an invention in return for fair compensation to the inventor at the time of transfer of rights. If this option is not exercised in a timely manner, IP rights remain with the inventor. This arrangement tends to limit the nature of the global interaction between Hanover and the ERC to student and technical exchanges, as the ERC cannot ensure that IP obligations under Bayh-Dole will be met in cases of joint inventorship between an ERC investigator and a German investigator. It may be possible to address this concern. Opportunities for the ERC to participate in the option discussions between the University and the German inventor are being explored.

As exchanges occur and joint IP becomes an issue, the agreement needs to include some mechanism to capture that IP under mutually protective terms. Additionally, ITAR and export control restrictions, especially with the development of new materials, need to be addressed in terms of international agreements. This could impact the exchange of information, materials, samples, and prototypes.

Faculty-to-faculty collaborations would operate under less formal terms, as is traditional in academic research. However, the ERC still needs to be mindful to protect ERC-funded IP.

5.1.1.4 ERC Agreement with ERC Researchers

One area that is easy to overlook is clarifying and codifying the relationship between the ERC and its researchers at the different partner universities. While this may seem trivial, as university faculty and students are typically accustomed to working in various research groups and with myriad affiliations, the ERC is different in that it has specific requirements of its researchers and also provides specific benefits (e.g., intellectual property rights) to industry partners. The ERC has an opportunity early in its existence to establish a clear understanding with researchers funded by the ERC as to what is expected of them and what they can expect of the ERC. While this agreement can be as complex as the ERC desires, simplicity usually serves all parties better. The agreement may be as simple as a letter of understanding between the ERC and relevant researchers outlining what is expected of them (e.g., participation in industry meetings, collaborating with industry partners on a reasonable and mutually beneficial basis, contributing to ERC reports to NSF or industry partners). Additionally, this communication should also inform the researchers of industry partner intellectual property rights granted through the ERC Industry Membership Agreement. Most universities outline researcher rights and returns from IP through a university intellectual property policy, and the ERC agreement may provide for rights that impact researcher returns from their technology (e.g., their return of IP royalties may be impacted if the ERC provides partners with a non-exclusive royalty-free right to use of inventions from ERC researchers).

5.1.1.5 ERC Agreement with Student Researchers

After knowledge generation, one of the most important outputs of the ERC is the students it graduates. But the ERC graduates and post docs are more than just statistical outcomes of NSF's investment. They are also stakeholders in the ERC enterprise and as such they have a voice (through the student leadership council) and rights that need to be protected. Given the Gen-3 ERC's drive to facilitate the translation of technology to the commercial sector, situations where an ERC participant has significant financial interests in the collaborating firm or other entities affected by the proposed research are beginning to emerge. These constitute conflicts of interest (COI) that must be managed by the participant's home university. An important aspect of managing the conflicts is for the home university to put in place policies that protect students, should their dissertation work potentially affect the value of a company in which the faculty advisor has an ownership or managerial interest.

CASE STUDY: Virginia Tech has various policies and procedures on managing conflicts of interest for the protection of students. For example, an informational page on protection of students and trainees in projects sponsored by faculty-owned businesses (Policy 13010, which can be found at http://www.policies.vt.edu/13010.pdf) contains the statement "This policy provides the basic framework for assessing potential conflicts of interest or commitment and outlines related procedures for the management and monitoring of external activities in a manner that will both promote and safeguard the interests and reputation of Virginia Tech, its faculty and students, and their research." Another example is Protecting the Interests of Students and Trainees (which can be found at https://www.research.vt.edu/conflict-of-interest/students-and-trainees). This document begins with the statement "The impact of a perceived or actual conflict of interest or commitment of faculty members on their students (including post-doctoral fellows and other trainees) is of special concern to the university. In particular, the university is committed to maintaining the content and quality of the educational experience for students whose research is sponsored by a for-profit business and whose faculty advisors have a financial interest or a management role in that business. The concern is even greater if the dissertation work could potentially affect the value of a company in which the faculty member has an ownership or managerial interest."

5.1.1.6 ERC Agreement with Industry Members

Along the same lines, ERCs under the direction of the ERC Director, ILO, and university technology transfer and contract offices should put significant effort into finalizing industrial partner agreements very early in the life of the ERC, ideally within the first few months of award. This is critical as ERCs typically start with a cadre of industry partners that have participated in the pre-award activities and this base can grow quickly with proper recruitment. Changing an industrial partner agreement becomes much more difficult, and dangerous in terms of losing current industry partners, the further downstream agreements are put in place or modified. This topic is covered in detail in Section 5.1.2.

5.1.2 Establishing the Membership Agreement

Within the first few months after the start of the ERC's award from NSF, each ERC develops a standard membership agreement that governs members' participation and sets out the forms of cash and in-kind contributions that constitute membership. It is critical that establishment of this membership agreement be completed as early as possible in the life of the ERC—certainly within the first year of NSF contract award—since establishing an agreement that is acceptable to the ERC, partnering universities, industrial partners, and innovation partners early will capture the partners' excitement as the ERC is established, resulting in establishment of the initial industrial partner consortium. In addition, if the ERC Program first year site visit team finds no firms or only a few that have signed on to be members of the center because the agreement took too long to finalize, that will not bode well for their judgments regarding management of the ERC.

An ERC should not to try to develop individual contractual arrangements for each company in lieu of a membership-defined program of industrial collaboration that encompasses all members. It's critical that the membership agreement be well established, as there will be little to no room for modification once the industrial membership base is built. Any downstream modifications to the membership agreement that potentially impact current member rights would then need to be renegotiated with all affected members—typically not a viable situation and one to be avoided at almost any cost.

Organizations that can be considered as ERC members include private firms as well as local and Federal government agencies that have joined as members, agreeing to financially support the ERC through the payment of fees and participation in its research and education programs, per NSF ERC policy. Organizations contributing staff to carry out research and educational projects in the center, such as other universities, government agencies or laboratories, institutes, and hospitals, should not be counted as members. In addition to paying fees in cash, member companies/practitioner organizations may augment their support to the center through in-kind contributions as part of the membership fee or in addition to the fee structure. Finally, additional support for directed sponsored projects or contractual arrangements is a way to speed the translation of ERC-developed technology into use.

Firms that are not members but provide directed project support often are classified as "affiliates" and firms and others that provide equipment and other donations are classified as "contributing donors." Additionally, entities that contribute primarily to the innovation mission of the ERC are considered Innovation Partners, as discussed in Section 5.3.3.

Guidelines for ERC industrial membership agreements, including example agreements, are available to registered users of the ERC Association website at www.erc-assoc.org/ilo-forum.

The overall intent of the Industrial Membership Agreement is to establish a contractual relationship that is:

1. mutually beneficial and equitable to both parties of the agreement;
2. scalable to a large ERC industrial membership;
3. applicable to companies of all sizes (small and large); and
4. clearly outlines the rights and obligations, if any, of company subsidiaries, sister, or parent organizations.

5.1.2.1 Necessary Elements of the Industrial Membership Agreement

In establishing an industrial membership agreement, the ERC must balance the need to keep the agreement as simple and straightforward as possible so as to make a single agreement palatable to the many companies the ERC will engage as industry partners vs. the need to assure that the document equitably addresses all of the critical elements of such an agreement to avoid downstream lack of clarity on terms and conditions (e.g., IP management and publication rights). In order to assist in this important activity, NSF has established a Gen-3 Membership Agreement Checklist to guide new ERCs in necessary elements of a membership agreement. The NSF Gen-3 Membership Agreement Checklist requires that ERCs consider the following in establishing industrial membership agreements[1]. Specifically, does the agreement:

1. Function as an ERC-wide membership agreement, encompassing the lead and core partner universities
2. Define which institutions are considered lead and core partner universities in the ERC and their responsibilities to the ERC
3. Define the types of organization that are allowed to join the Industrial Advisory Board (IAB) and specify the following IAB responsibilities to the ERC:
    1. meets a minimum of twice a year;
    2. develops an annual Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis;
    3. participates in NSF annual reviews of ERC performance and plans and present the IAB SWOT; and
    4. provides input on strategic research and education plan, ongoing project performance, and proposed project plans.

1. Define:
    1. IAB Membership categories;
    2. IAB Membership fee structure (perhaps include a table using the format of Table 5.1 below to tabulate membership fees for each member category);
    3. what it takes to maintain membership in good standing;
    4. benefits received for each level of membership;
    5. terms of membership and termination;

6. conditions for acceptance of “in-kind” in addition to cash. (This is permitted at the Center Director’s discretion, but it must be at a discount rate of 30% to 50% of retail value. Furthermore, the aggregate amount of dues collected as discounted in-kind payments should not exceed 25% of the cash dues collected);
7. core research and the sources of funding for the core research; and
8. non-core research and the sources of funding for associated and sponsored projects;

Table 5.1: Sample IAB Membership Structure Matrix

Rights and Benefits	Member Category #1	Member Category #2	Member Category #N
Right #1			
Right #2			
Benefit #n			

1. Define how information that is considered to be confidential will be handled among the ERC and IAB parties
2. Define how publications with potential IP implications will be handled, vis-Ãƒƒƒ -vis protecting the IP rights of IAB members
3. Define the following with respect to IP:
    1. require that joint IP agreements be in place across all universities;
    2. require that joint IP agreements be in place between ERC and industry researchers;
    3. when and how one determines that research developments are to be classified as intellectual property and who owns the IP;
    4. when must a firm be a member in good standing in order to qualify for the first option to license the technology;
    5. maximum time period that the members of the IAB are granted to review and claim the first option to license ERC-generated technology (if this is too short it can appear to industry that the faculty want to reserve technology for their own spin-out firms, or if it is too long it can retard the advancement of new technology);
    6. whether non-exclusive royalty free (NERF) licenses are granted for research only;
    7. whether exclusive licenses take precedence over NERFs;
    8. the conditions under which exclusive royalty bearing licenses are granted;
    9. IP terms for sponsored projects; and
    10. a process for qualifying to apply for translational research funding from NSF that is consistent with the flow diagram in Figure 5-6 of Section 5.3.2.1 and the Program Terms and Conditions (PTC) outlined in Section 4.e.iv of the ERC Cooperative Agreement (See Attachment 5-B).

5.1.2.2 Structure of the Industrial Membership Agreement

Attachment 5-C provides a sample membership agreement that can be used to inform new ERCs of the critical elements of an ERC Industrial Membership Agreement and sample language that has been successful in such ERC agreements over the years. It should be noted that this sample agreement is not meant to be prescriptive, but instead to act as a guide to ERCs as they establish their Industrial Membership Agreement specific to their university and industry needs.

The following is offered as general guidance as related to the elements of the Sample ERC Agreement provided in Attachment 5-C:

- General Obligations of the ERC Host University, Partnering Universities, and Industry Members—The university and industry partners must manage expectations and clarify what each entity can expect from their partners and, as importantly, what is not included as part of the partnership. This is especially critical early in the life of the ERC, as industry champions are engaged but provide a minority of the overall ERC funding.
- Relationship of the University Partners and Industry Members' Rights—This element is important in defining the extent to which the rights and obligations of the industry members extend across the ERC's university partners. It is standard practice that industry members enjoy consistent rights provided through their ERC Industrial Member Agreement (e.g., Intellectual Property) across all partnering universities; but this is an issue for the university partners to address, codify in Inter-institutional Agreements (IIAs), and clearly transmit to industry members.
- Expectations and Obligations of Industry Members—Industry members must understand that they are expected to play a critical intellectual role in the ERC in addition to financially supporting the center. Specifically, industry members are expected to support the research, education, diversity, technology transfer, and innovation goals of the ERC, including: demonstrating the scientific and technological feasibility of innovative methodologies and systems; assisting in the transfer of research discoveries and observations from the university to industry and vice versa; and developing an interdisciplinary education program that prepares diverse cadres of domestic ERC graduates for effective industrial practice with U.S. firms and provides opportunity for enhancing creativity and innovation. At a minimum, the industry members should commit to: meeting at least twice a year; developing an annual SWOT analysis; participating in NSF annual reviews of ERC performance and plans; and providing input on the ERC's strategic plan, ongoing project performance, and proposed project plans. Some ERCs have chosen to codify these requirements in the Industry Member Agreement while others have chosen to include them in ERC Bylaws that are then included by reference in the Industry Membership Agreement. Either is acceptable, but what is expected of industry members should be clearly explained in a broadly applicable document. This approach allows more flexibility in defining the role of the IAB without having to renegotiate the agreement with each firm.
- Entities that are Eligible to Serve as Industry Members—Various business entities and government agencies may become industry members. Some ERCs have chosen to include investment groups (e.g., venture capital entities) that technically meet this definition; but the ERC must be cognizant of the challenges and opportunities presented, and may

instead choose to include these groups as innovation partners or other partners. The details and implications are discussed in Section 5.3.3.

- Use of Resources—It's important to clarify the flexibility and bounds that the ERC has in allocation of resources, including industry member fees, so as to establish a support base for the entire scope of the ERC program (e.g.. research, education, outreach, technology commercialization, and innovation), as opposed to the restricted scope encompassed by a sponsored project..
- Term and Termination—Different ERC's choose to provide an initial term for the Industry Member Agreement of one to five years to suit the needs of the types of firms in the ERC's value chain. Obviously longer terms, with appropriate termination conditions as discussed here, are beneficial for planning purposes, but may not be palatable to all industry members, so some flexibility may be required. The Sample Agreement provided in Attachment 5-C provides for an automatic renewal (aka an "Evergreen Clause") for an annual term. This clause is desirable for the ERC to include regardless of the term of the agreement, as the agreement will then roll over to subsequent terms without further management or legal review triggered—simplifying renewal for both the university and the industry member. A mutually acceptable termination clause through written notice is considered standard so long as the notice period is sufficient to not disrupt research and education programs and student progress.
- Applicable Law—Most public universities must operate under the laws of their state and little flexibility may be available here, other than for the agreement to remain silent on this issue if acceptable to the university and the industry member.
- Publication Rights—Industry members must understand that publication of ERC created research results is of fundamental importance to universities, faculty, and students. At the same time, industry members should expect that they have the opportunity to harvest commercial value from ERC scientific advances as outlined in their Industry Membership Agreement. As such, clarity on the process, conditions, and timing of publications with regard to IP protection and review of data is essential in the agreement. The university and industry must be comfortable with these terms and the process that will be followed. One such version is outlined in the Sample Agreement of Attachment 5-C.
- Confidentiality—This clause captures the intent of both parties to maintain the confidentiality of information marked as such that may be passed between the parties. This can be through individual project collaborations as well as during Industrial Advisory Board meetings. The ERC should consider specific Confidentiality Agreements for such information transfer as appropriate, but this statement is important to include for general information that might be exchanged in order to foster more open communications between the parties. This statement should be reviewed carefully by the university legal counsel.
- Other Rights and Obligations—As outlined in the Sample Agreement, other rights and obligations that are usually non-contentious but important might include equal opportunity and non-discrimination, use of names, the legal relationship between the parties, liability, and representation. These and others that might be required by the universities should all be clarified in the agreement.
- Intellectual Property Rights and Management—IP management is typically the most difficult portion of the agreement on which to agree, and is also one area with the least flexibility once the agreement is executed with the first industry members. There is very

little to no room for downstream modification to IP terms as the ERC builds the industry member base, as any downstream modifications would typically affect rights of existing industry members, which would then require renegotiation and execution of the agreement or an addendum capturing the changes. This portion of the agreement is typically the most difficult to craft and, as such, is dealt with in detail in Section 5.3.2.
- Membership Structure, Fees, and Benefits—The membership structure can be simple or relatively complex, with tiers for both membership category and company size, and so is dealt with in detail in Section 5.1.2.3.

5.1.2.3 Membership Tiers and Fees

Across all ERCs, annual industry membership fees have ranged from $1,000 to $250,000, usually encompassing a tiered membership structure that includes two or three membership categories with corresponding fees and benefits of membership. While various benefits as discussed below can accrue to the highest membership tier, lower level members may not enjoy benefits such as favorable access to IP.

Many centers allow larger firms to affiliate either in limited ways (by research area or by specific contractual projects) or in a broader way (full membership with maximal rights), with fees usually ranging from $10,000 to $50,000

Company size can also be a differentiator in fee structure. ERCs often will provide a discount on the membership fee for mid-size or small companies, in some cases even for “start-up companies”, to encourage their full participation and spur technology transfer and innovation.

ERCs typically define mid-size or small companies by either number of employees (less than 1,000 employees for mid-size companies and less than 100 employees for small companies is within reason, but this may go as high as 500 employees for small companies) or sales of products or services that are in the field of the ERC. The cutoff for mid-size or small companies is subjective and at the ERC’s discretion, but should be perceived as fair to larger companies when considering benefits and the ability to contribute to the ERC. For small companies, fees are generally $1,000 to $10,000, and may be graduated. Fees for mid-size companies are generally $10,000 to $25,000, but again this is highly dependent on what is palatable to the ERC’s target industry.

In some cases, the ERC may choose to accept industry members’ fees on a quarterly or semi-annual basis, or alternatively to accept partial payment from multiple groups or departments in order to meet company departmental funding limitations or processes. Additionally, the ERC must balance the convenience of establishing contract and payment terms on the ERC’s preferred fiscal cycle (many times this is the university fiscal year) vs. being flexible to industry needs with regard to their fiscal cycles.

Even the definition of the “number of employees” can evoke discussion when recruiting industry members. Larger companies will sometimes argue that their research group focused on the ERC’s field is a small portion of the company and so the company should be able to participate at a mid-size or small company fee level. Many times, the company group with which the ERC works is in fact a smaller research or development oriented group, with smaller discretionary budgets. In the same light, companies may wish to share ERC information and technical results with affiliates or subsidiaries of the company. This is a difficult situation for ERCs. One suggestion provided by a number of industry partners is to define the company size by the number of employees that have free-flow access to that group's internal technical information as part of their normal business processes. In that way, the ERC relationship does not create an artificial firewall to the group's regular R&D information flow, since the ERC results flow in the same pathways, and to the same employees, as the group's internal information. At the same time, the ERC is properly compensated for access to its information and results.

Membership fees are pooled and allocated to center functions according to the strategic and operational plans established by the center's leadership. Industrial members may provide additional support above the membership fees for activities such as sponsored research projects, equipment donations, intellectual property donations, or educational grants. Potential industrial members that have not joined the center but that contribute support for associated projects that fall within the scope of the ERC's strategic plan and are included in the Center's annual report are not considered members, but are designated as "affiliates." Some centers use all membership fees to support research; some use them exclusively for support of student interns; others use membership fees for all operations.

5.1.2.4 In-kind Contributions in Lieu of Cash for Membership Fees

Centers' policies vary on how fees are paid—in cash, in-kind, or a combination. ERCs may find that in-kind contributions are valuable in the early stages, when equipment is needed and relationships require nurturing. Additionally, small companies that have unique equipment may not be able to pay a cash fee, but cutting-edge equipment donation can be of greater value to the ERC and other industry members who make use of ERC infrastructure or data from that equipment. If equipment is taken as in-kind, the ERC should strive to include maintenance and upgrade clauses in the agreement so as to protect against a downstream cash drain. For the purposes of membership fee payments, many ERCs value equipment at a 30-50% discount from industry retail value, not academic discount pricing. Additionally, many ERCs will limit overall in-kind contributions to no more than 50% of the overall pool of membership fees to assure a focus on cash membership fees, which provide liquidity and flexibility to meet the ERC's overall program needs. This is even more important as the Center grows and prepares for self-sufficiency beyond the NSF funding cycle. Exceptions can be made for cash-poor small firms.

In 2012, ERCs reported corporate memberships ranging from 7 to 47 companies per center (averaging 23 per center). The distribution of membership among large, mid-size, and small companies depends somewhat on the industry involved, but most centers have members in all three size categories. Overall, small firms (<500 employees) and large firms (>1,000 employees) make up 43% and 48% of the members, respectively. In addition, several centers have federal laboratories as members. Some include industrial consortia. In that case, the consortium joins as a member, but the members of the consortium must also join individually in order to reap the benefits of the ERC. Overall, for established centers industrial/practitioner member organizations provided 9.4% of the total ERC direct support in 2012 (5.4% unrestricted cash, 1% sponsored projects, and 3% in-kind contributions). Including support provided by organizations that were not members, this percentage rises to 11.7% of ERC direct support for 2012.

5.1.3 Industrial Membership Rights and Responsibilities

Clearly identifying and promoting what the ERC expects of its industry members and what they can expect of the ERC is key to a strong, long-term, mutually beneficial relationship.

5.1.3.1 Member Rights

While appropriate industrial membership rights are usually industry-specific and should be determined by the ERC's leadership to optimize value to their specific industry members and the ERC, general guidelines from the ERC program can inform new centers on what has successfully provided value to industry partners. Rights of industry members are typically tiered for the level of membership as discussed in Section 5.1.2.3 and may include:

- Rights to serve on the Industrial Advisory Board (IAB) and the opportunity to serve as an elected representative on the Technical Executive Committee (TEC) or equivalent, if one exists. The IAB typically consists of all industry members in good standing and the TEC is elected by members of the IAB to provide the highest level of guidance to the ERC in an effective and efficient manner. The TEC is constituted to ensure the overall synergy of the research carried out in various research thrusts and to recommend to the ERC Director any needed mid-course corrections in research and/or personnel.
- Rights to receive a discounted university overhead rate, applied to any additional research in the field of engagement with the ERC associated with ERC researchers which the members sponsors outside of the Membership Fees. The university may request that this also requires up-front payment of the sponsored research fee to minimize the overhead burden to the university.
- Priority access over non-members to ERC facilities and instrumentation, sometimes at reduced fees.
- The right to request on-location short courses provided by ERC researchers, at reduced fees.
- Access to the ERC's secure website, comprising an electronic information network containing ERC reports, publications, and invention disclosures
- Intellectual property rights as discussed in Section 5.3.2

Whatever benefits are offered, the ERC must assure that these rights extend only to the industry member departments, internal groups, affiliates or subsidiaries that are included in the definition of ERC Industry Members in the agreement (e.g., those that share in the free flow of the member's internal technical information as discussed in Attachment 5-C).

5.1.3.2 Member Responsibilities

In addition to payment of the annual membership fee, industry members of an ERC are expected to undertake appropriate interactions with ERC leadership and researchers to help the ERC accomplish its mission. Members are encouraged to pursue a high level of engagement with the ERC to best guide the center and to take maximum advantage of all the ERC has to offer. Interactions come in many forms including:

- Visits to the member firm/agency by faculty and students
- Discussions at professional society meetings or conferences
- Visits to the ERC as often as practical to work collaboratively on research projects, mentor students, learn specialized techniques, and give special seminars

- Providing advice on developing the ERC strategic plan
- Reviewing overall progress against strategic goals

- Suggesting changes to the strategic plan, research, and education efforts
- Identifying areas for cooperation with industry or, in some cases, other institutions
- Reviewing invention disclosures and suggesting patent and copyright actions
- Critiquing the progress and direction of each research project
- Providing resources the research program may need
- Suggesting industry speakers for workshops and seminars.

While these and other types of interactions should be strongly encouraged with all industrial members, there are certain duties and responsibilities that are <u>required</u> of members and that must be part of the Industrial Membership Agreement:

- Meeting with the ERC a minimum of twice a year
- Developing an annual SWOT analysis and presenting to the NSF site visit team
- Reviewing progress on ERC projects
- Providing input on ERC strategic plans
- Providing feedback on proposed project plans.

5.1.4 Engaging Industrial Consortia, Regulatory Agencies, & Industry Associations

In working with external industrial consortia and with state and local governments—particularly those agencies involved in economic development—the ERC will need to meet specific consortium or agency goals while assuring that such interactions pass the test of leveraging the center’s activities, augmenting the benefit to member companies, and contributing to student and faculty development. Several centers collaborate with state agencies in programs with small companies—from directed research projects with undergraduate students to state-assisted start-up companies based on center research as discussed below.

Some Centers have actively engaged their target industry's relevant regulatory agency or other non-traditional organizations in their programs. For example, the Food and Drug Administration (FDA) is actively engaged C-SOPS Industrial Advisory Board and Science Advisory Board[2]. Also, the engagement of the US Department of Agriculture (USDA) by CBiRC produces a distinctly positive relationship. ERCs should consider having regulatory agencies interact with the academic community and industry partners in ERCs where appropriate. Any regulated industry that is an ERC focus field should consider having regulatory bodies involved in a "neutral setting," to facilitate active interactions between faculty/students, industry, and the regulatory agency.

CASE STUDY: In the case of C-SOPS, faculty taught courses at FDA to provide knowledge of current and future practices in continuous manufacturing. The course was attended by many FDA employees and provided critical thought into science-based regulatory processes. The FDA proposed regulatory guidance, such as Quality by Design (QbD) and Process and Analytical Technologies (PAT) pertaining to continuous manufacturing, and through such courses FDA personnel gained a clearer understanding of detailed continuous manufacturing processes. This reduces the amount of uncertainty for industry. The C-SOPS Director served on FDA committees that draft guidance documents. C-SOPS recognizes the value of doing this independently to develop Best Practices. The limiting factor is not money, but the time of the personnel involved. Through closer alignment of regulatory and industry practices, C-SOPS can ensure that technological advances will be more readily accepted by the FDA and can subsequently be incorporated into industrial practice, providing significant impact to both.

Groups involved with standards development (e.g., ASME, IEEE) could be ERC education and dissemination partners. An ERC needing manufacturing capabilities might gain access to an industry group that could translate and manufacture outputs of the ERC and possibly collectively gain companies that would not join the center, but could add value to Center activities. In cases where the ERC has a significant life science / clinical focus, the ERC might consider engaging a Clinical Advisory Board, which is integral to the Scientific Advisory Board (SAB).

Several centers are participants in other federal programs (e.g., those of DARPA and NIST). On balance, most centers see such participation as beneficial. Benefits include the industrial relevance of the work, strong commitment and involvement by industry, and willingness of other universities to work together collaboratively. However, not every center finds these large programs beneficial. Disadvantages include "wicked timetables," volatility of funding (causing dislocation in the amount of technical effort in a given project area), and the negative impact that industrial cost-sharing can have on the direct sponsorship of university research by the same companies, given a fixed company budget for support of university research.

Some ERCs—especially those whose mission focus is in public infrastructure development—partner with federal, regional, state, and even local government entities to test and deploy their technologies. The collaboration mechanisms and issues encountered in working with these non-traditional stakeholders are very different from those involved in working with industry and usually entail unique case-by-case features. An example is given in the following case study.

CASE STUDY: The main data sources for U.S. severe weather warnings and forecasts of tornadoes and flash flooding are 159 National Weather Service (NWS) long-range radars. However, this system has coverage gaps, especially at lower altitudes. To address these gaps, the ERC for Collaborative Adaptive Sensing of Atmosphere (CASA) developed a paradigm to supplement the large radars by dense networks of small X-band radars. Traditionally, transfer of technology like this to the commercial weather enterprise was driven by NWS requirements and federal funding, but it has become hard for NWS to obtain the necessary funds. Therefore, rather than relying on federal resources, CASA has led a locally-driven model in which a regional catalyst brings together multiple private/public, local/national stakeholders to fund hardware and operational costs of a regional warning system. The goal is to create a replicable model for other U.S. urban areas. The platform for translational research and shared ownership is a 4-node radar network (expandable to 20 radars) that CASA is currently in the process of deploying in the Dallas-Ft. Worth (DFW) metroplex. Crucial to success of this research-to-operations effort is a contractual arrangement between CASA and a local organization known as the North Central Texas Council of Governments (NCTCOG). The NCTCOG brought together local towns and cities, stormwater departments, fire departments, TV stations, and local businesses to support the project. These organizations are bringing local resources (e.g., warehouse space, rooftops and towers for radar installations, network connectivity, electricity) at no cost to the project; they are also paying for installation and operations of the radar network and raising supporting funds through federal (e.g., FEMA) and state grants and local foundations. Members of CASA's Industrial Advisory Board, which include radar manufacturers, systems integrators, and NWS, are bringing additional funds or equipment. Managing this public-private-academic partnership is complex and requires frequent communication and coordination among the various stakeholders. If successful, it will demonstrate CASA's life-saving technologies in a densely populated metroplex and could lead to the installation of CASA radars all over the nation. CASA recently celebrated installation of the first radar in the DFW testbed at the University of Texas-Arlington with local stakeholders, who publicly welcomed the new CASA technology that will give them clearer, more precise weather information.

5.1.5 Involving Foreign Firms

NSF recognizes that an ERC can have a global dimension, since many research and education challenges and opportunities require overseas collaboration to bring the best resources to bear on a problem. NSF policy permits foreign firms to be involved in an ERC if they agree to operate on a *quid pro quo* basis, exchanging personnel, sharing support, risks, benefits, information, and their own facilities to the same degree as all other participating U.S. firms do. The ERC must be diligent to assure that there is a true two-way and equitable flow of information between the ERC and foreign firms—the same standard as domestic firms. In 2012, about 22% of the 326 ERC industrial members were foreign firms. This is an increase from a decade ago, when the average was 10-13%.

[1] Source: National Science Foundation, Dr. Deborah Jackson; 2012

[2] Attachment 5-A provides a key to ERC centers and their abbreviations for the convenience of the reader throughout the chapter.

5.2 Building An Industrial Constituency

5.2.1 R&D and Commercialization Strategies to Serve Industry

In fundamental research, a full understanding of the impacts and ramifications of the work is impossible at the outset. Industry, on the other hand, requires some projected future payoff to justify research funding. Bridging this dichotomy is at the core of the ERC mission. Of course, not all ERC research will result directly in a commercially viable discovery or technology; however, the likelihood of this result is increased by the periodic involvement of industry at critical points in the research planning and review process. This review process is akin to the product development model, which industry has used for many years. Applying this model to university-based research necessarily involves scaling back such things as market reviews and surveys posing hurdles that a new idea must clear. What is useful about the model is the scheduled interaction among various stakeholder groups at critical points in the development (research) process.

5.2.1.1 Developing and Maintaining an Industry-Relevant Research Agenda

Developing the research agenda is a fundamental aspect of ERC management and oversight. However, the perspective of industry has traditionally not been prevalent in this process in university research. It is essential that the ERC's research management team recognize the importance of industrial input, consider the opinions of industry representatives in their decisions, and encourage the research faculty and staff to do likewise.

Most ERCs have established mechanisms for including industrial input in formulating new research and overseeing ongoing work. Most often, this opportunity occurs during an annual or semi-annual meeting of the entire industrial members group or some subgroup thereof. Depending on the diversity of interests among this group, research focus meetings can be held during plenary sessions of the meeting or in industry-specific breakout sessions with only those representatives interested in a particular topic in attendance. For projects sponsored by a single member or a consortium of members, only contributors to the project under consideration need attend.

The diversity of interests among members can make a group meeting of them and ERC researchers a challenge in agenda-setting. Keeping these meetings focused on the goal of developing a consensus in the research direction is vital. Time should be set aside for constructive criticism of past work and decisions, if appropriate; but it is the role of the ERC research management team to keep the meetings on track and focused on setting realistic goals that are likely to produce tangible benefits to industry.

At times, some ERC members may want to explore research directions that do not map perfectly onto the ERC's core research goals. It is the ERC's responsibility to meet this need by collaborating with these companies under other mechanisms, such as sponsored contract research or fellowship research. ERC industry members should be made aware of the various collaborative opportunities and should have a clear understanding of the difference in IP policies under the various options, especially as it pertains to multiple ERC partner institutions. This is discussed further in Section 5.3.2.9.

5.2.1.2 Balancing the Needs of University Researchers and Industry

Throughout the research, development, and commercialization process, it is important to balance the needs of industry and the university. Whereas a university's central missions are teaching and generating knowledge though research and publication, industry is concerned with maximizing financial value. The potential for conflict between the two must be acknowledged and dealt with in a balanced manner. Questions about the nature of confidential information, the length of time a discovery must remain confidential, and how results can eventually be published are usually specifically addressed in the research contract and confidentiality agreement as discussed in Section 5.3.2.9. The terms of these documents are usually negotiated among the ERC, industry legal staff, and the university technology transfer office.

5.2.1.3 The Changing Roles of Academic and Industry Researchers in Commercialization

For ERC-generated IP, the ERC offers the option to license to the member firms. If a member firm exercises the option, then the technology may move directly to the firm or the firm may sponsor a translational research project, involving ERC researchers in the process but under IP arrangements specific to the project. In this case, the roles of the ERC project director or Principal Investigator and the industrial sponsor will likely reverse. The ERC researcher at this point moves from directing the project into the advisory role, which had been occupied by the industry representative, and vice versa. In some cases responsibility for scaling up the technology may move to someone in industry who had not been connected to its laboratory development. In either case, the ERC researcher should seek to remain available and involved. In cases in which the ERC researcher has a financial interest in the commercial success of the technology (such as inventorship of the IP), the incentive for involvement is obvious. The importance of input from the researcher in maximizing the chances of success of the technology (regardless of IP ownership) should not be overlooked, however.

For IP that member firms do not license, the ERC may offer the license to a large firms with resources sufficient to explore further development of the technology; or, to a small firm (member firm or not). Because small firms do not have funds available to advance the technology, the firm may seek support from the ERC Program's Translational Research Fund under the annual Small Business/ERC Collaborative Opportunity (SECO) solicitation. In that case, the small firm submits the proposal with a subaward to the ERC. IP generated from sponsored project support and translational research project support under SECO does not revert to the IAB or the university.

5.2.2 Attracting Corporate Members

The need to attract new industrial members continues long beyond the start-up phase, as all centers experience turnover in membership due to shifts in corporate strategies and fiscal constraints. Many centers have formal criteria, often developed with the Industrial Advisory Board, for identifying those companies that can belong to the center. These criteria deal with issues such as foreign firms and Multinational Corporations (MNCs), whether consulting firms may belong, and whether company size or location limits membership. It is noteworthy that, while some centers have a geographically concentrated membership, no center limits membership based on location, and some engage their members at long distance. This section addresses successful strategies for recruiting appropriate members.

5.2.2.1 Strategic Plan for Recruitment

The ERC's Industrial Liaison Officer (ILO) or Innovation Director manages this activity. Centers vary significantly in the formality of their strategic plan for recruiting member companies. Proactive approaches to industry member recruitment are highly recommended. As of 2013, the ERC Program Office requires ERCs to strategically plan to include the appropriate firms along the value chain most relevant to the ERC's engineered systems vision. In that way, the research is informed by the appropriate firms involved in the technologies underlying the system, as well as the system itself. In addition, these firms also find benefit in interacting across the ERC's value chain in the IAB. See Figure 5-1 for an example from CBiRC.

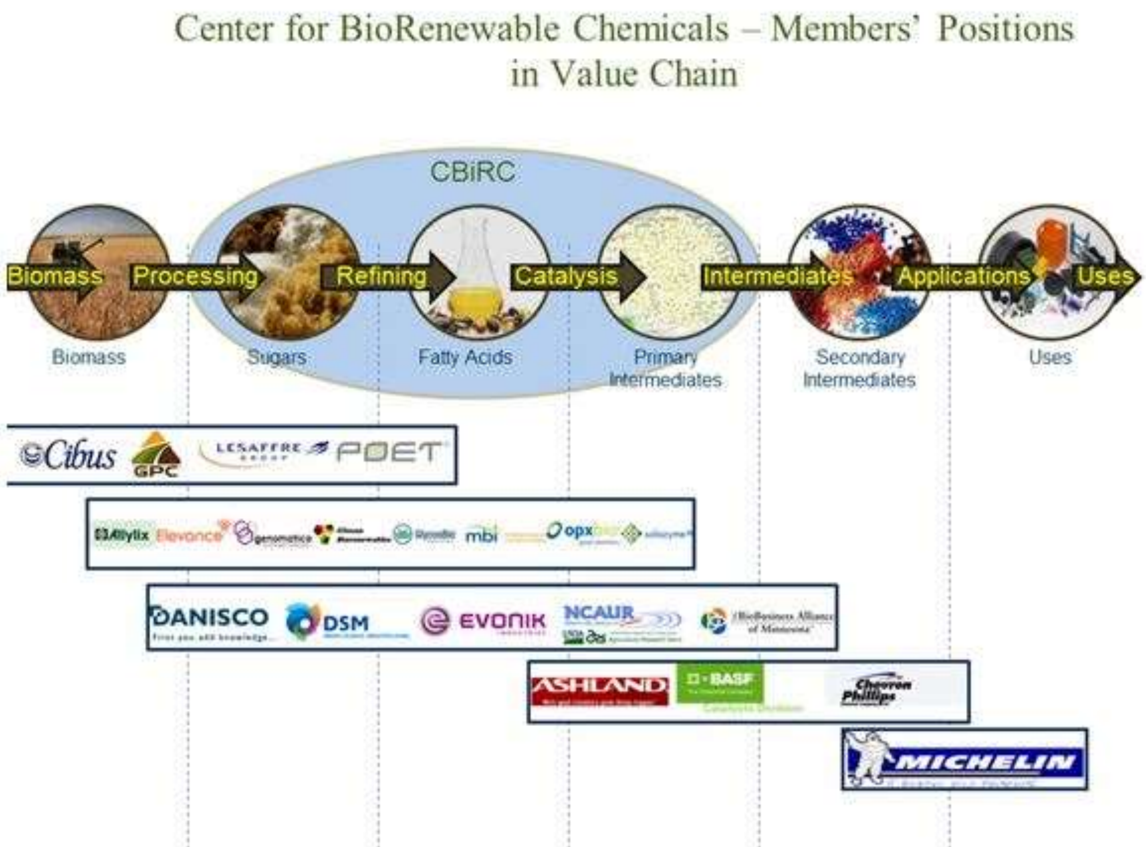

Figure 5-1—CBiRC Value Chain

Most ERCs focus on identified industry groups (sometimes with IAB input) and establish membership goals, do market research to further identify appropriate company prospects, and tailor recruitment strategies for each prospect.

5.2.2.2 Marketing the Center

An important component of the strategic plan for industrial interaction is a clearly defined marketing strategy for recruiting industrial sponsors. A well-developed marketing strategy typically includes an analysis of the industry sectors affected by the center's research, the value chain, and the value drivers that industrial sponsors will find attractive in a research and technology transfer relationship. The marketing plan includes financial and technology commercialization goals, specific actions and timelines needed to reach those goals, and a budget for the Industrial Membership Program. This plan includes strategies not only for recruiting new members, but also for retaining existing ones through customer service activities such as communications of center research activities and results, faculty interactions with sponsor companies, interactions with students to gain know-how and recruit, and regular visits to sponsors' sites.

Many ILOs have experience working in industry, but they also need to understand the academic culture and university/industry collaborations in research. The ILO position must be a full-time staff position reporting to the Director of the ERC. Selecting an ILO who is a staff member in the university technology transfer office, who might work part-time for the ERC, is not an effective strategy as the ILOs must first of all work for and promote the ERC.

Most ILOs report to the Center Director and work directly with faculty, industrial researchers, and often with students. If the Director has high industry exposure, then the industrial awareness of the ERC is heightened. Visibility of the ERC is further enhanced when the Director travels extensively and gives presentations at technology meetings attended by academic and industrial scientists and engineers. The visibility and reputation of the center rises to an even higher level if the key faculty also play a role in marketing the ERC when they are on the road giving presentations.

Advertising and “cold calls” to potential sponsors usually are not productive. Centers should instead target specific companies based on their involvement in the particular industry, their interactions with other sponsors, and their degree of involvement in technology development. The use of current industrial partners to identify leads is particularly effective in identifying potential new members. As in many business endeavors, perseverance is rewarded in recruiting members. Strong and continuous follow-up with several people in the organization, often involving visits to the center and to the company, is usually required after the initial contact. For a new ERC without a significant track record, it is a good idea to market the center’s program and vision. This approach can be particularly effective with companies that have been involved with other ERCs.

It is the high quality of research (and graduates) that is always most valuable to companies. An NSF study of industry member benefits provides insight into the value points and is presented in Section 5.2.4.1.

Every center uses its Director, staff, faculty members, and sometimes students in its marketing efforts, proactively or reactively. ERCs may also use consultants to contact potential sponsors to identify and explore areas of mutual interest. In any case, the ILO is primarily responsible for this marketing effort to industry and is challenged to call on all available personnel and resources, as discussed below.

Carefully identifying the companies that can benefit from the research in the center—that is, finding the right partners—is important in successful marketing. Presenting information about the center’s respected faculty members must be accompanied by clearly defining the value of center participation from the company’s perspective—what is known as the “Value Proposition.” This is particularly difficult in industries with a poor track record for R&D funding. Marketing techniques include literature, newsletters and brochures (hard or softcopy); visits to industry by directors and faculty; visits to the center by industry representatives; booths and exhibits at trade association meetings; participation at technical society conferences; publication of technical papers; participation in industry research consortia; a center website; informational videotapes; letters to potential industrial sponsors identified through contacts; and topical workshops.

Centers disagree on the value of various printed materials in marketing, but most believe that personal contact at professional and trade meetings or other "natural" venues and visits are very effective. Particularly valuable are visits to companies by teams comprised of center faculty, the Director, and the ILO. These visits not only introduce the center to a broad audience of company personnel; but also help the ERC understand the company's products, business climate, and issues so that the value of ERC membership can be specifically defined. In arranging such a meeting, the ILO should gather in-depth information on the company, brief the Director and faculty, and set objectives for the meeting in advance. The Internet is a highly productive source of low-cost leads. Contacts come from companies referring to the center's website, social media such as LinkedIn, and search tools for industry specific needs that meet ERC foci.

Consider that it may also be in the best interests of existing industry members to join in the recruitment process to broaden the support base and intellectual breadth and depth of the industrial membership, and by extension the ERC. It is important to arm member "recruiters" with information about the center and its industry partner program. Additionally, the center's recruitment of industry support might align with and add to university or school development program goals. If so, leveraging the assistance of institutional development officers may help in identifying prospective members. For example, when Peter Keeling developed the Value Chain for the CBiRC ERC, it was clear to the IAB that there was an opportunity to diversify the membership by developing a recruiting campaign targeting various member companies across the whole value chain.

Finally, successfully commercialized technologies are valuable tools in marketing the ERC to prospective members. To the extent that technological advances cross industry lines, a new process or idea may enhance the appeal of ERC membership to previously underrepresented industries. The ongoing process of market analysis for new membership should constantly evaluate the appeal of new technologies to potential sponsors.

CASE STUDY: The Mid-Infrared Technologies for Health and Environment (MIRTHE) strengthened its industry outreach and marketing efforts through the addition of the "Media Affiliate" membership category. They currently have Media Affiliates that provide marketing and exposure for MIRTHE on an in-kind basis (e.g., free advertising or publishing articles on MIRTHE technologies and applications, subject to normal editorial criteria for publications). The Media Affiliates, in turn, benefit from a window into emerging technologies and new product applications. For example, one of MIRTHE's 2009 high school student summer interns wrote an essay about her experience that was published in the Education section of Photonics Spectra Magazine. Other examples stem from the deployment of sensor systems into environmental testbeds, particularly in China and Ghana, which has provided excellent media content.

5.2.3 Engaging with Industry Members

Key to a center's impact through relevant research and potential student hires is the depth of commitment and active participation of industrial researchers in center programs. Exploration by centers of the best ways to achieve a sense of "seamless community" with their partners attests to the creativity and flexibility of center personnel. This section summarizes centers' experiences in engaging with industry members.

Maintenance of the company membership base and recruiting of new members is a continuing challenge, especially in times of economic stress in industry. Resource limitation is a problem at universities as well, with faculty time being a prime example. In some centers, no industrial recruiting is done by faculty because they are overloaded. In the absence of strong university rewards for successful recruiting of center members, faculty members generally choose to spend their time in other pursuits.

Other issues perceived as barriers to getting and keeping companies active in centers are:

- Increasing costs of research at universities;
- The problems of generic vs. proprietary research;
- Publication requirements of universities;
- The mismatch between short-term research issues important to some firms and the requirement that Ph.D. students focus their research on longer-term, higher-risk areas;
- Dealing with the imbalance among sponsors' views of desirable long-term research directions; and
- Ineffective communication with upper-level management in sponsoring companies.

Effective interaction with industrial sponsors is most often limited by the failure of either industry or the center to provide the resources (time and appropriate personnel) for interaction. Partnerships grow best with continuity in the people involved and a commitment to regular communication. It is important for upper management in sponsoring companies to understand that the greatest benefit from membership is the most costly in personnel time. Centers need to provide incentives to faculty members to continue developing partnerships with companies that will become members of the ERC as opposed to sponsoring research in the faculty's laboratories. Some centers report that the key is the reward of the intellectual challenges provided to the faculty member by the company partner; but for this to be effective, the faculty interests and those of the company researcher must be aligned and clear to both parties.

5.2.3.1 Effectively Engaging Industry Champions

It is important to develop one or more champions within each company. Usually these will be firms' representatives to the IAB, but there may also be an additional strong supporter of the center within the company's top research management or general management. These people go to bat for the center when continued membership is an issue. They may be proactive in disseminating center products and information within the company; and they look for joint research opportunities. An enthusiastic and forceful champion—preferably in a senior executive position at the company—makes the difference between a strong corporate member and a *pro forma*, uncommitted one. If the industrial representative must step down due to transfer, promotion, or other cause, it is crucial to enlist his or her help in identifying a suitable replacement champion. Having two or more champions is of obvious benefit at such times.

Because ERC / industry member activities are both technical and managerial, many ERCs have industry member liaisons that come from both those groups within companies, and in many cases from different groups within companies. This is an excellent practice, as ERCs are well served by engaging multiple internal champions within companies to best spread the impact of the ERC and establish redundancy in contacts should one champion leave the company. Engaging strong management as well as technical contacts in companies is a solid strategy to assure that company technical and business-oriented needs are being fulfilled.

In considering effectively engaging champions under the structure of an Industrial Advisory Board, several guidelines can be offered. First, it is important to remember that it is an advisory body. Final decisions must remain with the center management, and specifically the ERC Director. Of course, ERCs should always try to heed the advice given by this body, but extenuating circumstances, conflicting input from other company personnel and from NSF site visit teams, and other factors may have to be integrated into the final resolution. It is also important in the early years of a center to accustom the IAB to thinking longer range; the university structure is not equipped to put out today's fires. Another key point is that research results will be commercialized only if advances are relevant to industry needs. Thus, it is important to get the IAB involved in planning the research program to ensure that it will be relevant when completed.

5.2.3.2 Information Exchange with Companies

One challenge of ERCs is how to share information broadly within member companies when active participation often is limited to a few individuals within each company. This is a two-way problem, with faculty members needing to know more about the company’s interests and industrial representatives needing a fuller understanding of how they might benefit from the center. Most centers try to distribute written materials as widely as possible within member companies—a strategy that is substantially aided through electronic communications. Publications distributed by most centers include newsletters, technical reviews and annual reports, reprints of research articles, information on intellectual property, and summaries of meetings of advisory groups. Assessment of the effectiveness of these materials varies; each center must determine what works in its own industrial environment. Many are using extensive center websites and companies’ internal email systems to share information. Others are using electronic forums and video-conferencing as ways to broaden awareness.

All centers hold formal research review meetings and engage in discussions both during visits and informally, one-on-one. These sessions allow highly effective two-way personal interaction. Agendas for these meetings should include significant time for industrial participants to interact with the material and its presenters. The traditional academic one-hour presentation—with an introduction, methods, results, summary, and conclusions—involves one-way communication that may be inappropriate for an industrial audience. One center uses 20-minute presentations with the conclusions up front, a brief description of methods and results, and a repeat of the conclusions at the end, followed by 20 minutes for discussion. Others use shorter, 10-minute presentations with 5-minute discussion periods. The point is to meet the audience halfway by making the sessions interesting from their perspectives and leaving time for listening and interacting. No matter what format is used in research review meetings, it's important to plan and manage the presentations to ensure that they are aimed at the industrial audiences' interests and needs. The industrial audience wants to know the industrial relevance and applications up front, while academic presentations typically start with a strong focus on the "science" and pay little attention to applications, except as an afterthought. It is important to keep cultural differences like this in mind whenever the ERC presents its results to industry, to clearly demonstrate the value that industry sponsors are getting for their investment in the ERC.

Research review meetings include all researchers (faculty, students, and industry); in some centers they are open to all interested companies and in others are for members only. A number of centers with closed meetings allow prospective members to attend one session as a marketing tool. Some centers mix a public meeting/dinner on one day with a closed member meeting on the second day, thus giving prospective members the opportunity to interact with current members without being part of the exclusive group. Some of the centers charge company representatives for attending meetings; others include the cost in membership fees. Some centers use hotel meeting facilities, while others hold the meetings at university sites. In any case, proximity to ERC facilities allows tours and laboratory visits to be included, either formally or informally.

Centers' meetings with Industrial Advisory Board members vary considerably, but are usually 1-2 days long. The Chair of the IAB organizes the meetings, serves as a chair for each meeting, and works with the members to set the agenda. It is important for the entire leadership team of the ERC (Director, Deputy Director, Thrust Leaders, ILO, and Administrative Manager) to participate in this meeting. Industry participants should be made to clearly understand that this is their best opportunity to guide the ERC and therefore they should not be inhibited in their discussions for any reason. Distribution of the agenda and pre-meeting materials 1-2 months in advance facilitates the meeting. Including the last Board meeting minutes as part of the package is found to be extremely useful in conducting Board business.

For the IAB meeting that is contiguous with the ERC's NSF site visit, the IAB members need to attend the ILO's briefing of the site visit team (SVT) and then devote an hour to meet with the SVT in private to present their SWOT analysis of the center to the SVT and discuss their mutual findings. The ILO and Center Director are not present at this meeting because NSF and the IAB meet as joint funders of the ERC. In assessing its performance, each ERC is required to assess its strengths, weaknesses, opportunities, and threats in a specified, structured manner. This SWOT analysis is a vital tool for the center in its efforts toward continuous improvement. It is also among NSF's most important measures of the centers' performance. The purpose of the SWOT is to:

- Analyze the *strengths* and *weaknesses* of the ERC's vision, strategic plan, research, education, industrial collaboration, leadership and team, and management system;
- Identify any *opportunities* for the ERC to increase its impact; and
- Identify any serious *threats* to the ERC's ability to fulfill its vision; these include both internal and external threats.

Industry members summarize the results of the analysis in bulleted slide presentations, for the use of the NSF annual Site Visit Team and the ERC leadership. The ILO and IAB chair have to determine how best to develop the SWOT analysis so that it is ready for the annual site visit presentation. The IAB Chair, at least, also will discuss the results of the IAB SWOT with the ERC's leadership team.

This exercise provides an integrative forum for industry members to focus on center goals; builds more cohesive industry support; provides focused input to the ERC and to the NSF site visitors to help strengthen the ERC; and strengthens the investment partnership between NSF and industry by clarifying industry's priorities and concerns.

The second IAB meeting, about six months after the first, will include separate research reviews ("ERC Research Days"), the agendas of which vary from center to center. Typically such a review is held during a 1½- to 2½-day meeting, which may include: a plenary session overview of activities; consecutive or simultaneous technical sessions covering major research areas; roundtable discussions (sometimes including an outside perspective, e.g., clinicians for biotechnology); poster sessions (at several centers this is combined with lunch or a buffet supper); and industry feedback sessions. Some centers use the "raw" feedback from such whole-group sessions for guidance; others have representative technical advisory committees that meet in formal session to codify input. Experience suggests that these committee meetings are more effective with a clear agenda (ideally prepared with industry input), minutes, and action items, and seating around a table rather than classroom style. This type of meeting is necessary for the IAB to be able to provide input on the progress of ongoing projects and the plans for new projects.

Another typical formal center meeting type is a topical workshop, often with topics recommended by industrial participants. These are often one-day sessions led by an academic or industrial organizer (or team). Presentations or panel discussions are arranged with sufficient time for discussion. Such meetings are an effective way to explore possible new research directions for a center.

Informal interaction with IAB members between meetings is common. Visits by companies to the center or by center faculty to companies are often informal interactions facilitated by center staff and/or faculty. The purpose of the visit determines which faculty members, students, and administrators are included. Tours of center laboratories may be appropriate for prospective members or new visitors from member companies. It is helpful for all participants to know the purpose, the participants, and the agenda. Briefing materials for a visit should be digestible during a one-hour plane trip. It is often the responsibility of the Industrial Liaison Officer to determine and track follow-up action items from the session.

Finally, it's critical to note that one of the most important roles played by the Industrial Liaison Officer in communicating between the ERC and industrial sponsors is that of ombudsman or the "voice of the customer" in the ERC. The ILO typically has more direct experience in industry and with everyday industry contacts than anyone else in the Center and he or she must be seen as an impartial advocate for the interests of the industrial members—in essence, their internal advocate. Undertaking this role makes the ILO an invaluable resource to members and serves the purpose of the ERC in fostering closer industrial collaborations.

5.2.3.3 Industrial Input into Strategic Planning

Strategic planning for the center's research, education, diversity, and industrial collaboration and technology transfer programs is a vital segment of the activities of all ERCs. Their charter with NSF requires that ERCs periodically identify goals in each area of operation, establish paths to their objectives within an identified time, outline how resources will be organized to achieve objectives, make assumptions about the state-of-the-art and future expectations, and evaluate their progress toward their goals.

Most centers rely heavily on their sponsors and industrial advisory groups for input into their strategic planning. There are several vehicles for doing this, some formal and others informal. Some advisory boards and technical advisory groups hold special strategic planning sessions; some consortia engage in road-mapping activities. Several centers survey members to gather initial information for planning discussions, including recommendations for and evaluation of new projects. One-on-one interviews are also employed.

CASE STUDY: CCEFP introduced the Technology Readiness Level (TRL) system to its industry members as a tool for program and project management. The TRL system was originally developed and refined by the US Department of Defense (DoD) and NASA to define the maturity of a technology. It is widely used in both agencies. TRL numbers range from 1 to 9. A project rated TRL 1 is the least mature (it could be just an idea or a sketch on a napkin) and TRL 9 represents full commercialization. Projects above roughly TRL 4 are moving from pre-competitive to competitive, so when Center research projects reach this level they are "graduated" (i.e., Center funding is stopped). The technology resulting from the research can then be transferred to industry directly or matured through a directed / sponsored project partnership between industry and the PI. The use of the standardized TRL terminology has provided a common language that makes communications about the maturity of a project much easier. The use of TRL assessments for project review, selection, and tracking provides a clear means to show progress of a project toward commercialization and a project's maturity relative to other Center projects. It also helps explain the so-called "Valley of Death" that exists between the pre-competitive research done at an ERC (generally progressing up to TRL 4) and the level of technology readiness at which industry is typically interested in using significant internal resources to commercialize a product or technology (typically TRL 6 and above). The TRL structure utilized by CCEFP (adapted from the DoD TRL) is shown in Figure 5-2.

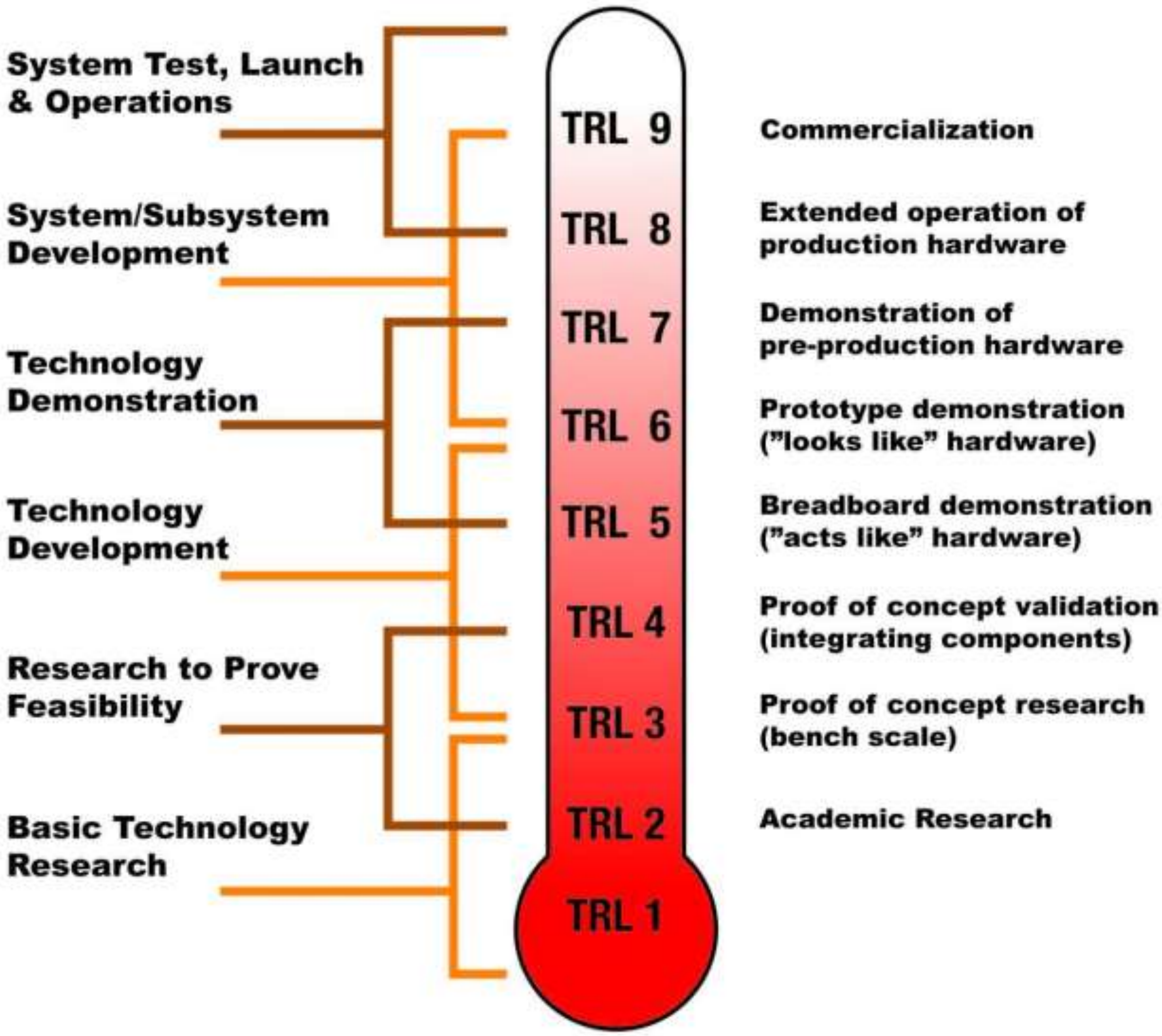

Figure 5-2. CCEFP Technology Readiness Levels

5.2.3.4 Mechanisms to Enhance Interactions

Of all the approaches used to expand and deepen industry involvement in centers, nearly all centers agree that the most effective are personnel exchanges and joint research activities, both of which foster one-on-one interaction. Successful collaboration must benefit both the collaborating individuals and the cooperating organizations sufficiently that obstacles (and there are many) will be overcome. One center Industrial Liaison Officer uses the "health club analogy" with industrialists—the more you participate, the more you benefit.

Most centers attempt to broaden their interaction with member companies and provide a variety of ways in which companies can interact. Frequently used mechanisms that have been found to be effective include:

- Student internships at company sites
- Student mentoring by industry
- Industry participation on thesis committees
- Faculty sabbaticals in industry
- Extended visits to the ERC by industrial researchers
- Technical review meetings (review and topical)
- Industrial Advisory Board meetings
- Visits (of varying lengths) by industry to the center and by the center to industry
- Collaborative research projects
- Contract research projects
- Consortium meetings
- IP licensing
- Hosting center tours for members and their clients/prospects
- Tours of member facilities by visiting colleagues
- Short courses.

CASE STUDY: The MIRTHE education program reflects strong industry connectivity. Every August there is a weeklong Summer Workshop that is held on a core partner university campus, on a rotating basis, and culminates in an industry/student networking dinner on the last day. During the workshop, students are the lead organizers for a "students-only" afternoon that provides opportunities for MIRTHE students to present research to the IAB and SAB. The Student Leadership Council (SLC) facilitates student meetings with the MIRTHE program evaluators and has significant input on the choice of career workshop speakers. Also, the SLC advises the faculty on how to choose the best student papers and posters and its members are often tapped to chair student-related sessions.

<u>5.2.3.5 Industry / University Collaborative Research Teams</u>

ERCs have found that close, personal liaison and one-to-one collaborations between faculty and students with industrial sponsors at the project level are very effective methods of technology transfer. Most centers have established cooperative projects where center personnel and industry partners have specific responsibilities and meet regularly to review progress and determine directions. In some cases industrial researchers provide leadership on project teams.

Faculty members join ERCs because of their interests in industrial problems and in systems-oriented, interdisciplinary research. Centers encourage this inclination by encouraging research done cooperatively with industry.

In some centers, research collaborations have extended to groups of companies, consortia, and other universities. Successful research collaboration between faculty and industrial researchers then becomes part of the culture of a center. Graduate students trained in this environment assume that it is a normal and effective way to pursue industry-relevant research. They take that orientation with them as they go into careers in academe and industry.

CASE STUDY: At the Rutgers University-based C-SOPS, industry mentors are integrated at the project level. Industry mentors are invited to co-mentor students and postdocs on all projects, and matches are facilitated by C-SOPS. Companies designate specific personnel to serve as mentors, with the number of mentors determined by the level of participation—Level 1 sponsors have several mentors; Level 2 sponsors are limited to two project mentors. Each project has multiple industrial mentors, with one serving as a lead mentor. Roles are clearly defined, including communication and progress standards. Mentors provide formal assessment of specific project progress at IAB meetings to focus on results and deliverables. Mentoring allows for input at the industry "grassroots" level within a company, while maintaining upper-level strategic involvement at the IAB level. Mentoring with the testbeds may play a critical role as these are closer to commercialization, and industry involvement may play a translational research-to-development role. There are distinct pluses, downsides, and challenges to this model.
<u>Pluses</u>: The industry mentor has a vested interest in solving a process or manufacturing problem and technology partners are engaged, since the project is focused on their future product. This distributed model of industry engagement makes it more valuable to companies, as interactions are not limited to one person within the company (both high-level strategic and "grassroots" engineering support). Companies often have meetings to bring together all of their mentors participating in projects. The value of the overall engagement can be communicated to upper management, thus making participation in C-SOPS more tangible to upper management.
<u>Downsides</u>: Creation and management of the mentor activities is very time-consuming. Discipline may lag at critical periods if teams have scheduling challenges. There tends to be more one-way communication from the center to industry, and this may not be as interactive as desired, since most of the team meetings are done via teleconferences due to restriction of industry travel. In some cases, certain industry personalities may dominate. <u>Challenges</u>: The IP protection process is challenging with outside mentors closely involved in projects. On the flip side, the industry mentors may be too close to what they are doing within their company, and may remove themselves from projects to protect the company's interests or intellectual property.

5.2.3.6 Tracking Interactions with Industry and Innovation Partners

As in any customer-oriented enterprise, it is important to develop systems for tracking interactions with companies and assessing the effectiveness of the industrial collaboration and innovation programs. ERCs and NSF regard this capability as vital to any center's success. A customized database or commercially available contact tracking software package is a necessary tool. Most centers find it useful to maintain a contact log, to augment memory and to provide reminders on follow-up action items. In planning such a system, it is important to consider who will use or access it, how it will be backed up, and what features are important. At minimum, a center needs a complete company mailing list and a procedure for keeping it current. Security issues may arise if companies require that the list be used for center activities only (a reasonable request). In designing the system, one might also plan for the impromptu reports that will be needed, such as lists of currently active member companies or current fiscal information. NSF's database and reporting requirements call for accurate data on company membership, support, and other forms of involvement, which must be validated by the university's office of sponsored research.

CASE STUDY: SynBERC has created an in-house electronic (web-based) project proposal submittal and review tool that captures all relevant information in a very concise and complete way. There is a separate, excellent review and scoring process to go along with this "Project Center" and it gives a good overview of the SAB and IAB view of the overall proposed project portfolio to guide the Leadership Team in funding decisions. Other ERCs have adopted similar systems based on the SynBERC model.

5.2.3.7 Balancing Long- and Short-Term Research

Despite industry's perennial need for short-term problem-solving, several centers reported few problems in matching long-term university research with industry's need for longer-term R&D. The continued participation of companies in centers, based on corporate assessment of the value of the investment, provides centers with a clear measure of the relevance of their longer time-horizon research efforts.

Centers that work with small companies or have contract work in their operation tend to have more short-term research in their portfolio. Examples of some of the balancing strategies used are involving undergraduate and/or postdoctoral research associates on short-term research projects, separation of general center research (long term) and contract research (short term), and obtaining additional direct funding of short-term projects.

**CASE STUDY: The RMB program management system helps the ERC to assess the balance of basic and applied research efforts, putting each project into a progress- or milestone-driven process. This helps RMB to assess each project from quarterly reports for progress and deliverables, keep track of student advancement, determine when projects may begin to intersect or align, and it provides a mechanism for determination of go/no-go decision points. Not only does the project management system drive research progress, but it also provides an "efficiency framework" for faculty to operate within, creates parity and transparency in funding decisions, and supports an educational environment for student development relevant to industry. This also is a system that allows industry to offer input at critical research decision points, and can point a project towards a market opportunity not previously imagined.*

5.2.3.8 Industry Support for Consortia vs. Directed Research

At times, industry tends to move away from supporting academic consortia in favor of directed sponsored research. A commonly heard company argument is that with tight industry research budgets, companies must focus scarce resources on:

- a list of favored universities for each company (usually top-down driven), and
- specific researchers who are well known in their field and are doing work that is specifically targeted toward the company's interests (usually industry researcher / bottom-up driven).

With that said, industry seems to understand the significant benefits of leveraging the NSF investment in key fields of development, as evidenced by the large number of companies supporting ERCs. An ongoing challenge for the ILO is keeping industry engaged in longer-term research wherein specific benefits to the company are not clearly demonstrable. This is the same issue that ILOs have faced since the inception of the ERC program and is inherent in a program that balances basic research with industrial collaboration.

ERCs may see more opportunities to partner with industry in innovation-focused research proposals jointly submitted to federal funding agencies. The ILO and Associate Director for Research or Thrust Leaders should survey leading agencies for such opportunities, as funding for innovation and translational research is a growing opportunity.

5.2.3.9 Measuring Program Effectiveness

Metrics used to assess the effectiveness of the industrial collaboration and innovation programs vary among the different centers, but NSF does have some common expectations, as discussed here and required by NSF in the ERC's annual report. Other metrics will be useful in reporting to the center's Industrial Advisory Board. Still others may be used only internally for program management and improvement. All centers should keep track of the impacts of their work on companies—what was adopted, how it was used, the impact on the company and on the industry, and other indicators. Data quantifying the impact are especially powerful. In all cases, success "nuggets" describing the impact on industry are useful in explaining the center's accomplishments and should be preserved to expand on the numerical listings. In addition to the center's own use, this information is used by NSF for a variety of purposes. Metrics used in ERCs can include:

- number of joint research projects with industry;
- number and names of students hired by member companies;
- number and titles of publications;
- number of patents/licenses;
- company funding figures and in-kind corporate contributions;
- number of companies attending center meetings;
- number and industrial collaborators on projects; and
- number of faculty visits to companies.

Some centers have found it useful to individualize the data by company to support center industrial representatives in their justification of membership renewal, if requested.

As discussed in Section 5.2.3.2, industrial members perform an annual SWOT analysis. Additionally, each center's students perform a second, parallel SWOT analysis. Members of the ERC's Student Leadership Council gather and synthesize input from participating students (as both participants in and customers of the ERC). Students use the same criteria and techniques as those of the industry members' SWOT analyses. Like their industrial counterparts, they communicate the analysis to the NSF site review team and the ERC's leadership for the purpose of continuous improvement

CASE STUDY: CBiRC's SLC has an especially strong SWOT (strengths, weaknesses, opportunities, threats) analysis protocol that exposes, from student perspectives, critical issues relating to how well the ERC is achieving its goals. The annual analysis, which partners students, ERC leadership, and the NSF to strengthen the enterprise, is designed to mitigate the influence of individual (one-off) opinions that might not be shared by the larger student group. The analysis has five main steps: (i) brainstorming to generate question topics (e.g., the ERC's collaboration with industry is a strength?); (ii) analyze results to create key questions for survey; (iii) survey students (e.g., strongly agree/agree, no opinion, disagree/strongly disagree); (iv) analyze results (quantitatively and qualitatively to assess all student responses); and (v) present findings to the ERC and NSF. An example of how findings can be presented is as follows: student responses indicated that "lack of scientific knowledge being shared by industrial partners" was a CBiRC weakness in 2011 (44% strongly agreed/agreed, 27% had no opinion, and 29% disagreed/strongly disagreed). Action items can be derived from stated weaknesses (e.g., ways to strengthen opportunities for internships). Additionally, results from prior years can be compared to current-year results to assess progress (e.g., have communication and collaboration with industry increased?). In summary, this type of SWOT analysis can be very informative in communicating to ERC leadership and the NSF regarding the overall health of the ERC.

A final note on technology utilization metrics: Licenses are an easily measured record of success. Perhaps a more significant cumulative impact, however, is gained from the little ideas and bits of information that spark an inspiration for someone, and when they take it back to their company it becomes an non-measurable (but important) piece of some large system. One way to measure this is through testimony by working engineers within the company who have benefited from the interaction. Thus, perhaps another metric should be, "Has the center established an effective forum for intellectual exchange within its technology focus area?"

5.2.3.10 Start-up and Small Company Challenges and Opportunities

Identifying mutually beneficial relationships with start-up firms and small companies has specific challenges for most centers. These companies' small R&D staffs and immediate product concerns often hinder them from participating proactively in center research projects and activities. When approached, their initial reaction often is that they may need immediate consulting assistance or they want to hire students, but may not benefit from full membership in a center when considering the membership fee and time commitment. Nevertheless, in high-risk research areas such firms may represent an important mode of technology commercialization. Most centers have developed special ways of working with small companies to make joining possible (such as reduced-rate memberships or short-term project teams of undergraduate students with faculty and industry researchers). Marketing the center to such firms can emphasize benefits such as access to prospective product buyers from large companies at meetings; a window on the future directions of the technology; access to prospective employees; and any special programs developed. Teaming with small firms on proposals to other agencies also is an effective way to establish a partnership—especially with a government agency focus on innovation in solicitations.

Care must be taken to manage conflicts of interest for any spin-off firms that involve the ERC's faculty, executive managers, or ILOs. The ERC must develop a conflict of interest (COI) management plan with the university COI officers.

The ERC must be diligent that small and large company engagement is perceived as equitable. One concern is that larger companies may be reluctant to contribute a substantially larger cash or cash / in-kind investment with an ERC's perceived focus on smaller company-focused innovation and technology commercialization programs. Additionally, some ILOs have voiced concern that the focus and time spent on engaging small companies can tend to decrease the ERC's overall industrial membership fees, as small companies typically pay less than large-company fees for equivalent benefits, especially access to IP. Clarity as to the expected mix of large and small company focus for each ERC should be carefully considered, as each center's potential industrial support base is unique and sometimes quite dissimilar from other centers (e.g., biotech/emerging medical technology vs. electronics-focused centers). Above all, the industry and innovation partners need to perceive as equitable the industrial partnership and fee structure and the opportunity to leverage ERC technology outputs to the benefit of the partner.

Longer-term engagement of small companies, especially in difficult economic times, can be less stable than for large companies, as trimming of what's sometimes perceived of as "non-essential activities" spending is usually the first step in retaining capital for core functions. This can lead to higher small-company turnover and therefore more time spent in recruiting new companies. These concerns can be valid in that the ILO's time is typically stretched, especially with the added innovation duties of the Gen-3 centers, and ILOs' need to prioritize their recruitment attention and time.

Most states have innovation programs to support the development and commercialization of technology by small companies. They may provide business incubators, help in applying for Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) grants, matching funds for federal grants, or even direct equity investments through venture or seed capital funds. A useful source of information is the State Science and Technology Institute (www.ssti.org), a nonprofit research and education organization that tracks such state programs and monitors the state-federal relationship in science and technology.

5.2.4 Benefits and Challenges of Interacting with ERCs

Studies of ERC industrial sponsors' satisfaction with and benefit from the ERC programs were completed in 2004[1] and 2012[2] and the results provide a clear view of the benefits and challenges of industry interacting the ERCs that is instructive to ILO's and other center leadership. This section will highlight the major findings of those studies, but the reader is directed to the referenced reports for further detail.

5.2.4.1 Benefits to Industry of Engaging with ERCs

Overall, both studies found that ERC industry members were generally very satisfied with the ERC programs. The 2012 study found that almost 90% of the members felt that their expectations of the ERC had been met or exceeded and in both studies, approximately 75% of industry respondents felt that the benefits received matched or exceeded the financial commitment that they had made to the center. While the entire ERC package (research, education, outreach, industrial collaboration, innovation) is designed to support industry, a more granular look reveals the specific benefits that industry values.

The 2012 study confirmed that industry members recognize the strengths of the ERC IAB model for a number of reasons. Industry felt that the ERC systems-level approach and industrial consortium model kept a focus on cross-disciplinary research in complex fields that addresses important problems in industry and gives industry input into how best to direct the NSF funding. Additionally, industry valued the ERC's ability to work on pre-competitive research that brings together scientists and engineers (from sometimes competing companies) with academic researchers to advance technology. Ultimately, the study showed that industry valued their participation to improve the chances that the technology will transition to industry and be scaled up. In addition, they valued development of the talented young ERC researchers/students in preparation to joining industry.

A company makes a decision to join and maintain membership in an ERC based on its expectation of benefits. It is important for the ILO and center leadership to understand industry's specific expectations in order to highlight these benefits as part of the center's marketing efforts. The 2012 study queried industry sponsors as to the single most important factor influencing the company's decision to join the IAB, as well as the three most important factors. The cumulative responses to both questions were very consistent and so only the survey results regarding the three most important factors in joining the ERC are given here, but the reader is again directed to the report for further detail. Industry members identified their three most important factors influencing the company's decision to join the IAB as:[3]

- Follow developments in a field related to my company's business (61%)
- Support advances in a technology space important to my company (53%)
- Gain access to specific expertise resident in the ERC (37%)
- Establish relationships with ERC faculty (33%)
- Network with other IAB members (28%)
- Evaluate students as potential employees (26%)
- Leverage company resources through collaborative research (23%)
- Access ERC developed intellectual property (19%)
- Seek partnerships with other IAB members (11%)

- Gain access to ERC facilities / equipment (9%)
- All other responses (5%)

The 2004 study showed similar findings of industry benefits as the 2012 study. In the 2004 study, industry members were asked to estimate the relative importance of specific reasons for their firm joining the ERC. That study indicated that the most important reason for joining the ERC was access to new ideas and know-how (rated by 78 percent of respondents as very or extremely important), followed by access to faculty and to ERC technology, and then by prior connections or relationships with individuals at the ERC.

Of significance in the 2004 study, 40% of industry members reported that they had hired center students or graduates. Among those industry members who received benefits, the value of hiring students or graduates was rated more highly than any other benefit studied. On every one of a wide range of performance criteria shown in Figure 5-3, a large majority of ERC students or graduates hired were rated somewhat or much better than comparable non-ERC hires.

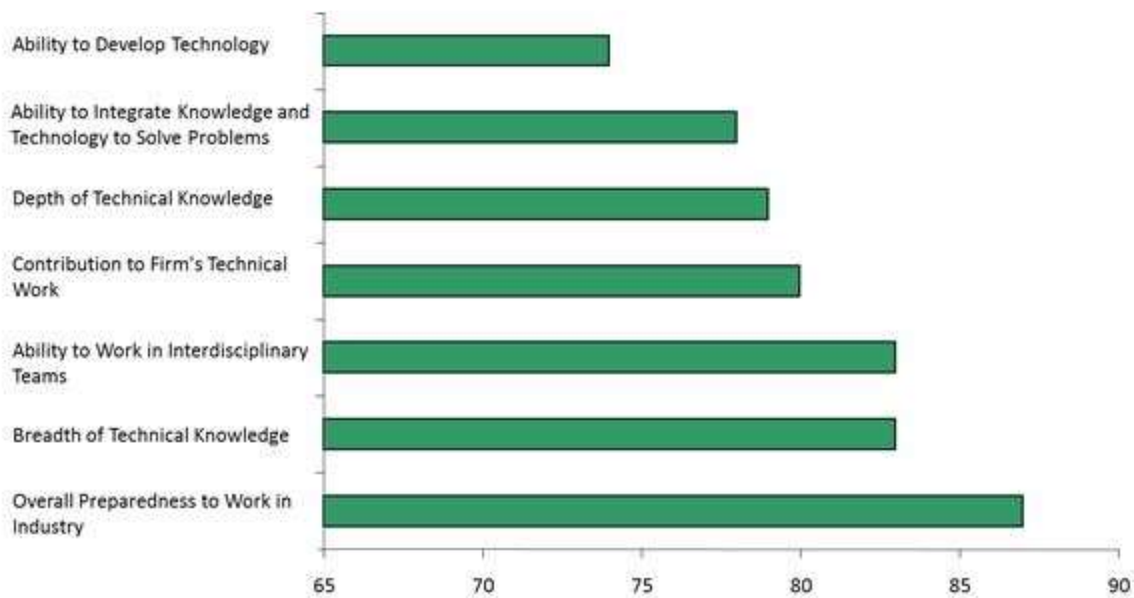

Figure 5-3—Percentage of industrial supervisors rating the former ERC students / graduates hired by their firms as "Better Than" or Much Better Than" equivalent hires without ERC experience.

The message to ILOs is to encourage industry members who hire ERC graduates to get the message out to the other companies regarding the value of these students, and for the ILO to carry this message to new companies they are recruiting.

Industry members in the 2004 study were also asked to identify and rate factors that might contribute to the benefits their companies gained from ERC participation. The top factors that were rated as very or extremely important by the highest proportion of representatives (between 48% and 53%) were:

- The continuous existence of a strong ERC “champion” in the company unit (53%);
- Responsiveness of ERC faculty/researchers to our needs (51%);
- Management support of the ERC within our company (49%);
- The closeness between the ERC’s specific technical focus and ours (48%); and
- The ERC’s efforts to communicate and stay in contact with sponsors (48%).

ILO’s should take note each of that these top factors can be heavily influenced by the ERC’s leadership, with the ILO as the point of contact, putting in place a sound industrial member retention strategy.

When considering the barriers to companies receiving benefits from their ERC membership, industry members overall felt that the ERC consortium model was effective in that none of the barriers presented extreme difficulties for most members. “Other company matters” (45% of respondents) and “difference conceptions of time” (38% of respondents) were the most significant barriers identified.

When one considers the time and effort typically spent on discussion of IP clauses of the Industry Membership Agreement when recruiting a company, it’s interesting to note that access to ERC-developed intellectual property ranked relatively low compared to the value that companies put on more general benefits such as following development and supporting advancements in the company’s field, according to both the 2004 and 2012 studies. The 2004 study showed that 90% of industry representatives reported gaining access to ideas and know-how, 60% reported improving or developing new products and processes, while only 15% licensed center-produced technology or software. Additionally in the 2004 study, the ability to license inventions or software developed by the ERC ranked as one of the least important reasons given to join the ERC (along with access to equipment, facilities, and/or testbeds and the ability to leverage the firm’s research investment with money from other ERC sponsors).

General experience (time in the trenches) can provide guidance to new ERC industry members as much as studies. In order for industry to gain maximum benefit from their partnership with the ERC, the following best practices guidance for industry from Gen-II ERCs is provided:[4]

- Early and long-term engagement enables members to reap the most rewards; do not sit on the sidelines as an affiliate. This has been proven through Gen-II and now Gen-III ERCs. The level of active industry member participation over years of membership is directly related to benefits accrued.
- Active participation in strategic planning, providing guidance on research and education through the IAB, brings relevance. As shown in the referenced studies, both industry and the ERC gain significant benefits in high level, long-term partnerships to guide the center’s strategic plan.
- Bring students to your firm for ERC-relevant internships. ERC students are different in terms of their skill sets and experiences; and these differences can be leveraged by companies that actively engage with these students early in their academic careers.
- Become a champion for a thrust or a testbed. Nothing engages and impacts like active engagement and championing of a specific project. Get in the trenches.

- Provide sponsored project in addition to membership support for the most payback to the firm. Companies who benefit most understand that the value of the research and education goes beyond core research. Companies can tailor results to their benefit through support of directed research that builds on the ERC core research base.

5.2.4.2 Benefits to the Center of Industrial Involvement

Interaction with the leading companies in the industry increases the center's credibility and prominence in the field and can be very instrumental in attracting other companies to become members. This advantage is even stronger when existing members are willing to network actively with the center and prospective member companies.

For ERCs involved in emerging technology areas, the critical mass represented by the industrial members actually nucleates and creates new industries as companies, by incorporating the technologies, give them higher visibility. The center thus grows along with the industry and becomes centrally associated with it.

As the ERC-Industry partnership adds value to industry members, so it also adds significant value to the ERC. The 2012 study highlighted the breadth of benefits that center directors and ILOs felt were gained from the IAB. ERC Membership Advantages for the ERC as reported by the center leadership included:

- The ability to pursue small development projects to help vet and advance some premature technologies towards commercialization;
- Support for industrial outreach efforts;
- The ability to expand educational outreach and support for special ERC projects (e.g., testbed expansion);
- The ability to increase the number of students and postdocs that are funded; and
- The ability to hold workshops on specific topics of interest to industry.

The 2012 study polled center leadership as to the single most important area where additional guidance from the IAB is needed, as well as the three most important areas. As with the benefits to industry results, the responses to these queries were similar, so only the three most important areas where additional guidance from the IAB would aid the ERC are reported here. Those areas were (with the percent of respondents):

- Technology road mapping / strategic research direction (54%);
- Sustainability planning (46%) (note: 33% of the ERCs polled were older than six years);
- Understanding how to position technology in the marketplace (31%);
- Technology assessment (23%);
- Support for internships (23%);
- Referrals for partnerships (23%);
- Market assessment (15%);
- Enhancing technical capabilities (staff, equipment, etc.) (15%);
- Student preparation for research in an industrial setting (15%);
- Understanding ERC’s value proposition to industry (15%);

- Understanding the competitive environment (8%);
- Entrepreneurship training (8%);
- Support for seminars and workshops (8%); and
- Developing center messaging (8%)

Studying these benefits through the referenced report is instructive to ILOs in confirming that industry serves a key role for the ERCs in high level, longer-term functions (e.g., technology road mapping, sustainability planning) as well as shorter-term functions (e.g., technology assessments, internship support). ILOs should keep this in mind as they best engage their industry members to forward the ERC mission and programs.

The 2012 study also informs on the avenues for the most helpful guidance from IAB members. While input from industry members should and does come in many forms, center leadership felt that the maximum value of industry member input is provided (on a scale of 1-6, with 1 being the most useful):

- in private conversations (2.15);
- during IAB meetings (3.0);
- through conversations between IAB members and the ILO (3.54);
- during one on one discussions with the ERC management team (3.85);
- from the IAB SWOT (4.15); and
- during one-on-one discussions with project teams (4.31).

5.2.4.3 Benefits of the ERC to the University

It is important to recognize that the universities are perhaps the greatest beneficiary of the NSF ERC Program. Today’s academic environment is being swept by change in both the quantity and quality of industrial interactions. The ERC provides a challenging yet well-honed paradigm for achieving these goals. Most U.S. universities are becoming more effective in learning how to work efficiently with industry, and the ERCs have led the way. An ERC stands to benefit greatly, as its host university and affiliated institutions continue to regard the ERC system as a trailblazing effort. Some of the chief benefits to the university are:

- If it can successfully conduct one consortium, it can grow to adopt new ones.

- The skills and coordination required to manage a consortium become fundamentally integrated with the various departments involved in university administration—especially in coordinating R&D contracts, IP management, and commercial licensing.

- An R&D consortium, built over many years, is an “instant marketing” system comprising a set of well-informed partners (as opposed to a series of one-at-a-time and one-to-one handoffs)—the consortium partners will tend to “pull on the rope,” rather than pushing on it, as most universities do today.

- A well-managed group of targeted R&D consortia can be used to steer the university in new directions and to capitalize on underutilized assets, especially for faculty needing and seeking new research directions.

- For both new faculty and highly successful senior researchers, the consortium model developed along the lines of the ERC system can lead to greater scientific and technological accomplishment overall, as the scientific enterprise in such a highly coordinated, multidisciplinary system is an enormous drawing card to the best engineering researchers[5]

5.2.5 Driving Toward Self Sufficiency

NSF supports the ERC program to provide international leadership in engineering research, education, outreach, and innovation that goes well beyond the NSF ERC funding cycle of 10 years. It is the Foundation's intent that the NSF funding be catalytic and result in growth in center programs to the point that other entities (e.g., industry, universities, and other federal programs) will sustain the centers to serve future generations. As such, the ERC team, under the leadership of the Director and ILO, need to plan for self-sufficiency from the early years of the center's life.

A clearly defined value proposition can be a key to success in retaining members in the drive to self sufficiency. How each ERC chooses to articulate its specific value proposition, it must show how the center can provide substantial benefits to stakeholders, especially industry, beyond the NSF funding cycle. Industry needs to understand that the ERC can continue to provide financial impact; knowledge; technology; talent; and relationships.

A 2010 NSF-commissioned study of graduated ERCs[6] found that 83% of the then-35 graduated ERCs are self-sustaining. Several major factors contributed to this high rate of ERC self-sufficiency post the NSF funding cycle and a review of major findings with regard to successful transition of ERCs to self-sufficiency is instructive:

- Broad involvement of faculty, staff, industrial partners, and university administration in transition planning is critical. Self-sufficiency, which includes replacing substantial NSF support (financial and otherwise), is not a trivial challenge and all stakeholders need to be engaged and brought into the process from an early stage. Effective implementation of a realistic transition strategy that builds on and enhances the center's strengths is key. While the Center's attention will be focused on forming and growing programs in the early years, a realistic self-sufficiency plan should be crafted, with input from all stakeholders, prior to the sixth year review.
- Institutional factors such as the degree of university commitment, the extent to which the center is prized, and whether or not the center's policies support cross-disciplinary research and education, are critical. The ERC should be a leader on campus in terms of establishing a systems-level approach to research and development, fostering research and education collaborations with industry, and building strong innovation programs.

These should serve as templates for other programs to establish the "ERC culture" across the partnering universities.

- At the end of the NSF funding cycle, the education, outreach, and industrial collaboration programs are typically under the most stress, since the research program can to a degree rely on more traditional funding sources for a university. In order to maintain a true ERC culture, these programs, especially education, must be sufficiently valued by faculty and students such that they will be maintained. This usually requires a core group of faculty dedicated to these functions.

Maintaining the active participation of industry post NSF funding is difficult and requires a redoubling of efforts by the center leadership. Retaining the ILO is critical. Companies that have ERC graduates as valued employees will feel a greater allegiance to the center and will have a greater self-interest in its continuation. It is key to use the early and growth years of the ERC to foster industry champions who believe strongly in continuation beyond the NSF funding cycle. A history of having involved industrial members closely in the center's strategic planning of research, in joint research projects, and successful transfer of technologies that have been valuable to companies in product/process commercialization are crucial factors in convincing industry to remain in the center following graduation. Around Year 5, it is important to begin discussing with the IAB the eventual cutoff of NSF funds and to involve them in the center's self-sufficiency planning as valued partners in the continuing life of the center.

CASE STUDY: IPrime was formed in 2000 from successful industrial collaborations begun under the Center for Interfacial Engineering (CIE), which operated at the University of Minnesota with NSF funding from 1988 to 1999. IPrime is now self-supporting based on substantial annual membership fees from m,ore than 40 diverse, large and small industrial partners. IPrime focuses on collaborative two-way knowledge transfer and provides important benefits to its members by offering a "one-stop-shop" entry point for industrial connections to the university research infrastructure (numerous faculty plus several technology departments and research program areas, some still supported by NSF-funded Materials Research Science and Engineering Center activities). IPrime's Director reports that the groundwork for successful transition from ERC status to self-supporting operation must be established long before an ERC is ready to "graduate." In his view, key elements of that early groundwork include: (a) broad coverage of technologies of interest to industry; (b) an Industrial Fellows program, which consists of scientists from industry who are resident on campus for a time to work on a research project of mutual interest with a faculty member and perhaps graduate students; (c) ability to solicit and act expeditiously on industrial input; (d) Technical Advisory Committees, through which companies can influence the general direction of university research programs and also suggest research that they would like to see but do not have the time or resources to pursue; (e) mutual faculty and industrial interest in continuing interactions, including expressed faculty interest in <u>applied</u> science as well as basic science; (f) senior faculty modeling of successful interactions with industry in order to train younger faculty; and (g) staff that embraces the industry-oriented customer focus, that makes it easy for industry to do business with the ERC (e.g., approaches that minimize legal wrangling), and that understands R&D management issues. IPrime's experience demonstrates that graduated ERCs can retain a strong industrial partner base if the necessary factors are in place beforehand. The end result, demonstrating tangible benefits for both university and industrial organizations, is a "win-win" for both sides --

complementing industry as well as the enduring elements of the former ERC. [For more information, see: www.iprime.umn.edu*.]*

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[1] The Impact on Industry of Interactions with Engineering Research Centers—Repeat Study; SRI International: Arlington VA, December 2004.

[2] IAB Involvement in ERCs: Assessing and Strengthening the Role; Peter Seoane; presented at the NSF ERC Annual Meeting: Washington, DC, November 2012.

[3] Percentages shown are those companies identifying that benefit as one of their top three.

[4] Best Practices for Industry Members of an Engineering Research Center; 2012 ERC Startup Briefings Presentation; Lynn Preston, Leader of the ERC Program: NSF, November 2012.

[5] See, for example, Impact of ERCs on Institutional and Cultural Change in Participating Institutions, SRI International: Arlington VA, June 2001.

[6] Post-Graduation Status of National Science Foundation Engineering Research Centers, Report of a Survey of Graduated ERCs; SciTech Communications LLC: Melbourne FL, January 2010.

5.3 BUILDING AN INNOVATION ECOSYSTEM

5.3.1 Defining the ERC Innovation Ecosystem

The ERC Gen-3 Program rest on the core key features of the historic (Gen-2) program and adds innovation features. However, a primary mission of the Gen-3 ERCs continues to be industrial collaboration and technology transfer to member firms. This is augmented by a focus on innovation and entrepreneurship for students and a reliance on small firms to carry out translational research when member firms fail to license ERC-generated IP. In addition, Gen-3 ERCs are required to build partnerships with innovation facilitators (university and/or state and local government organizations devoted to entrepreneurship and innovation) to help accelerate the transfer of ERC technology to the marketplace when member firms are not involved in that process.

Thus the original mission of the ERC Gen-2 industrial collaboration program is to build a strategic industry alliance to develop and deploy new technology. This is the primary industrial mission of Gen-3 centers as well. The Gen-3 small firm component and the innovation facilitators are additions to that original mission.

The overall strategy for innovation and technology commercialization can best be described by the following narration from Dr. Deborah Jackson, and ERC Program Director in the NSF ERC Program Office.

"Moving innovations from discovery through to commercialization involves numerous actors, often including academic researchers, small businesses, the investor community, and commercial industry. At one end of the spectrum—academe—there is a heavy concentration of government investment in fundamental research. At the other end, in the commercial marketplace, there is a much higher level of industry investment in direct product development. In between lies the so-called Valley of Death, where many potential innovations die for lack of the resources needed to develop them to a stage where industry or investors can recognize and exploit their commercial potential. Crossing that valley requires a complex interplay of relationships along the innovation spectrum. Common approaches include creating formal vehicles for collaboration, such as non-disclosure agreements and memoranda of understanding, or creating opportunities for actors to circulate among different entities through visiting-scientist or post-doctoral programs, sabbaticals, or consultant arrangements. Additional vehicles for promoting interaction—topical conferences, cross-disciplinary institutes, or centers of excellence—create the intangibles of the innovation ecosystem, improving the odds a venture will succeed.

Beyond the intangibles, one-time investments in the innovation infrastructure by the government can make the overall operation more efficient and thus either help lower the threshold cost to industry of launching new ventures or remove obstacles to reduce the time to market. These investments may include physical infrastructure, such as rapid prototyping facilities, or bundled start-up and intellectual property legal services that are accessible to most players in the ecosystem. Lowering the threshold cost and reducing time to market result in more ventures successfully crossing the valley and entering the marketplace."

This philosophy is illustrated in Figure 5-4.

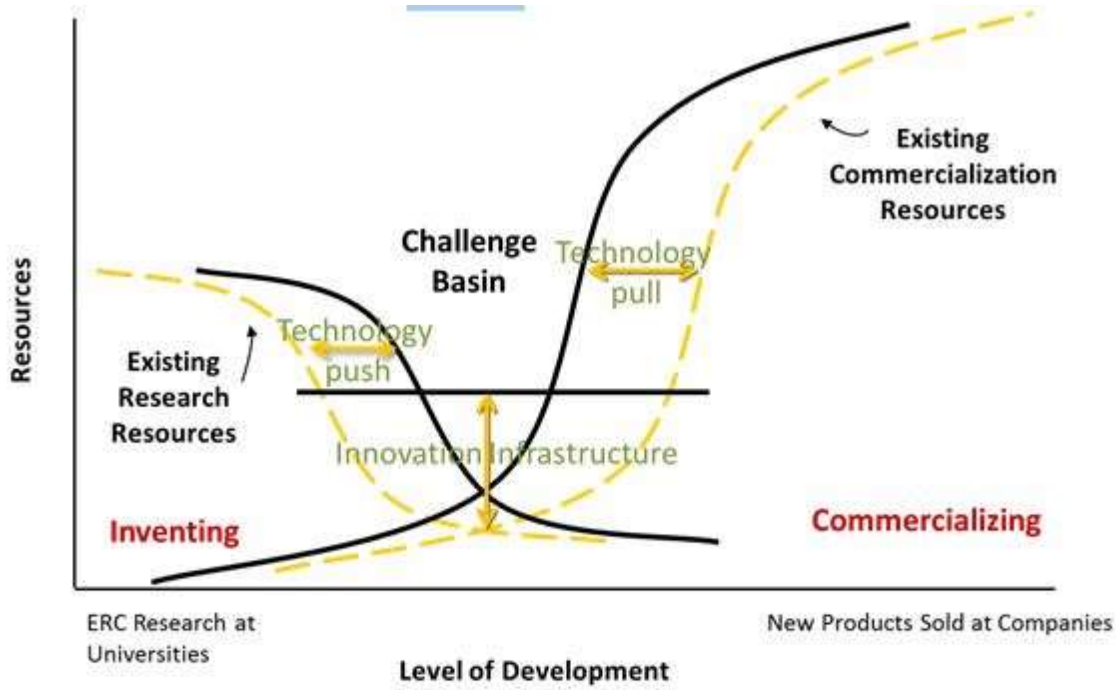

Figure 5-4—Innovation Bridge Structures Turns the “Valley of Death” into a more approachable “Challenge Basin”[1]

The major objectives of the ERC program include both developing and commercializing technologies to bolster the competitiveness of U.S. industry. To successfully bridge the gap between technology development and commercialization, ERCs must take a holistic, integrated approach to technology (creation, experimentation, development, and implementation) that is unique among NSF-funded organizations. The involvement of industry representatives in goal setting, project review, technology evaluation, and technology implementation is vital to the success of this effort. In addition, if they are to be successful at commercialization, they must have ways to ensure the equitable treatment and ownership of intellectual property (IP) resulting from research by individual researchers, the ERC, the university, and industry sponsors.

Technology commercialization at ERCs is an ever-expanding art. The process is significantly more complex than it is where technology is developed and commercialized wholly within a single company or at a small business spin-off based on a university invention that is not licensed by ERC members. The challenge lies in melding a commercially promising research agenda with the often disparate goals of individual industrial sponsors, guiding the resulting work to a point at which industry can use the product, and supporting the commercialization effort through continued close contact between ERC researchers and industry representatives. Both university investigators and industry scientists must understand that their roles will change from advisor to project director as a commercialization effort moves forward.

These challenges are significant, but ERCs are well positioned to take advantage of the considerable experience of industry in generating value from new ideas. The ERC model has a built-in mechanism for maintaining industrial relevance, in the form of periodic project reviews and direction by industry representatives. Technology transfer takes the forms of directly commercializable technologies as well as the transfer of ideas, which industry can refine and cultivate into saleable products.

5.3.1.1 The Virtuous Innovation Cycle

NSF provides guidance on some of the critical success factors and infrastructure needed to establish and grow a strong innovation ecosystem, and these factors feed directly into a complete ERC industry communications and marketing program.[2] The ERC structure has a strong focus on industrial collaboration and innovation, bringing together necessary resources and talent to build a “virtuous innovation cycle” that combines the strength of the “Research Economy” and the “Commercial Economy.” ERCs are uniquely positioned to engage resources from both of these economies to push technologies from the research spectrum as well as pull technologies to market applications from the commercial spectrum. This combined push-pull strategy relies on the coordinated application of resources (funding, talent, innovation champions, educational programs, etc.) from both economies and a well-articulated and delivered industry communications and marketing program will clearly illustrate the value to industry and innovation partners of engaging with the ERC and translating technology and talent from the academic to the private sector. This is illustrated in Figure 5-5.

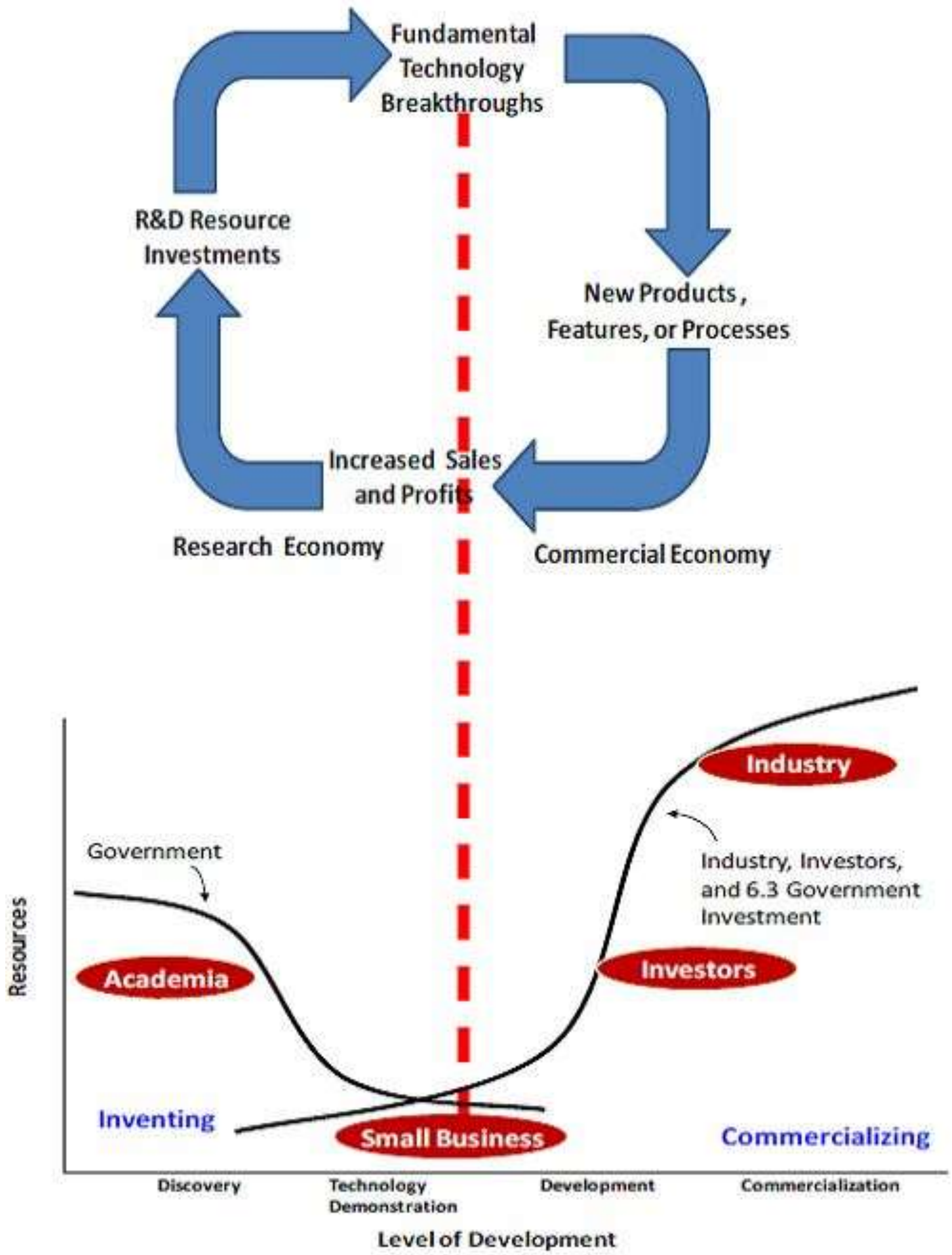

Figure 5-5—The "Virtuous Innovation Cycle" Relationship to the Valley of Death

5.3.2 Intellectual Property Management and Delivery

Because the potential for commercial success of ideas is difficult to forecast or control, it is important that ERCs and industry forge a more fluid relationship with university administrations concerning ownership rights to intellectual property. For industry, one of the main attractions of belonging to an ERC is the potential access to breaking technology that could bring competitive advantage. Indeed, this is a central purpose of the ERC.

Intellectual property rights specified in the membership agreement are influenced by the type of industry, by the university's experience, and by common sense. The type of membership structure also should influence IP decisions. If all of the center's core research activity is precompetitive and supported in common, shared rights for all members may be appropriate. If the center has, in addition to core research, special project support by a company, the arrangement should reflect that company's unique contribution and rights. In a typical center, the university owns IP and licenses are available to members. Access to licenses is based upon membership category, varying from royalty-free license to all center-developed IP to no access for any members. Other IP issues that may be included in the agreement or dealt with on a case-by-case basis include restrictions on licenses, who pays for and maintains patents, and royalty amounts. A more extensive discussion of IP rights is presented in Section 5.3.2.

Sections 5.1.1 have already discussed the need for pre-establishing agreements among the ERC, host university, partner universities, industry members, and ERC researchers to assure that systems and protocols are in place to get the ERC successfully launched. As discussed in those sections, Intellectual Property management clauses and terms is a key component of those agreements and so will not be repeated here.

5.3.2.1 The ERC IP Process Flow

However, it is instructive to discuss Intellectual Property Management protocol in a more granular fashion—that is, from invention disclosure to ultimate licensing. It is anticipated that development leading to commercially viable products and processes will be primarily performed by industry members, rather than the ERC; but it is truly a partnership to develop and translate ERC research to market-impacting offerings. This section describes best practices in the steps of that process. Note that further detail can be found through examination of the Sample ERC Industrial Membership Agreement in Attachment 5-C. The basic ERC IP Flow Process is illustrated in Figure 5-6 and is discussed below.

When the figure is read from left to right, it illustrates the hierarchy of potential commercialization pathways, ranked from lowest to highest risk. The available options for innovation commercialization are (a) translation to industrial partners for further development, (b) licensing technology to a non-member firm for further development, and (c) licensing technology to a university-initiated start-up focused on translating the technology. NSF intends that the ERC will place the highest priority in developing industry relationships on cultivating IAB members and other firms that co-invest with NSF in the ERC enterprise. Small businesses in all three options are eligible to apply for funding from the NSF translational Small-Business/ERC Collaborative Opportunity (SECO) fund. Since NSF is not in the business of launching start-ups, nor does it have the resources to shepherd a start-up through to success, the start-up option should be used only as a last resort when no other options avail themselves.

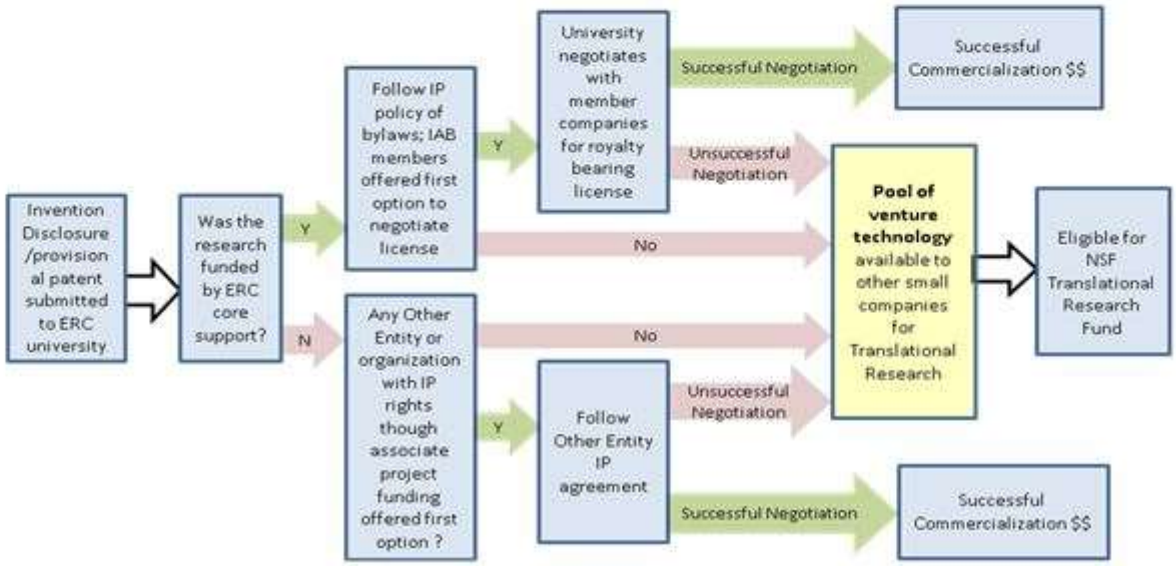

Figure 5-6: ERC Intellectual Property Flow Diagram

5.3.2.2 Membership Levels and IP Rights

Many ERCs have developed "tiered" approaches to industrial membership, wherein companies may opt to increase their access to IP or licensing rights on projects they fund in addition to their membership dues in exchange for higher annual dues—see, for example, the discussion of Section 5.1.2 and the Sample ERC Industrial Membership Agreement of Attachment 5-C. The advantages of this system are that the ERC obtains increased annual membership funding based on the expected future value of IP and licensing rights. The details of the tiered membership system must be formulated in concert with the university technology transfer office and existing or prospective members.

The membership system in multi-institutional ERCs presents an added level of complexity. Here, membership rights often reflect the least common denominator. For example, one university may be able to offer companies better access to intellectual property than other universities in the center can. But it is important for the center to present a single criterion of industry benefits, reflecting the consensus of all the partner institutions. Variations can be addressed internally, so as not to confuse the member companies. It is therefore imperative that negotiations between the multiple institutions of the center be started as early as possible, because the development of an agreement suitable for all institutions can be very time-consuming.

5.3.2.3 IP in Relation to Funding Source

Treatment of IP rights varies depending on the source of the funds that generated that research:

- *ERC Core Research* – This is research that is funded through Center unrestricted, discretionary funds. As with most university intellectual property, IP generated from ERC core research is not normally subject to ownership by industry, although ERC industry members enjoy preferential licensing rights to this technology over non-associated companies. Industry members enjoy a first option on licensing, a non-exclusive royalty free (NERF) license or other benefits, compared with non-associated companies, for IP generated from ERC core research, per the ERC Industrial Membership Agreement.
- *ERC Sponsored / Directed Research* – This category of research comprises projects usually funded by a single company through a separate research agreement that outlines terms and conditions specific to that research project, and is managed through the ERC. IP resulting from research funded by a single company may be subject to IP rights by the sponsoring company, depending on the specific agreement between the university and the company. Some ERCs confer ownership of IP from sponsored research to the sponsoring industry member based on a premium level of membership. This is the first mode for translational research in ERCs.
- *Associated Research* – Associated projects are also sponsored or directed research projects in the scientific/technical field of the ERC, but are funded through the home department of a center researcher rather than through the ERC. Associated projects are only included in the ERC's research project portfolio if all or part of the project is critical to the ERC achieving its strategic research plan. Many of the characteristics of the ERC sponsored research project apply here as well. It is important for ERCs and the NSF to capture and report the level of ERC Sponsored / Directed and Associated Research, as this captures the breadth of the impact of the ERC and its researchers in the field of focus of the ERC.
- *Research Funded by a Consortium of Companies* − IP ownership and licensing rights are further complicated by the involvement of several companies (usually a subset of industry members) in funding work as a consortium. An important distinction to note is that these consortia are funding a project in addition to paying normal membership dues to the ERC. In this case, it is typical that all members of the consortium have equal access to the technology and equal rights for IP ownership or use through licensing, although this can be specific to the ERC and specific consortium needs.

5.3.2.4 Invention Disclosure to University and ERC

The ERC has a contractual obligation to its industry members to provide ERC Core Research invention disclosures in a timely manner so that members can get an early look at inventions and decide whether to exercise any IP rights (e.g., first option to negotiate a license or NERF license) provided through the Membership Agreement. The key is to establish a system between the ERC and the university (host and partners) to identify ERC inventions in a timely manner. ERCs have implemented systems such as:

- ERC researchers being instructed to submit ERC supported research inventions to both the university technology transfer office and the ERC ILO simultaneously;

- The ERC ILO communicating regularly (e.g., monthly) with their university technology transfer offices to assure that ERC funded research subject to Industrial Membership Agreement rights are identified timely;
- University technology transfer offices customizing their invention intake systems to flag the NSF ERC agreement number to identify ERC core research inventions; and
- ILOs communicating regularly (e.g., monthly) with ERC funded researchers to query if any invention disclosures have been submitted or are in preparation.

Each ERC will need to determine the system that works best for it with its lead and partner universities. The ERC also has to determine a time period within which the IAB members can review the IP and either exercise the right to license or decline. The time period should be long enough for a reasonable corporate review but short enough to facilitate other avenues for commercialization. If it's too short, it may imply to the IAB that the faculty are not interested in technology transfer to member firms but would rather spin-off the technology to their own firms. It should be again stressed that ERC-related IP must follow the flow of the IP Flow Diagram of Figure 5-6 assuring ERC members a first opportunity to license and commercialize ERC derived IP.

5.3.2.5 Intellectual Property Vetting

For non-ERC inventions, university technology transfer offices typically vet university researcher invention disclosures for commercial potential through the experience of members of the office, sometimes with guidance from outside subject matter experts or groups. Due to the significant costs involved in applying for patent protection for IP, most universities have full-time staff and/or a committee that decides if an idea, design, or process is worthy of patent prosecution. Committees of this kind may include university administration, legal staff, and researchers. ERCs have the distinct advantage of having a consortium of companies interested in the field of research and so can add substantially to review of inventions for commercial potential.

Some ERCs have established an IP Protection Fund, usually taken from the partial proceeds of industrial membership fees of a higher level tier of membership. This provides the dual advantage of engaging industry members in IP vetting and providing funds for initial protection of IP (e.g., Provisional Patent Applications).

CASE STUDY: The FREEDM Systems ERC established an Intellectual Property Protection Fund (IPPF) as a resource to be used to secure protection associated with the most promising disclosures of Center Intellectual Property, defined as inventions created by Center Core research supported with NSF funds and Members' fees. Annual contribution to IPPF is $5,000 per Full member, which comes out of the membership fees paid to NC State. Associate and Affiliate members do not contribute to the IPPF. Contributions to the IPPF are held separately from the membership pool funds. Unused portions of the IPPF may be reassigned periodically to provide support to Center research projects funded out of the membership pool. A teleconference is held where Industry Advisory Board members discuss and review invention disclosures and make recommendations on IPPF protection actions. The Center may reimburse the patenting cost using IPPF funds up to $10,000 per invention.

5.3.2.6 Invention Disclosure to Industry Members

The next step in the process is transmission of the invention to industry members, assuming that right is included in the Industrial Membership Agreement. Tiered membership structures will most often differentiate IP rights between tiers, so not all industry members may have rights to review Invention Disclosures, or abstracts thereof. For those that do, the Membership Agreement typically provides that the ERC will forward invention disclosures to industry members in a timely manner and provides members with a fixed time frame (usually 60-120 days from mailing of the invention disclosure) to indicate whether the company wishes to exercise any IP rights given in their Membership Agreement. The university will typically agree through the Membership Agreement to not engage in license discussions with non-members in the time frame allowed for industry member review.

Transmission of ERC Invention Disclosures to members is usually done through U.S. mail, but sometimes through email, and preferably through posting on the secure portion of the ERC website. Sending emails to industry members indicating that new invention disclosures are available for review through the ERC's secure website provides the advantages of being able to track members that access the information and also allows multiple groups that are authorized to access the information in a member company to easily review the invention disclosure.

However the invention disclosure is introduced to members, sometimes companies may not want to read the full invention disclosure (or even receive invention disclosures) in order to not compromise company intellectual property that may be under development—commonly known as "contamination" of company internal IP. The ERC can mitigate this concern:

- By providing only a non-enabling abstract of the invention to industry by regular mail or email and inviting them to request the full invention disclosure if they wish;
- If providing the invention disclosure by regular mail, enclose it in a sealed envelope with a non-enabling abstract external to the sealed envelope and a tear-off return slip indicating whether the industry member reviewed the full disclosure and whether it wishes to exercise any IP rights granted in the Membership Agreement; or
- If providing the invention disclosure by access to the ERC's secure website, assure that the member is directed first to a non-enabling disclosure on the site and then clicks through to the full invention disclosure if they wish, using a password or some other trackable form of access.

CASE STUDY: The BioMimetic Engineered Systems (BMES) ERC, based at the University of Southern California (USC) utilizes a unique approach with respect to its IP portfolio. Specifically, their university's tech transfer office assumes all patent prosecution expenses without participation from the Center industry members. Center management takes a very proactive role in developing robust provisional patent applications with strong support from the Stevens Institute. This level of attention is attributed to the tremendous track record of past BMES start-ups, which is well known to USC administration. Director Dr. Mark Humayun estimates that some 80-85% of BMES patents are eventually licensed, which provides great credibility for future Stevens Institute patenting decisions. This level of support provides BMES with much greater freedom than most ERCs have in managing their IP portfolio. For instance, *BMES typically only notifies industry partners when a patent is getting ready to issue—much later than other ERCs, which notify industry partners upon invention disclosure. In some cases, BMES lists invention disclosures at the discretion of the faculty members.*

5.3.2.7 Industry Member Rights

Typically, ERC inventions conceived or first reduced to practice by ERC researchers in the course of ERC Core Research have ownership (title) vested in the researcher's home university. If there are joint researchers from multiple universities, or researchers from one or more partner universities along with industry researchers (a less common case), IP ownership is typically jointly shared among all of the inventing parties—typically the universities or companies as designee of ownership through the researcher employee agreements.

Ownership rights are usually not transferred through the ERC Industrial Membership Agreement. Rather, license (commercialization) rights are usually provided to at least the top tier of industrial membership through the Membership Agreement as discussed below.

IP rights granted by each ERC to its industrial membership are specific to that ERC / university and the needs and standards of the target industry. The Sample Industrial Membership Agreement of Attachment 5-C provides a typical scenario, but this should be tailored to each ERC's specific situation.

Many ERCs grant industry members a right to a non-exclusive, royalty-free license for in-house (research only) use of inventions that come from ERC Core Research. This specifically excludes any commercial application of the technology and any companies that wish to exercise this right will typically share in patent application, processing, and maintenance costs. This scheme allows the industry member to explore development of products and services that might come from the core research, while providing the university with financial (license royalty) returns should the company wish to fully commercialize the technology. This strategy shares the risks and returns of development and commercialization of ERC Core Research.

If such NERFs are granted, or if other IP non-exclusive rights such as field-of-use license rights are granted through the Membership Agreement, the ERC / university must decide if exclusive license rights that may be granted to and exercised by industry members should take precedence. This is a decision for the ERC and university based on their vision for maximizing IP returns overall. In any case, industry members should be notified of any exercise of rights that may infringe on their rights (e.g,. exclusive IP rights over NERF rights), so that each company can make the best business decision for moving forward with exercise of their rights.

These licenses may provide for sublicense rights to industry member affiliates or subsidiaries, or even to third parties at the discretion of the ERC universities and may also include rights to derivative works (future developments) based on the subject IP. The agreement among the partnering university on these terms is captured in their Inter-institutional Agreement, discussed in Section 5.1.1.3.

Finally, the Industry Membership Agreement should always include a grant-back right for university researchers to continue development of the research for academic purposes.

5.3.2.8 License Negotiation

License negotiations are typically handled by the university as non-ERC university IP. One ERC-specific consideration is that with multi-university ERCs, the Inter-institutional Agreement discussed in Section 5.1.1.3 should include a clause assuring that one university takes responsibility for license negotiations so that the company is dealing with one entity, even where the inventors are from multiple universities.

5.3.2.9 Sponsored Projects with Member and Non-Member Large Firms

Industry recognizes that the value to be gained from ERC membership can take many forms, including early exposure to results from the ERC core research and the ability to engage with leading faculty and students in the field of interest to industry members. This can provide industry members with an advantageous position to engage in sponsored research projects with ERC faculty to further advance ERC research of specific interest to the industry member. While all industry members share in the ERC core research results per the ERC membership agreement, industry members also have an opportunity to gain a proprietary IP position in further research that is sponsored by an individual company. In this way, the industry member can take advantage of the knowledge provided by the ERC core research base, which is shared among all industry members, as well as developments from directed research, for which the company sponsor will have commercialization rights as determined by the specific sponsored research agreement—usually a first option to negotiate a license for IP that is developed in the sponsored research project.

Companies that are not members have the opportunity to sponsor research with the university faculty, but will not have the advantage of having the early view of the advancements from the ERC core research provided by ERC membership.

In either case, sponsored projects provide an excellent opportunity to engage more deeply with industry members, engage with companies that are not yet members, and move ERC technology to industry for further development and commercialization. However, the ERC must assure that ERC core research is clearly delineated from sponsored research in application of industry member and sponsored project IP rights.

5.3.2.10 NSF Translational Research Fund

NSF recognizes that ERC research can result in technology that has commercial potential but is at an earlier stage than industry is ready to adopt through licensing. In some cases, ERC research results in inventions that have gone through the standard IP management process of Figure 5-6, do not result in licenses, and could be moved further in commercial potential through incremental funding. ERC-developed IP is qualified to compete for NSF Translational Research Funds only if it has been evaluated and reviewed following the center’s membership bylaws per the Center IP Flow Chart of Figure 5-6. A proposal is submitted by a small member or non-member firm to the SECO solicitation with a sub-award to the ERC faculty associated with the initial technology. In this way, because the research is separately supported by the ERC program and not by the ERC itself, any secondary IP emerging from the translational research project stays with the small firm awardee and does not revert to the IAB or the source university.

5.3.3 Engagement of Innovation Partners

Discussion of Innovation Partners here includes internal organizations such as university technology transfer groups and centers for entrepreneurship and innovation, as this is essentially an issue of leveraging complementary resources, whether internal or external to the university.

The ERC ILO should fully utilize university and appropriate external resources to meet the center's industrial collaboration and innovation goals, but must remain mindful of each organization's drivers or this activity can result in a force fit that produces little of meaningful value, as will be discussed here.

There is a strong need for ERCs to engage all of the university and external innovation partner resources in recruiting industrial partners and transitioning technology to the marketplace. Engaging with economic development groups, alumni affairs and development offices, etc., can be a foreign concept to most university-based research centers that are very much focused on basic research and that rely on the university's standard intellectual property management protocol (e.g., invention disclosure submission, vetting for patenting, marketing for licensing or spinoff, technology licensing). ERCs are unique in a university with regard to their industrial interaction requirements to go a step beyond in their focus on innovation, and so require a special focus on leveraging resources from within and outside the university that can support their mission.

ERCs should regularly review whether they are engaging all the potential innovation and administrative partners in the process of identifying and recruiting new members to the IAB. This list would include:

- All technology transfer offices of the ERC Partner Universities;
- IAB Members;
- University Partner Business Schools, and especially centers focused on entrepreneurship and innovation;
- University and department development, alumni and corporate relations personnel;
- Innovation organizations in the region;
- Angel investors and venture funds; and
- Regional and State Economic Development Organizations.

These groups can be engaged to utilize their existing infrastructure and processes to vet university technology, and networks to broader segments. These groups will benefit by increasing their opportunity pipeline with high quality technological innovations that they can promote to their contacts, and therefore increase their value to their constituents. The ERC is a unique structure in a university that engages industry in basic to systems-level developments with an innovation focus, and this can be attractive to these partners.

For instance, economic development groups are usually looking for opportunities for industry to leverage university research to benefit company directions, and recruitment to the state or area—an opportunity specifically suited to ERCs with their focus on industry and innovation. University-based centers for entrepreneurship can increase their influence on campus by providing workshops and courses in entrepreneurship to faculty and students that can support the ERC's innovation program. Technology transfer offices many times produce technology showcases for entrepreneurs, investors, and companies that can be well served by inclusion of ERC research and advances. University Development Offices are always looking for great case studies of university research programs that can significantly impact quality of life for development of philanthropy targets, whether individuals or companies.

There many mutually beneficial opportunities to work with these groups and these should be leveraged, but only to the direct benefit of the ERC and partnering organization. Force fits in order to count Innovation Partners usually don't result in any significant benefit to either party and the ILO should constantly be on watch to assure that these groups are best utilized for front-end industry/entrepreneur recruitment to the industrial or innovation partners programs or on the back-end as technology commercialization outlets.

This feature is required of Gen-3 ERCs but is a means of strengthening the technology impact of Gen-2 ERCs as well.

CASE STUDY: ERCs can act as a venue for commercial vetting of a broader university research base, such as is done by the QoLT Foundry. Although the QoLT ERC is actually a Gen-2 ERC, it has implemented a vibrant innovation-to-commercialization program that is a front-runner among ERCs and could serve well as a Best Practice for Gen-3 ERCs. The QoLT Foundry is focused on identification, evaluation and commercial advancement of technologies from core ERC and associated research within Carnegie Mellon University (CMU) and the University of Pittsburgh. Established in 2008 with support from CMU, a local foundation, and an ERC Program Innovation grant, the Foundry has demonstrated remarkable success: 12 companies created since its inception and more on the way. Rather than waiting for researchers to form start-up companies, QoLT has taken the innovative approach to reduce the time-to-market for QoLT technologies by being proactive about identifying and cultivating opportunities to form start-ups. The Founder is led by experienced Entrepreneurs-in-Residence (EIRs) who serve as consultants on time-limited (6-9 months) contracts and are chartered to find their "next new thing" in the form of a spin-off company. Foundry interns—CMU and Pitt students in business, law, and management programs—work with the EIRs to conduct market analyses, assess intellectual property strength, scan competitors and develop business models. Those are presented to potential investors, industry advisors, and innovation partners (regional technology-based economic development organizations) in "Opportunity Meetings" organized twice a year. Because they are a proven success, Foundry elements have been adopted by new campus-wide CMU programs that have broader reach within the university.

5.3.4 Real and Perceived Conflict of Interest

NSF policy limits the involvement of ERC faculty and staff members in positions of responsibility in member companies or, conversely, involvement of ERC member company personnel in decision-making roles in ERCs. The following is the National Science Foundation's "Engineering Research Centers Program Statement on Conflict of Interest in Technology Transfer on the Dual Role of Center Faculty in an Industrial Capacity":

> It is generally recognized that technology transfer may be enhanced when ERC faculty or students spin off start-up companies. A conflict-of-interest situation may occur when ERC personnel, including those from the lead university and any core partner universities, have outside interests in companies—financial or otherwise—that may be affected by ERC activities. This applies whether the company is a member of the ERC or not, as long as the company's interests fall within the field of the ERC's technical focus. ERC personnel should exercise the greatest care and sensitivity so as not to give the impression that public funds are being used to enhance the private income of faculty and students supported by the ERC, or to deter participation by other industrial partners in the ERC.
>
> *In accordance with Article 33, "Investigator Financial Disclosure Policy," of the General Conditions, which incorporates by reference Section 510 of NSF's Grant Policy Manual (GPM 510), Principal Investigators (Center Directors), Co-PIs and any other Key Personnel who are responsible for the design, conduct or reporting of NSF-funded research are required to disclose to their universities any significant financial interest (exceeding $10,000 in salary, other payments for services, intellectual property rights, or equity interests) that would reasonably appear to be affected by NSF-funded research. In addition to the Center Director, this would also apply to the Deputy or Associate Director(s), Thrust Leaders, and individual PIs working in the Center who carry out the above functions. GPM 510 also requires Awardees to have a written and enforced conflict-of-interest policy and to submit the required certifications as a condition of future funding increments.*

NSF policy with regard to ERC spin-off companies, if they are members of the ERC, is the same. For nonmember spin-offs, the conflict-of-interest concern applies only to principals of the ERC (Director or Deputy Director, member of the center's Leadership Team, or Thrust Area Leaders). Essentially, anyone in decision-making authority over resource allocation within the ERC cannot be a principal of a spin-off company. Again, it is vital to guard against even the appearance of a conflict of interest.

Conflict of interest (COI) and particularly financial conflict of interest (FCOI) can be a looming challenge in ERCs, and especially so as ERCs drive toward an increased focus on innovation. (See the material on COI at http://erc-assoc.org/ilo-forum). The NSF encourages ERCs to work closely with start-up firms to carry out translational research, promote entrepreneurship, and impact economic development. As such and appropriately so, several ERC faculty members, including in some cases the director, have been tightly coupled with start-up companies, either as founders, officers, advisors, or consultants. Large companies can be reluctant to join or heavily contribute to an ERC that has a focus on innovation if they see this as a pipelining of technology to small companies, or even potential ERC spin-off companies. There can be an inherent COI challenge for faculty or ERC leadership that start up companies or are involved in spin-offs if those companies compete for ERC technologies with industry members. Project funding decisions that are being driven to a great degree by, or at least heavily influenced by, ERC leadership who have a personal stake in the outcomes of those decisions through start-ups, might be perceived as compromised, and this could be extended to the ERC. The university COI policy is typically not set up to address this situation (companies being reluctant to join if they see innovation programs as stymieing their ability to access technology), as the university COI policies are typically focused on managing the back end—post invention and into licensing. While each partner university typically has a conflict of interest policy and management plan, a process to identify and manage COI at the ERC level (across all institutions and partners) has sometimes not existed, but should be established early.

5.3.5 Education Programs with Industry

Industrialists are involved in center education programs as both receivers and contributors. Several centers have industrially focused short courses, workshops, and seminars and industrial degree programs that are offered on campus, at professional meetings, or at company sites. As contributors to center education programs, industrialists lecture, teach entire courses (sometimes as team teachers with faculty), serve on thesis committees, work with students on project teams, act as mentors, and support students financially and with internships. (See Chapter 4 of the Best Practices Manual for a more extensive discussion of industrial involvement in ERC education programs.)

The Gen-3 ERC innovation strategy has a large component of student (and faculty) training in innovation and entrepreneurship as well as a focus on bringing in industrial and innovation partners to provide workshops, experiential education opportunities, technology assessments, internships, etc. As such, the ERCs have a three-fold education mission:

- Develop ERC graduates who will be more effective in industry and more creative and innovative leaders in a global economy;
- Integrate the ERC's research into the undergraduate and graduate curricula; and
- Develop partnerships with pre-college institutions, engaging teachers in engineering research to bring engineering concepts to the pre-college classrooms in order to attract students to careers in engineering.

For this education mission to be effective, the ERC ILOs and Directors for Education need to partner to nurture the culture of the innovation ecosystem. The Center Director should insure that there is seamless coordination between the ILO and the Education Director to avoid the development of conflicting education and innovation ecosystem agendas.

One challenge to ERCs is to capture the excitement and interaction of the industrial partner meetings/retreats at other times. Students and industry can come out of semi-annual meetings energized from their one-on-one interactions, but this excitement quickly fades as each party goes back to their everyday activities. The key is to find ways to increase the frequency of interactions, which can occur in everything from ERC-wide events to individual project industry guidance. ERCs should explore creating avenues for students to meet with industry, such as by sponsoring a reception at appropriate society meetings or other natural gatherings. ERCs might also explore unique means for students to present their research projects and industry to provide feedback in an exciting environment such as a reception with "2 Minute–2 Slide" presentations (essentially student Elevator Pitches of their research projects), with industry providing real-time feedback.

CASE STUDY: Beginning in 2011, the ERC Program has sponsored a Program-wide "Perfect Pitch" competition that begins at the center level and culminates in a competition among center winners at the ERC Program Meeting. This competition focuses on the ability of ERC students to explain their research and its importance clearly and succinctly to a broad audience. The competition is judged at the meeting by a panel of industrialists, entrepreneurial faculty, and venture capitalists. The winning student is awarded a substantial cash prize and the student's home institution takes custody of the Lynn Preston Perfect Pitch trophy until the next competition. Cash prizes are also awarded to second- and third-place students.

CASE STUDY: Student Leadership Councils can design creative ways to engage industry. For example, the Center for Integrated Access Networks (CIAN) hosts a speed-introduction event with one-page project summary slides in a quad-chart format (summary, schedule, deliverables/impact, and graphic). Additionally, the Student Leadership Council's Student ILO coordinates monthly Industry web presentations. However, SLCs need ERC leadership support in terms of direction and guidance, funding, contacts, and organization in order to gain maximum benefit from such activities.

CASE STUDY: C-SOPS organizes "Lunch and Learn" seminars to bring in industry speakers and expose faculty and students to industrial practice. They have also hosted lectures and workshops that have industry speakers or panelists. There is strong participation in an industry mentorship program and great involvement of industry mentors on center projects providing exposure to industry practices through research teams. C-SOPS has designed a well-integrated set of programs that connected undergraduate and graduate education, curriculum development, continuous education for industry members, and programs to enhance public awareness. Of particular interest is the PharmaHub web site (http://pharmahub.org/) that is being used as a "knowledge repository" to make presentations and modules openly available. Presentations and teaching materials can be downloaded, along with numerous tools and resources listed.

CASE STUDY: Recognizing the challenge of getting from discovery to proof-of-concept (the "Valley of Death"), the ERC for Biorenewable Chemicals (CBiRC) is meeting that challenge (which it terms the "Ditch of Despair") with a technology-led entrepreneurship program that builds awareness of faculty and students regarding the various issues. At the core of CBiRC's approach is a course covering the steps in creating a startup. This Entrepreneurship Course builds understanding of what it takes to develop a technology-led idea into an early-stage entrepreneurial business proposition. Topics include (i) discovery research and how technology relates to innovation and the potential for entrepreneurship; (ii) critical techno-commercial *analysis, intellectual property, and how to evaluate risk and reward; (iii) how to define key assets in the context of generating a Business Model Canvas; (iv) working through the elements of a business proposition; and (v) the process of founding a company and securing early-stage funding. In addition, Entrepreneurship Mentoring helps startups by providing a process for evaluating the business opportunity within the context of the Business Model Canvas, which formulates good understanding of a future customer's needs in relation to the technology being developed and what it takes to meet these needs. This Entrepreneurship Program is broadly managed within CBiRC's "Biobased Foundry." The program was started and is led by CBiRC's Innovation and Industry Collaboration Director, Dr. Peter Keeling.*

5.3.6 Role of Venture Capitalists and Other Investors

Going back to the early days of the ERC program, some ERCs (e.g., University of Florida ERC for Particle Science and Technology, Georgia Tech/Emory Center for the Engineering of Living Tissues) were approached by venture capitalists to join the Industrial Membership Program. The venture capital interest was to gain an early look at the commercialization potential of ERC technology and engage with researchers who could help to locate new advances in a field and serve as subject matter experts to help in due diligence of company technologies under consideration by the venture capital firms. ERCs have traditionally avoided formal engagements with investors, primarily due to concerns that individual investors will come in, add little value to the research and education missions of the ERC, and simply abscond with the technologies. However, inclusion of the investment community can be a strong positive for an ERC if managed properly. The MIRTHE Investment Focus Group is an example.

CASE STUDY: MIRTHE established an Investment Focus Group (IFG) with full IAB endorsement. Venture capitalists, corporate, and angel investors have joined the IFG. The IFG objectives are to: a) educate the investment community on the promise and potential of mid-infrared technologies; b) provide mentorship for students and important networking opportunities for faculty, students, industry/practitioners to interact and leverage the knowledge and expertise of seasoned technology investors; c) establish pathways to speed innovation and accelerate commercialization opportunities; and d) assess technology readiness and determine potential approaches to commercialization. In summary, the IFG is configured to add value to MIRTHE's research, education, industry/practitioner, and innovation programs.

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[1] Jackson, Deborah J. (2012). What Is an Innovation Ecosystem? National Science Foundation, Arlington, VA (http://erc-assoc.org/sites/default/files/download-files/DJackson_What-is-an-Innovation-Ecosystem.pdf).

[2] Jackson, Deborah J. (2012). What Is an Innovation Ecosystem? National Science Foundation, Arlington, VA; (http://erc-assoc.org/sites/default/files/download-files/DJackson_What-is-an-Innovation-Ecosystem.pdf)

5.4 ROLE OF THE INDUSTRIAL LIAISON OFFICER

Even though no standard model exists, NSF requires every ERC to have someone on staff, often called an Industrial Liaison Officer (ILO) or Innovation Ecosystem Director, who is responsible for establishing and maintaining a liaison between the ERC and its industrial sponsors, innovation facilitators, and faculty. Each center needs to decide during the start-up and development phase how they are going to carry out this function; guidance is provided in this section as to the key requirements, challenges, opportunities and benefits to the ERC and industry of this position.

5.4.1 Requirements and Functions of the ILO Position

Clarity as to what is expected of industrial collaboration and innovation programs in terms of outcomes (number of members, total membership fees, mix of small and large companies, companies representing different parts of the industry value chain, inventions, patents, licenses to large or small companies, spin-offs, small companies involved in translational research and technology commercialization, Innovation Facilitators involved in stimulating entrepreneurship and innovation, number of students trained in entrepreneurship and innovation, etc.) is critical to the success of the ERC industrial collaboration and innovation programs. While it is almost impossible—and probably not wise—to prescribe one set of metrics that fit ERCs across technology clusters, which involve myriad industry cultures (e.g., emerging biotech vs. established materials and manufacturing industries), ERCs must be clear on expected metrics as the ILOs are typically stretched in terms of time and attention. For instance, ILOs can choose to focus their attention on recruiting large vs. small companies into the Industrial Membership Program, and licensing offices can choose to target technology licensing to larger companies vs. spinning off companies in transitioning research to the marketplace.

A primary consideration is what role the Industrial Liaison Officer will play in the center. Marketing of the center, as discussed in Section 5.2.2, is the responsibility of everyone in the center. With that said, if the senior faculty and Center Director are too busy or not prepared to market the center, then the ILO's role in marketing is primary. The ILO must then be someone who has the recognition and respect of both the faculty and industry, who can articulate what the center has to offer and can generate enthusiasm for it. If the center's reputation is already well-established and/or there are effective salespeople in the form of the Director and key faculty, then what may be needed is a capable, people-oriented, detail person whose primary objective is to provide customer service. He or she can make meeting and other arrangements, coordinate industrial visits, disseminate information, and deal with routine issues that may arise. In most centers, the ILO is somewhere between these two poles.

The skillset needed to perform the ERC ILO function is succinctly summarized as follows:

1. Ability to work with the Center Director in developing/implementing a Technology Transfer Strategic plan for the Center;
2. Ability to work closely with the Center Leadership Team to recruit new industry partners by networking and actively seeking opportunities for industrial participation in research as well as educational center activities;
3. Ability to retain and increase interaction with current center industry partners.
4. Ability to facilitate student/industry relations through internships, student participation in joint projects with industry, fellowships, seminars, career placement, etc.;
5. Ability to assist in the formation of new industry partnerships, start-ups, and other industrial enterprises;
6. Ability to work with the Tech Transfer Offices at the core universities in filing disclosures, technology transfer and licensing agreements;
7. Ability to develop invention handling procedures and participate in licensing negotiations in conjunction with industry partners and ERC core partner campus Technology Transfer offices;
8. Ability to organize periodic meetings with center industry partners;
9. Ability to maintain an active website for industry partners;
10. Ability to document financial contributions from center industry partners; and
11. Ability to prepare a report of industry collaborations for NSF.

The traditional ILO position is probably mis-titled, as liaising with industry only partly describes this professional's responsibilities. Different titles that more accurately capture the responsibilities of the position have been discussed within the ILO community and in some cases applied, and this should be decided by the Director of each ERC. Many who occupy this position in Gen-3 ERCs are titled Innovation Ecosystem Director, Industry/Innovation Director, or Industrial Collaboration and Innovation Director.

The Industrial Liaison Officer is not always a single individual. In a number of cases, the ERC's ILO has teamed with previous ILOs or other professionals inside or outside of the ERC to undertake the responsibilities of industrial collaboration and innovation. In some cases, previous ILOs or those temporarily taking that role operate in broader economic development-focused organizations and this provides a great way to increase the center's exposure.

One concern voiced by several ILOs is the lack of perceived value and recognition for their function by the university, and by a few Center Directors. One suggestion to improve the image and perceived value of the ILOs within the university is to have them give regular university-wide seminars, with overviews of the technical challenges and opportunities afforded by the ERC's technology and research. Another suggestion might be to include them as members of teaching teams, to bring the industrial perspective to students in a broad range of courses.

It’s important to establish the ILO position as an integral part of the center management team during the formation of the center. The ILO should play a key role in the development of the center by providing a direct interface with industry members. Faculty/industry interaction can effectively address only engineering and science issues, while the ILO becomes responsible for nurturing the long-term relationship with the industry members and Innovation Partners. It is these relationships with industry and innovation catalysts that will become important to the center as it approaches self-sufficiency.

5.4.2 Critical Qualifications, Experiences, and Characteristics of a Successful ILO

ERC ILOs have always been well served by having an industrial background in their ERC’s target industry because it is critical that the ILO have a working understanding of the research program, industry technology and talent needs, and industry landscape (major players, new entrants into the market, trends, regulatory environment, etc.). ERC program history has shown that an engineering or scientific educational background pertinent to the ERC’s technology is certainly highly advantageous, if not requisite, to the foundation of a well-prepared ERC. Additionally, the ability to converse with the spectrum of researchers to senior administration in companies and the university has proven to be critical to successful ILOs, as industry decisions to collaborate with an ERC/university is typically driven by a combination of exciting research and a strong and demonstrable fit to business unit needs and future products or services. Additionally, a working knowledge of intellectual property agreements and processes (e.g., patent, copyright, trademark, service mark, trade secret, confidentiality agreements, sponsored research agreements, material transfer agreements, technology licenses, etc.) has served ILOs well as they are sometimes called upon to act as a broker between the university, ERC, and industry (including multinational corporations, small and medium-sized enterprises, and entrepreneurs or startup companies) in these areas. With the Gen-3 ERC focus on innovation, ILOs now require at least a fundamental understanding of the technology entrepreneur and investor world to better guide technologies through the “Valley of Death” to commercialization through small entities, startup companies, and investor-driven initiatives.

5.4.3 Most Satisfying Aspects of the Role

Just as they define their job responsibilities differently, various ILOs also define job satisfaction in different ways, to some degree as a function of their specific job structures within particular centers.

Generally, ILOs enjoy the excitement and intellectual stimulation of working at the intersection of cutting-edge research and technology development; developing education experiences to produce a new type of high-value industry professional; working closely with ERC leadership, faculty, and industry partners in designing research programs to meet industry needs; and creating an environment that fosters innovation. While there are many challenges to the ILO position, as discussed in Section 5.4.4, the ILO position presents a rare opportunity to work in a creative environment of university/industry/government collaboration.

The constant challenge in building an industrial partnership base and maintaining the relationships with industry to serve the center, industry, and nation can be especially satisfying as the ILO sees the fruit of that labor with every research collaboration and knowledge and technology transferred to the private sector to impact the US economy and our citizens' quality of life.

Additionally, the ILO has the opportunity to work with Education and Outreach Director(s) in crafting education programs that provide ERC students—and faculty—with an understanding of industrial research and development practice, technology commercialization, and innovation. The ERC provides a unique structure that enables industry, the NSF, and universities to collaborate deeply and broadly.

Last but certainly not least, the ILO position provides for a unique experience that serves ERC ILOs well as they move to other positions in their careers. The ERC ILO is a high-profile national position and ILOs are typically known to many industry and university professionals as they promote the ERC.

5.4.4 Most Difficult Aspects of the Role

Two difficulties plague many Industrial Liaison Officers: (a) insufficient time for multiple activities and (b) the challenge of motivating faculty members to take timely action on opportunities to interact with industry. Time management skills are an absolute requirement for success as an ILO. Lack of support staff is a serious drawback for many. Most ILOs are realistic about budgetary constraints, but still would value technical support staff. Some expressed concern about having insufficient input into center budgetary decisions.

Other challenges faced by the ILOs have included:

- Mediating between industry and faculty researchers when projects don't go as planned;
- Additional coordination among industry champions and faculty researchers on the respective campuses in the various subthrust areas, especially for multi-institutional ERCs;
- Protecting the intellectual property of individual companies while developing opportunities to expand industrial involvement;
- Learning to work with both company and university personnel in parallel to move an idea forward;
- The loss of member companies from the center;
- Providing mechanisms for researchers and industry representatives to meet and exchange ideas that may lead to sponsored research projects in the center; and

- Creation of a team environment where center and industry researchers can effectively collaborate and communicate on their projects.

In the case of a multi-institutional ERC, the ILO may assume the delicate role of coordinating inputs from industry champions and their respective faculty researchers on various campuses. Competing for the attention of these various individuals, with varying priorities, personalities, and working styles, is a real challenge. To avoid overwhelming and overloading the center's resources, the ILO must make sure that announcements are made in a timely manner and requests are sent with clear and precise instructions.

One of the more challenging aspects of the ILO's role often involves issues regarding intellectual property. IP rights are an important benefit of center membership for industry. However, intellectual property obligations to sponsors can also impose barriers in negotiating new joint ventures and licensing technology to other companies. It takes work to learn enough about the options in dealing with conflict of interest and how to handle rights, but these skills are at the center of the ILO's responsibilities.

5.5 NSF ERC PROGRAM SUPPORT FOR INDUSTRIAL LIAISON

The National Science Foundation is a catalytic partner in each ERC. It selects experimental situations to leverage federal resources with those from industry and other private sources in targeted technology development. This section summarizes the best practices of ERCs in using the NSF relationship to fulfill the industrial liaison function.

5.5.1 Importance of NSF Imprimatur to ERCs

The NSF imprimatur lends credibility to a center. In addition, the opportunity to leverage industrial funds with NSF funds is attractive to sponsors. The tie to NSF also lends support to the center's pursuit of long-term or basic research. The ERC has an NSF-funded management and operations infrastructure that makes the difference between a mere collection of faculty and a cross-disciplinary center with an ambitious mission. In a center that is in start-up mode, the NSF connection is especially critical. Some ERCs report that, without the NSF leveraging, they would not exist. Others, after NSF support has lapsed, are testing the NSF imprimatur as "graduated" ERCs. The great majority (over 80%) find that they do maintain reasonable industrial support from the established membership, based on their track record and reputation, although in many cases the nature of the relationship changes, as does the configuration of the membership.

5.5.2 NSF Support for Industrial Liaison

An ERC is expected to have an active, long-term partnership with industry and practitioners in planning, research, and education so as to achieve a more effective flow of knowledge into innovation and to help the ERC produce a new breed of engineers. Since the circumstances for each ERC vary greatly, the methods of achieving this expectation are very different. However, there are many similarities across the ERCs, as well as lessons each can learn from the others. Consequently, NSF has created periodic forums in which ERCs can draw on the knowledge and experiences of others. Those of most value to the ERC Industrial Liaison officer are:

- ILO closed sessions and breakout sessions before and during the NSF ERC Program meeting (now held every other year, usually in late November);
- NSF-sponsored ILO retreats organized by the ILOs to focus on topical issues of importance to active ERCs;
- Monthly ILO Working Group web conferences organized by NSF to disseminate information of use to the ILOs and gain feedback from the ILOs regarding program policies and operational procedures; and
- ILO consultancy visits to train new ILOs (generally in the first 18 months after a new ERC is established).

The biennial Program meetings are intended to bring together key people involved in the industrial liaison function from new, existing, and graduated ERCs to promote cross-fertilization, establish networks of contacts, share experiences and insights, and open channels of communication. The consultancy is a team of experienced ILOs who visit new ERCs and ERCs with new ILOs to provide personalized guidance and insight into establishing more effective industry collaboration and technology transfer.

5.5.3 NSF Program Director Role in Industrial Liaison

To foster an appropriate ERC environment and provide a personal line of communication, NSF assigns each active ERC a Program Director (PD). PDs provide guidance to ERCs based on experience from other situations and technologies. They also play a vital role in communicating the ERC culture and philosophy to industrial members. The following suggestions are provided as ways to build a trusted partnership between NSF, industry, and the ERC:

- Invite the PD to industry meetings, perhaps via electronic means, to communicate the NSF ERC culture and philosophies;
- Encourage industry to communicate directly with the PD if there are pressing issues, both positive and negative; and
- Although preparing the industry SWOT analysis is typically a closed-door activity, the PD should be invited to help focus the discussion. This is especially important in the early years of an ERC. Depending on the circumstances, the PD might be invited to provide a few remarks at the beginning and then leave, or to remain as an observer or facilitator.

5.5.4 NSF as Evangelist and Shepherd

The ERC Program is a new paradigm for academia, with two new strategies. One strategy is to create a large, multidisciplinary, coordinated research center, where professors from numerous fields collaborate to address complex problems from a systems perspective, under the leadership of a Center Director. This strategy is substantially different from the traditional academic model, in which professors work independently on isolated issues and collaborate only on an ad-hoc basis. The second strategy is to operate as an ongoing partnership with industry and innovation partners, ultimately to attain a state of financial self-sufficiency (that is, independence from NSF core ERC funding). This strategy also differs from the traditional model, in which only a small fraction of professors collaborate with industry on an individual basis—not as part of centers with strategically integrated research and education programs—and often only for defined periods and projects, not on an ongoing basis.

The ERC paradigm is innovative and has already provided many benefits to the nation. Still, since the ERC Program challenges the traditional academic culture and traditional views of university-industry collaboration and innovation partnerships, some faculty in the departments and even in the center may be resistant to aspects of the program. Such resistance can be burdensome to a Center Director and the other members of the leadership team. Even among those not directly resistant, time is required to change their outlooks and get them to subscribe to the ERC concept. Over time, however, the ERCs have had a cumulative impact on academic engineering in the US that has softened this resistance—part of the "culture change" envisioned in the original founding of the Program.

NSF serves a vital role as evangelist and shepherd of the ERC concept for both the faculty and industrial participants. The Foundation helps sell the ERC model not only at the beginning of the center, but on a continuing basis, as new participants are added. It helps guide participants away from old ideas and paradigms, toward the current best practices of a strong ERC. Critical assessment of the center's progress is crucial to this role, as is the firm but gentle use of the shepherd's staff.

5.6 OVERALL SUMMARY

The perspective of the ERC's Industrial Liaison Officer is a bipolar one, which involves championing industry's views to academics as well as representing the university center and culture to industry. Most ILOs find common ground in these seemingly divergent points of view, working to promote mutually beneficial interactions between partners from the two cultures. Achieving this balance requires personal and programmatic flexibility as well as diplomacy. Programs developed by effective ILOs often challenge the status quo in both the university and industry. The desire to facilitate their success and learn from their failures is the basis for the suggestions that follow.

The most important lessons learned regarding industrial collaboration are:

- Keep at it—industrial collaboration is difficult and requires continuous effort.
- Inform new members early that satisfaction and benefits accrue to those firms that interact frequently with the center—participating in collaborative research, attending meetings regularly, making contacts, supporting students, seeking information, and giving advice.
- Trust, not a contract, is the basis of a long-term relationship.

- Industry wants a solid return on its investment—demonstrable, personalized value for each member company. Therefore:

- For many companies, access to valuable ideas or processes is a significant motive for joining. ERCs must provide members meaningful access to technology on an equitable basis.
- For technology that is not appropriate for protection as intellectual property, members should be given the utmost chance to incorporate it in their operations.
- Industry must have a strong role in setting the center's research agenda.

In recruiting members, especially for a new center, there are a number of "rules of thumb":

- Tailor recruitment strategies to each prospect; partnership is achievable only if there is a true confluence of interests.
- Maintain frequent and direct personal communications and visits.
- Clearly state the purpose of the center and the role of the company in the proposed center's research and education programs.
- Share the plans for any characterization or instrumentation facility to be developed.
- Clearly state the intellectual property rights issues and proposed or developed solutions.
- Share the university's plans for long-term viability of the center.
- Convince the companies that leveraging resources through center membership provides a strong return on investment, and that the more they participate the more they will gain.
- Discuss with prospective members the uses to which industry funds are put; also note whether overhead charges on industry contributions will be waived.
- Discuss the commitment of the university and college administration to the long-term viability of the center.
- Create opportunities for industry professionals to interact with students and faculty in such a way that they can influence center programs.
- Discuss center plans for distance learning and short courses.
- Be honest about what you think the center can do for a company, and deliver what you promise.
- Follow-up with required information.

The favorite practices developed by ERCs to facilitate industrial collaboration are:

- Canvassing the Industrial Advisory Board for ideas on directions in research, education, outreach, and innovation;
- Cooperative research projects and personnel exchanges;
- Student internships in industry;
- Using senior-level students as links to industry;
- Workshops;
- Keeping a current contacts tracking database; and
- Developing solid metrics for assessing the industrial interaction.

NSF, and in particular the Leader of the ERC Program and the individual ERC's Program Director, serves a vital role in helping ERCs achieving the support of both industry and universities. Simply by providing its imprimatur, the agency opens doors for the Industrial Liaison Officers and builds support for the ERC concept of industrial-academic partnership.

Attachment 5-A - ERCs and Abbreviations as of January 2013

Manufacturing

- Synthetic Biology ERC (SynBERC)
- Center for Biorenewable Chemicals (CBiRC)
- ERC for Compact and Efficient Fluid Power (CCEFP)
- ERC for Structured Organic Particulate Systems, (C-SOPS)
- Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT)

Biotechnology and Health Care

- Quality of Life Technologies ERC (QoLT)
- ERC for Revolutionizing Metallic Biomaterials (RMB)
- Nanosystems ERC for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)
- Biomimetic MicroElectronic Systems (BMES) ERC
- NSF Engineering Research Center for Sensorimotor Neural Engineering (CSNE)

Energy, Sustainability, and Infrastructure

- ERC for Quantum Energy and Sustainable Solar Technologies (QESST)
- Future Renewable Electric Energy Delivery and Management (FREEDM) Systems Center
- Smart Lighting ERC
- ERC for Re-Inventing America's Urban Water Infrastructure (ReNUWIt)
- ERC for Ultra-wide Area Resilient Electric Energy Transmission Networks (CURENT)

Microelectronics, Sensing, and Information Technology

- Center for Integrated Access Networks (CIAN)
- ERC for Extreme Ultraviolet Science and Technology (EUV ERC)
- Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems (TANMS)
- ERC for Collaborative Adaptive Sensing of the Atmosphere (CASA)
- ERC on Mid-Infrared Technologies for Health and the Environment (MIRTHE)

Attachment 5-B - NSF’s Cooperative Agreement Program Terms and Conditions on Industrial Collaboration in ERCs

1. The ERC's industrial/practitioner partnership program will be governed by an ERC-wide membership agreement, including a uniform IP policy for ERC-generated IP at the lead and each of the ERC’s partner universities. The membership agreement defines the scope and function of the ERC's partnership with industry/practitioner organizations, the types of membership such as full, affiliate, contributing, etc, the respective membership fees, and the ERC's Intellectual Property (IP) policy. The ERC has developed an IP policy that facilitates the roles of industrial partners in Gen-3 ERCs and is flexible in recognizing IP jointly developed by faculty in different universities or that developed by joint industry and university research.
2. Foreign firms may be members of the ERC as long as they participate in accordance with the same membership agreement as U.S. firms do. Domestic and foreign member firms/practitioner organizations will contribute financially to the ERC and will have first rights of refusal for ERC-generated Intellectual property (IP), according to the terms of the agreement.
3. The ERC will function with an Industrial Advisory Board (IAB) involving all of its Industry/practitioner members. The IAB will meet at least twice a year, carry out an annual analysis of the ERC's strengths, weaknesses, opportunities and threats to survival (a SWOT analysis), and participate in the annual NSF review of the ERC's performance and plans. During the meeting with the NSF site visit team, the Chair of the IAB will present the IAB’s SWOT analysis to the review team and discuss the findings. The SWOT will be updated annually and progress of the ERC in addressing the SWOT will be discussed with the NSF site visit team as well. The Chair and the IAB members also will discuss the annual SWOT analysis with the ERC Director and the ERC Leadership team to determine appropriate future strategies to deal with the weaknesses and threats.
4. Industrial consortia may join the ERC, but benefits of membership do not accrue to firms that are consortia members, unless they are also paying membership fees to the ERC as members separate from the consortia
5. Throughout the course of the ERC’s funding by NSF, the Center shall continue to develop and refine its technology transfer and innovation strategy and its Intellectual Property policy, the latter in accordance with NSF’s Intellectual Property guidelines (NSF Award and Administration Guide, Chapter VI.D., “Intellectual Property”) and the Awardee’s policies.
6. Industrial membership fees are treated as Program Income, and must be allocated for use for Center purposes. Industrial membership fees that are not expended in the year in which they are received must be placed in a Center account and reported to NSF and industry as ‘unexpended funds’ that are held in reserve for future use. Progress reports on the expenditure of these funds should be included in the Center's annual report and reported to IAB during the IAB meetings. Industrial members may provide additional

support for activities such as sponsored research projects, equipment donations, intellectual property donations, or educational grants.

7. Costs for organizing meetings with industry members will be borne by the ERC or the participants through a registration fee, as deemed appropriate. Costs for attending these meetings by industry members will be borne by their organizations.
8. All ERCs will have member firms engaged in translational research through sponsored projects, and small firms carrying out translational research supported by funds from the ERC Program's Translational Research Fund or other non-ERC, non-university sources for ERC-generated Intellectual Property (IP) that member firms do not license.
9. In addition, as a Gen-3 ERC, the ERC will develop and nurture the innovation ecosystem for the purposes of accelerating the translation of knowledge into innovation, by:

i. Stimulating member firms to support sponsored projects for the purposes of translating ERC-generated IP to commercialization;

ii. Forming collaborations with small firms for the purpose of translating ERC-generated IP to the marketplace, if member firms do not license the IP—(This should be done via licensing IP, knowledge transfer to the firm, and/or securing translational research funds to accelerate commercialization of the technology by the small business in partnership with the ERC. Translational research funds could be secured from the ERC Translational Research Fund and/or from funding from other non-ERC/non-university sources);

iii. Building partnerships with federal, state, or local government programs designed to develop entrepreneurs, support start-up firms, and otherwise speed the translation of ERC-generated knowledge and technology into practice and products; and

iv. Leveraging technology commercialization opportunities offered by the federal Small Business Innovation Research (SBIR)/Small Business Technology Transfer Research (STTR) programs. The ERC will include analyses to determine the most effective methodologies to use to achieve these innovation goals through these types of partnerships.

v. In reference to 9(ii) above, ERCs will classify their IP generated from research under the scope of the ERC's strategic plan as core IP (IP resulting from center-controlled unrestricted funds) and Project IP (IP resulting from restricted funds that flow through the center or flow directly to a PI). For Core IP and Project IP, the member firms / practitioner organizations or the sponsoring firm/practitioner organization, respectively, will be offered the first option to negotiate a license. If there is no license forthcoming in either case, the IP can be offered to a small firm and a partnership formed between that firm and ERC faculty to carry out translational research to accelerate product development. Support for a translational research project to accelerate product development can be sought from NSF through the ERC Translational Research Fund; in that case, the small firm would be the submitting organization, with a subaward to the ERC faculty. In addition, in that case, the university must screen the project for ERC faculty, Industrial Liaison Officers (ILO) and/or ERC Executive Management personnel conflicts of interest. When conflicts are disclosed for any of the above three categories of personnel, the university impacted must develop a conflict management plan for each disclosure.

vi. In the case of a conflict, there will be a conflict of interest management plan. Progress and impacts of the project would be reported in the ERC's annual report. Because NSF would support such a project as an associated project outside the center's core funds, any additional IP developed from that project would not revert to the university or member firms.

Attachment 5-C - ERC Sample Industrial Membership Agreement

SAMPLE INDUSTRIAL PARTNER AGREEMENT[1]

UNIVERSITY NAME

ERC NAME

This Industrial Partner Agreement (hereinafter called Agreement) is made on this ____ day of _________________, by and between XXX (hereinafter called UNIVERSITY), and ___________________ (hereinafter called MEMBER).

WHEREAS, the parties to this Agreement intend to join together in a cooperative effort to support ERC FULL NAME (hereinafter called ERC) at UNIVERSITY to establish a mechanism whereby the educational and research environment can be used to develop better understanding of GENERAL FIELD OF RESEARCH and stimulate industrial innovation.

AND WHEREAS, this program will strengthen ERC's and MEMBER's, technological and service capabilities.

NOW, THEREFORE, for the mutual premises and covenants contained herein, the parties hereto agree as follows:

1. UNIVERSITY agrees that the personnel and facilities required for the ERC will be available for research, education and service as needed to fulfill the purpose of this Agreement. ERC shall be operated by UNIVERSITY under the leadership of a Director. ERC will be supported jointly by various private and public sponsoring organizations, including MEMBERS, the National Science Foundation (hereinafter called NSF), UNIVERSITY, and the State of XXX.
2. UNIVERSITY, on behalf of ERC, will put into place agreements with XXX, XXX, and XXX (hereinafter called ERC PARTNERING UNIVERSITIES and collectively with UNIVERSITY called ERC UNIVERSITIES) to assure that the rights and obligations of MEMBER that apply to UNIVERSITY, will also apply to ERC PARTNERING UNIVERSITIES.
3. ERC's Industrial Partners Program (hereinafter called IPP) has been created to establish partnerships with companies or other entities which may promote ERC's mission. IPP participants are expected to play an important role in the research, education, technology transfer, and innovation goals of ERC including creating and demonstrating the scientific and technological feasibility of innovative methodologies and systems governing FIELD

OF RESEARCH, assisting in the transfer of research discoveries and observations from university to industry and vice versa, and developing an interdisciplinary education program.

Any corporation, company, partnership, sole proprietorship, or any other legally recognized business entity, or any agency of government, government office, or government organization duly authorized by the United States Government or government of any State or Nation may become a MEMBER of the IPP.

The rights and obligations of MEMBER under this Agreement shall extend only to MEMBER's affiliates or subsidiaries who routinely share in a free flow of MEMBER's internal technical information.

4. The fee for participating in the Industrial Partners Program comprises a cash contribution as defined below. In addition, appropriate interactions with ERC administration and researchers to help ERC accomplish its mission are required. The interaction with ERC may include visits to the Center by the partner representatives, visits to the partner by faculty and students, and discussions at professional society meetings or conferences. IPP MEMBERS, during visits to ERC, can work on a mutually agreed upon research projects, mentor students, learn specialized techniques, and give special seminars. It is expected that during the course of their stay, they will develop strong interactions with ERC researchers. Required member duties include:
    a. Meeting a minimum of twice a year
    b. Developing an annual SWOT analysis and presenting to the NSF site visit team;
    c. Reviewing progress on ERC projects;
    d. Provide input on ERC strategic plans;
    e. Provide feedback on proposed project plans;

5. MEMBERS of the IPP are entitled to the following benefits:

- MEMBERS will receive a non-exclusive, royalty free grant of rights to all intellectual property developed by the ERC subject to the provisions defined below in this Agreement.
- MEMBERS may serve as elected representatives on the Technical Executive Committee (TEC). The TEC will be constituted so as to represent the broad spectrum of membership and will ensure the overall synergy of the research carried out in various thrust areas, and recommend to the ERC Director any mid-course corrections in research and/or personnel, as necessary. The TEC will be elected by voting members of the Industrial Advisory Board (IAB). The IAB will consist of all MEMBERS who shall have voting privileges. IAB MEMBERS will participate in recommending priorities of educational and research programs to the Center Director and in evaluation of progress towards the ERC's goals and objectives.
- MEMBERS will have rights to receive a discounted overhead rate of 25% UNIVERSITY Modified Total Director Cost (MTDC), reduced from UNIVERSITY standard 45% MTDC overhead rate, applied to any additional FIELD OF RESEARCH related research associated with ERC researchers which MEMBER sponsors. This favorable rate applies

to contracts entered into with UNIVERSITY during MEMBER's participation in the IPP and requires full payment for the additional research in advance.

- MEMBERS will have priority access over non-partners of ERC to ERC facilities and instrumentation in the ERC at nominal fees to cover the operating costs.
- MEMBERS may request on-location short courses to be provided by ERC at fees to be negotiated between ERC and MEMBER to cover costs.
- MEMBERS will have access to the ERC Secure Web Site, which comprises an electronic information network maintained by the Center for timely exchange of information and facilitates access to the ERC created knowledge base of research advances. MEMBERS will have access to all ERC reports, publications, and invention disclosures, per the conditions in this agreement, through the ERC Secure Web Site.

6. Upon execution of this Agreement, payment shall be made as indicated below:

The annual fee for a MEMBER is based upon the number of full time employees within the MEMBER's corporate entity as defined in Section 3, Paragraph 3:

Number of Employees	Annual Fee
Less than 100	$XX
Between 100 and 500	$XX
More than 500	$XX

Payments shall be made annually, with the first payment being due within thirty (30) days of the execution of the Agreement. The initial term of the membership will be from execution of the Agreement through the following 12 months with subsequent terms continuing for 12 months thereafter.

Checks shall be made payable to: XX

Checks shall be mailed to: XX

7. All educational, research and other programs and administrative activity of ERC will be conducted with pooled resources with contributions from MEMBERS, and other sources, including NSF, as long as expenditures from these pools are deemed appropriate for the establishment and operation of the ERC.

8. This Agreement will be renewed annually with no action required of either party hereto. Either party of this Agreement may terminate annual continuation of the Agreement by providing the other party with written notice at least three months prior to the anniversary date of this Agreement. All notices shall be in writing and addressed to MEMBER's stated address or as follows:

UNIVERSITY ADDRESS

9. The organization and operation of the ERC shall be in accordance with existing procedures established by UNIVERSITY and all applicable State and Federal laws.

10. Intellectual Property and Publication Policies - It is anticipated that development leading to commercially viable products/processes will generally be performed by industrial partners rather than the ERC. If new technology is developed through ERC research, the following policies shall apply:

<u>Invention Disclosure to ERC UNIVERSITIES and MEMBERS</u> – UNIVERSITY researchers supported by ERC core funds are required to submit invention disclosures and/or copyrightable materials disclosures (Federal copyright registrations) to ERC UNIVERSITIES and ERC in a timely fashion. When ERC receives an invention disclosure and/or copyrightable materials disclosure, a copy will be provided to MEMBERS for their review, through either direct mail or the ERC Secure Web Site. UNIVERSITY agrees to a delay in licensing to non-partner companies for a period of 90 days following the disclosure of patentable inventions or copyrightable materials to MEMBERS.

<u>Rights of MEMBER for Non-Exclusive, Royalty Free License for In-House Use of Inventions</u> - All patentable inventions and copyrightable materials conceived or first actually reduced to practice by ERC supported researchers in the course of research conducted at the ERC shall have title vested in the researcher's home university. MEMBERS shall have a right to a non-exclusive, royalty-free license for in-house use of patentable inventions or copyrightable materials developed under the auspices of the ERC. For clarity, in-house use is limited to in-house research and development purposes only and specifically excludes commercial application(s) of the subject invention. If a MEMBER exercises its right to a non-exclusive license, the MEMBER shall inform UNIVERSITY of their intentions within 90 days of receiving or accessing the subject invention disclosure, and MEMBER shall pay its pro rata share, divided evenly among all MEMBERS who choose to exercise their rights to a non-exclusive license of the subject patent, of patent application, prosecution, and maintenance costs, or copyright registration costs quarterly, as defined in a separate agreement with UNIVERSITY to be negotiated at that time. MEMBER rights to a non-exclusive license to patentable inventions and copyrightable materials shall be subject to the conditions of MEMBER exclusive or exclusive for a defined field of use license rights as defined below.

<u>Rights of Member for Negotiation of Exclusive License</u> - All patentable inventions and copyrightable materials conceived or first reduced to practice by ERC personnel in the course of research conducted at ERC shall have title vested in the home university(ies) of ERC supported researcher(s). MEMBER may request an exclusive or exclusive for a defined field of use, royalty-bearing license for patented or patent pending inventions or copyrighted materials developed hereunder within 90 days of receiving or accessing the invention disclosure. UNIVERSITY agrees to consider such requests to negotiate with MEMBER(S) on exclusive or exclusive for a defined field of use, royalty-bearing license(s). Should such license(s) be granted, granting of all other non-exclusive licenses for in-house use to other MEMBERS shall be with-held to the extent that exclusive license(s) require. MEMBER shall pay its prorata share, divided evenly among all MEMBERS who choose to exercise

their rights to a license of the subject patent, of patent application, prosecution, and maintenance costs, or copyright registration costs quarterly, as defined in a separate agreement with UNIVERSITY to be negotiated at that time. UNIVERSITY will not unreasonably withhold granting said exclusive or exclusive for a defined field of use license(s).

All exclusive licenses granted in accordance with this provision shall include the right for MEMBER to sublicense to its subsidiaries in accordance with any and all applicable State or Federal laws and/or statutes. Each such sublicense shall be subject to the terms and conditions of the license granted to MEMBER by UNIVERSITY. ERC agrees to promptly notify all MEMBERS of any request for an exclusive or exclusive for a defined field of use license to use any patentable invention or copyrightable material developed by the ERC.

Sublicense to a Third Party - The issuing of a sublicense by MEMBER to a third party to use any patented invention or copyrighted material developed under the auspices of the ERC will be subject to a royalty bearing license agreement to be negotiated with the appropriate ERC UNIVERSITY.

Use of Patented Inventions or Copyrighted Materials by UNIVERSITY - UNIVERSITY shall be free at all times to use patented inventions or copyrighted materials for educational and university research purposes only.

Reasonable Commercialization Efforts - Because of the public interest that pervades UNIVERSITY research programs, any license entered into by UNIVERSITY will embody a clause permitting cancellations thereof if reasonable commercial use of the licensed invention or copyrighted material is not being made or diligently attempted by the licensee.

Publication of Research Results - Publication of ERC created research results is of fundamental importance to universities, faculty members and their research programs. Therefore, UNIVERSITY reserves the right to publish in scientific journals the results of all research performed at the ERC (excluding proprietary information received from MEMBERS), giving due consideration to scheduling such publications in order to allow time for obtaining appropriate patent or copyright protection for any patentable invention or copyrightable materials that might result from the research. UNIVERSITY agrees to provide a copy of all experimental data resulting from research in ERC program to MEMBER representatives on the IAB for review prior to publication. MEMBER may request delay of the proposed publication of said data for a period not to exceed 90 days from the date of submission or presentation to MEMBER. MEMBER agrees to request said delay only in order to permit the filing of appropriate documents (i.e., patent application, copyright registration, etc.) on any patentable invention or copyrightable materials made by ERC, and MEMBER must make said request in writing, including justification thereof, within 30 days from the date the experimental data was presented or transmitted to MEMBER. Should the proposed publication be a student thesis or dissertation, UNIVERSITY and MEMBER hereby agree to use their best efforts to complete all reviews of material contained therein and any necessary intellectual property protection filings so as to not impede the completion of activities satisfying graduation, degree, or publication requirements by such a student.

Rights to Future Developments - MEMBERS who develop a specific technology based on basic data provided by UNIVERSITY are entitled to any derived patent(s) or copyright(s) without compensation to UNIVERSITY.

11. The parties agree to comply with all applicable State and Federal laws and/or rules concerning equal opportunity and non-discrimination.

12. MEMBER shall not use the name of UNIVERSITY or ERC in any advertising or promotional material without the specific written consent of UNIVERSITY and vice versa. A general exception is hereby granted to MEMBER to use the name of ERC and to cite the fact that ERC is operated by UNIVERSITY in written advertising and other promotional materials provided that: (1) such use is limited to describing the MEMBER relationship to ERC as herein defined by this Agreement, (2) no endorsements by ERC or UNIVERSITY of MEMBER products or other commercial activities may be reasonably inferred from such use, and (3) such use does not represent that a partnership, joint venture or other legal entity has been formed between and among the parties to this Agreement.

13. The relationship between MEMBER and UNIVERSITY shall be that of independent contractor. As an independent contractor, MEMBER assumes all risk and liability for injury to persons or damage to property caused by acts of its employees during the period of the Agreement while they are using facilities or equipment owned and/or controlled by UNIVERSITY. This Agreement shall not constitute either UNIVERSITY or ERC as agents or legal representatives of MEMBER. UNIVERSITY assumes all risk and liability for injury to persons or damage to property occurring during the period of the Agreement and caused by the acts of its employees while performing work at MEMBER’s facility under the terms of this Agreement. The obligations of UNIVERSITY hereunder shall not apply to liability arising from use of information furnished pursuant to this Agreement.

14. All noted confidential information submitted to UNIVERSITY by MEMBER will remain as such unless written permission granting public dissemination is received and vice versa.

15. The provisions contained herein constitute the entire Agreement and supersede all previous communications or representations, either verbal or written, between the parties hereto with respect to the subject material hereof. This Agreement may not be changed, altered, or supplemented except by written amendment hereto, signed by all parties. It is further agreed that nothing contained in the Agreement shall modify, amend, or supersede any prior or subsequent arrangement between MEMBER and UNIVERSITY with respect to activities outside the scope of this Agreement.

IN WITNESS WHEREOF, this Agreement is effective as of the last date of signing set forth herein below, which day and month in subsequent years in which MEMBER adheres to the terms of this Agreement shall be called the anniversary date of this Agreement.

UNIVERSITY MEMBER

Authorized signature signature

Authorized

Title Title

Date Date

Initial to indicate appropriate partnership category:

MEMBER $XX; $XX; $XX

[1] While this sample agreement is intended to an example of the structural framework of an agreement, the actual language in the agreement should be developed in conjunction with the university's legal counsel.

--------------------- RESUME HERE 11/15/19

Chapter 6: Administrative Management

(rev. Dec. 2014)

6.1 Introduction

This chapter addresses the daily operation of a National Science Foundation (NSF) Engineering Research Center (ERC). Suggestions are based on common experiences shared by existing centers, but there is no "right" way to manage an ERC. Major differences among institutions call for diverse management strategies; it is important to understand the institutional environment and then use the most relevant and helpful ideas. The lead institution of the ERC is responsible for administrative management, but the distribution of effort should be shared among the center's partner institutions. Specific tasks and responsibilities will change over time and may vary depending upon the management structure of the specific ERC, the university culture, and the experience and strengths of the leadership team. This chapter addresses the functions required to administer a diffuse enterprise with multiple academic partners, outreach institutions, industrial partners, faculty, professional and classified staff, and graduate and undergraduate students – across multiple time zones, cultures, and geographic areas. A new Administrative Director (AD) will discover that the most valuable resource is the vibrant and supportive community of ERC ADs that exists across the country. The Google Group site and listserv, the biennial NSF-ERC meetings, and the AD summer retreats all offer opportunities to collaborate with peers and build a network. A successful AD will utilize interpersonal, organizational, and management skills to facilitate the work of the center and foster an environment of collaboration and excellence.

6.1.1 Structure and Organization

There is no ideal organizational scheme for an ERC; every center will be (and should be) unique. The creativity that the ERC team brings to the development of the center can serve as a model for future developments within the lead institution and the academic partner institutions as well. Managing such a complex enterprise requires a sophisticated administrative structure and resources which are not typically available to a standard university department or single-investigator project. Every center is required to create and update an organization chart which should reflect the role of the department chair, dean, and other university officials in the center's infrastructure. Keep in mind that the governing instrument for an ERC is the NSF Cooperative

Agreement, which is a specific type of award that emphasizes substantial agency involvement. The ERC Annual Reports and Site Visit Reports are key components of this involvement and the NSF Program Officer (or Program Director) is the individual who helps to guide the center throughout the life of the project. NSF does provide a start-up visit for the leadership team and also offers a consultancy visit for the new AD to help get things organized.

See Attachment 6.1 – Sample Organization Charts

See Attachment 6.2 – ERC Consultancy Guidelines

Critical Questions

- Will the center be a financially autonomous unit with independent bookkeeping or will financial management be distributed?
- How is the university-sponsored research office organized? Does it have separate "pre-award" and "post-award" units or are the responsibilities delegated by sponsor? Does the university offer training for sponsored-program management and accounting? Who is the Authorized Organizational Representative (AOR) for the lead institution?
- How will the partnerships with subcontractors be managed?
- How will the projects and thrusts be organized across multiple institutions to facilitate the implementation of the strategic research plan?

Key Definitions

Core Project (or center-controlled project) – Projects that are supported with center-level funds from NSF and possibly other unrestricted funds under the center's control (e.g., membership fees from the Industrial Advisory Board) and in a center account. For reporting purposes, individual projects should be grouped together into clusters or thrusts that have multiple faculty members and a substantial budget.

Associated Project – A project that is central to either the research strategic plan or education strategic plan that is awarded to the home department of an ERC faculty member. Associated project funds are not controlled by the center and are reported as indirect sources of support. Only direct costs for these projects should be reported (no indirect costs or reserves remaining).

For associated projects whose funding is part of a larger award that includes faculty outside the center, include only the funding percentage that is directly in support of the center's strategic plan or vision, and only the percentage budgeted for the Current Award Year. It should be documented how this prorating was calculated. (This definition might be updated by NSF.)

Sponsored Project – Projects with a restricted or directed purpose that is specified by the funding source. Sponsored projects augment the center's core activities. The award goes directly to the center for a specific project and is classified as restricted cash. Examples of sponsored projects include Research Experiences for Undergraduates (REU) supplements, Defense Advanced Research Projects Agency (DARPA) awards to the center, and industry-sponsored projects with clearly intended outcomes or activities.

6.1.2 Role of the Administrative Director

As a key member of the management team, the Administrative Director will serve the entire ERC as the guardian of resources, policies, and myriad detail. To be effective, the AD must have some knowledge of all center activities and maintain a big-picture perspective. The AD will need to consider the needs of all stakeholders (NSF and the ERC program, academic and industrial partners, funding sponsors, faculty, students, foreign collaborators, and staff) and balance potentially competitive internal resource demands among research, education, technology transfer, and management initiatives.

The AD needs to develop a strong and efficient infrastructure to enhance collaboration and facilitate the work of the center. The AD plays an important role in strategic planning by adding an operational perspective and by providing the "glue" that holds the various administrative functions of the center together. Below are some of the key characteristics of an effective Administrative Director:

- Executive mindset
- Optimistic and positive attitude
- Organizational skills and attention to detail
- Strong interpersonal skills such as being respectful of differences in work styles, , diplomatic, and having a collaborative attitude toward meeting challenges Flexibility to respond to changing demands
- Financial management experience
- Ability to guide and advise the leadership team in a forthright manner and with clear and thorough information
- Ability to work independently and exercise good judgment and discretion
- Excellent problem-solving skills to address difficult, complex issues
- Ability to multitask, prioritize, and delegate
- Institutional knowledge and experience with sponsored research.

***Tip**: It is recommended that the AD become actively involved in at least one professional organization that monitors changing standards, such as the National Council of University Research Administrators (NCURA), the Society of Research Administrators International (SRA), or the National Association of College and University Business Officers (NACUBO).These contacts and resources for continuing professional education are very valuable.*

See Attachment 6.3 – Sample AD Job Descriptions

6.1.3 ERC Operational Functions

The first order of business will be to review all the ERC operational functions and create a staffing plan in close cooperation with the leadership of the center. The administrative structure should be designed to support the strengths and expertise of all the team members. The AD will need to delegate tasks and responsibilities and establish priorities and goals for center administration. ERC operational functions typically include the following:

- Administrative coordination of center activities
- Program grant/contract administration and compliance
- Accounting/financial planning
- Human resources management
- Information Technology – systems development, database design, and management of data
- Annual report production
- Communication and public relations
- Conference and events planning and management
- Facilities management.

6.1.4 ERC Life Cycle

ERCs attract creative, entrepreneurial individuals who are eager to build something new. An ERC continually balances a dynamic tension between creative change and organizational stability. The focus on innovation helps to explain the unique character of the NSF ERC, and management expectations will shift over time. The exciting bursts of activity required to do something for the first time are replaced by a heightened focus on longer-term goals so that delegation, collaboration, and teamwork become increasingly important as the center evolves. . An effective AD should be able to handle any of these challenges to help the center achieve its stated vision.

Major transition periods may be precipitated by NSF Annual and Renewal Site Reviews, industrial and advisory board input, construction of new facilities, major remodeling activities, physical moves, and the eventual phase-down of NSF support in the later years of the award. Centers will need to respond to significant changes affecting the university partners, government and industry. Changes in the leadership team, participating faculty, key program staff or University officials may also impact the strategic plans of the center. Management plans need to be flexible and responsive to these forces in addition to the evolving research. Figure 1 illustrates the key components of an ERC “year.”

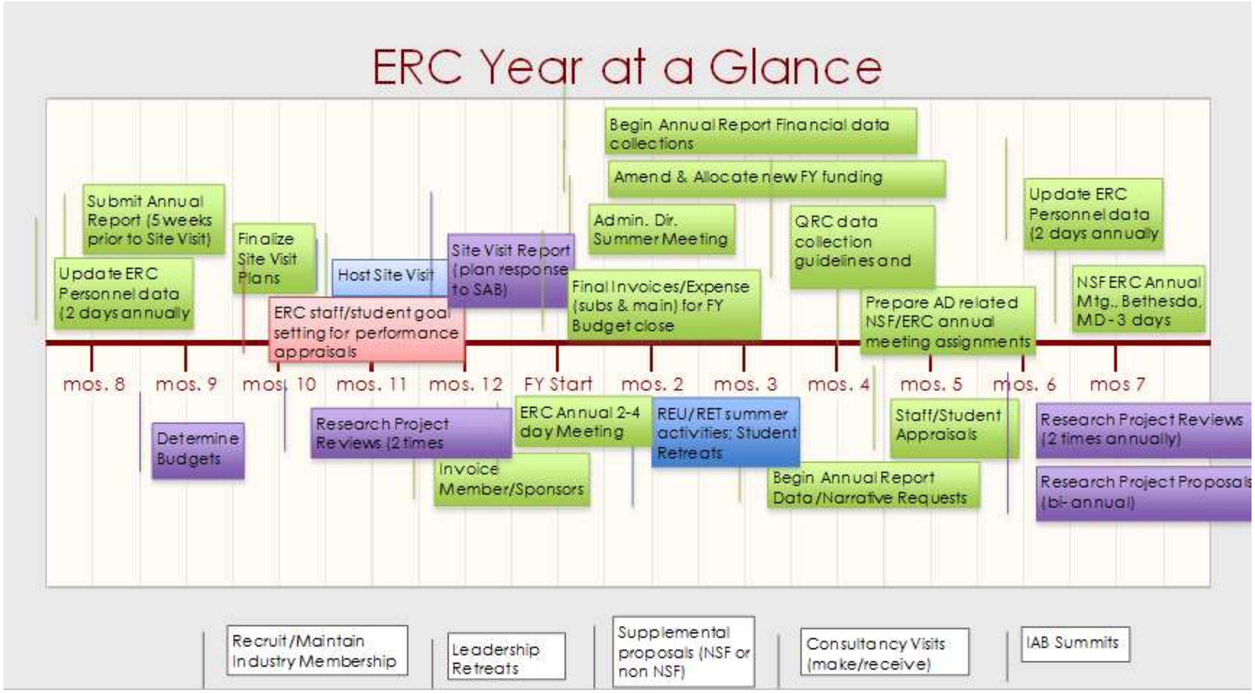


Figure 1. ERC Year at a Glance (Credit: Lisa Wissbaum, ERC for Compact and Efficient Fluid Power, University of Minnesota)

6.1.5 Reporting Time Periods

It is critical to understand the multiple fiscal and reporting time periods for an ERC. This information will guide the development of financial and management systems.

Key Definitions

Award Year – A 12-month period that begins on the date that the ERC first receives NSF funding, which is the official "award date." The Award Year start and end dates remain constant throughout the life of the center.

Reporting Year – A 12-month period established by the timing of the annual site review and established when a center is first formed. The Reporting Year end date is set by the center and is no more than 2 months before the Annual Report due date which is 5 weeks prior to the first site visit date. Once the Reporting Year has been set, it remains constant throughout the life of the center and covers 12 months of data. (There is an exception to this rule for some of the Class of 2006.) A Reporting Year is established to allow for consistency of data, since the Annual Report is submitted several months before the actual end of the Award Year.

Fiscal Year – The Federal Fiscal Year runs from 10/1 to 9/30. Each partner institution's Fiscal Year and State Fiscal Year can differ.

The term "year" may also refer to the Calendar Year or the term of an industrial partnership. In addition, the ERC program requires data based on the Prior and Current Reporting and Award Years as well as promised and actual funding information. These distinctions have a profound impact on management and reporting of budgets, revenues, and expenses. It is important to understand the ERC reporting requirements and the University's financial system in order to generate reports for specific time periods, and it is usually necessary to create a shadow system. The Guidelines for ERCWeb Data Entry provide more detail.

6.10 Summary

"The goal of the ERC Program is to integrate engineering research and education with technological innovation to transform national prosperity, health, and security. ERCs create an innovative, inclusive culture in engineering to cultivate new ideas and pursue engineering discovery that achieves a significant science, technology, and societal outcome within the 10-year timeframe of NSF support." *NSF 15-589*
https://www.nsf.gov/pubs/2015/nsf15589/nsf15589.htm

It takes time to design an organizational structure that will facilitate achievement of these goals. The Administrative Director can lead the effort to provide stable yet flexible management systems, while working with and challenging existing institutional policies and procedures. In addition, the AD can play a key role in establishing priorities, managing conflicts, dealing with barriers and promoting the work of the Center. The ERC will evolve as the team is constructed and all members work together to integrate and implement the ERC key features of research, workforce development and innovation ecosystem development.

6.2 Program Administration and Compliance

It is important to work closely with the institutional sponsored programs offices to manage this large, complex cooperative agreement with many academic and industrial partners. ERCs push the envelope in regards to research, technology transfer, education and outreach, and administration as well. The AD should take the time to meet with the people who help manage proposals and awards and understand their roles in order to learn how to move things through the system. In addition, the AD should do the same with administrative staff at partner institutions, since most people feel excited and proud to be part of such a dynamic program. The AD will create a "win-win" situation by integrating administrative personnel into the project and inviting them to meetings and reviews. The "Authorized Organizational Representative" (AOR) is usually the director of the institutional sponsored programs office, and the AD will interact with her/him throughout the life of the center. The goal is to fulfill the terms of the cooperative agreement while adhering to laws and rules of federal, state and local government, the academic institutions, the ERC program, and the NSF – this is not always straightforward. Understanding the rules and keeping good records is a shared responsibility between the lead institution and the academic partners.

Tip: *Regular teleconferences with financial and sponsored programs staff at each partner institution can facilitate communication and minimize misunderstandings and problems.*

6.2.1 Award Management Resources

It can be confusing to know where to look for information or guidance. The AD should become familiar with key award management reference documents and websites.

- **ERC Library** – This website is maintained by the developer (ICF International) of the ERCWeb Annual Report Data Entry System. The library contains Guidelines for Preparing Annual Reports and Renewal Proposals, Guidelines for ERCWeb Data Entry, Annual and Renewal Site Visit Guidelines, Performance Review Criteria and Protocol, Glossary of terms, and other useful ERC program specific documentation. *https://www.erc-reports.org/public/library*
- **ERC Association website** -This website is a resource for all those involved in the NSF ERC program. It contains information on the program, the individual centers, and their achievements, research initiatives, innovation ecosystem development, education programs, and the ERC Best Practices Manual.*http:/erc-assoc.org*
- **Cooperative Agreement** – Each center's official cooperative agreement with NSF can be found on the NSF Fastlane website under the Principal Investigator's login. *https://www.fastlane.nsf.gov/*
- **NSF Award Conditions** *http://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF*
- **Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards2 CFR Chapter I, and Chapter II, Parts 200, 215, 220, 225, and 230** . This "omni-circular" or "supercircular" consolidates the regulations of eight OMB circulars (A-21, A-50, A-87, A-89, A-102, A-110, A-122, A-133) into one uniform set of regulations for all grant recipients. Effective December 26, 2014. *http://www.ecfr.gov/cgi-bin/text-idx?SID=1d6de4ac49815c17087194eb72498042&tpl=/ecfrbrowse/Title02/2cfr200_main_02.tpl*
- **Proposal and Award Policies and Procedures Guide** (includes Grant Proposal Guide (GPG) and Award and Administration Guide (AAG) *http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf14001&org=NSF*

Circulars which will be replaced by the super-circular on December 26, 2014:

- OMB Circular A-21, Cost Principles for Educational Institutions-Relocated to 2 CFR, Part 220 (30 pages) *http://www.whitehouse.gov/omb/circulars_a021_2004/*

- OMB Circular A-110, Uniform Administrative Requirements for Grants and Other Agreements with Institutions of Higher Education, Hospitals and Other Non-Profit Organizations - Relocated to 2 CFR, Part 215 *http://www.whitehouse.gov/omb/circulars_a110/*
- OMB Circular A-133, Audits of States, Local Governments and Non-Profit Organizations (includes revisions published in the Federal Register *http://www.whitehouse.gov/sites/default/files/omb/assets/a133/a133_revised_2007.pdf*

Key Definitions

Authorized Organizational Representative (AOR)/authorized representative – The administrative official who, on behalf of the proposing organization, is empowered to make certifications and assurances and can commit the organization to the conduct of a project that NSF is being asked to support as well as adhere to various NSF policies and grant requirements. *http://www.nsf.gov/pubs/policydocs/pappguide/nsf14001/index.jsp#definitions*

Cooperative Agreement – Type of assistance award which should be used when substantial agency involvement is anticipated during the project performance period. Substantial agency involvement may be necessary when an activity is technically and/or managerially complex and requires extensive or close coordination between NSF and the awardee. Examples of projects which might be suitable for cooperative agreements if there will be substantial agency involvement are: research centers, large curriculum projects, multi-user facilities, projects which involve complex subcontracting, construction or operations of major in-house university facilities, and major instrumentation development.
http://www.nsf.gov/pubs/policydocs/pappguide/nsf14001/index.jsp#definitions

6.2.2 Compliance Decisions

Official guidance on grant compliance is contained in the Office of Management and Budget publication, 2 CFR Chapter I, and Chapter II, Parts 200, 215, 220, 225, and 230 Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards. This "omni-circular" or "supercircular" consolidates the regulations of eight OMB circulars (A-21, A-50, A-87, A-89, A-102, A-110, A-122, A-133) into one uniform set of regulations.

Figure 2 illustrates the many factors involved in making grant management decisions The NSF Cooperative Agreement is the ruling document for each center, but this document must be considered in relation to institutional policies and public laws, as well as the ERC Program Rules, the NSF Agency Terms and Conditions, and the OMB Circulars. It is always smart to document the reasoning behind complex decisions as the center works to establish clear and consistent policies.

Figure 2. Compliance Diagram

6.2.3 General Cost Principles for Educational Institutions

Academic institutions will have procedures and policies in place to ensure that all costs charged to federal grants are allowable, allocable, and reasonable.

- **Allowable** – must meet the sponsor's definition of categories permissible to be charged to the project it funds
- **Allocable** – costs must be charged to a project in proportion to the benefit received
- **Reasonable** – the action that a prudent person would have taken at the time the decision to incur the cost was made.

This determination can be complicated however, especially since an ERC is charged with creating an innovative innovation ecosystem and must interact with industry and a Student Leadership Council in non-traditional ways. It can be challenging to characterize the various types of support such as grants, industrial membership fees, donations, gifts, and other contributions. Document the decisions and reasoning and be as consistent as possible.

6.2.4 Audits of Federal Awards

Annual audits of federal awards are conducted at each academic institution, and the NSF ERC program award may be selected for audit at any time. Expenditures on federal awards must comply with the Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards. Always check institutional rules and work with local accounting offices to monitor compliance; but some high-level guidance is provided below:

Mandatory Cost Share and Matching Funds Information – Closely monitor compliance with mandatory cost sharing obligations stated in the cooperative agreement and keep documentation. Committed cost share effort should also be tracked. Note that industrial membership fees are considered program income generated as a result of a federally sponsored project, making program income unallowable as eligible cost sharing

Sub-recipient Monitoring – PIs are required to monitor the activities of sub-recipients to ensure that performance goals included in the subaward are achieved and cost share commitments are documented. All sub-recipient invoices must be approved and signed by the PI attesting that charges are consistent with the scope of work and within the approved budget for the sub-recipient.

Cost Transfers and Timeliness of Charges – All charges and cost transfers should be processed within 90 days of the original transaction. Transfers exceeding the 90 day limit will usually require a detailed justification. All cost transfers require explanation of the original error and justification of transfer to the grant.

Administrative and Clerical Salaries – The salaries of administrative and clerical staff are not normally directly charged to a federal grant, but direct charging of these costs is allowed for major projects such as an ERC if the budget explicitly provides funds for administrative or clerical staff to complete specific tasks. New guidance suggests that administrative support that is integral to the project may be allowable.

Administrative Supplies and General Purpose Equipment – Administrative supplies (copy paper, toner, bottled water, etc.) and general purpose equipment (desktops and laptops, cell phone charges, fax machines, and copiers) are not normally directly charged to a federal grant unless there is a specific requirement in the grant for these items and the items are used primarily and directly for the project.

Subsequent Changes in Level of Effort from Proposal – PIs are required to notify NSF if their percentage of effort changes significantly from the level specified in the proposal.

Program Income – PIs should ensure that all program income is properly calculated, recorded and expended in accordance with program requirements.

Disclaimers and Acknowledgments Contained in Publications – PIs should ensure that all publications and presentations include proper disclaimers and acknowledgments of NSF support.

See Attachment 6.4 – Sample NSF Acknowledgment Language

Timely Filing of Progress and Technical Reports – PIs should ensure that the Annual Report is submitted to the NSF Program Officer, to Fastlane and Research.gov, and that print and CD copies are mailed to NSF by the required due date.

Disposition and Transfers of Equipment – Be sure to track the purchase, transfer, and disposal of all equipment. Equipment transfers to other institutions, changes in location and disposals of equipment need to be authorized and processed correctly according to the rules of the institution.

6.2.5 Responsible Conduct of Research (RCR)

Each academic institution is required to ensure that research is conducted in an ethical manner. Determine the institutional requirements and set up a plan to facilitate compliance. This can entail an online training program or a simple signed acknowledgement, but it is specific to each institution. Refer to Section 7009 of the “America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act (42 U.S.C. 18620-1).” This section of the Act requires that “each institution that applies for financial assistance from the Foundation for science and engineering research or education describe in its grant proposal a plan to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduate students, graduate students, and postdoctoral researchers participating in the proposed research project.”*http://www.nsf.gov/bfa/dias/policy/rcr.jsp*

6.2.6 Protection of Human Subjects

Each academic institution in the ERC will need to adhere to the Code of Federal Regulations for the Protection of Human Subjects (45 CFR 46)

There is usually an office on campus responsible for monitoring protection of human subjects and the center research may require approval of an Institutional Review Board (IRB). The experts on each campus can offer guidance to ensure compliance.

The NSF supports research involving human subjects when the project has been certified by a responsible body to be in compliance with the federal government's "Common Rule" for the protection of human subjects. The official NSF version of Code of Federal Regulations 45 CFR 690.101-124 is available at *http://www.nsf.gov/bfa/dias/policy/docs/45cfr690.pdf*. The regulations give grantee institutions the responsibility for setting up "Institutional Review Boards" (IRBs) to review research protocols and designs and ensure the protection of the rights of human subjects. *http://www.nsf.gov/bfa/dias/policy/human.jsp*

6.2.7 Effort Reporting

Effort reporting is the federally-mandated process by which the salary charged to a sponsored project is certified as being reasonable in relation to the effort expended on that project. Each academic institution establishes a process for effort reporting and the documented policies and procedures must meet the federal standards. Effort reporting is usually done on an annual basis, but it is important to understand the concept so that salaries can be apportioned appropriately throughout the year.

6.2.8 Conflict of Interest

Each academic institution will have a Conflict of Interest (COI) policy and will construct a management plan when a conflict is disclosed. An actual, potential, or appearance of conflict between the personal interests of the individual and the University or the public are addressed by a University Board or central administrative office. Financial conflicts of interest can arise in an ERC due to the involvement of industrial partners and the development of the innovation ecosystem. Refer to the Guidelines for Preparing Annual Reports and Renewal Proposals for specific reporting requirements and see Chapter 5, Section 5.3.4 of this Manual for further information.

6.2.9 Intellectual Property

ERC researchers work at the interface of discovery and innovation, and will therefore generate intellectual property and deal with technology transfer. Section 5.3.2 of the this Manual presents detailed information, but the Administrative Director should be prepared to work closely with the ERC's Industrial Liaison Officer and the lead and core partner institutional offices to facilitate transactions such as:

- Documentation of Invention disclosures
- Licenses
- Patent process
- Materials Transfer Agreements (MTAs)
- Confidential Disclosure Agreements (CDAs)
- Intellectual property clauses for Sponsored Research Agreements
- Industry membership agreements.

6.2.10 Sub-recipient monitoring

Academic partners of the ERC will have subcontracts (or subawards) that outline the responsibilities of each party. These institutions may be called sub-awardees, subcontractors, or sub-recipients. The technical and programmatic section of the contract will detail requirements for progress reports, deliverables, and milestones. The financial section will specify dollar amounts and invoicing procedures, and the contract will always follow the institutional policies and terms of the NSF Cooperative Agreement. The AD should work closely with the Sponsored Programs office to make sure that the means of monitoring activities and measuring compliance are appropriate.

6.3 Financial Management

Once the Cooperative Agreement award has been received and reviewed by the university research office, a notice of award is sent to the Principal Investigator. The notice should contain the award/proposal number, budget period, any cost-sharing requirements, a continuation statement, terms and conditions, the Principal Investigator and key personnel, the sponsor's code for type of funding, period of the award, report dates, and a copy of the full Cooperative Agreement. These are key documents for every ERC.

6.3.1 Developing a Financial Management System/Chart of Accounts

A new center then needs to establish a financial management system in order to allocate and disburse funds and begin work. The system should reflect the interdisciplinary nature of an ERC and the complex program reporting requirements, and should function in compliance with federal, state, and institutional regulations. It's important to work with the university accounting department to design a Chart of Accounts (COA) and determine how the shadow system will interact with existing institutional systems to manage all center sources of support and expenditures. Read the Guidelines for ERCWeb Data Entry to understand the level of detail required. Give careful thought to the coding system as well, since this is the heart of the center's internal reporting structure. For example, some centers establish a "parent-child" account relationship in order to maintain stronger control of subsequent resource distribution. The "parent" account(s) may be sub-divided into various "child" accounts for the purpose of distributing funds to the proper research thrust and sub-thrust areas. Keep in mind that “center control of funds” is a key ERC management principle and impacts reporting in all areas.

Critical Questions

- Does the university provide financial management information in a timely manner? Will reports reflect activity and encumbrances immediately and give an accurate report of funds remaining?
- Do the codes embedded in the university's central system include all of the expense and revenue categories required for ERC reporting?
- Does the general ledger system allow posting of "soft" money or "pre-encumbrances"?
- Is the system interactive or query-only? How are the parameters for queries set?
- Can the center’s shadow system be linked with the university system? How will the ERC’s system records be reconciled with the central ledger?

The center will need to develop the operating budget and then determine the schedule for routine and in-depth budget reviews. Periodic summary activity reports or spending projections may be required; their frequency will depend upon the complexity of the budgets and the needs of the center management team, thrust leaders, individual PIs, and the university administrators. Evaluate the system from each of these "customer" perspectives to see if the necessary detail is captured. The structure should help to organize, support, and enhance center activity, but not rule the strategic planning process. Ensure that all on the leadership team understand the center budget principles.

6.3.2 Time Periods

In establishing the system and developing budgets, it is essential to understand the reporting time periods (Award and Reporting Years; Current, Prior, and Proposed) and concepts such as funds that are “received” or “promised.” Refer to the Guidelines for ERCWeb Data Entry and be sure to make use of the glossary. The Award Year will be based upon the award date of the NSF Cooperative Agreement and will be noted in all official correspondence. The Reporting Year is established by the center in the first year of operation to facilitate consistent data reporting due to the fact that the Annual Report is submitted before the Award Year is complete. Once set, these dates do not change over the life of the center. Other sources of funding may have different fiscal periods, and these differences will have an impact on the management of budgets, revenues, and expenses.

Critical Questions

- Which funds can be "rolled forward"? (Must you "use it or lose it"?)
- How is "carry forward" calculated and managed? Is carry forward managed consistently at each partner institution and is it sponsor dependent? Clarification is needed to avoid reporting problems.
- Will you need to budget split fiscal years for revenues and expenditures? How will you reconcile different fiscal years in summary reports for all funds?
- How will you "close" your books at the end of each fiscal year? What steps are needed to ensure that internal re-budgeting decisions are posted within the central system?
- How will you manage grant close-outs and final reporting?

6.3.3 Financial Support

Financial support for the ERC comes from many sources, and the way the institution handles the funds might not match the way the support is reported to the ERC program. It is important to know the type, sector, location, and size of each organization that provides support. It is also necessary to understand the type of support and value of the support that is being provided. The institution may differentiate between grants, cooperative agreements, supplemental awards, contracts, gifts, and membership fees for account setup, and then the ERC program reporting will require additional specificity. Refer to the Guidelines to ERCWeb Data Entry for specific details.

Key Definitions

Direct Costs – Costs readily identifiable and related directly to the goods or service provided. Examples include salaries (including tuition remission), fringe benefits, general operating expenses such as materials and supplies, travel, facilities, and equipment.

Direct Sources of Support – Funds provided directly to the center and identified as either "Restricted Cash" (for a purpose specified by the sponsor such as an ERC sponsored project) or "Unrestricted Cash" (no specific purpose specified).

Indirect Costs – The overhead cost charged to a grant or contract by the institutional sponsored program's office. Also referred to as "overhead" or "facilities and administrative costs."

Indirect Sources of Support – Funding to an ERC faculty member's department for a project that is vital to the ERC's research and is in its strategic research or education plan. These projects are called "associated projects." Only direct costs for associated projects should be reported (no indirect costs or reserves remaining). Indirect support is reported at the project level in Tables 2 and 11 and collectively in Table 9 on ERCWeb.

Tip: *Include specific language regarding how financial data should be reported in the subcontracts to partner institutions.*

In-Kind Contributions and Gifts – If the center is the beneficiary of in-kind support (new construction, new facilities, visiting personnel time, etc.), the value of these contributions or gifts will need to be determined and recorded. Become familiar with university policy and procedures for recognizing such gifts as revenue and recording them in the property inventory.

Tip*: Collect in-kind documentation throughout the year and, ideally, as soon as the contribution is received, but definitely before the end of the calendar year. Companies will want their records to accurately reflect contributions for tax purposes. Document the value with a letter signed by the contributor and verify the amount.*

Cost-share – It's important to clarify terms such as "cost-sharing" and "matching," as they may have different interpretations at the agency, program, and institutional levels. Cost-share requirements for the ERC program will be spelled out in the NSF ERC Cooperative Agreement, and the institutional policies will impact how cost-share is implemented and documented. Cost-share certification is required yearly, so it is useful to work with the Authorized Organizational Representative (AOR) of the lead institution to determine how this will be accomplished. The subcontract agreement should specify what is required of the partner institutions.

6.3.4 Budgets/Re-budgeting

AnERC must create and maintain budgets by expense category as well as by function, for reporting purposes and for center management across thrusts and institutions. The requirements are detailed in the Guidelines for ERCWeb Data Entry. Re-budgeting is often required in response to the annual site review or sponsor needs. Although the process can be time consuming and complex, it may be necessary as milestones are achieved, timelines fluctuate, and strategic plans evolve. Effective financial management strategies make best use of total resources and manage cash flow aggressively.

6.3.5 Expenditure Budget Categories

The ERC Expenditure Budget includes the expense categories that match the standard NSF Form 1030. Output of this information is displayed in Annual Report Table 10.

1. Salaries – Senior personnel
2. Salaries – Other Personnel
3. Fringe Benefits
4. Equipment
5. Travel
6. Participant Support
7. Other Direct Costs
8. Indirect Costs

6.3.6 Functional Budget Categories

The ERC Functional Budget is input to the ERCWeb on several screens and the output is displayed in Annual Report Tables 8 and 8c.

- Research Thrust
- Education Programs
- Pre-College Activities
- University Education
- Student Leadership Council
- Young Scholars
- REU
- RET
- Assessment
- Community College Activities
- Other (explain in narrative)
- General and Shared Equipment
- New Facilities/New Construction

- Leadership/Administration/Management
- Industrial Collaboration/Innovation Program
- Center-Related Travel
- Residual Funds Remaining
- Indirect Cost

Tip: *It may be useful to develop initial budgets for each major funding source, documenting the intended use or purpose of separate funds and identifying any restrictions or cost-sharing requirements.*

Tip*: The return of Facilities and Administration (F & A) funds, also referred to as "overhead" or "indirect," is a significant factor in the budget of some centers. Take the time to understand how this is calculated at your institution and incorporate this into the budget.*

6.3.7 Leveraging Funds

The concept of "leveraged funding" is important for the achievement of ERC goals. By design, projects are highly interwoven and dependent upon one another, and the budget for an ERC does not come solely from NSF. The center's budget may be complex, reflecting multiple funding sources with different award periods and different expectations. Utilize funds to maximize the return on investment by each sponsor. A mixture of long-term and short-term awards means that the center budget may exceed the limited time frame set for most university budget development processes. Allocations will cross department, college, and institutional boundaries.

Reporting on Associated Projects can be complicated, as there is judgment involved in determining the percentage of the award that is applicable, and the start and end time periods will vary. If the award is split funded and treated as such in the University accounting system up front, then the center will have control of the funds and reporting is more straightforward. If not, then the rules for Associated Project reporting apply.

Key Definition

Associated Project – A project that is central to either the research strategic plan or education strategic plan and that is awarded to the home department of an ERC faculty member. Associated project funds are not controlled by the center and are reported as indirect sources of support. Only direct costs for these projects should be reported (no indirect costs or reserves remaining).

For associated projects whose funding is part of a larger award that includes faculty outside the center, include only the funding percentage that is directly in support of the center's strategic plan or vision, and only the percentage budgeted for the Current Award Year. It should be documented how this prorating was calculated.

6.3.8 Financial Reporting

The financial reporting for the center will be shaped by the ERC program requirements as outlined in the reporting guidelines and in conjunction with existing institutional policies and the center management needs. Work to understand the ERC program requirements and then determine what variations or additional information may be needed. Maintaining documentation is critical for audit purposes and the ERC leadership team should be able to justify and backup everything that is submitted in the Annual Report. Be sure to also follow institutional retention policies. The following information must be easily accessible either centrally or within the ERC:

- Proposals and revisions or amendments
- Award notice with terms and conditions
- Budget and expenditure detail
- Cost share documentation
- Subcontracts with all associated documentation
- Equipment requisitions
- Service agreements
- Financial reports, including narrative/technical reports
- Invoices
- Project/grant close-out documents
- Agreements and MOUs
- Checks received as payments
- In-kind donations documentation of value
- Industrial relationship correspondence if a membership agreement is not in place.

Tip: *Remember that final reports may be required by the university as well as each sponsoring agency as part of the grant closeout requirements. Detailed information on expenditures, residuals, personnel (including person-months per category), technology licensed, patents, publications, and a research progress report may be needed.*

6.3.9 Financial Accounting

Financial accounting functions may be performed by the university central accounting office, department and\or ERC staff. There are varying levels of authority required for transaction processing and approvals, so work to confirm institutional role expectations early on and create efficient procedures. Financial accounting tasks include:

- Account set up and maintenance
- Budget creation and maintenance
- Membership and service fee invoicing
- Accounts Payable
- Accounts Receivable
- Expenditure review and projections

Key Definitions

Cash Basis Accounting – records revenue when received, records expenses when paid.

Accrual Basis Accounting – records revenue when earned (but not necessarily received), records expenses when incurred (but not necessarily paid for).

6.3.10 Pre-Award Spending Authorization

A PI may sometimes request authorization to begin spending before the official award has been received by the university. This will require sponsor confirmation of the award amount, start and end dates, and an estimate of when the formal award will be processed. It can be useful to set up accounts and begin spending as soon as notification is received, so look into the institutional requirements for pre-establishment of accounts. Pre-award authorization may also facilitate the distribution of continuation or renewal funds.

6.3.11 Human Resources

The financial management of human resources is integral to center operations. Personnel and positions change over time and the systems should be flexible.

Key Considerations

- Development of position descriptions
- Tracking staff appointments, changes, and terminations
- Payroll processing
- Effort reporting
- Compliance with union requirements
- Negotiation/processing of classified vs. professional positions
- Resolution of Visa/citizenship issues

Tip: *Research universities are required to maintain an effort-reporting system that allows faculty, staff, and student employees to certify the portion of their total effort expended in support of each sponsored project. Be sure to understand the institutional effort reporting system when making appointments or salary commitments.*

6.3.12 Purchasing

The university will have established policies and procedures for purchasing goods and services that adhere to federal regulations. The cost principles governing expenditures of federal funds and procurement procedures are contained in the Office of Management and Budget publication, Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards 2 CFR Chapter I, and Chapter II, Parts 200, 215, 220, 225, and 230.

Design a system to support the acquisition of materials, supplies, and equipment in a timely and efficient manner. Determine responsibility for processing and tracking purchase documents, approval of acquisitions, and processing of payments. Centralized purchasing functions allow for strict monitoring and control of center funds. Decentralized systems may seem more efficient, but may not facilitate collaborative research as effectively. Decisions regarding purchasing strategies should be made early on and communicated to the entire center leadership team.

If funds are available for physical plant/infrastructure needs, the center will need to manage the funds and be responsible for inventory records and property accounting. In some cases the expenditures for physical plant will also meet cost-sharing commitments. Refer to institutional policies regarding depreciation of equipment, as this is often handled differently at each university.

6.3.13 Audits

The center is subject to both internal and external audits. Audits may be financial and/or operational and the purpose is to show that the ERC is well managed and in compliance with the institutional policies and federal regulations. An auditor may review all records, processes, and purchases. See Compliance section.

Tip: *There isn't adequate time to organize your records during an audit; be prepared from the first day of the award setup. Retain as much detailed information as possible.*

6.3.14 Proposals and Supplemental Funding Requests

Each university has a proposal submission process that complies with sponsor requirements and state and federal regulations. This is usually managed by the sponsored programs office. An ERC will submit renewal proposals in Years 3 and 6, and may also submit proposals to other sponsors or request supplemental funding from NSF throughout the life of the project. Each of these requests for funding will be managed according to sponsor and institutional requirements. There might be a published solicitation with very specific guidelines, or the funding opportunities might be more open-ended and flexible. Sponsors can include federal, state, or local government agencies, industry, academia, foundations, or non-profit entities. An ERC is expected to supplement the main award with funds from multiple sources, so submitting proposals and managing new awards and supplements is an ongoing activity which ramps ups as plans for self-sufficiency develop.

6.4 Human Resources

NSF expects the ERC to rest on a culture of inclusion where faculty, students, and staff from all backgrounds have an opportunity to succeed in research, education, innovation, and administration. Thus, the leadership team, faculty, students, and staff involved in an ERC will be diverse in their experiences as well as diverse in gender, race, and ethnicity—i.e., women, African Americans, Native Americans, Pacific Islanders, Alaskan Natives, Hispanic Americans, or persons with disabilities who are U.S. citizens or permanent residents. The ERC also will be multicultural through the involvement of faculty and students from other countries by virtue of their role as faculty or students in the center's domestic institutions. The ERC may also include veterans as faculty, students, and staff, as well as members of the ERC's RET teacher corps. The goal is to have broad participation of groups underrepresented in engineering that exceeds the academic engineering-wide national averages and continues through time on an upward slope in relationship to those national averages. See the discussion under Infrastructure in the Gen-3 ERC solicitation: *http://www.nsf.gov/pubs/2013/nsf13560/nsf13560.htm*.

This diversity is expected of the participants from the lead and each of the partner academic institutions. While one of the partner institutions must serve large numbers of students majoring in STEM fields who are from groups underrepresented in engineering, that institution cannot be the only contributor to the diversity of the ERC. Collaborating foreign faculty are expected to respect the diversity of the ERC's faculty and students and provide inclusive research and education environments. Because of the multicultural nature of the ERC, the participants have to be mindful that the language of discourse in the ERC's laboratories will be English to maintain an inclusive environment for all. The lead and domestic partner universities are likely to have programs—some of them NSF-funded (e.g., ADVANCE, etc.)—and offices that are established to impact a culture of inclusiveness at the respective campuses. These programs and offices must be leveraged by the ERC. Annual reports will include quantitative information on the demographics of the ERC personnel, benchmarked against engineering-wide averages. Reports also will include information on progress and impacts in developing a culture of inclusivity and success for all of the ERC's faculty and students.

6.4.1 ERC Functions/Staffing Plan

To cover the required functions of an ERC, each center will need to develop a staffing plan based on existing talents, available resources, and priorities; and this plan will change over time. An informal study of 17 ERCs during the 1990s indicated that center support staff ranged in number from 3 to 19. The average number of administrative support staff was 7 FTE (full-time equivalents). The center's position in the ERC life cycle from startup to maturity will affect staff size and demand for support may be especially high during start-up and key transition periods. Effective staffing is essential to the success of the ERC; yet the pressures of starting a new center may lead to hurried hiring. Take the time to perform an analysis of the necessary functions, budget, and space available. Consider the use of temporary vs. permanent employees, student assistants, and outsourcing to university and external services or consultants. Remember the need for flexibility in managing ERC resources. Review the ERC's master planning calendar and evaluate peak periods and functional conflicts. In drafting employment agreements, be prepared to balance the pressures of ERC growth and new program development against a simultaneous need for downsizing and reorganizing due to program shifts and funding changes over time. Understand that orientation and training for all personnel is an ongoing task and facilitates the development of a cohesive team. Below is a general outline of ERC functions to help guide the process.

<u>General Management/Administration</u> – The Director, Deputy Director, and Administrative Director work together with the research leadership team to manage center operations and execute the mission of the center. Responsibilities include:

> *Program Grant/Contract Administration and Compliance* – Work with central university offices to comply with institutional regulations and to establish supplemental center policies to ensure compliance with NSF Cooperative Agreement terms and conditions.
>
> *Finances/Accounting* – A dedicated staff position will be needed to provide sound financial management of the ERC. Development of budgets and management of the sources of support and expenditures are critical functions and are immediately necessary. Establish a financial reporting system that reduces risk and enables proactive management. Include staffing to handle high-volume, routine tasks such as daily accounting, purchase orders, invoice processing, data base upkeep, and payroll operations. Determine how financial reports and projections will be produced; internally, at the department level, or by central staff.
>
> *Human Resources* – There are frequent organizational and personnel changes during the life span of the center, and it is an ongoing task to manage hiring, employee supervision, and delegation of responsibilities.
>
> *Information Systems* – Staffing this function adequately is pivotal to a smooth-running center. As an ERC matures, computer systems save valuable time and enable a small, coordinated ERC team to handle growing demands and constant change. Some centers have added system administrators to their staff. Others rely on faculty, students, or existing staff to introduce new technology and train others. Find the expertise to design databases, develop management systems, collect data for reporting, and maintain a website. The lead or partner institutions may provide resources, or the center may need to hire external vendors.
>
> *Communication* – There is a great deal of variability among existing centers in staffing this area. All centers must write, edit, and produce general and technical materials. Some centers have dedicated positions devoted to graphics, editorial, and/or multimedia/computer systems support, while others outsource the production of publications. Often, there are many professionals within the ERC able to make creative contributions to center publications.

Conference/Event Planning and Management – Site Visit, Research Retreats, planning and Advisory Board meetings all require extensive advance planning and attention to detail.

Infrastructure/ Facilities – Procuring and managing the physical space for the center is an intense startup activity but also an ongoing responsibility.

Administrative Assistance – Whether in a one-person office or a large staff, the individual who answers the phone and greets guests is the face and voice of the center. This first point of contact is tremendously important and the position demands professional judgment. Administrative assistance is required for all center functions and there are a multitude of routine tasks. Many centers have experienced problems in trying to find and keep good people in these posts; one solution is to supplement regular staff with student help.

Tip: *When university students are employed, the center must determine what constitutes appropriate student involvement that does not interfere with their educational objectives. Duties vary from routine office tasks to dissemination of information on the web; technical assistance; coordination of REU and other educational outreach activities; and computer support.*

<u>Research Thrust Leaders</u> – The leadership team includes faculty members from across the domestic partner universities responsible for leading and managing major research thrusts and testbeds of the ERC.

<u>Industrial Collaboration and Innovation Ecosystem</u> – The director for this function should be a staff member at the lead university who is responsible for developing the ERC's innovation ecosystem, marketing the ERC to industry/practitioners, gaining their financial support, developing and coordinating industrial/practitioner involvement with faculty and students, and managing the other partnerships for innovation and the translational research program.

<u>University Education Program</u> – The director of this function is a faculty member who is responsible for the development and execution of the ERC's university education program and is supported by other faculty, students, and staff in the execution of the program.

Student Leadership Council (SLC) – A student President and a student co-President lead the SLC, which is comprised of undergraduate and graduate students from all the partner universities. The SLC is responsible for coordinating activities in support of the ERC research, education, and technology transfer agenda.

<u>Pre-College Education Program</u> – The director of this function is a faculty or staff member who is experienced in pre-college education and is responsible for development and execution of the pre-college education program. The position is supported by faculty, students, and staff.

<u>Diversity</u> – The director of this function is a staff or faculty member who leads the development, implementation, and assessment of the center's diversity strategic plan. This person will have

proven success in recruitment and retention of underrepresented groups in engineering or STEM fields. This may be the sole role of this person within the ERC's Leadership Team or he/she may hold another role in the ERC as well.

CASE STUDY: How we staffed our administrative office

The ERC was in its first year when the AD began work nearly four months in. At that time, she was the only person doing all the administrative tasks associated with running the center. This situation was untenable. She worked with the Center Director to develop a strategy for effective staffing to manage the tasks. They reviewed the functions required to separate and identify the various categories and tasks. One of the most important and time-intensive functions was managing the expenditures. It was decided that the second admin person would maintain shadow budgets, manage expenditures, make and monitor purchases and invoices, provide financial reporting to the AD, university officials, and NSF, and provide database management and support. The AD would continue to work on all other administrative functions of the center. At that time, the University was going through a hiring freeze. Therefore, they were able to upgrade an existing position for someone already working with the Director on another grant as admin assistant. They worked with the university's Human Resources office to work this out and after some time, were able make this arrangement official. This position was supported by the College of Engineering and served as part of the institutional commitment.

(Submitted by Lois Dalton Deve, AD, NSF Engineering Research Center for Revolutionizing Metallic Biomaterials, at North Carolina Agricultural and Technical State University)

6.4.2 Position Descriptions

Many centers have found that existing university personnel titles and pay scales are outdated and do not fit their needs. It is smart to take the time to explore alternative titles and options, rather than accepting the most commonly used classifications. Review overall center functions and tasks before finalizing position descriptions. Institutional personnel experts should be able to offer guidance on employment categories/titles and they will ensure that the university complies with laws and regulations regarding recruiting, hiring, conditions of employment, and termination. The university's personnel policies should also address regulatory issues such as equal employment opportunity, nondiscrimination, conflict of interest, sexual harassment, and drug and alcohol abuse. Determine essential qualifications before you begin to recruit and screen individuals.

Tip: *If you are having difficulty with your university's Human Resources or Compensation offices in classifying positions or allowing appropriate salaries because there are few, if any, similar positions on your campus, check with the ADs at existing ERCs. They may be able to provide you with comparable job descriptions or salary ranges in order to help you convince your university of the appropriate levels of compensation to match ERC needs.*

Tip: *Include allocations for both staff development and computer upgrades in the management budget. Be sure to stay within university guidelines in rewarding or paying center staff; don't develop your own pay scales outside these guidelines.*

6.4.3 Departmental Interaction and Coexistence

Establishing the center's identity as a unique entity on campus is important. Problems can arise when both the home department and the center vie for individual loyalties, resources, or recognition. The ERC must build a separate identity, without competing with participating departments. Initial decisions regarding financial management and accounting, paperwork flow, and the levels of responsibility and interaction with departmental administrative staff will set the tone for the establishment of the center on campus.Alternative appointment strategies may need to be considered, since most of the ERC funding is considered “soft” (not backed by continuing state allocations or private endowments). Decisions regarding new hires of tenure track faculty will require cooperation and management of cost share. The department, the center, and the university should understand that NSF will ask each center to examine the progress of young faculty towards tenure. The center may have the option to appoint non-faculty staff directly within the ERC or through participating academic departments. Consider which approach will better enhance cross-disciplinary cooperation within the institution and evaluate the operational and resource issues. Also keep in mind that the ERC can be a powerful mechanism for fostering interdisciplinary research at the lead and partner academic institutions.

6.4.4 Personnel Records and Reports

A system to collect demographic and other personnel data over the life of the center is essential. A database is the easiest way to maintain the information, create historical reports and upload yearly statistics to the ERCWeb database. Affiliations and classifications change over time, so the system should be flexible and indicate start and end dates for each person. Remember that all demographic data must be submitted voluntarily by the individual and treated as confidential. Each institution will have policies in place regarding compliance matters such as Effort Reporting, Conflict of Interest, and Responsible Conduct of Research and it’s important to understand those requirements.

Tip: *Keep updated lists of personnel you interact with at each institution. These lists should include financial, sponsored programs, departmental staff, and higher-level administrators such as Department Heads, Deans, Chancellors, and Provosts.*

Key Definition

> **ERC Personnel** – individuals who are directly involved in executing activities funded by the center. They may be paid or unpaid and there are no minimum time requirements, but the type of involvement must be documented.

Take the time to make sure all participants understand the definition of ERC Personnel and provide them with an easy way to keep the information up to date. Below is the minimum required information needed for each individual:

Table 1. ERC Personnel Data Requirements

First Name
Last Name
Email address
Citizenship/Country
Institution/Organization
Role – Thrust and Project Association, NSF Classification and Personnel Type
Department
Discipline
Title within Institution
Gender
Disability status
Ethnicity
Race

See Attachment 6.5 – ERC Classification/Personnel Types

Tip: *Respect the confidentiality of personnel data and indicate that the information you collect will be used only in the aggregate for NSF reporting purposes. Explain that statistical reports do not include data about any particular individual, and that the information is available only to administrative staff.*

Be sure to track the employment history of ERC students when they graduate. Maintain a database or spreadsheet with the following additional fields for students:

Table 2. Additional ERC Student Data Requirements

Student Faculty Advisor
Student Graduation Date – Year
Student Graduation Date – Month
Degree Type-BS
Degree Type-MS
Degree Type-PhD
Name of Hiring Organization
Type of Hiring Organization
ERC Member Firm
Other US Industry

Other Foreign Industry
Government
Academic Institution
Other
Undecided or Still Job Hunting

Tip: *Record the home institution for REU students, rather than the institution where they are conducting research.*

Tip*: When initially collecting demographic data, include a statement requesting permission to contact participants in the future for program evaluation and study. This is referred to as "future use consent."*

6.4.5 Advisory Boards

Each ERC is supported by advice or guidance from external and internal boards and councils and the leadership team works to create and maintain relationships with the following boards:

Scientific Advisory Board: The Scientific Advisory Board (SAB) is comprised of outside experts who are selected by the ERC Leadership Team and meet collectively as a board at least once a year with the center.

Industrial/Practitioner Advisory Board: The Industrial/Practitioner Advisory Board (IPAB) will be comprised of 10 representatives of member companies/agencies/hospitals who meet collectively as a board twice a year to advise the ERC's leadership team and meet with the NSF site visit team. The IPAB will have a chair who organizes the board's activities in coordination with the Industrial Collaboration and Innovation Ecosystem Director and the Center Director.

Internal Academic Policy Board: Administrators from the lead university, including the Dean of Engineering, who meet collectively as a board with the ERC Director to coordinate ERC plans and policies with departmental and university leaders.

Council of Deans: Led by the Dean of Engineering from the lead university, the Council of Deans from the lead and partner academic institutions meets collectively as a board to provide administrative support of the ERC and to help facilitate the ERC's research, education, and innovation efforts across the lead and partner campuses.

6.5 Information Technology and Management

As early as possible, the ERC should design a systematic process for collecting and storing the large quantities of information needed to manage a multimillion-dollar operation. It is a challenge to determine the most effective and cost-efficient way to gather data across the institutions and miles. Be open to developing multiple strategies for data collection and reporting. A comprehensive, all-encompassing system might seem ideal, but designing such a system requires a level of experience and understanding that takes time to acquire. It may be best to begin with a step-by-step approach while simultaneously planning for a long-term solution. Be sure to consider user needs and ease of use for all participants. Determine how to leverage existing institutional information systems and collaborate with personnel from the accounting, grants management, and IT departments to come up with the best solution. Collect and maintain information on the activities of the center for multiple users and purposes, as is detailed below.

6.5.1 IT Requirements

Annual Report Data – The NSF ERC program requires extensive and detailed reporting. Key reference documents are online in the ERCWeb library*https://www.erc-reports.org/public/library*. The Guidelines for Preparing Annual Reports and Renewal Proposals and the ERCWeb Data Entry Guidelines are updated yearly on October 1 and contain detailed information regarding data that need to be collected and the tables and figures that will be produced for the Annual Report. The general categories are:

- Support
- Academic Institutions
- Personnel
- Research
- Budgets
- Outputs and Impact

Website/Intranet – Each ERC must design and maintain a website for outside constituents. Many centers will simultaneously design an intranet for center participants, specific research groups, and industrial or advisory partners. Other centers may instead use existing institutional software to facilitate online collaboration, or they may purchase and maintain their own collaboration tools.

Mailing Lists – Useful lists include: all center participants; participants by institution or organization, individual working groups, or project teams; and personnel categories such as faculty, staff, graduate students, undergraduate students, administrative support staff, and program or thrust leaders. Copy the ERC Leader or designate with updated Center mailing lists.

Calendar – An online resource that is easily updateable by select participants at each institution.

Agreements and Certifications – Work with the sponsored programs, accounting, and technology transfer offices to determine how to maintain official documentation. Be sure to track the NSF cooperative agreement base award and amendments, as well as supplemental and other grant proposals and awards.

Inventory – Hardware and software licensing details are usually required by each institution.

Financial Records – Maintaining and communicating accurate financial records is crucial. Ideally, new centers should meet with the sponsored programs and/or accounting offices in the first months of operation to find out how well the university system will support the NSF annual financial reporting requirements. Many ERCs create shadow systems using spreadsheets or databases. Every ERC should expect to be audited and must maintain documentation to verify all data submitted in the Annual Report. As noted above, the Guidelines to ERCWeb Data Entry contain detailed information regarding financial data that need to be collected and the tables and figures that will be produced for the Annual Report.

***Tip**: You will need to manipulate data by month and by cluster, thrust, and project level to develop the ERC's functional budget as required by NSF. Design a flexible system to accommodate that need.*

6.5.2 System Design

The IT system must allow for multi-platform access, which is why a comprehensive web-based system can be so useful. Be sure to document system development so that modifications can be made as needs and requirements change. Design a flexible, user-friendly system so that data input and output tasks can be delegated as warranted.

Key Considerations

- Hardware and software acquisition and maintenance
- Integration with University information systems
- Institutional IT policies
- Security
- Integration with theERCWeb Annual Report Data Entry System

Look for technical expertise within each academic partner institution and utilize the skills and strengths of the ERC team members. It may be necessary to hire outside consultants or pay for in-house system development; but in any event, significant time and resources will be required. Consider how to integrate with existing institutional systems, since much of the needed information might already be available.

The ideal system will be easy to use and maintain. The goal will be to accommodate the needs of all users and to educate them on the value and use of the system. Much of the data will be collected to meet ERC and institutional reporting requirements, but it’s also important to support center-wide policies and goals. When designing the system, consider the multiple users of the data:

- National Science Foundation
- Academic Institutions – lead and all partners
- Center personnel – faculty, research staff, administrative staff, students
- Sponsors – industry and other organizations
- Advisory Board Members

Tip: *Some centers have worked with a vendor to customize an open-source, web-based data collection system using Drupal. This system was originally developed in conjunction with the Synberc Engineering Research Center.*

6.5.3 Electronic Tools and Resources

Centers use a wide variety of tools to enhance collaboration and collect data. There is a cost involved with updating and change, so plan for testing, user education, and rollout tasks when considering upgrades or the purchase of new software. Email, word processing forms or templates, spreadsheets, online survey and questionnaire software apps may all be useful for different purposes. Examples:

- Cisco WebEx – meetings, webinars
- Citrix GoToMeeting – meetings, webinars
- Dropbox – online collaboration tool, file sharing
- Survey Monkey – questionnaire
- Survey Gizmo – questionnaire
- Google Apps – suite of collaboration tools
- Doodle – meeting scheduler

6.5.4 External Systems

The ERC Administrative Director will need to use a number of government and external systems for proposal and award management. Here is a partial list:

- Grants.gov – Federal government centralized location for grant seekers to find and apply for federal funding opportunities: *http://www.grants.gov/web/grants/home.html*
- NSF Fastlane.gov – NSF proposals, awards, and status: *https://www.fastlane.nsf.gov/*
- NSF Research.gov – NSF grants management system upgrade to Fastlane. Use to submit Annual Report: *http://www.research.gov/*
- ERCWeb – ERC Program Annual Report Data Entry System:*https://www.erc-reports.org/public/login*

6.6 Annual Report

The Annual Report presents a comprehensive picture of the strategic scope of the research, education, and inclusive ecosystem for interdisciplinary and industrial collaboration and innovation at the ERC. The report includes details about individual research projects and how each is integrated with the center's vision, as well as information on milestones achieved and future plans. Data is collected and benchmarked against other ERCs in multiple sectors and national diversity statistics are referenced. The process of writing the report can be a useful exercise, since all ERC participants are involved and the report serves as a foundation for the upcoming Site Review, but it is definitely a major undertaking. Keep in mind that there are multiple audiences for the report including NSF personnel (ERC program officers and staff); external reviewers; institutional administration, faculty, and staff; ERC personnel; and industrial and advisory board members.

Key reference documents are available in the ERCWeb library. The Guidelines for Preparing Annual Reports and Renewal Proposals and the Guidelines to ERCWeb Data Entry are updated yearly on October 1 and contain information regarding data that needs to be collected and the tables and figures that will be produced for the Annual Report.

Production of the Annual Report requires extensive and detailed project planning and is a year-round, ongoing activity. The report consists of two volumes and specific requirements for each are detailed in the guidelines. It is important to thoroughly read and understand these guidelines, use the glossary, and then devise a project plan.

6.6.1 Project Planning

Many ADs find it useful to create their own outline of required components after studying the guidelines. The next step is to develop a timetable and production schedule and then assign responsibilities. Project management software can be very useful, if there's time to train key users. An alternative is to create a spreadsheet or Word document to develop the project management plan that can be shared with the management team.

In setting up a schedule, be sure to set reasonable deadlines and notify all authors of the general plan. Be clear about assignments and share relevant guidelines with all contributors. It's important to strike the right balance with the amount and type of communication; be as concise and efficient as possible. Allow time to validate information and also for integration, editing, review, and proofreading. The Annual Report is complicated to produce, since the time between the end of the Reporting Year and the due date is very short. There are multiple contributors and all will want to present the very latest results, which means that authors will resist deadlines. Be sure to have reliable administrative collaborators at each institution to help collect data and drafts.

Consider the sequence: Volume II project summaries provide research detail, so these can inform the Volume I narrative sections. Stand-alone documents such as "Current and Pending Support" and "Biographical Sketches" are low-hanging fruit, so collect these as early as possible. It is smart to complete the ERCWeb data entry immediately following the Reporting Year end date, since these metrics will help to tell the center's story. The ERCWeb tables and figures are referred to and explained in the Volume I narrative, so they need to be complete and accurate before writing begins. Certifications need multiple signoffs, so they too should be among the first tasks.

***Tip**: Give the many contributors time (24 hours) for one final review of the entire report, to ensure that there are no major errors and to get their sign-off and buy-in on the report. Allow access to a non-editable pdf, and stress that only critical errors will be corrected in this final draft.*

6.6.2 ERCWeb Data Collection

Gather information continuously and systematically all year round. Refine processes and systems as the center evolves, but try to limit new or complicated ways of doing things. Documentation of any data submitted to ERCWeb must be procured and maintained for audit purposes. Be sure to allow plenty of time for entering and validating data, as there is a significant amount of finely detailed information that is input to multiple screens. Expenditure Budgets as well as Functional Budgets must be prepared and it is sometimes tricky to validate all the numbers. Note that the lead institution is responsible for reporting and obtaining certifications for the entire center. Begin gathering this information early in the process since some require multiple signoffs at each partner institution. The Authorized Organizational Representative (AOR) is usually the Director of Sponsored projects at the lead institution. A scanner will be needed.

***Tip**: Try entering some initial financial data early in the process to test how the different tables validate.*

Key Definitions

> **Award Year** – A 12-month period that begins on the date that the ERC first receives NSF funding, which is the official "award date." The Award Year start and end dates remain constant throughout the life of the center.
>
> **Reporting Year** – A 12-month period established by the timing of the annual site review and established when a center is first formed. The reporting year end date is set by the center and is no more than 2 months and 5 weeks prior to the first site visit date. Once the Reporting Year has been set, it remains constant throughout the life of the center and covers 12 months of data. (There is an exception to this rule for some of the Class of 2006.)
>
> **Fiscal Year** – The Federal fiscal year runs from 10/1 to 9/30. Each partner institution's fiscal year and state fiscal year can differ.

The term "year" may also refer to the calendar year or the term of an industrial partnership. These differences will have a profound impact on management and reporting of budgets, revenues, and expenses. You will need to understand the ERC reporting requirements and your University's financial system in order to generate reports for specific time periods.

6.6.3 ERCWeb Data Categories

Below are the categories of data submitted to ERCWeb which produce the ERCWeb Tables and Figures that are inserted in the Annual Report:

- **Support** – financial and in-kind support from the National Science Foundation (including but not limited to the ERC program), other federal agencies, organizations such as industrial\practitioner members, innovation partners, funders of sponsored and associated projects, contributing organizations, state and local agencies, and other sources.
- **Academic Institutions** – name, location, and additional detail on those academic institutions and diversity alliances executing ERC research, tech transfer, and education programs.
- **Personnel** – demographic and occupational data on those individuals directly involved in executing activities funded by the center.
- **Research** – research effort reported in terms of project, thrust, and cluster.
- **Budgets** – annual expenditures, functional and educational budgets.
- **Outputs and Impact** – quantifiable outputs such as publications, technology transfer (invention disclosures, patents, and licenses), and educational outputs of the center.

6.6.4 Data Collection Challenges

<u>Faculty</u> – Most Administrative Directors agree that collecting information from faculty is a significant challenge during the early years of a new center. Remember that faculty time is a scarce resource and most center participants are highly accomplished experts with multiple commitments. Start by gathering what is already known, and request updates to that information. It's helpful to get to know assistants, post-docs and grad students; these people are VIPs in the administrative network. Multiple strategies will be required; use the online system, email, voicemail, texts and in person visits. Peer pressure is a strong motivational strategy. Remind participants that their contribution to this prestigious project is valued and needs to be showcased in the group report.

<u>Tech Transfer</u> – Work closely with the center Industrial Liaison Officer to collect technology transfer data. Develop a strategy for capturing information on company visits, student and faculty time at companies, technology transferred, success stories, technical and economic challenges affecting your industries, as well as the required data elements listed in the Guidelines to ERCWeb Data Entry.

Demographics – It can be difficult to capture information on diversity (gender, ethnicity, race, citizenship, and disability status) from a busy, dispersed group of individuals who may be reluctant to share this information. Develop a standard format (online, distributed by email, or paper) that all ERC personnel can use to voluntarily self-disclose this demographic data. The center is not authorized to make judgments about where a person fits in these categories. Emphasize to users that the data will be reported only in the aggregate to NSF, when encouraging them to share this information.

Students – Keep track of program alumni at graduate, undergraduate, REU, and RET levels from day one. It will be important to know what happens to them, where they go, and how to reach them throughout the life of the center and beyond. Design the information collection process to capture information on alumni systematically at the end of each university term. Get to know the department staff responsible for processing graduating students, since they can be an invaluable source of information. Have a plan for how to communicate with alumni, and do so at least two or three times each year. It is effective to use resources such as Facebook or LinkedIn to keep up with students.

6.6.5 Annual Report Volume I

The Center Director/Principal Investigator is the person responsible for the Annual Report, yet many authors contribute content. Each Director will approach this task differently, but presenting a cohesive narrative is always the goal. Progress in the current year toward achieving the center's vision in comparison with state of the art advances external to the center should be clearly indicated by milestones achieved and by key barriers overcome along critical path activities. . These milestones constitute "Highlights of Significant Achievement and Impact" which are especially important, so all should be aware of the guidelines and requirements for writing these.

Advances in thrust area research that overcome critical gaps in the field should be linked strategically to the center vision and calibrated vs. state of the art as well as vs. testbed-driven needs, using quantitative metrics. It is important to emphasize synergies from interdisciplinary and cross-institutional interactions that support metrics and milestones and deliverables anticipated by the center in its lifetime. A professional document with self-consistent, accurate, up-to-date data reflects the high quality and standards of the work performed by all members of the center, so take the time to set up templates and design style guidelines. Determine how to share document drafts and encourage all ERC personnel to participate in the development and production of the report

Tip*: Allow time to format the ERCWeb generated Tables. They must be readable and it can take considerable time to tweak the format and integrate the ERCWeb tables into the report.*

6.6.6 Annual Report Volume II

Volume II is comprised of the following components:

1. Table of Contents
2. List of ERC Projects
3. Project Summaries
4. Associated Project Abstracts
5. Data Management Plan
6. Biographical Sketches
7. Current and Pending Support (only required for renewal proposals)

The Project Summaries make up the bulk of the Volume and typically are drafted by grad students, project leaders, and thrust leaders. Allow time in the schedule for writing, editing, and formatting, as information in these summaries will be used to write the Volume I narrative. The data management plan, associated project abstracts, biographical sketches, and current and pending support forms usually just need updating rather than original content, so it's smart to collect them early.

***Tip**: Provide online or word templates which will minimize the formatting time needed during final production.*

6.6.7 Renewal Proposals

Renewal proposals have all the same requirements as Annual Reports, but include additional detail regarding plans for the future and multi-year budgets.

6.6.8 Annual Report Production and Submission

Formatting and compiling all the report components is a time-intensive activity. Bring in temporary help and utilize all resources as the deadline approaches. Work with a printer to create a timetable for submitting files, draft review, and final editing. Time for mailing the printed copies should also be built into the schedule.

There is detailed information in the guidelines regarding submitting the report electronically to Research.gov, the NSF ERC program staff, and to the reviewers. Five printed copies are also required. One additional important step is to certify Cost Share in Fastlane. This is a task for the lead institution's Sponsored Programs Office. The center needs to gather accurate certified information from all the subcontractors in a format that will allow the lead institution to submit this information, so it's important to work this out ahead of time.

6.7 Communication and Public Relations

Internal and external communication initiatives require constant effort and attention in the complex ERC structure. Participating individuals are geographically disbursed and they often have differing loyalties and priorities. Consensus building takes considerable time and effort, but is essential to realizing the center's vision. There are many electronic tools available to facilitate communication, but there is no substitute for "in-person" interactions. Research retreats, industrial meetings, advisory board meetings, budget conferences, and the annual Site Reviews all offer opportunities to solidify the team.

Tip*: Consider including staff from your business or sponsored program office at some of these events so they can develop a personal connection and investment in the center's success.*

Public relations are important as the center works to build an industrial membership program and procure additional funding to support the mission. Centers do vary considerably in how they view publicity. Some desire maximum exposure, while others find these activities to be a drain on time and resources. Strike the right balance, develop a policy, and readdress it as the center evolves.

Key Considerations

Technical and graphic design expertise is required. Look to individuals on the ERC team, in the department, college, institution, or industry consortium, or external vendors to meet the needs of the center. Students can be an excellent resource.

Publications reflect the high standards of the center. Take the time up-front to design a professional logo, slide template, and web site.

Develop a website that will serve the ERC participants, industrial partners, other researchers and professionals, potential sponsors, and the general public as well. Review the websites of other ERCs at the Engineering Research Centers Association site. *http://erc-assoc.org* .

Create a communications team to oversee publications and posters and contribute editorial feedback. Some centers work with individuals from advisory boards to add a professional perspective.

Be sure to include the appropriate NSF acknowledgement language on all publications. Educate all ERC participants and provide easy access to sample language for this purpose.

Purchase camera equipment (video and still) to document events and activities. Create a central archive for documents, photos, and video footage. Institutional shared space may be available or explore options such as Google Sites, Google Groups, or Picasa.

Brochures, newsletters, fact sheets, pop-up banners, and stands can all be useful for the ERC. Some centers also prepare an executive summary version of the Annual Report to use for marketing purposes. Keep in mind that producing a newsletter or other printed materials can be a time-intensive activity. Make realistic staffing plans and periodically evaluate the cost-effectiveness of these efforts, as this will change over the life of the center.

Recruitment of companies, students, and sponsors is more successful if the entire team is aware of and supportive of these activities. Target audiences for public relations materials might include:

1. Companies, including prospective members
2. Prospective students and ERC alumni
3. National Science Foundation and other federal agencies
4. State legislators and personnel working on economic development
5. Partnering university VIPs and participating departments
6. External universities
7. Other ERCs
8. Local and national press
9. National legislators, the general U.S. public, and international interests.

Maintain a Calendar of meetings and events online and make sure that key participants from each institution can easily update the schedule.

Connect with individuals from the news office at each institution in order to present a cohesive message and to be able to quickly respond to breaking news and events.

Facilitate virtual meetings with video or teleconferencing capability. There are many low- or no-cost options available such as:

- Free Conference – conference calling
- Google hangouts – video, voice conversations
- Cisco WebEx – meetings, webinars
- Citrix GoToMeeting – meetings, webinars

Work toward use of a common language. Use the ERCWeb Glossary and take every opportunity to educate all participants on key definitions.

Consistently use the appropriate qualifier for the word "**Year**" – Reporting Year, Award Year, Calendar Year, Federal, State and Institutional Fiscal Year, Prior Year, Future Year.

Consistently use the appropriate qualifier for the word "**Tables"** –NSF Tables, ERCWeb Tables, Microsoft Word Tables.

6.8 Event Management

Meetings play a vital part in the life of an Engineering Research Center. During the course of a year, a typical center will host industry meetings, external research reviews and retreats, advisory board meetings, faculty and staff meetings, seminars, workshops, short courses, and the all-important Annual/Renewal Site Review. Detailed planning and organization can contribute to a successful outcome and can also illustrate the professionalism of the center at all levels. The Guidelines for the Annual/Renewal Site Visit are in the ERCWeb library and they contain detailed information and a useful checklist.

See Attachment 6.6 – Site Visit Checklist

Key Considerations

Date/Location – Set the date early to ensure there are no major conflicts with the ERC schedule, university academic calendars, major professional meetings, or holidays. Check on possible locations to ensure there is adequate space and availability to meet the objectives of the meeting. Doodle is a useful tool to poll your leadership team at each partner campus. Many centers find it useful to coordinate the timing of ancillary events with their main industrial meetings or with the Annual Site Review. This increases attendance and saves money and time.

Tip*: Consult with your NSF Program Officer months in advance to set the Site Visit date and be sure to check the schedule of Deans, Chancellors and Provosts at each institution.*

Attendees and Speakers – Determine who should be invited and estimate numbers. If the center sometimes pays expenses for external speakers, clarify expectations in advance. Note that NSF and industry have placed growing emphasis on presentations by students and young faculty. Identify speakers, communicate expectations, and issue invitations as early as possible to ensure good attendance.

Tip: *Collect business cards during key events. This is an excellent way to update your mailing list, including new titles, e-mail addresses, and other contact information.*

Vendors – If available, it is ideal to work with the campus conference planning office to organize large meetings. Identify campus departments and external vendors for services such as catering, audiovisual, computer support, and transportation providers and reserve meeting rooms as soon as the date is set. Outside vendors may require significant lead time, so secure contracts and inquire about preferred and/or negotiated rates. Site reviewers and industrial personnel appreciate access to labs and students, so keep this in mind when considering location for meetings that include those individuals.

Agenda – Encourage faculty and industry leaders to collaboratively plan the purpose and agenda for meetings when possible. This will increase buy-in and participation. Consider travel time and the meeting objectives when choosing a location and developing the agenda. It's best to send a final version to all attendees as early as possible and minimize distribution of draft versions.

Tip*: Be sure to include breaks between sessions, where participants from several thrust areas can meet together. Some of the best interactions happen during the breaks!*

Budget – Confirm the budget, including funding expectations for meals, travel, and supplies. Ascertain the availability and necessity of discretionary funds for payment of honoraria and determine if a registration fee is required. Alcohol is not an allowable expense, so look into options for industry sponsorship or a cash bar if this is important for your meeting.

Timetable – Create a project plan with a timetable for any major meetings. Identify tasks and deadlines, assign responsibilities, and decide if rehearsals or dry runs are required. Be sure to distribute the timetable to the appropriate participants and schedule regular check-ins. A written checklist is invaluable and it's also important to plan backup systems and reconfirm all arrangements a day or two before the event.

Tip: *You can never have too many helping hands at a large event or meeting. Faculty, staff, and students can all play a role in organizing and executing an event. A well-chosen graduate student escort can often make a great impression on an industrial or NSF site visitor.*

Handouts – Prepare and distribute general logistical information, information packets, public relations materials, copies of slide presentations, attendee lists, and name tags as warranted.

6.8.1 Site Visit Tips

In addition to the responsibilities noted in the guidelines –

- Be sure to offer a healthy and varied selection of good food and accommodate special preferences.
- Don't minimize the importance of comfortable chairs.
- Cohesive presentations may require a red team and IAB or SAB review – build time for this into the schedule.
- Plan for a "dress rehearsal" in the actual space if possible and test the AV equipment, the timing, and the order of the presentations.
- Set a deadline to collect all final slide presentations in order to print and make copies for the Site Review Team.
- Stock up on supplies and be sure to have extension cords, power strips, USB sticks, and even umbrellas available.
- NSF site review teams will ask to meet privately with students and advisory boards (i.e., industry, scientific, professional). Make sure that all understand their role within the ERC.

6.8.2 After the Meeting

Allow time for the natural "letdown" after a major event, but do plan for a post-meeting wrap-up session with staff. Gather feedback and note suggestions for future meetings and document details. Don't let down the meeting momentum until all of the following tasks have been accomplished:

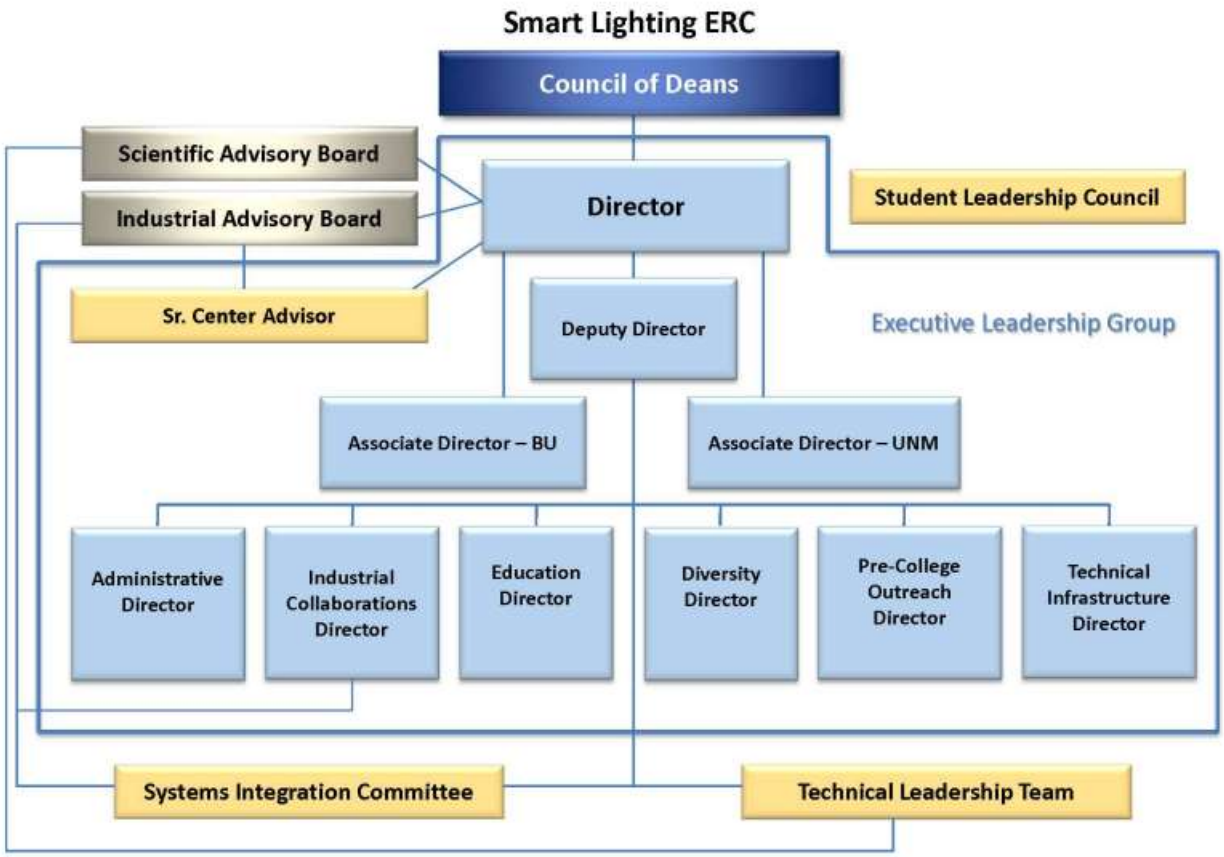
- Pay speakers and reimburse faculty and staff.
- Edit and distribute minutes (or other follow-up materials).
- Update databases (industry, students, etc.) with appropriate information.
- Prepare final expense report and update the budget for future events.
- File all copies of meeting information and handouts in the master files.
- Send thank-you notes – acknowledge those who did an excellent job.

Tip*: It's useful to keep final versions of the agenda, participants list, handouts, minutes, venue information and prices, etc., for each major meeting. This allows you to delegate more effectively the next time around.*

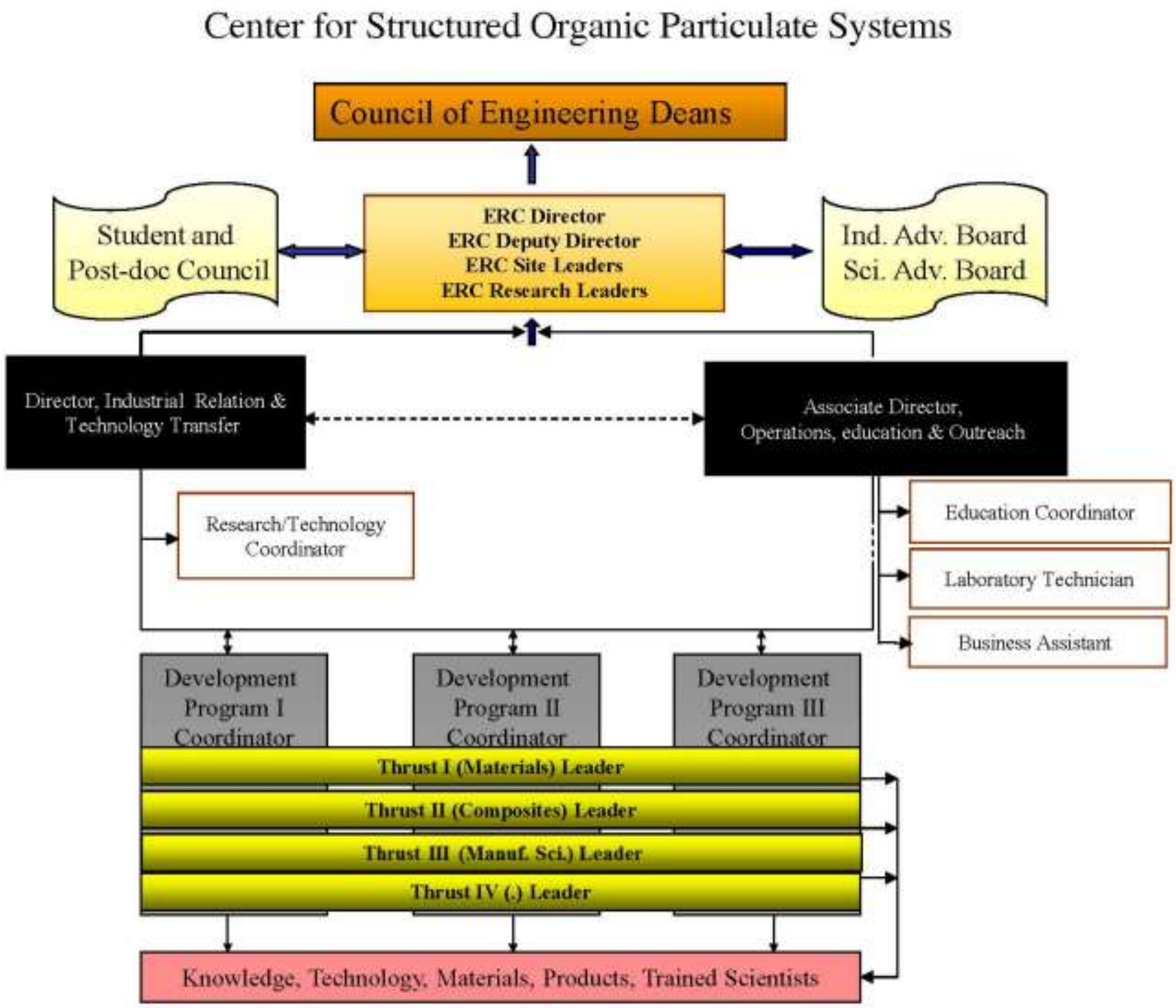
6.9 Facilities Management

Attachment 6.1: Example ERC Organizational Charts

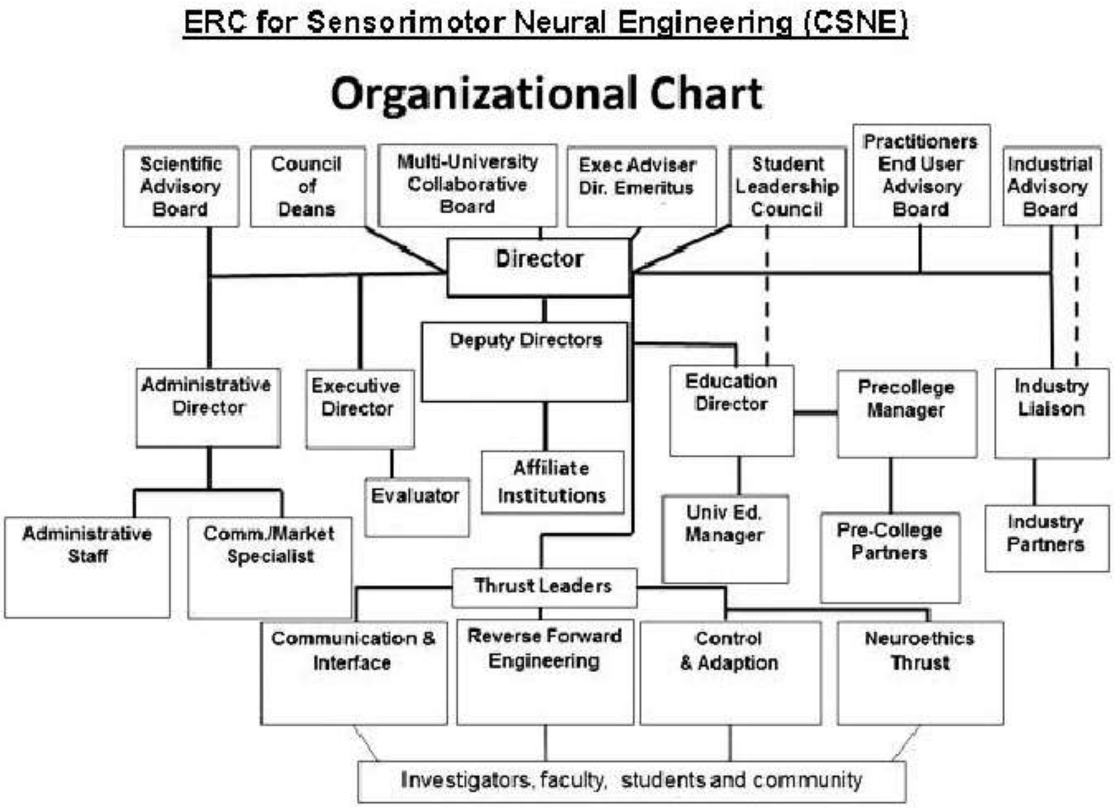
Example 1: Smart Lighting ERC



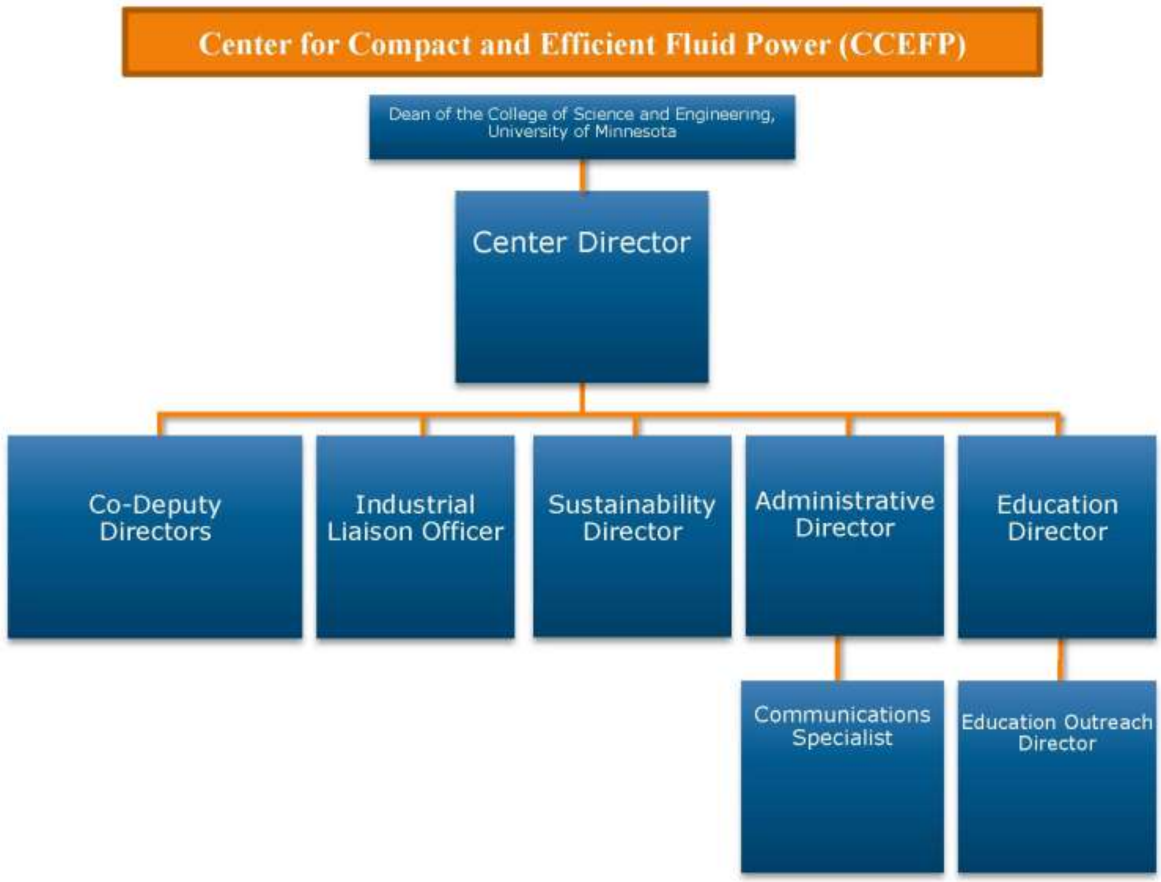
Example 2: Center for Structured Organic Particulate Systems



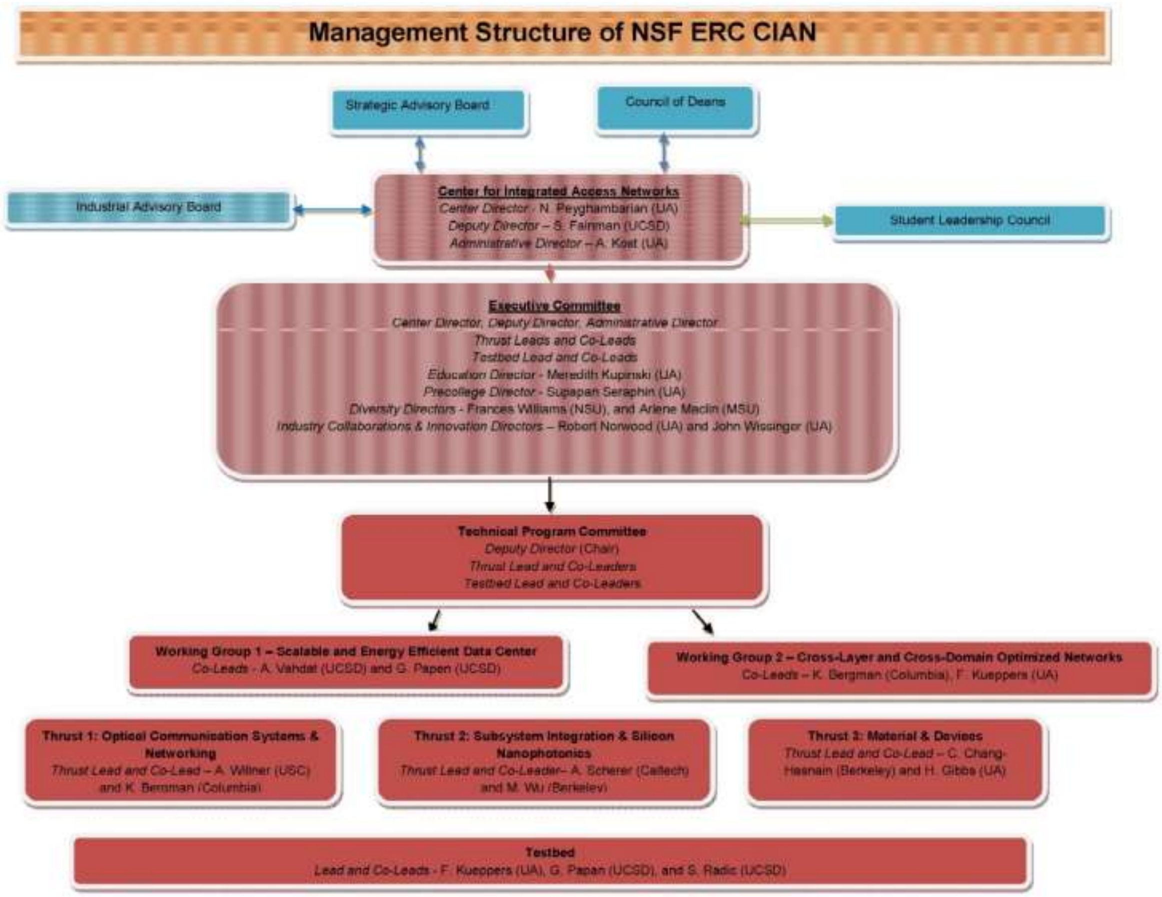
Example 3: ERC for Sensorimotor Neural Engineering



Example 4: Center for Compact and Efficient Fluid Power



Example 5: Center for Integrated Access Networks



Attachment 6.2: Administrative Director Consultancy Visit Guidelines

Administrative Director Consultancy Visit Guidelines

National Science Foundation Engineering Research Centers (ERC) Program

Introduction

The purpose of the Administrative Director (AD) Consultancy visit is to provide support and management insight to the new Engineering Research Center AD and leadership team. Two experienced ADs travel to the ERC Lead Institution to review best practices and offer suggestions for efficient Center administration and management. The timing of the visit is important, and it should be scheduled a month or two after the cooperative agreement is awarded and prior to the first Annual Report due date for new Centers. Existing Centers may experience

AD staff turnover, and in that case, one additional visit may be scheduled at a time that is convenient for the Center.

The new AD should develop the agenda in conjunction with the consultants during an initial conference call and then follow up regarding logistical details. The visit should be tailored to the needs of the Center and the experienced ADs can then serve as a resource during the life of the Center.

Participants

It is critical to include a meeting with the Center Director (and the Deputy Director or Executive Director) when planning the agenda for the Consultancy Visit. Additional participants could include other members of the leadership team involved in management systems such as the, Industrial Liaison Officer and the Education and Outreach Program Director. Since institutional support is so important to an ERC, it might also be useful to schedule time with Sponsored Programs or business office staff.

Agenda

The one day agenda should accommodate the needs of the Center. The new AD should set the priorities as far as timing, participants and topics so that immediate concerns of the new Center can be addressed.

Typical issues include:

- Authority and Responsibility of the Administrative Director
- The Role of the Administrative Director in the ERC’s Leadership Team
- The AD community – Google groups listserv
- Management functions, staffing and workload
- Resources and references
- Accounting and Financial Management
- Management of sub-awards
- Contract administration and compliance
- Data Collection and ERCWeb

- Annual report planning and guidelines
- Acronyms and definitions
- Site Visits and event planning

Reporting

The consultants will provide a feedback report to the ERC's Program Director, Director of the ERC Program and the Manager of the Post-Award Oversight System. However, this report is not an evaluation or a review. Observations, suggestions, challenges will be noted and the report can be shared with the Center Director if requested.

Attachment 6.3: Example ERC Administrator Job Descriptions

[Note: These descriptions were current as of July 2014]

Example #1

ERC for Structured Organic Particulate Systems (C-SOPS)

Instructions for Submitting via Applicant Tracking System (ATS)

The Classification and Recruitment form (CARF) is submitted to initiate the recruitment and/or classification process for all bargaining unit and administrative/professional/supervisory (A/P/S) position requests at the university. **Please attach the completed form as indicated in ATS.**

To fill A/P/S vacant position that does not need to be classified (the key duties of the job have not changed), complete:

Section 1 Job description and requirements section. Please attach a current organization chart.

(Existing job descriptions can be substituted for section 1).

COLT Vacancy - Simply enter the job class code of the vacancy when you submit your request. You do NOT need to complete the CARF.

To classify or reclassify a position (whether it is new, vacant, or encumbered), complete:

Section 1 Job description and requirements section. Please attach a current organization chart.

Section 2 Position detail section. The questions cover many different types of positions across the university. If a particular question is not relevant to the position under review, please indicate N/A (not applicable).

Section 3 Business/Accounting addendum. (ONLY FOR A/P/S BUSINESS, ACCOUNTING AND FINANCIAL POSITIONS).

Section 4 Information Technology addendum. (ONLY FOR A/P/S INFORMATION TECHNOLOGY POSITIONS).

Current Title & Grade: Business Specialist

Proposed Title & Grade: Administrative Director

SECTION 1 - JOB DESCRIPTION AND REQUIREMENTS

1. Position Summary

Provide a brief summary that expresses the primary role or reason the job exists

Administrative Director(AD) will serve the entire ERC as the guardian of resources, policies, and myriad detail. The operative word is service. Working closely with the Director, s/he must consistently maintain a "big picture" perspective. The Director and the AD must consider the needs of all stakeholders (NSF; member companies; the university; other funding agencies, including foundations, state or other government agencies; center faculty; students; and other staff). The AD usually provides the "glue" that holds the various administrative functions of the center together. The AD is apt to wear many hats.

The AD usually:

- •Assists the Center Director in the overall management of the ERC;
- • acts as guardian of rules, regulations, and policies;

• serves as the information "gatekeeper" and resource for all members of the center; and
• is the center's financial and personnel manager.

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2. Job Description

Briefly list and describe in order of importance, the key duties for this position. For each key duty state in a few words:

- What are the expected outcomes
- How are the key duties performed

Please identify the percent of time spent on each.

1. Administrative Coordination of Center Activities NSF Engineering Research Centers are dynamic organizations serving industry, university, and government needs in rapidly changing high technology areas. A complex organization, the ERC has multiple missions (research, education, and service) and is accountable to multiple funding sources (federal, state, local, university, and private). The AD reports directly to the Center Director and will manage multiple fiscal years; many different sets of rules and regulations; an annual budget of $15 million; an average of 227 full-and part-time researchers, faculty and students; and supervise a staff of 7.	40%
2. Financial Management Responsibility for budgeting, accounting, and reporting in order to maximize efficient use of funding, while ensuring compliance with rules and regulations.	30%
3. Liaison with University/Sponsoring Agencies Guardianship of university and agency system requirements (federal regulations, proposal processing, etc.) and responsibility for networking with university administration and NSF to keep abreast of latest changes.	10%
4. Information Management and Communication Information System Management: Oversight of management information system and report generation process (multiple reports to sponsoring agencies, university) and response to requests with accurate and timely information in format required.	10%

5. Personnel Management and Other Duties As Assigned

Hiring, supervision, and development of center administrative personnel and management of documents/human resource policies for academic, research, and student appointments in compliance with university personnel regulations. 10%

Event management, communications, and public relations, as assigned.

100%

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3. Education, Experience, Skills, and Special Conditions:

Please state the minimum level of education, experience, licenses, certifications, specialized training, additional skills, abilities, physical, environmental, or special conditions required to successfully perform the key duties for the position.

Requires a minimum of a bachelor's degree in accounting, finance, business administration, or related field; and five years of related professional experience in a financial/accounting function in a leadership or managerial role of increasing responsibility. Also requires skills in planning and organizing, integrating information, making decisions, and attaining results; excellent communication skills; and computer literacy.

Please state any education, experience, certification, licenses, knowledge, skills, or abilities that are not essential to the position but preferred.

Example #2

Center for Sensorimotor Neural Engineering (CSNE)

ADMINISTRATIVE DIRECTOR

Professional Staff

Job Duties

Personnel

- Coordinates activities by scheduling work assignments, setting priorities, and directing the work of at least two direct subordinate employees.
- Evaluates and verifies employee performance through the review of completed work assignments and work techniques.
- Identify staff development and training needs, ensuring appropriate training is obtained.
- Ensure appropriate university, state, federal, and union labor relations and conditions of employment are identified and maintained.
- In association with Center leadership, plan and forecast staffing needs, develop job descriptions, and oversee the recruitment, hiring, and termination of personnel.
- Manage payroll function, including distribution changes, separations, new appointments and hourly timesheet approvals.
- Encourage effective performance and high morale throughout center

Facilities

- Evaluate Information Technology and physical space needs and develop plans to meet center staffing and work needs
- Negotiate with university and outside vendors to obtain needed facility and I.T. repairs, services, and improvements
- Organizes and directs records storage and maintenance in accordance with NSF, state and university regulations

Fiscal

- Develop and evaluate center-wide budget as well as individual budgets for each funding source and center project in order to maximize efficient use of resources and ensure compliance with appropriate rules and regulations.
- Supervises the receipt and distribution of supplies and equipment, the maintenance of inventories, and the control of purchases and supplies.
- Develops bid specifications, then coordinates and monitors vendor contracts.
- Create and revise fiscal policies and procedures in accordance with university, state, NSF and donor regulations
- Develop and lead an effective working relationship with sub-contracted universities, monitoring budgets, spending and cost-share commitments.
- Review and approve monthly reconciliation, Procard, and CTA reports, as well as travel and reimbursement requests
- Prepare and distribute specialized financial reports as required by center leadership.
- Manage university and funding source fiscal reporting requirements such as cost sharing, FEC, and GCCR.
- Assist in the creation and submission of new grants.

Annual Report

- Lead and manage data collection process from all center members and partners

- Oversight of management information system and report generation process (multiple reports to sponsoring agencies, University) and respond to requests with accurate and timely information in format required
- Manage shared folders, grant access to mailing lists and secure documents
- Collaborate with Center Director and Center Executive Director to complete required narrative sections
- Lead and manage data collection process (e.g., abstracts; personnel information; CVs, etc.) from all Center members across all partner institutions
- Enter data into ERCWeb for institutions, organizations, personnel, outputs, research and money
- Draft management, infrastructure and facilities sections of annual report
- Create all tables for annual report (Center-produced and ERCWeb)
- Following NSF protocol layout and organize all NSF required reports
- Responsible for all fiscal reporting for annual report
- Create glossary, list of acronyms and table of contents
- Collect and certify items for appendices
- Sole authority to submit annual report
- Submit Annual Report and required support documents to NSF FastLane

Communications

- Serve as point of contact for external and center individuals and organizations, referring issues as appropriate

- Attend NSF and university workshops and conferences as required
- Represent the center to other ERC administrators throughout the nation.

Other

- In association with Program Coordinator, oversee all center events, workshops, meetings and seminars.
- Manage all Human Subject applications, approvals and reporting.
- Contribute to strategic planning of the center
- Initiate and implement improvements in all areas of center administrative operations to encourage greater efficiency and success of center priorities.

Job Responsibilities and Duties

Administrative Director (AD)

The position coordinates a large NSF-funded center that spans the three largest colleges at the university and several national and international partner institutions. It has a very high profile with impact to educational, research and IP dimensions of the university. The Administrative Director reports directly to the Center Director and will manage multiple fiscal years; many different sets of rules and regulations; an annual budget of $3.5 million; an average of 80 full-and part-time researchers, faculty and students; and supervise a staff of 4. Administrative duties include any or all of the following areas of expertise.

Financial Management

The AD serves as central fiscal/operations administrator for the Center, acting within the policies and procedures of the University, and the National Science Foundation Cooperative Agreement, to achieve Center goals. A complex organization, the ERC has multiple missions (research, education, and service) and is accountable to multiple funding sources (federal, state, local, university, and private).

- Financial management of the Center grant totaling over $25M over a five year period plus 30% University cost share and industrial sponsors
- Responsible for independently budgeting, accounting and reporting to maximize efficient use of funding, while ensuring compliance with rules and regulations
- Approve expenditures; allocate resources according to funding type and purpose; alert project leaders of concerns in spending patterns
- Manage fiscal personnel at partner institutions; host and/or lead orientation and training sessions
- Administering multiple subcontracts to partner institutions, reviewing invoices and ensuring spending is done in timely manner
- Reporting and tracking complex cost-sharing commitments from a variety of sources, including Provost, departments, and industry
- Administer funds to campus departments (sub-budgets) and allocate according to internal call for proposals for Center funds
- Supervise and oversee the work of a fiscal specialist
- Forecast and advise directors on budgetary issues
- Create budgets for proposals that will add to the sustainability of the Center
- Oversee, manage and monitor the 30% NSF-mandated cost-sharing obligation
- Create budgets in varying formats for executive review
- Manage Partner University funding and invoicing
- Review and approve all Pro-card spending for the Center
- Create and update eGC1s
- Approve expenditures
- Manage faculty’s student funding plan and advise on budgeting
- Work closely with partner institutions to administer subcontracts, collect data for reports and monitor spending and compliance issues
- Create and maintain systems for purchasing, reimbursements, travel and human subject payment

Annual Report

The annual reporting is an extremely complex process that involves an average of three months of work, culling data from hundreds of participants and ensuring that all ongoing projects are appropriately aligned with research thrusts, clusters and testbeds. The AD is responsible for creating/implementing a system to track/compile the complex data and produce the annual report with all necessary elements for the annual site visit.

- Direct faculty, staff and students to meet targets and maintain timely reporting
- Oversight of management information system and report generation process (multiple reports to sponsoring agencies, University) and response to requests with accurate and timely information in format required
- Manage shared folders, grant access to mailing lists and secure documents
- Collaborate with Center Director and Center Executive Director to complete required narrative sections
- Lead and manage data collection process (e.g., abstracts; personnel information; CVs, etc.) from all Center members across all partner institutions
- Enter data into ERCWeb for institutions, organizations, personnel, outputs, research and money
- Draft management, infrastructure and facilities sections of annual report
- Create all tables for annual report (Center-produced and ERCWeb)
- Following NSF protocol layout and organize all NSF required reports
- Responsible for all fiscal reporting for annual report
- Create glossary, list of acronyms and table of contents
- Collect and certify items for appendices
- Sole authority to submit annual report
- Submit Annual Report and required support documents to FastLane

Personnel Management

Responsible for hiring, supervision, recruitment and development of center administrative personnel and management of human resource policies for academic, research and student appointments in compliance with university personnel regulations.

- Make formal decisions regarding hiring, terminations, promotions, reclassifications, salary adjustments and handling of complaints and employee performance problems
- Train and mentor on the specific requirements of the ERC program and work to integrate those with University policies
- Write job descriptions, research appropriate salary and job classifications; coordinate with department HR administrators
- Direct reports include up to 2 staff plus 1-3 temporary staff
- Approve leave requests for staff; conduct performance evaluations and professional development planning
- Advise Center Directors of ongoing changes to HR and Union policies
- Serve as chief personnel of operational control for the Center
- Manage payroll for Center, including distribution changes, separations, new appointments and bi-monthly payroll approval
- Regularly review staffing needs with Director and Exec Director and revise staffing plan as needed
- Post open recruitments
- Organize and schedule interview teams for open positions

- Work closely with Human Resources and compensation offices to get positions approved
- Post job advertisements to external vendors as needed

University/Sponsors/Partners Liaison

The AD serves a key role as liaison between the director, center personnel and partner institutions to assure the goals of the research and educational projects are met and meet expectations of NSF and advisory committees. This person is responsible for coordination of issues between the Center, sponsor agencies, and University offices.

- Guardianship of university and agency system requirements
- Networking with University administration and sponsor to keep abreast of latest changes
- Field questions from partner institutions regarding budget issues, personnel, upcoming events
- Advise sponsor regularly of progress, news and any issues with the operation of the ERC
- Train partner institution representatives on best practices for reporting and documentation

Scheduling

Handles Center-related scheduling needs for the Director

NSF-related Duties

The AD must navigate the sometimes competing demands of both the ERC and University policies and procedures. The AD participates in training, evaluating the operations of other ERCs, and moderating panels and the participation in the annual ERC meeting in Washington, DC.

- Attend annual conference and other NSF required meetings
- Represent Center at annual ERC Administrative Director Retreat and annual ERC meeting
- Consult regularly with other ERC ADs across the nation and present at all ERC faculty/staff meetings on best practices
- Keep up-to-date on all policies and procedures (Annual report, PAPP. .)
- Maintain thought knowledge and uphold Cooperative Support Agreement
- Go-to person for NSF-related questions regarding the Center
- Interface regularly with funding agencies, responding to requests for information or updates.
- Collaborate with Center Director, Administrative Director, Deputy Directors, Thrust Leaders, Lab Directors and students to ensure a successful annual site visit (e.g., collection of information/data; posters; presentations)

Events/Operations/Facilities

The AD will administratively manage the operations of three major research thrusts involving over 100 faculty and graduate students, a growing industrial member program with 30+ members participating at varying levels.

- Create innovative solutions for all ERC problems that arise with respect to communication, information, efficiency and compliance
- Plan meetings, including those involving teleconference and videoconference needs
- Work with campus facilities to ensure proper safety measures are taken and areas are regularly serviced
- Manage outside vendors to ensure safety and security of building and that work is performed satisfactorily
- Work with a wide range of faculty and staff to find meeting times and locations
- Plan site visits, annual meetings, workshops and other events related to the Center
- Work with vendors to make decisions on venues, hotel room arrangements, catering, A/V and other details while staying within budget
- Work with Center Executive Director and Fiscal Specialist to develop and enforce Center policies and procedures
- Work with Center Director, Executive Director and Fiscal Specialist to maximize use and efficiency of Center facilities (e.g., videoconferencing system, computers, space, and equipment)

Example #3

Administrative Director for Engineering Research Center Center for Integrated Access Networks (CIAN)

To be considered for this position, please mail three letters of recommendation to:

Dr. Robert Norwood
c/o Rick Franco
University of Arizona
College of Optical Sciences
1630 E. University Blvd.
Tucson, AZ 85721

Position Summary

Recognized internationally for its strong research programs, the University of Arizona College of Optical Sciences is considered a national asset for technical leadership in all the sciences related to optics and the technologies and industries enabled by optics and photonics.

The mission of Optical Sciences is to provide the State of Arizona and the nation with the internationally preeminent program in education, research, and outreach in all aspects of the science and application of light.

The College of Optical Sciences at the University of Arizona invites applications for the position of Administrative Director of the NSF-funded Engineering Research Center for Integrated Access Networks (CIAN). The Center encompasses research, education, technology transfer and outreach and is comprised of 9 participating universities of which the University of Arizona is the lead. The chief responsibility of the incumbent will be to serve as central administrator and manager for the Center, acting within the policies and procedures of the University and the National Science Foundation Cooperative Agreement, to achieve Center goals. The Administrative Director is the primary interface between Center research, educational and diversity personnel and the Director. Specific responsibilities include Center-wide coordination of activities, financial management, budget preparation, facilities support, proposal preparation, grant administration, human resources, general administration and resource allocation.

Outstanding UA benefits include health, dental, and retirement plans, life insurance, disability programs and investment plans, paid vacation, sick leave, and holidays; tuition reduction for employee and qualified family members, Qualified tuition reduction U of A/ASU/NAU and access to UA recreation and cultural activities, plus more.

Duties and Responsibilities

Assists the Center Director in the overall management of the ERC

Develop and recommend, and once approved, administer program policies and budgets.

Establish policies, methods, procedures and work rules for Center administrative staff.

Interview and recommend selection of applicants, conduct training, assign and schedule work, act upon leave requests, conduct annual performance evaluations and recommend disciplinary actions.

Assure that Center programs conform to institutional and departmental policies and regulations.

Oversee the administrative and management functions of the Center, including day-to-day management of Center grant totaling $18.5M plus university cost share and industrial sponsorships.

Supervise professional staff while coordinating the efforts of numerous other professionals and staff employed by partner and participating universities.

In coordination with the CIAN Management Team, update the Center’s Strategic Plan as needed and ensure this plan is carried out effectively

Serve as liaison with University departments, NSF and a broad spectrum of Center partners.

Oversee and coordinate Center website development, internal database and communications.

Coordinate annual NSF Site Visit and other Advisory Board and Oversight Committee meetings.

Work with Center's Education and Diversity Directors to ensure planned goals and programs are carried out according to established timelines.

Work with Center's Industrial Collaboration and Innovation Director and Associate Director for Industry Collaboration to ensure efficacy of IP Management Agreement and servicing of tech transfer needs within the Center.

Prepare annual report and contribute to proposal writing for external funding.

Lead overall compliance with NSF Cooperative Agreement.

Assume other duties as requested by the Director.

Minimum Qualifications

Ph.D. in a scientific field and 5 years of experience in a scientific research or academic setting

Proven leadership, communication and team building skills

Experience with a research institute or academic institution, working within a scientific research setting, dealing with research-related administrative matters will be given priority.

Demonstrated ability to effectively address complex administrative issues

Highly developed ability to prepare written communications

Proven administrative, organizational and problem-solving skills

Demonstrated competence in budget management, large event planning and coordination and facilitation of substantive research through administrative means

Demonstrated experience coordinating projects involving many individual and institutional participants

Experience with initiatives aimed at enhancing diversity is desirable

What kind of criminal background check is required for this position?This position is security sensitive based on the job duties and requires a finger-print criminal background check

To apply for this position use the link below

www.uacareertrack.com/applicants/Central?quickFind=197229

Example #4

Administrative Director, Center for Compact and Efficient Fluid Power

Fiscal Responsibilities:

- Responsible for overall center budget, including $3 million in National Science Foundation (NSF) funds, $700,000 in industry member funds, and $180,000 U of M cost-share funds.

- Work closely with center director in development of overall center budget.
- Manage long-range fiscal planning.
- Responsible for managing budgets of all center sub-awards.
- Ensure that invoicing/reporting from all sub-awards complies with federal regulations.
- Responsible for reporting to NSF regarding all financial aspects of the multi-institutional center, including expenses incurred for all sub-awards, tracking of funds, functional budget costs, and costs incurred by project.
- Work closely with sponsored projects grants administrator on all accounts associated with the center and administering sub-award contracts.
- Authorize payments for all sub-awards.
- Manage membership agreements with industry partners, including all financial aspects.
- Track and process industry dues.
- Authorize and implement University of Minnesota expenditures.
- Track all University of Minnesota expenditures using shadow system. Familiarity with EFS and ability to run various financial reports required.

Administration Responsibilities:

- Develop and implement processes by which partner institutions can comply with reporting.
- Serve as point-of-contact with NSF regarding changes in reporting regulations, proposal processing, and other issues as needed.
- Serve as point-of-contact with all partner institutions regarding reporting regulations and financial matters of Center.
- Advise faculty on reporting requirements.
- Hire personnel for Center and oversee human resource/payroll issues, including write and post job descriptions, ensure accuracy of faculty and student appointments, and supervise student workers.
- Oversee compilation of Center annual report, including collection of all data required by NSF. The annual report is a 450 + page document. Compilation includes analyzing and assessing data from over 30 faculty at seven institutions, working with the NSF-aligned contractor on system output, collecting bio sketches, program summaries and financial information, obtaining all certified documents needed, formatting entire report, and working closely with printer to ensure job is completed on time.
- Represent the unit to other administrators and outside agencies with regard to business and administrative policies and procedures.

- Handle all facilities, procurement and office service operations for the center.
- Manage yearly NSF "Site Visit" which includes hotel contract, catering, agenda and tracking of all attendees.
- Coordinate travel arrangements for center staff for several trips through out the year.
- Order office supplies for the Center.
- Reconcile purchasing cards for center-related purchases.

Example #5

Center for Compact and Efficient Fluid Power (CCEFP)

Executive Office and Administrative Specialist

(Working title: Administrative Specialist)

Required Qualifications:

- Knowledge of University fiscal and administrative policies (e.g., effort certification, purchasing, travel, professional services, payroll).
- Experience with University of Minnesota's business procedures including functional use of UM Reports.
- Knowledge of the U's policies and procedures relating to grant administration.
- Finance and accounting experience both inside and outside of an academic setting.
- Computer skills, including knowledge of Microsoft Word, Excel, Adobe, and University applications (EGMS, E-Cert, PeopleSoft, EFS).
- Excellent oral and written communication skills. Knowledge and/or demonstrated ability needed to perform administrative, event planning, education program support in a fast-paced environment.

Summary of Tasks:

Budget/Financial (33%):

Assist Administrative Director in overall Center budget operations
Complete timely and accurate account reconciliations
Compose and distribute non-sponsored and sponsored reports to PIs on a regular basis
Review budget justifications for consistency, accuracy, and completeness Prepare Center financial reports for management review
Create PeopleSoft (PS) friendly budgets and re-budgets
Review purchase orders and employee reimbursements
Prepare budgets for grant proposals
Reconcile P-Cards

Submit PRFs
Handle facilities, procurement, and office service operations for the Center

Administrative (33%):
Assist Administrative Director in HR/Personnel tasks
Track NSF and Industry Invoices
Forward invoices to SPA
Handle offer letters
Handle Industrial Membership letters and payments
Handle Annual Membership Fees/Invoices/Thank you letters
Track In-kind Donations
Take minutes on Executive Committee Conference Calls
Assist in annual report coordination
Update procedure manual

Event Planning/Project Coordination (33%):
Plan travel arrangements
Organize events such as the faculty retreat and NSF site-visit
Coordinate the SLC Travel and Project Grant program
Update Facebook and Twitter regarding upcoming events

Example #6

Center for Subsurface Sensing & Imaging Systems (CenSSIS)

JOB SCOPE DESCRIPTION

For Administrative/Professional Jobs

Job Title	Director Finance and Operations	**Date Prepared**	7/13/2000
Department / College	Center for Subsurface Sensing & Imaging Systems		

	(CenSSIS) / College of Engineering		
Employee's Name	Jacquelyn L. Wheeler	**Number of Employees in Job**	1
Manager's Name & Title	Michael B. Silevitch Director		

Please:

- Focus on the important end-results for the job rather than on tasks.
- Ensure that the completed description provides a clear picture of why this job exists.
- Indicate the minimum level of job qualifications for successful performance of the job.

1. Job Summary (This section will be used to post this job.)

Provide a brief statement indicating the basic mission of the job as well as any special problems and unique challenges of the job.

Northeastern University will be the fiscal agent and lead partner of a new National Science Foundation (NSF) -supported Engineering Research Center (ERC) for Subsurface Sensing and Imaging Systems (CenSSIS). The initial five (5) year NSF grant will be $16.2 million which does not include other sources of funding anticipated to exceed $3 million per year, totaling $30+ million over the next 5 years. Winning an Engineering Research Center award from the NSF is a cornerstone of Northeastern's Strategic Plan for positioning the University to move from a Tier 3 level to a Tier 2 level institution and for the College of Engineering to become ranked as one of the top 50 in the nation.

CenSSIS is a multi-constituent, distributed "enterprise," composed of: four (4) Academic Partners – Northeastern University, Boston University, Rensselaer Polytechnic Institute, and the University of Puerto Rico at Mayagüez; four (4) Strategic Affiliates - Brigham & Women's Hospital, Massachusetts General Hospital, Lawrence Livermore National Laboratory, and Woods Hole Oceanographic Institution. This partnership incorporates eight (8) academic disciplines, and over fifty (50) faculty and research staff. In addition, affiliated students are anticipated to number seventy (70) undergraduate and forty (40) graduate students in the first year of the ERC. Industrial and government supporting organizations are expected to number over twenty-five (25) by the end of the first year.

The Director of Finance and Operations is responsible for all non-scientific aspects of this multi-University Center. This includes financial oversight, operations, and administration management. The Director is a major contributor to the marketing and strategic planning of CenSSIS, and is a member of the multi-university Senior Management Team and various ad hoc groups, e.g. Computer Infrastructure, Space Planning, and Financial Planning and Control. The Director attends the NSF Annual Meeting of ERC's, ERC Administrative Directors' Meetings, and other NSF-related meetings, such as NSF Administrative Consultancy and NSF ERC Start-up Meeting. The Director oversees and attends the annual NSF Site Visit to the ERC, the CenSSIS Semi-Annual Research Review / Industrial Meetings of approx. 150 attendees. The Director of Finance and Operations plays a critical role in planning, control, and communication, thus providing the essential "glue" to enable a complex Center to achieve its goals and effectiveness. This position is equivalent to at least that of a Vice President of a small business with 50-100 employees, requiring autonomy of action and decision-making responsibility at a senior level.

2. Key Responsibilities & Accountabilities

Please identify each key responsibility, in 3-4 sentences, required to complete the important end-results of the job and the typical amount of time required for each responsibility (please limit your response to the four most important responsibilities of the job in addition to Customer Service).

• **Customer Service**	**30%**
Interfaces with multi-constituencies: university senior management, faculty, staff, undergraduate, graduate students at Northeastern University, partner institutions / affiliates, industry /government organizations, etc.	**% of Total Time**
• **Financial Planning, Monitoring & Control**	**30**
In concert with the Division of Sponsored Project Administration (DSPA), develops systematic methods for reporting, tracking, and monitoring fiscal elements of the Center. This includes multiple funding "sources," multiple funding "uses" (subcontracts, numerous projects within Northeastern and with partner and other institutions).	**% of Total Time**
• **Marketing, Marketing Communications, and Strategic Planning**	**20**
Makes recommendations on Marketing, Marketing Communications and Strategic Planning to the CenSSIS Director and Senior Management Group; e.g. coordinating with Public Relations Department, speech	**% of Total Time**

writing. Oversees the planning and execution of major Meetings & Special Events.

- **Office Management & Hiring** **20**

Oversees the Office Management of CenSSIS Headquarters including: coordination of hiring for CenSSIS staff appointments and graduate students; space planning; day-to-day operations; supervision of support staff. **% of Total Time**

3. Financial Measures

This section helps to provide perspective on the financial responsibility of this job. Please provide relevant data to the extent it is available.

- **Annual Operating Budget** that the job manages (excluding payroll, one-time supplements or temporary expenditures such as capital equipment). **Explanation:**

While the Center technically does not have an Operating Budget, sources of funding for the Center approximate $8-10 million / year. Funding sources include: the National Science Foundation, Industrial / Government organizations, both as members of the Center and through proprietary Center research projects. There also is internal cost sharing of $ $500,000 per year committed to the Center by the University. In addition, subcontracts to partner institutions must be monitored in conjunction w/ the Division of Sponsored Project Administration to be in accordance with NSF requirements.

- **Other Relevant Quantitative Information** (e.g., monetary programs such as fundraising, financial aid, tuition revenues, project size or costs). **Explanation:**

Managing NU CenSSIS Renovation Budget of $500,000.

4. The Organization (Please attach an organization chart for this area)

- **Title of the immediate manager:**

Director, Center for Subsurface Sensing and Imaging Systems (CenSSIS) and

Professor, Electrical and Computer Engineering

- **Other jobs reporting to the same manager:**

10 person Multi-University Senior Management Team including: Deputy Director, Co-Principal Investigators, Research Co-Leaders, and Industrial Liaison. Other non-CenSSIS personnel include 1 principal Research Scientist, Director Project SEED.

- **Number of employees reporting directly to this job:**

Professional and Administrative (Exempt)	Office / Support and Technical Staff (Non-exempt)	Co-op Students	Other Students (Graduate Assistants)
	2		3

From College of Business & College of Engineering

5. Knowledge, Skill Sets, and Experience

Provide the minimum level of qualifications required for an employee to succeed in this specific job.

- Masters degree in Business (MBA) or comparable degree
- Substantial business management experience and acumen in:
- Operations and planning for complex corporate and academic environments
- Accounting, preparation and analysis of financial statements / budgets;

Financial planning and control monitoring

- Client account management and customer service for interfacing with diverse constituencies at all levels externally and internally, such as: various levels of the NU community, University Administrators, faculty/researchers and students at partner universities, industrial partners, prospects & friends
- Management and Supervision of a multi-task office environment
- Strategic marketing, marketing communications experience for external and internal promotion of Center activities and to enhance effectiveness of Center's

strategy; strong communication skills, both oral and written, with the ability to articulate Center's mission, policies, and write varied types of communications.

2. **Signatures:**

2. Employee 2. Date 2. Manager 2. Date

CHECKLIST

Please take a moment to review this checklist:

- Have you responded fully to each item?
- Do your responses focus on the important end-results for the job rather than on tasks?
- Does the completed Job Scope Description provide a clear picture of why the job exists?
- Do the job qualifications reported reflect the minimum level for successful performance rather than the Employee's personal background and profile?
- Have you limited your responses to the space provided?
    - Have you attached a copy of an organization chart for your area?

Thank you for taking the time to complete this Job Scope Description in a thoughtful manner.

HUMAN RESOURCES MANAGEMENT

Example #7

Confirmed *Returned* *Date* *ERCode* *Initials*

(Theabovesectionwillbecompletedbythe CompensationUnitfollowingreviewofjobmappingrecommendation)

5/27/20084:42:55PM

Synthetic Biology Engineering Research Center (SynBERC)

Academic Program Mgt Officer 4

Job Description

Instructions:

1. The “track changes” feature has been activated in this job description template.

2. Edit all pre-filled information belowto specifically reflect the employee’scurrent responsibilities, with the exception of the following sections whichdo notchange: Job Title, Job Field, Job Family, Job Category, Job Level, Generic Scope.

3. Provide a copy of the most current department organization chart.

4. Keep the “trackchanges” functionality activated in the final submitted copy

Name: Employee ID:

Department: QB3 /SynBERC **Division: Current**

Payroll Title: Sr. Admin. Analyst

Job Title: Academic Program Mgt Officer 4

Recommended

Working Title: Administrative Director

JobField: Research Administration **JobFamily:** Academic ProgramManagement

JobCategory: Professional **JobLevel:** Advanced

Supervisor

Name:

JobMapping

SubmissionDate: 11/18/2008

1. Job Summary (Purpose of the Position – please give a brief descriptionof the overall purpose of the position. "Why does this position exist?" The Job Family Summary has been provided as a starting point.)

The Administrative Director (AD) servesthe entire,multi-institutionERC community as the guardian of resources, policies, and process. Working closely with the Directorand researchleaders, s/he serves as the primary point of contact in the day-to-dayoperation ofthe center, assists the in the overall management and development of the ERC, and servesasmanager for finance, HR, IT, contracts/grants, and student services. General management includes long and short rangestrategic planning in determining the mission and directing all activities of multi-disciplinary departments throughsubordinatemanagement staff. The AD is the primary liaison between the centerand external agencies (includingNSF), promotes andparticipates in strategic proposal andprogram development, and is primarily responsible for executing the center's internal and external communications.

2. Scope

Generic Scope (Uniform across all jobs atthis level - do notmodify):Technical leaderwith a high degree of knowledge inthe overall field and recognized expertise in specific areas; problem-solving frequently requires analysis of unique issues/problemswithout precedent and/orstructure. May manage programs that include formulating strategies and administeringpolicies, processes, and resources; functions with a high degree of autonomy.

Custom Scope: Independently oversees a moderately sized academic orresearch program and represents the program to outside organizations. Oversees all administrative operations, finance, human resources and facilities for program. Designs and develops major program components, and administers the full range of the program's operational requirements. Works with faculty on formulating short-term planning andprocedures. Develops and organizes conferences and other public forums. Works under direction of Principle Investigator to establish center agenda, funding, objectives.3. Key Responsibilities (Indicate key functions and the estimated percentage of time spent performing each function. If there are more than 10 key responsibilities, some of the similar functions may be grouped together and an estimated % applied.Please indicate which responsibilities are considered "essential" to the successful performance of the job as defined by the Americans with Disabilities Act. Visit the Career Compass Glossary for an explanation of essential functions: http://careercompass.berkeley.edu/jobstandards/resources/glossary.html)

If applicable, describe theposition's rolein planning theprograms,functions, activities, and processes of the organizational unit to achieve unit goalsand objectives.

%

of time

Essential Function (Yes/No)

Key Responsibilities

(To be completedby Supervisor)

25 Directs and administers an independent program with complete administrative, financial and programmatic responsibility.

25 Participates in the program budgeting and accounting processes to support financial infrastructureof program.Manages, plans, and administers a full range of reporting functions where the operations are significantly complex in terms ofbudgetary funding, number of faculty, staff and students, and/or are broad in scope due to focus of operations orfunderrequirements.

10 Identifies andpursues funding opportunities and revenue streams.

10 Assists in developing research byserving on committees representing the program, participating in short termand long termplanning. Assesses program's effectiveness, and recommends changes to program'scontent, policies and procedures accordingly. Provides post-award financial administration and management for research funds in accordancewith campus policy and agency requirements.

10 Develops andimplements programs, events and/or communication strategies designed to inform external constituencies of institutional programs, activities, and practices; constituencies may includethe general public, prospective students, parents, donors, campus visitors, government and/orcommunityrepresentatives. Mayprovide presentation of course or program.

20 Researches, develops, and implements electronic and traditionalmedia (including content and design) designed to inform external constituencies of institutional programs, activities, policies, and practices; constituencies may include the general public, prospective students, funding agencies, campus visitors, and/or community representatives.

0% **(To update total%, enter the amount of time in whole numbers (without the %symbol- e.g., 15, 20) then highlight the total sum (e.g., 1%) at the bottom of the column and press F9. The total sum should add up to 100%.)**

4. Knowledge and Skills (typically requiredof the position)

- Academic background and experience in selected area of research.
- Advanced knowledge of administrative, budgetary, human resources and financial principles and practices.
- Advanced oral and written communication skills.
- Advanced ability to think creatively and independentlyon concepts requiring advanced analytical skills.
- Advanced interpersonal skills and ability to work withdiverse groups to achieve results.
- Advanced ability to work collaboratively with internal and external peers and managers.
- Highly skilled fundraising experience.

5. Education and Training

If needed, edit the pre-filledinformation below.

Education/Training:

Advanced degree in related area and/or equivalent experience/training

Licenses or certifications, if any:

6. Problem Solving

Please provide 2-3 examples of problemsolving for this position as described below (please be brief: 1-3 sentences).

Common problems solved by the employee:

- Change of subcontract scope of work and budget
- Reconciling cost accounting for multi-university center

Unusual or complex problems solved bythe employee:

- Developing small (less than $100k), non-technical project proposals
- Developing web-based project data collection and reporting

Problems/situations that are referred to this employee's supervisor:

- Funding agency criticism ofcenter’s strategic plan
- Significant changes in budgeted versus actual costs for center

7. Supervision (NOTE: Complete this section ONLY if the incumbent in this position,**in addition to the personally performed duties**, performs at least 3 ofthe following):

- Independently selects subordinates OR participates in the interviews and recommends who should be hired;
- Independently determines subordinates' performance ratings OR recommends performance ratings;
- Independently decides within budgetary limitations the amount of subordinate merit increases, whom will be selected for promotional opportunities, and whether to request the reclassification of a position, OR recommends these actions;
- Has independent authority to issue written warnings and suspensions and determines what discipline should be imposed upon a subordinate OR recommends such actions;
- Has independent authority to resolve grievances or complaints OR formulates and recommends a resolution to grievances or complaints.

"Recommendations" are customarily given substantial weight by higher-level supervisors/managers and are typically accepted. Positions that give work assignments to other employees and review their work products, but do not perform at least 3 of these functions are typically LEAD positions,not supervisory positions.

Indicate employeessupervised, job title and FTE.

Employee Supervised Job Title FTE

Please follow your department's or division's procedures for management review and then subm it to your Department HR Manager.

Document Retention

Review the job descriptionwith the employee before submitting it and annually thereafter at the time of the employee's performance evaluation. Sign and date below and placea copy in thepersonnel file.

(Signature below is only required for hard-copy retention within thedepartment. Electronicsubmission does not requiresignatures.)

Supervisor Name:

Employee Signature:

Date:

Supervisor Title:

Supervisor Signature:

Date:

Attachment 6.4: Sample Acknowledgement of NSF Support

(Check individual Cooperative Agreements for specific language requirement)

The Awardee is responsible for assuring that an acknowledgment of NSF support is made:

1. In any publication (including World Wide Web pages) of any material based on or developed under this Agreement; and
2. During all news media interviews, including popular media such as radio, television, newspapers, and newsmagazines.

This acknowledgment of NSF support through the Engineering Research Centers Program must appear or be stated in publications, presentations and interviews resulting from ERC-supported activities, using one of the following statements:

Either: *"This work was supported primarily by the Engineering Research Centers Program of the National Science Foundation under NSF Cooperative Agreement No. xxxxxx Any Opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation."*

Or: *"This work was supported in part by the Engineering Research Centers Program of the National Science Foundation under NSF Cooperative Agreement No. xxxxxx. Any Opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation."*

For research supported by other sources but making use of ERC Shared Facilities, the following statement should be used:

"This work made use of Engineering Research Centers Shared Facilities supported by the National Science Foundation under NSF Cooperative Agreement No. xxxxxx. Any Opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation."

Attachment 6.5: NSF Classification\Personnel Types

Attachment 6.6: Site Visit Checklist

Chapter 7: Diversity and Culture of Inclusion

Notes:

While this chapter is part of the ERC Best Practices Manual, the DCI Leaders community would like to emphasize that the guidance within the chapter might more aptly be termed "promising practices."

This chapter takes an aspirational view in outlining what ERC DCI programs can achieve. The intent is not to set unreasonable goals, but to provide DCI personnel with frameworks, suggestions, and actionable tips that can be applied within the unique contexts of different ERCs.

Within this chapter, ERCs will be referred to by their acronyms. For a complete list of ERCs and links to their websites, please visit the ERC Association home page, Centers tab.

7.1 OVERVIEW

7.1.1 Why Are Diversity and a Culture of Inclusion Important in ERCs?

Since the inception of NSF Engineering Research Centers (ERCs) in 1985, the incorporation of diversity efforts has been a focus. However, the evolution of emphases and practices has been different both across individual ERCs and across time, as well as within the overall ERC Program itself. The early ERCs were established with the understanding that increased participation of individuals from underrepresented backgrounds would be essential for the development of a competitive science, technology, engineering, and mathematics (STEM) workforce in the U.S. It was also recognized that diversity of participation would be important for ERCs to produce the most innovative, creative, and robust solutions to the complex challenges facing our global society. Over time, it was recognized that in addition to diversity of ERC participants, a culture of inclusion—an ERC climate that accepts, values, and recognizes as a strength the differences among all participants—is required to realize the full potential of ERCs.

7.1.2 Evolution of the Focus on Diversity in ERCs

Early ERCs focused mainly on increasing the numbers of individuals who share identity characteristics with those who have been historically and systemically excluded from participating in similar STEM efforts. Across the generations of ERC calls for proposals, there has been an increasing emphasis on understanding and improving the culture of the center organization and creating ERCs as spaces where diverse communities of STEM professionals and students could thrive. By the second "class" (award year) of third-generation (Gen-3) ERCs, awarded in 2011, the emphasis was explicitly on not viewing diversity efforts as simply increasing headcounts of ERC participants from underrepresented groups, but as an expectation that ERCs will promote Diversity and a Culture of Inclusion (DCI).

In 2017, at the request of NSF, the National Academies of Sciences, Engineering, and Medicine (NASEM) issued *A New Vision for Center-based Research*, a report that explored the future of center-based engineering research, the skills needed for effective center leadership, and opportunities to enhance engineering education through the centers. In 2019, an NSF ERC working group considering the NASEM report recommended that NSF insist that convergent[2] engineering research centers continue to build upon the success of ERCs in expanding the diversity of the engineering workforce. The NASEM Report included the finding that "The goal of expanding diversity in science and engineering is not only good for the creativity and productivity of research teams, it is good for expanding the capacity of the United States to innovate and compete." Accordingly, the emphasis on strengthening the culture of inclusion is very visible in the refined calls for Gen-4 ERCs, beginning in 2020.

In early 2021 with input from existing ERC DCI Directors, the NSF ERC Program issued a Statement on Diversity and Culture of Inclusion that: (i) established clear definitions for diversity and a culture of inclusion, (ii) explained the importance of the DCI Director's role in an ERC, (iii) outlined high-level goals for ERC DCI programs, and (iv) listed suggested processes ERCs can implement to demonstrate a strong culture of inclusion. The manner in which achieving these goals is carried out still remains at the discretion of the individual ERCs, with input from NSF site visit teams and ERC advisory boards. However, the availability of the definitions greatly clarifies the expectations of NSF and supports the transformational change work of ERC DCI professionals. The statement is reproduced in full within this chapter in Section 7.1.4.

2 Convergent research is defined by NSF as "High-risk/high-payoff research ideas and discovery that pushes the frontiers of engineering knowledge; ERC convergent research is a deeply collaborative and cross/transdisciplinary effort that results in positive societal impact."

It is important to note that, as with diversity efforts in all types of organizations, there was a time when the responsibility for diversity efforts often fell to one person within the organization. The 2021 definitions and expectations clearly move the thinking and expectations to that of an integrated model. In this integrated model, *all* members of the ERC's leadership team, faculty, and staff are responsible for contributing to promoting and facilitating a culture of inclusion within ERCs. In this new paradigm, all ERC participants, at all levels, are expected to be aware of and participate in ERC DCI efforts. Furthermore, they are trained on DCI topics, and may even have defined DCI roles or responsibilities.

7.1.2.1 Evolution of DCI Terms

Like the work itself, the language of DCI is ever evolving. Terms and phrases such as "diversity," "diversity and inclusion," "diversity, equity, and inclusion," and "broadening participation" have evolved over time, with "culture of inclusion" added more recently. While some terms may be common knowledge and heard regularly in casual conversation, there are many related terms and concepts that may not be familiar. DCI personnel are encouraged to read DCI literature to continually update and add nuance to their working knowledge of these terms.

7.1.2.2 New Features of Gen-4 ERCs

While DCI has long been a key facet of ERCs, the Gen-4 ERC framework further emphasizes Diversity and Culture of Inclusion as one of an ERC's four foundational components, alongside Convergent Research, Engineering Workforce Development, and Innovation Ecosystem (see Figure 1 in the solicitation; and NSF's October 2020 orientation presentation on DCI to new Gen-4 ERCs). In the mid-1980s, ERCs were built on a "three-legged stool" of research, education, and technology transfer—with "diversity" being generally understood as a component of ERC education programs. The foundation of research, education, and technology transfer has evolved over time with DCI now coequal with these three components.

7.1.3 The Data: ERCs vis-à-vis National Averages

NSF requires ERCs to both report on headcounts within their organizations and benchmark those headcounts against national engineering averages and other ERC averages. Specifically, data on the participation within leadership, faculty, postdocs, undergraduates, and graduate students are captured across several demographic categories (e.g., Women, Underrepresented Racial Minorities, Hispanics/Latinos, and Persons with Disabilities). Definitions are available for each of these groups in Section 7.6.1.1. NSF expects ERCs to recruit and retain researchers and participants at levels that exceed national averages for underrepresented groups (across gender, race, ethnicity, and disability status) across all ERC partner institutions.

Overall diversity of ERC participants has increased over time and has historically exceeded national averages at all levels and for each demographic category reported. While these data imply that ERC efforts are impacting participation from groups historically underrepresented in STEM, it remains clear that there is still significant work to be done to increase representation. It is also important to ensure that ERCs remain ever-evolving in their efforts to establish ERCs as spaces in which individuals who share identity characteristics with those who have been systemically excluded from participating in STEM efforts want to work and develop academically, professionally, and personally.

7.1.4 NSF ERC Program Statement on DCI

The 2021 NSF ERC Program Statement on DCI provides foundational information and framing for ERC leaders and DCI personnel. It is available for download via the ERC Program website, reproduced in full within this section, and referenced throughout this chapter.

"In an effort to provide greater clarity among NSF program directors, and ERC leadership and personnel regarding expectations for ERC Diversity and Culture of Inclusion programs, the ERC team is issuing the following common definitions and responsibilities for ensuring access and opportunity for success for all ERC participants.

*What do we mean by **diversity**?* Diversity is defined as a spectrum of human differences, such as social, ethnic, and gender backgrounds. The ERC Program supports broadening participation in groups that historically have been underrepresented in STEM due to marginalizing and discriminatory practices. Although there are many ways that diversity can be understood and many different facets to individuals' identity, the ERC program is primarily focused on broadening participation with respect to **race, ethnicity, gender, disability, socioeconomic status, veterans, and first-generation students.** The ERC program promotes diversity across all participating institutions and across all levels of ERC participation, including leadership, faculty, staff, postdocs, and students, as diverse teams have greater potential for impact and innovation (AlShebli, Rahwan, & Woon, 2018; Freeman & Huang, 2014; Nielsen et al., 2017).

*What do we mean by **culture of inclusion***? The ERC program defines a culture of inclusion as an environment in which all members feel valued and welcomed, creatively contribute, and gain respect and mutual benefit from participating. A culture of inclusion also requires accessibility practices, such as those that ensure facility, technology, and activity access for individuals with a wide range of disabilities. A culture of inclusion is a necessary foundation for effective teaming (National Research Council, 2015). In addition to forming a diverse team, the culture of the ERC and teams within the ERC should support convergence through inclusive collaboration.

*Why is the **ERC Diversity Director** or equivalent position important?* All ERC personnel have a responsibility to contribute to a culture of inclusion. To develop and lead the ERC's strategic approach to Diversity and Culture of Inclusion, the role of the ERC Diversity Director is critical. This includes having responsibility, authority, and accountability to set and achieve diversity goals and cultivate a culture of inclusion. The Diversity Director must have the ability to impact budget decisions and be provided the resources needed to accomplish diversity and culture of inclusion goals. We suggest this person be a part of the leadership team, and the person in this role must interact with research thrust leads and industry representatives, as well as education and workforce development personnel. Clearly, the person selected for this role must have demonstrated knowledge and expertise in broadening participation.

*What are the high-level **goals** of the ERC DCI program*? Since a major goal of the ERC program is to train a domestic workforce, the majority of ERC participants should be US citizens or permanent residents within categories of faculty, postdocs, graduate and undergraduate students. The ERC program also values the diversity contributed from international perspectives in achieving ERC goals. The ERC program strives for ERC participation that is representative of the diversity of the national population. ERCs strive to exceed national engineering average levels of participation for underrepresented groups defined by gender, race, ethnicity, and disability status across all ERC partner institutions.

What processes can ERCs implement to demonstrate strong cultures of inclusion? ERCs can demonstrate continually fostering a strong culture of inclusion by:

- Demonstrating a strong **commitment to diversity and inclusion** from the leadership team
- Balancing **shared accountability** so that the ERC Diversity Director is not solely responsible for accomplishing the diversity goals or the culture of inclusion goals
- Applying evidence-based **universal/inclusive design** and accommodation practices to ensure that all activities and resources are accessible to and inclusive of individuals with a broad range of characteristics, including disabilities
- Maintaining a transparent **living strategic plan** where goals and objectives align with institutional initiatives, and are revised on a regular basis, programmatic elements are aligned with goals, and evaluative data is fed back into program goals and implementation
- Setting a **shared vision** with common expectations and goals among all ERC personnel
- Providing safe and secure **communication channels** for underserved voices
- Establishing clear **codes of conduct** for participating in the ERC, including team interaction and meeting.
- Engaging **partners** designed to reinforce ERC culture of inclusion including industry partners, university groups, professional societies, and other stakeholders
- **Onboarding** new ERC personnel and partners to establish clear expectations and shared values
- Offering on-going **trainings** and resources to reinforce expectations for individual conduct and build knowledge, skills, and attitudes in key areas of diversity and inclusion
- Providing opportunities for **mentorship** among all ERC personnel (multi-directional)
- **Communicating** a clear message of the ERC's culture of inclusion and values and attitudes regarding diversity, across multiple formats and media
- Creating systems for **rewarding and recognizing** contributions that reinforce the ERC's culture of inclusion
- Implementing an **assessment strategy** with SMART (specific, measurable, attainable, relevant, time-bound) metrics
- **Retaining** both diverse students through completion of degrees and staff and faculty within the ERC with opportunities for mutual benefit that increase the diversity of the ERC.

These listed approaches are intended to serve as suggestions for processes that ERCs may implement as part of an intentional culture of inclusion and are not to be construed as comprehensive, or a recipe for success. ERCs should adopt and adapt those approaches that best align with institutional contexts and resources, and demonstrate progress toward meeting Center goals and objectives."

7.1.5 DCI Community of Practice

ERC DCI Directors and personnel have formed a Community of Practice that meets virtually on a monthly basis and in-person at ERC Biennial Meetings. They also conduct focused workshops to create connections, discuss and disseminate DCI strategies and systems, and explore DCI collaborations across ERCs. The Community maintains a list of ERC DCI personnel as well as a nanoHUB focus group. If you are an ERC DCI professional who wants to be added to the list or the nanoHUB focus group, please ask your DCI Director or NSF Program Officer to connect you.

Examples of meeting topics and workshops from the ERC DCI Community of Practice include:

- Resources and programs related to mental health and well-being as they relate to fostering a culture of inclusion within ERCs
- Examples, frameworks, and strategies to encourage and/or support student-led and/or Student Leadership Council-led DCI initiatives
- Assessment and evaluation strategies, reporting, systems for DCI programs
- "Bias Busting Across the Center: A Model to Interrupt Bias and Promote Inclusion" train-the-trainer workshop offered by NASCENT for adoption of workshop curriculum by other ERCs
- Overview and discussion of resources from AccessERC designed to engage people with disabilities in NSF-funded ERCs
- Overview of CNT's partnership with Theater for Change UW (University of Washington) to highlight instances of bias and oppression, stereotypes, and discrimination and to role play and practice interventions and difficult conversations.

Outcomes from the ERC DCI Community of Practice include cross-ERC collaborations and reduced duplication of efforts through shared programming and resources. For example, a consortium of three ERCs obtained an NSF supplement to support a cross-ERC evaluation study that will provide the community with customizable, adaptable, consistent, shared instruments. In addition to the ERC DCI Community of Practice, ERC DCI Directors and personnel often participate in other institutional, regional, national, or international organizations and conferences where DCI research and practices are disseminated. Examples include:

- STEM professional societies at the regional and national levels such as the American Indian Science and Engineering Society (AISES), Great Minds in STEM, National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE), National Society of Black Engineers (NSBE), National Society of Black Physicists (NSBP), Out in Science, Technology, Engineering, and Mathematics (oSTEM), Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), Society of Hispanic Professional Engineers (SHPE), and Society of Women Engineers (SWE)

- The National Association of Multicultural Engineering Program Administrators (NAMEPA), an umbrella organization for engaging Minority Engineering Program (MEP) leadership at universities across the nation

- The Women in Engineering ProActive Network (WEPAN), an umbrella organization for engaging Women in Engineering Programs (WEPs) leadership at universities across the nation

- The American Society for Engineering Education (ASEE), a nonprofit committed to furthering education in engineering and engineering technology, leads many DCI engineering education initiatives and supports DCI-focused membership divisions including the Minorities in Engineering Division, Women in Engineering Division, and the Military and Veterans Division

- ASEE annual conference with sessions focused on DCI research and practices and meetings for DCI-focused membership divisions
- Collaborative Network for Engineering & Computer Diversity (CoNECD) annual conference for exploring current research and practices to enhance DCI of all underrepresented populations in the engineering and computing professions.

7.2 DIVERSITY & CULTURE OF INCLUSION PROGRAM PLANNING AND DIRECTION

7.2.1 ERC DCI Program Expectation

As has been stated, ERCs have a broad mandate to increase diversity and invest in a culture of inclusion. DCI programs are expected to integrate with all aspects of the ERC and to benefit all individuals within the ERC community; this includes faculty, staff, postdocs, students, K-12 learners, industry partners, and stakeholders. It is expected that ERCs' DCI programs will impact the ERC, the broader engineering community, the scientific enterprise, and society. They will also collectively serve as examples for other organizations to follow. According to the NSF Gen-4 ERC program solicitation, the expectation is that each ERC is "diverse at all levels of the Center and employs an intentional and evidence-based approach to developing a culture of inclusion".

DCI work is ongoing and never complete. It is hard, emotionally demanding, often uncomfortable, and incredibly necessary work that challenges the individual, the institution, and the systems in which the ERC operates.

7.2.1.1 DCI-informed Research

ERCs have the opportunity to advance DCI through research within the ERC's DCI program or through the ERC's overall research program. For example, collaborative DCI research across ERCs that investigates constructs within ERCs can illuminate promising DCI practices with positive impacts on advancing a culture of inclusion. An ERC's overall research program may also have a DCI focus with societal impacts, such as advancing social justice or improving public health.

7.2.2 DCI Program Management

7.2.2.1 Roles of DCI Program Personnel

NSF is not prescriptive regarding how each ERC structures and supports its DCI program staff. While earlier-generation ERCs sometimes employed a single staff person to manage both the Engineering Workforce Development (EWD) and DCI programs, the increased focus on DCI in Gen-4 ERCs makes specialized and dedicated DCI staff essential. This is especially critical if the DCI Director is a faculty member or administrator with additional responsibilities. Providing additional strategic staff support will facilitate a more robust and comprehensive DCI program.

While all ERC personnel have a responsibility to contribute to a culture of inclusion, the 2021 NSF ERC Statement on Diversity and Culture of Inclusion describes the role of the ERC Diversity Director as including "having responsibility, authority, and accountability to set and achieve diversity goals and cultivate a culture of inclusion. The Diversity Director must have independent decision-making capabilities, the ability to impact budget decisions, and be provided the resources needed to accomplish diversity and culture of inclusion goals. We suggest this person be a part of the leadership team, and the person in this role must interact with research thrust leads and industry representatives, as well as education and workforce development personnel." This includes supporting the recruitment and retention of ERC participants at all levels (students, faculty, staff) whose identity characteristics place them in historically marginalized groups. Additional DCI program staff support the implementation of the DCI strategy at the direction of the ERC's DCI Director.

7.2.2.2 Qualifications of the DCI Director

As described in the 2021 NSF ERC Statement on Diversity and Culture of Inclusion, the DCI Director "must have demonstrated knowledge and expertise in broadening participation." Given the position's roles and responsibilities, additional qualifications and expertise should include at least the following:

- Expertise in recruitment and retention of underrepresented groups in engineering
- Familiarity with DCI research, literature, and evidence-based practices and/or active on past DCI-focused research
- Ability to influence, communicate with, and actively collaborate with university administrators and faculty as well as students and postdocs across institutions
- Experience with strategic planning and program development, implementation, and assessment
- Engagement in the broadening participation community (professional organizations and conferences, university communities of practice, etc.) and having an ability to leverage that association to form strategic partnerships that are beneficial to the ERC

Other qualifications will be dependent on the needs of the individual ERC, such as experiences in strategic planning, assessment and evaluation, or engaging participants from specific groups historically underrepresented in STEM.

7.2.2.3 DCI Director's Position in Center Leadership

The 2021 NSF ERC Statement on Diversity and Culture of Inclusion highly recommends that the DCI Director be a fully participating member of the leadership team and interact regularly with research thrust leads, industry representatives, and Engineering Workforce Development personnel. While each ERC structures its leadership teams differently, the DCI Director is integral to overall center operations and should be included as a respected and valued team member alongside Directors of the other three ERC foundational components (Convergent Research, Innovation Ecosystem, and EWD) on the leadership team.

7.2.2.4 Roles of Broader ERC Leadership Team

To maximize impact of DCI programs, it is essential that ERC leadership has a significant, visible, and authentic role in DCI strategy and programming. Authentic engagement of ERC leadership can reinforce the importance of DCI efforts to the entire ERC community and foster shared accountability across the ERC. The ERC Director's role is to use their influence to lead the rest of the ERC to advance DCI goals and to fully engage the DCI director in the leadership team. It is the leadership team's role to ensure that all ERC processes and procedures are inherently inclusive and supportive of DCI goals.

As stated in the 2021 NSF ERC Statement on Diversity and Culture of Inclusion: "ERCs can demonstrate continually fostering a strong culture of inclusion by:

- Demonstrating a strong **commitment to diversity and inclusion** from the leadership team
- Balancing **shared accountability** so that the ERC Diversity Director is not solely responsible for accomplishing the diversity goals or the culture of inclusion goals."

To that end, the leadership team is responsible for ensuring that the ERC's policies and practices are inherently inclusive, and that a culture of inclusion is core to the design and implementation of all ERC activities (i.e., funding allocation, center meetings, fellowships, recruitment, etc.). The ERC leadership team is also responsible for ensuring that its DCI efforts remain vibrantly and optimally engaged with the all-important DCI efforts at all of the partner institutions over the life of the ERC.

7.2.2.5 Cross-institution Program Management

It is important that all ERC partner institutions, not just the lead institution, be actively involved in DCI activities. While there is no single prescribed partnership model, one strategy that has worked well for several ERCs is to have DCI-focused representatives from each partner institution form a committee that meets regularly. Some examples include:

- NEWT has an Inclusion and Oversight Board composed of the Diversity Director (lead institution) and members from each core partner institution.
- CISTAR's DCI Director has biweekly meetings with the leadership team, EWD team, and SLC.
- ReNUWIt's DCI Manager (lead institution) serves as a liaison across institutions and between the Center's faculty/staff and student/postdoc DCI committees--each of which includes representatives from each ReNUWIt institution.

Cross-institution DCI program integration can leverage ERC recruitment of participants from underrepresented groups, advance co-authorship and co-mentorship, and enhance partner institution diversity.

7.2.2.6 Cross-component Program Management

Many DCI Directors describe a strong relationship between the DCI Director and other ERC leaders as particularly critical to meeting the ERC's DCI goals; this includes integrating DCI throughout all four ERC foundational components. For example, DCI Director and EWD leaders' collaborations will advance DCI within the Engineering Workforce Development component. In addition to incorporating DCI best practices in Recruitment, effective collaborations with EWD leaders may include:

- Ensuring that outreach activities consider access and equity (e.g., translating materials to Spanish and/or other relevant languages, using materials that are low-cost and readily available in the home or easy to obtain, etc.)
- Encouraging undergraduate research experiences for students from minority-serving institutions that maximize publication-quality results for participants, involve (when possible) faculty mentors at the home minority-serving institution as co-authors, and provide students with multiple-summer experiences
- Designing in-person and virtual programs including mentor trainings, outreach programs, speaker or seminar series, etc. that follow inclusive principles, including universal design
- Participating in AccessERC programming and advancing EWD initiatives that promote the engagement of people with disabilities

- Providing mentoring and coaching for students to apply for fellowship support from programs such as the NSF-funded Alliances for Graduate Education and the Professoriate (AGEP) and Graduate Research Fellowship Program (GRFP).

DCI Directors may also collaborate with industry liaisons and the ERC Industry Advisory Board—oftentimes along with EWD leaders—to foster inclusive mentoring programs, to engage industry role models in EWD programming, and other initiatives to advance a culture of inclusion and workforce diversity.

7.2.3 Strategic Planning

Each ERC is expected to develop a strategic plan to guide their DCI programs. The strategic plan is a living document that is updated throughout the life of the ERC to reflect changing conditions such as evolving ERC priorities, ERC or partner institution demographic shifts, or new or enhanced ERC collaborations over time. The strategic plan is included in the Annual Report in an appendix. Several examples of DCI strategic plans are provided here.

7.2.3.1 Strategic Planning Considerations

While the DCI strategic planning process and strategic plan are unique to each ERC, there are some important common aspects to consider, including:

- Engaging representatives from all ERC partner institutions within a given ERC in the DCI strategic planning process allows the DCI strategic plan to reflect both ERC-wide and campus-specific contexts.
- Aligning the ERC's DCI strategy with university or department-level DCI plans and initiatives of partner institutions themselves strengthens the overall plan and supports sustainability.
- Developing the DCI strategic plan in light of, and even in coordination with, the overall ERC strategic plan helps to ensure leadership buy-in and awareness of DCI goals and plans while embedding DCI programs more deeply in the full range of center activities.
- Establishing metrics and timelines helps facilitate program assessment and drive progress.
- Sharing the strategic plan with the entire ERC community provides transparency and fosters the culture of inclusion.
- Including a strategy for accountability and/or incentives for meeting DCI goals emphasizes the importance of DCI to the ERC community.
- Creating processes to review and modify the strategic plan, metrics, and timelines in response to formative assessment increases program durability.

7.2.3.2 Assessment and Evaluation

Assessment and evaluation of DCI programs are essential to identify areas for formative improvement and to understand program impacts. Program assessment and evaluation should be led by an evaluator, with input from the DCI Director. In many cases, the same individual/team serves as evaluator for an ERC's EWD and/or DCI programs, which can streamline assessments throughout the center and provide a comprehensive understanding of intersecting or integrated EWD, education, and/or DCI program impacts. As outlined by NSF in the Gen-4 ERC solicitation, "Evaluator(s) may be internal or external to ERC institutions, but should be positioned to carry out the evaluation plan as objectively as possible." Ideally the evaluation strategy is tied to the DCI strategic plan and guided by a logic model (see NSF logic model webinar slides/transcript and here for examples of both).

Examples and considerations for DCI program assessment and evaluation include:

- Several ERCs administer annual climate surveys or periodic pulse check surveys to assess overall DCI program impact and the culture of inclusion within their ERCs. In addition to Likert-scale items, climate surveys often include open-ended questions such as “share about a time when you did not feel included in the center/program and why” or “what suggestions do you have that would make the center/program more inclusive?” to gain greater insights into the culture of inclusion.
- Most ERCs administer pre- and post-surveys with EWD/DCI programs that may include the summer Research Experiences for Undergraduates (REU), Research Experience for Teachers (RET), and Young Scholars programs. In these programs, measurable changes in such items as "interest in research" or "confidence in lab skills" are expected over the course of the program.
- Several DCI Directors disaggregate ERC participant demographic data by gender and ethnicity for deeper analysis of the impact of and any disparities in recruitment or retention efforts, participation and learning through programs and events, and culture of inclusion throughout the center.
- A consortium of three ERCs obtained an NSF supplement to support a cross-ERC evaluation study that will provide the community with customizable, adaptable, consistent, shared instruments.

7.2.4 Developing a Budget

It is recommended that the DCI Director discuss budget considerations directly with the ERC Director and budget committee. These conversations should begin as early as possible, ideally during the planning phases of the ERC, and be revisited every year. Unless there are significant resources being leveraged, core ERC funding will be necessary for a fully functional and robust DCI program. Since DCI is a core component of an ERC, there should be a shared expectation that the budget reflects its importance to the ERC. Further, it is expected that the budget consistently and continuously reflects attention to DCI over the entire ERC lifespan.

Depending upon the strategic plan and goals of the individual ERC, budget items to consider include (but are not limited to) the following:

- DCI staff salaries
- Diversity fellowships

- DCI programming for ERC participants at all levels
- Guest speakers or workshop presenters
- DCI-focused research
- Stipends, incentives, and/or awards for students, faculty, and/or staff supporting DCI programming
- ERC participant recruitment, with associated travel
- ERC community outreach, with associated travel
- DCI assessment and evaluation including evaluators, if DCI evaluation is not already included in ERC-wide evaluation efforts
- Teaching buy-out for faculty who serve as DCI Directors
- Seed grants for pilot DCI programs within the ERC.

In addition to core ERC funding, DCI Program support can be obtained through additional grants, supplements, corporate or organization partnerships, and by leveraging institutional resources.

Some examples of supplemental funding obtained by ERCs include:

- CBBG obtained an NSF Veterans Research Supplement (VRS) grant to support two veterans to conduct research.
- CISTAR, CMaT, TANMS, POETS and ReNUWIt obtained NSF Research Experience and Mentoring (REM) supplements.
- CNT obtained a supplement to fund their efforts with a local theater company that led diversity awareness training for the ERC.
- CNT obtained supplements for AccessERC and ERC-INCLUDES, both of which promote sharing of DCI best practices across NSF ERCs and projects.
- NASCENT and POETS leveraged institutional resources to have a recruiting presence at national diversity conferences.

7.2.5 Role of NSF

NSF provides general guidance regarding ERC DCI programs, such as with the 2021 NSF ERC Statement on Diversity and Culture of Inclusion, and offers input during monthly DCI Leaders' meetings and the ERC Biennial Meeting. The ERC Program funded a contractor to prepare this chapter of the ERC Best Practices Manual, working with a group of ERC DCI Directors. NSF representatives lead seminars and panels to inform the community about grant opportunities. ERC Program Officers also consult on ERC-specific questions and assemble Site Visit Teams. The NSF Engineering Education and Centers Division, which houses the ERC Program, also includes a dedicated Program Director for Broadening Participation in Engineering who is available as a resource and works in concert with the ERC Program in an advisory capacity.

7.3 RECRUITMENT

7.3.1 Recruiting Goals and Strategies

NSF expects ERCs to recruit and retain researchers and participants at levels that exceed national engineering averages for underrepresented groups (across gender, race, ethnicity, and disability status) across all ERC partner institutions. Recruiting at all levels throughout the ERC is a collaborative responsibility inclusive of ERC leadership, faculty, staff, and students. DCI should be considered in all aspects of recruitment (and retention) for the ERC, including the identification and recruitment of students for pre-college programming, undergraduate research experiences, and graduate student study and exchange programs, as well as the recruitment of staff, postdoctoral researchers, and faculty. Priority areas for recruitment and corresponding recruitment strategies will vary from ERC to ERC based on goals and needs. Diversity at all levels of each ERC is benchmarked against both national and all-ERC averages annually. These national averages can help an ERC identify priority areas for recruitment and establish goals for participation. The ERC's academic and engineering disciplines along with partner institutions' demographics, communities, and cultures can influence participant diversity and may also influence priority areas and goals.

Each ERC should establish recruitment goals that are both attainable and aspirational within its own particular context, providing an opportunity for achievement and celebration of early and consistent efforts. In goal-setting and strategic planning, ERCs should consider the demographics and diversity in partner institution regions, authentic partnerships with and regional access to minority-serving institutions, and historical trends and sources for recruitment at all levels. Examples include:

- POETS' overall diversity goal is to be 10% above the national average on specific, identified primary diversity demographics. This strategically does not include the prioritized recruitment of Native Americans, since partner institutions are not located near high concentrations of Tribal lands.
- Given the large Hispanic populations in the states represented by NASCENT lead (Texas) and partner institutions (New Mexico, California, Texas), one of NASCENT's goals is to significantly exceed the national average of Hispanic participants at all levels of the ERC.

7.3.2 Recruitment of Students

7.3.2.1 Pre-College Students

Pre-college students are most frequently engaged with ERCs via Engineering Workforce Development programs, including Young Scholars programs, local school partnerships, camps, and outreach events. DCI Directors can provide input and support to ensure that pre-college program leaders recruit diverse participant cohorts, form and maintain mutually beneficial strategic partnerships with diverse schools and organizations, and lead accessible and inclusive programs.

Schools and school districts, non-profits, science centers, and museums near ERC partner institutions can be important strategic partners for broadening participation. Virtual educational programming can extend recruiting and strategic partnerships to schools and organizations at greater distances. The National Clearinghouse for Educational Statistics (NCES) can be used to identify schools and school districts near ERC partner institutions or in targeted communities with greater racial, ethnic, gender, and socioeconomic diversity. The NCES database also provides a school's Title 1 status and locale (rural, urban, etc.), two additional factors that contribute to the diversity of student participants. The National Afterschool Association (NAA), NAA State Affiliates, and the Association of Science and Technology Centers (ASTC) can help identify out-of-school time programs and partners.

Examples of how ERCs are recruiting pre-college students and creating strategic partnerships include the following:

- NASCENT strategically partners with Texas School for the Deaf and Texas School for the Visually Impaired to reach young learners with disabilities for pre-college outreach programs, including after-school STEM clubs.
- TANMS collaborates with UC San Diego's Center for Excellence in Engineering and Diversity (CEED) and leverages its connection to the Mathematics Engineering Science Achievement (MESA) program platform and its established long-term relationships with K-12 schools to reach Hispanic and URM students from low-income communities across 21 schools and 9 school districts.
- ReNUWIt partnered with Stanford's Office of Science Outreach to recruit into its Young Scholars Program local students who are lower income and first in their family to pursue college.
- POETS partnered with DREAAM House to recruit for their Young Scholars program. DREAAM House is a non-profit that provides a pre-kindergarten to college pipeline program for boys aimed at cultivating academic excellence and positive citizenship. Because this non-profit is highly involved with the community, POETS is able to gain unique access to participant families for a more holistic education approach.

7.3.2.2 Undergraduate Students

Undergraduate students become affiliated with an ERC primarily through participation in summer Research Experience for Undergraduates (REU) Programs and by conducting undergraduate research in ERC labs during the academic year. Recruiting for REU students is often national in scope. Recruiting for non-REU undergraduate research students most often occurs at local ERC partner institutions. Both national and local recruiting strategies may include participation in conference or campus career fairs, leading workshops or information sessions, facilitating faculty presentations, or marketing undergraduate student ERC opportunities to raise awareness and broaden participation. ERCs frequently partner with or participate in events through organizations, institutions, and programs that reach diverse undergraduate student populations, including:

- STEM professional societies at ERC partner institutions, at other universities, and at the regional and national levels such as the American Indian Science and Engineering Society (AISES), National Society of Black Engineers (NSBE), National Society of Black Physicists (NSBP), Society of Hispanic Professional Engineers (SHPE), Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS), Society of Women Engineers (SWE), Great Minds in STEM, Emerging Researchers National Conference, and Out in Science, Technology, Engineering, and Mathematics (oSTEM)

- Institutions which serve large numbers of individuals from groups underrepresented in STEM, such as Historically Black Colleges & Universities (HBCUs), Hispanic Serving Institutions (HSIs), Tribal Colleges and Universities (TCUs), Alaska Native- and Native Hawaiian-serving Institutions (ANNHs), Native American-serving, Nontribal Institutions (NASNTIs), and Women's Colleges

- Institutions that exclusively serve persons with disabilities (e.g. Gallaudet University in Washington, DC) or major research institutions with significant investment in serving persons with disabilities such as the University of Washington (AccessERC and DO-IT)

- Minority Engineering Programs (MEPs) at ERC partner institutions and the National Association of Multicultural Engineering Program Administrators (NAMEPA), an umbrella organization for engaging MEP leadership at universities across the nation

- Women in Engineering Programs (WEPs) at ERC partner institutions and the Women in Engineering ProActive Network (WEPAN), an umbrella organization for engaging WEP leadership at universities across the nation.

Below are a few examples of undergraduate recruiting partnerships:

- Many ERCs share REU recruitment information through NAMEPA and WEPAN listservs and newsletters to encourage applications from diverse audiences.
- Many ERCs list REU program information on the AccessERC "ERC Summer Opportunities for Individuals with Disabilities" website to encourage applications from undergraduate students with disabilities.
- CMaT supports two to four undergraduate students per year from minority-serving institutions external to CMaT to attend CMaT institutions for year-long mentored research experiences.
- POETS has strategically partnered with two minority-serving institutions for REU recruitment. This focused approach has allowed POETS to build a mutually beneficial relationship where students and faculty know each other and support recruitment efforts through program alumni.
- NASCENT shares recruitment information about its Texas-based REU program with NSBE, SHPE, SWE, SACNAS, oSTEM, AISES, and other STEM student societies and faculty advisors at institutions across Texas.

7.3.2.3 Graduate Students

Graduate students are recruited from ERC REU and undergraduate research programs as well as through similar organizations, institutions, and programs described previously for undergraduate recruiting. Graduate students may also come from the workforce, veteran community, or other non-traditional pathways into graduate school. Local, regional, and national professional STEM organizations, discipline societies, and alumni organizations can be useful resources or strategic partners for graduate recruiting. The National GEM Consortium student database, the GRE Search Service, and ERC partner institutions' graduate admissions centers can also be sources of prospective student lists for outreach and recruiting.

Students recruited from an ERC's REU Program and other undergraduate research activities are already familiar with the ERC's research, programming, and network. By working closely with ERC EWD staff, ERC undergraduate program alumni applying to graduate school can be identified and mentored through their application process. To encourage consideration for graduate admissions, a list of these ERC alumni applicants can be circulated to faculty involved in graduate admissions at the ERC partner institutions.

Coordinated and collaborative graduate student recruitment can be challenging across institutions, especially where recruitment occurs within separate departments or research groups and the ERC has limited control over the process. Coordinating efforts locally with graduate recruiting or admissions offices at ERC partner institutions can help leverage resources and access recruiting opportunities that may otherwise be cost or time prohibitive. In addition, encouraging ERC faculty or staff to engage in recruitment efforts (graduate admissions committees, recruiting weekends, etc.) on their home campuses can increase ERC visibility and support the ERC's recruitment goals and strategy.

Additional examples of the varied strategies developed by ERCs for recruiting graduate students include the following:

- ReNUWIt graduate students created "how to apply" guides for (1) graduate school and (2) the NSF Graduate Fellowship Research Program.
- ReNUWIt paired (1) REU alumni and (2) REU applicants from groups underrepresented in STEM and primarily undergraduate institutions with graduate student and postdoc mentors who provided feedback and encouragement during the graduate admissions process.
- NASCENT hosted virtual Graduate Recruiting Meet & Greet events where prospective graduate students who would increase diversity in the graduate student community were invited to meet current NASCENT graduate students in a virtual networking platform (Gatherly), learn more about the ERC, and ask questions.
- POETS and NASCENT partnered on a graduate student recruiting event and presentation at The University of Texas at San Antonio, a Hispanic-Serving Institution.
- POETS' DCI Director collects information from ERC faculty on promising candidates they would like to recruit. The DCI Director reaches out individually to gauge prospective student interest, build a relationship, share how the center can support their graduate work, and connect them with current center graduate students with similar backgrounds or interests.

Several ERCs have also used targeted fellowships as tools to recruit graduate students, including:

- NASCENT incentivized recruitment of women and URM graduate students with 25% matching funds from NASCENT for up to three students.
- The TANMS Doctoral Fellowship Program offers fellowships to candidates from underrepresented groups who are nominated by faculty and approved by a panel of external reviewers. This has encouraged TANMS faculty to explore students they may not have previously considered due to a variety of factors, including implicit bias.

7.3.3 Recruiting Post-doctoral Scholars

To ensure a diverse applicant pool for ERC postdoc positions, the DCI Director should provide guidance to the hiring faculty member throughout the recruiting and selection process. Guidance might include the following:

- Assisting in crafting the postdoc job description to include inclusive language welcoming candidates who would increase diversity in the ERC's postdoctoral community to apply
- A carefully crafted and high-quality postdoc mentoring plan that can give the ERC faculty compelling arguments to recruit postdoc talent; co-mentorship and career development considerations are two best practices to consider
- Supporting active recruiting through job boards or career centers that reach candidates who would increase diversity in the ERC's postdoctoral community (e.g., NAMEPA,

WEPAN, ASEE's Women in Engineering Division (WIED), ASEE's Minorities in Engineering Division (MIND), Pathways to Science, NSBE, SHPE, SWE, Institute on Teaching and Mentoring, LinkedIn)
- Sharing with leadership at synergistic ERCs, department chairs or deans at targeted universities including HSIs and HBCUs
- Providing training or resources to mitigate bias throughout the review, interview, and selection processes.

7.3.4 Recruiting Faculty

ERC faculty are recruited in two ways: expansion via collaborative research and direct hire into a specific department or faculty line. Expansion via collaborative research occurs when non-ERC faculty are added to the ERC, either by joining existing project teams or through the creation of new projects that align with the ERC's research strategic plan. Since the added researchers are already faculty at one of the ERC's institutions, this mechanism does not require hiring a new faculty member.

Faculty recruitment via direct hire is less straightforward, because ERCs are rarely the actual hiring agent for the role. When possible, ERCs may seek to influence departmental search processes regarding the use of best practices to attract and hire individuals that increase the diversity of the faculty, including those practices listed above for postdoc recruiting. Aligning ERC DCI efforts with institutional efforts can optimize institutional engagement—for instance, in securing "trailing spouse" support. Some ERCs have had success working with institutional leadership (Deans, Provosts, etc.) to secure new faculty lines, and in those cases they are often able to apply DCI best practices to the search.

Proactive identification of candidates is an important ERC faculty recruiting strategy for both collaborative research and direct hires. It is good practice for ERCs to regularly identify potential collaborators and faculty hires (current faculty, advanced doctoral students, postdocs) who are working on research that aligns with the ERC's research field. ERC leadership can be proactive in their efforts to both forecast needs and constantly identify potential candidates well before a call for collaboration or an official hiring search is announced.

In addition to the same proactive practices listed previously for postdoc recruiting, there are many strategies, processes, and resources that support the recruitment of faculty that will increase diversity, such as:

- Women in Science & Engineering Leadership Institute (WISELI) "Searching for Excellence and Diversity: A Guide for Search Committees"
- NSF ADVANCE programs toolkits, guides and processes that advance diversity in faculty hiring processes
- ERC partner institutions' faculty hiring guides, such as UC-Berkeley Research to Support Faculty Searches, Climate, and Retention
- Creating postdoctoral-to-tenure-track-appointment opportunities that create a pathway for scholars who would increase faculty diversity to be mentored by faculty as a postdoctoral scholar, which then culminates afterward in a potential tenure-track appointment.

7.3.5 Recruiting Staff

Staff hiring is fully within the control of ERC leadership. To design recruiting and hiring practices that lead to increased staff diversity, similar strategies as those described for postdocs and faculty should be used, i.e.:

- Intentional crafting of job postings to remove unnecessary or biased job requirements, use inclusive language, and encourage applications from individuals who could increase the diversity of ERC staff
- Maximizing career development and "train the replacement" processes to avoid inadvertent glass ceilings
- Posting the position through services or systems that reach candidates who could increase the diversity of ERC staff (diversity staff organizations on university campuses, etc.)
- Utilizing partnerships with minority-owned placement agencies and/or human resource offices at partner institutions to increase the potential to attract many candidates who would increase the diversity of ERC staff
- Providing training or resources to mitigate bias throughout the review, interview, and selection processes.

Always a good resource to consider are DCI staff of recently graduated ERCs, as well as networking among the current members of the DCI Community of Practice for suggestions of possible candidates.

7.4 RETENTION

Retention within an ERC includes retention of individuals whose participation contributes to the diversity of the ERC at all levels both within the partner institutions and across the ERC. DCI-focused strategies and considerations for retention vary based on the target audience (students, faculty, or staff); however, there are some essential components of retaining individuals whose participation contributes to the diversity of the ERC. These include:

- Timely, strategic, and inclusive onboarding that introduces ERC norms and unwritten rules, fosters relationship building with peers and other ERC participants at varying levels, clearly communicates expectations, shares resources available through the ERC and ERC partner institutions, etc.
- Structured and informal mentoring opportunities and training
- Inclusive and value-adding practices at ERC reviews, IAB meetings, and retreats, which reinforce DCI-related retention
- Clear and open communication and resource-sharing across the ERC, using tools such as newsletters, collaboration spaces (e.g., Zoom, Slack, Microsoft Teams), regular meetings, etc.
- Fostering a culture of inclusion where all ERC participants feel welcomed, included, supported, seen, and heard while examining the impact of culture and climate within the departments and institutions that form the foundation of the ERC (see Section 7.5).

ERC participants whose background and experiences add to the diversity of the ERC can be influenced by different factors that affect their engagement and performance and that manifest both internally and externally. While DCI practices are becoming more responsive to how community members are supported within organizations, it is sometimes easy to focus solely on performance and overlook the challenges faced within our systems, institutions, and society.

Overlooking, minimizing, or ignoring these factors and/or challenges can alienate and isolate ERC participants and lead to damaged relationships, poor retention, reduced productivity, and loss of institutional knowledge. A few examples are shared below:

- Recognize the phenomenon known as ‘cultural taxation’ where participants from underrepresented groups are frequently asked to undertake extra, often uncompensated work to address DCI aspects of the center; ERC leadership can compensate participants for extra work and recognize disparities in requests for engagement.

- Understand that local, regional, national or international events may unequally impact participants or their communities; ERC leadership may share ERC-wide messages reiterating ERC values centering on DCI or hold “town halls” for discussion while recognizing possible effects on individual ERC participants (e.g., Black Lives Matter movement, hate crimes against Asian Americans and Pacific Islanders, wars or conflicts in foreign countries, etc.); specific, intentional, and authentic actions must follow messaging and discussions.

- Recognize that bias, discrimination, and harassment are experienced and/or internalized differently by each individual; ERC leadership can directly address bias, discrimination, and harassment and foster a culture of inclusion within the ERC while also recognizing that external systems and structures may continue to affect ERC participants.

7.4.1 Retention of Students

Student retention at both the undergraduate and graduate level is a critical aspect of any institution of higher education, and this is no different for ERCs. DCI Directors, in collaboration with EWD and education leads, play an important student affairs role in monitoring and supporting student progress towards the degree, engagement in ERC activities, sense of belonging, and other factors that influence retention both within partner institutions and the ERC.

In addition to the onboarding, mentoring, communications, and DCI components listed previously, activities that contribute to the retention of students that increase diversity at all levels of the ERC include:

- Structured and informal peer mentoring and faculty mentoring opportunities and training; resources include:
  - National Center for Women in Information Technology’s guide: “Set Up a Mentoring Culture for Graduate Students: Roles of Faculty and Peers”
  - Purdue University’s mentoring handbook: “Mentoring: For Graduate School and Beyond”
  - National Academy of Sciences publication: “The Science of Effective Mentorship in STEMM”
- Regular and inclusive interaction with ERC faculty and leadership fostered by open door policies, regularly scheduled office hours, networking events or socials, etc.
- Awareness of changes in individual, small group, or ERC-wide student engagement or retention where check-ins on student perspectives, experiences, and needs may be necessary
- Peer-led networking and social events to foster relationships across the ERC

- Focus groups with students at each partner institution led by the DCI Director or external evaluator on an annual basis to allow students the opportunity to elaborate upon climate survey questions, discuss DCI challenges or opportunities, share feedback on ERC activities, and/or provide input on future ERC directions
- Workshops, professional development, and resources incorporating the student voice in the planning and dynamically adjusting based on community needs (e.g., mental health and wellbeing support during the COVID-19 pandemic).

Specific examples of retention-focused activities within ERCs include:

- PATHS-UP offers a Diversity Mentoring Program to all team members, with flexibility for students to choose mentors at any PATHS-UP partner institution.
- NASCENT incorporates DCI-related icebreakers into graduate student orientation in order to help build relationships among students and to celebrate the diversity across the ERC.
- NEWT, CBBG, and PATHS-UP offer an anonymous reporting system where students can report their concerns without fear of repercussions.

7.4.2 Retention of Faculty

While DCI Directors should be aware of faculty retention considerations, implementation of retention-focused activities will likely rely on ERC leadership, partner institution leadership, and research faculty.

In addition to the onboarding, mentoring, communication, and culture of inclusion components listed previously, other activities that contribute to the retention of faculty who augment the ERC's diversity include:

- Providing a formal mentoring program for new ERC faculty, with particular emphasis on supporting new faculty whose identity characteristics place them in historically marginalized groups
- Supporting ERC faculty with mentoring and professional development for NSF CAREER award and other grant preparation
- Mentoring junior ERC faculty who must balance individual research accomplishments required for tenure with the collaborative research characteristic of ERCs
- Fostering professional relationships between ERC faculty within and across partner institutions that may result in collaborative grant-writing efforts
- Encouraging ERC and partner institution leadership to build robust counteroffers for high-performing faculty.

7.4.3 Staff

ERC staff provide an important foundation and source of continuity of ERC and institutional policies, practices, and culture over the lifespan of the ERC. It is important that ERC faculty leadership establish strong and empowering relationships with all staff and ensure that those in leadership positions within ERCs regularly demonstrate how they value the people filling staff positions. Care must be taken not to establish practices that overburden staff—especially people whose identity characteristics place them in historically marginalized groups—as they often find themselves being drawn upon by multiple ERC constituents who all view their needs as high priority.

In addition to the onboarding, mentoring, communication, and DCI components listed previously, other activities that contribute to the retention of staff that contribute to the ERC's diversity include:

- Connecting staff with their counterparts at other ERCs and supporting peer-mentoring and professional development
- Seeking input from staff, recognizing that staff are professionals in their specific vocations, with expertise that contributes to the success of the ERC
- Including staff in decision-making that can affect them and their responsibilities
- Working with institutional DCI leadership to maximize career advancement opportunities within the ERC so that diverse talent can be retained.

7.5 FOSTERING A CULTURE OF INCLUSION

ERCs serve as change agents for advancing DCI and establishing the importance of inclusive cultures in academic engineering programs and the engineering community at large. ERCs can drive innovation and advance a culture of inclusion throughout systems and institutions even where DCI is not a priority or where DCI efforts have been previously unsuccessful. This section outlines general approaches to fostering a culture of inclusion, followed by some concrete examples of promising ERC activities.

7.5.1 Engaging ERC Participants at All Levels in DCI

As has been noted repeatedly, NSF expects ERC participants at all levels to be actively engaged in DCI; one of the Gen-4 Performance Criteria for high-quality DCI is "All faculty, staff, and students are engaged in DCI program and rewarded for their efforts."

Examples of strategies ERCs use to engage participants at all levels include:

- NEWT awards annual cash prizes to recognize faculty or staff and students who have made significant DCI program contributions; the committee accepts nominations and selects awardees based on a shared rubric.
- CBBG expects that all ERC participants attend DCI-related modules and build in time during workshops to move beyond awareness into self-reflection, ERC reflection, and action.

7.5.1.1 Engaging Students

Many ERCs have found success with involving students in their DCI work and providing opportunities for students to lead DCI efforts, while being careful not to overburden them. Students often feel heavily invested in DCI issues and want to contribute. ERCs can empower students via their Student Leadership Council (SLC)[3] and other avenues. It is important to value student contributions while balancing their need to focus on their research.

Specific examples of ERCs engaging students in DCI include:

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3 Every ERC has a student group, the Student Leadership Council (SLC), which provides mutual academic and social support for ERC-affiliated graduate and undergraduate students. The SLC provides feedback to the center leadership and participates in a student-led strengths, weaknesses, opportunities, and threats (SWOT) analysis of the ERC itself in conjunction with the ERC's site visits.

- PATHS-UP has a student DCI liaison on the SLC and engages students in outreach activities. Student liaisons who are heavily involved with DCI programming help ensure that all students are apprised of upcoming events. They are also great ambassadors for recruiting efforts.
- ReNUWIt has a Student/Postdoc Committee on Diversity and Inclusion, the leader of which also sits on the SLC. The SPCDI meets monthly, interfaces with the Faculty/Staff Committee on Diversity and Inclusion, and stewards DCI-related initiatives.
- NEWT has two DCI liaisons on the SLC who aid in communicating DCI activities among not only the student population, but also across the entire NEWT community including its faculty and staff. The liaisons lead Center-wide DCI sessions, coordinate an alumni panel, work in conjunction with the SLC social chairs on social events, and coordinate sessions where students can discuss their research to build collaborations, ask questions, and seek help among their peers within the Center.
- Many ERCs incorporate DCI themes into training workshops for graduate students who will serve as mentors in the ERC's EWD programs (e.g., REU, RET, REM, Young Scholars, etc.).

7.5.1.2 Engaging Leadership and Faculty

Again, the importance of ERC leadership and faculty participation in achieving the ERC's DCI goals cannot be overstated. Members of the ERC community look to leadership for cues, as the leaders set the tone and reinforce community norms. ERC leadership and faculty are expected to champion and engage in center efforts to increase diversity and foster a culture of inclusion.

Some examples of ERC leadership demonstrating DCI support include:

- CBBG added diversity and inclusion as a weighted category in their evaluation criteria for active and proposed projects. The category includes both the diversity of team members and the project's impact on broader populations.
- CMaT developed a Center-wide code of conduct that declares the ERC's commitment to "fostering, cultivating, and preserving a culture of integrity, collegiality, service, and diversity and inclusion."
- NEWT and PATHS-UP issued inclusivity statements, displayed prominently on their website's homepages, that the ERC "is committed to a culture of inclusivity, and all of our members reject and condemn all forms of racism, discrimination, brutality, and violence."
- CISTAR's Director, in consultation with DCI Directors, sent a Center-wide email in response to summer 2020 events and protests for racial justice to reiterate the ERC's dedication to DCI issues and encourage everyone to join in the fight against institutional racism by learning how to be a better ally.

As an incentive for DCI engagement, ERC leadership may tie key DCI objectives to project, student, staff, or postdoc funding.

7.5.1.3 Engaging Staff

There should be clarity in the role that staff who are not assigned DCI roles have in contributing to an inclusive culture. Concrete examples of the importance of staff contributions to an inclusive culture are essential. Even if they aren't actively interacting with students or hiring faculty, staff are the face of the ERC and their interactions with all personnel establish and reinforce the culture. Their role in creating policies and procedures affects the structures everyone has to navigate. This is a core aspect of retention and the culture of inclusion.

7.5.2 Awareness and Training Activities

To support the shared responsibility of all ERC participants in fostering a culture of inclusion, most ERCs offer in-person or virtual workshops designed to raise awareness of DCI concepts and terminology, increase understanding of the role biases play, reduce the impact of bias in our community, introduce the concepts of allyship and accompliceship, foster more inclusive mentoring and role modeling interactions, and/or practice interrupting bias with role plays. Workshops are often hosted in conjunction with Annual Meetings or IAB Meetings, retreats, new student orientation, or REU or RET programs. ERC DCI staff, external DCI professionals, or ERC partner institution DCI professionals, such as staff from a Gender Studies Program or Multicultural Center, often serve as workshop facilitators and presenters. Engaging DCI professionals outside of the ERC with complementary areas of expertise, including DCI professionals from other ERCs, can broaden the scope of the ERC's awareness and training activities.

Many ERCs have examples of awareness and training activities, such as the following:

- CBBG offers educational DCI webinars at regular intervals throughout the year, which are also recorded and archived in a repository.
- NASCENT offers a BiasBusters workshop modeled after the BiasBusters@CMU and Google's Bias Busting@Work programs to increase awareness about implicit bias and stereotypes and to reduce the impact of bias in their community.
- CELL-MET, CNT, and ReNUWIt hired theater-based groups to provide DCI programming at Annual Meetings.
- PATHS-UP offers a biannual Equity, Diversity, and Inclusion workshop series, held on a Center-wide basis, that addresses implicit and explicit biases.
- CISTAR held a training on "Global Dexterity" to create more understanding of how to adapt effectively cross-culturally and become a global leader.

Many also create online resources:

- NEWT created a suite of mandatory online modules that cover topics ranging from inclusion best practices to faculty-student interactions to bystander intervention and de-escalation. These modules are accessible through nanoHUB.
- ReNUWIt's Inclusive Excellence Initiative offers actionable tips for creating more inclusive classrooms, research groups, and peer-to-peer interactions.

One ERC invested in individual DCI training:

- CURENT hired an external consultant to lead a comprehensive, in-person training with ERC leadership (17 faculty and students), with one-on-one follow-up sessions and creation of individual development plans in the DCI realm.

7.6 DCI IN REPORTING AND SITE VISITS

DCI Directors provide formal updates on the ERC DCI strategic plan as well as the ERC's DCI activities and accomplishments through the ERC Annual Report and annual NSF Site Visit. Additional DCI reporting may be required for internal ERC meetings, partner institution process, grant writing, conference presentations or papers, and other ERC or campus reporting needs. The ERC's website should also include DCI content and may include ERC DCI strategic plan updates, DCI-related activities, and ERC demographics.

7.6.1 Annual Reports

DCI data and evaluation results are included in each ERC's Annual Report via two main mechanisms: (1) demographic data entered into ERCWeb, and (2) the DCI chapter narrative. The ERC's DCI Strategic Plan is included as an Appendix and one or more DCI-themed "highlights" should be included in Appendix IV. DCI projects and project updates may also be included in Appendix V and Appendix VI (see example). DCI Directors are encouraged to review the most recent Annual Report guidelines for any changes to NSF requirements that might impact the DCI chapter narrative or reporting for appendices.

Collecting and entering personnel data into ERCWeb is typically handled by the center's Administrative Director (See BPM 6.6). These data populate a number of diversity tables and figures that are required for the Annual Report. Since the DCI chapter includes a discussion of these data, the DCI Director should coordinate with the Administrative Director to establish dates for finalizing personnel data entry, leaving sufficient time for the DCI Director to analyze, disaggregate, and discuss the data.

The DCI Director is typically responsible for writing the DCI chapter narrative. The purpose of the narrative is to capture the ERC's activities and accomplishments over the past year, describe their integration with the other main ERC efforts, summarize demographic data, present DCI assessment and evaluation results, and report progress towards DCI goals and outcomes. This may include some overlapping DCI-related highlights from EWD programming or other areas of the ERC, requiring collaboration with other ERC leaders for overall annual report and narrative completion. The format for the DCI chapter narrative varies across ERCs, with some ERCs aligning the narrative to the ERC's DCI Strategic Plan. Site Visit Team members review this narrative prior to the Site Visit.

7.6.1.1. NSF (Federal Government) Definitions and ERCWeb

It is helpful to keep NSF's definitions[4] handy when considering ERC demographics and associated Annual Report DCI tables and figures. It is also important to recognize that while these are the race categories required by NSF, race is not a biological construct. Rather, it is a social construct and as such it is continually evolving. The definitions below are currently used in NSF reporting:

- **Black or African American**: A person having origins in any of the black racial groups of Africa.

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4 https://www.census.gov/topics/population/race/about.html

- **American Indian or Alaska Native**: A person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment.
- **Asian**: A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent; for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
- **Native Hawaiian or Other Pacific Islander**: A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific islands.
- **White**: A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.
- **Hispanic or Latino**: A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin. People who identify their origin as Hispanic, Latino, or Spanish may be of any race.

Figures produced by ERCWeb, NSF's demographics reporting system, benchmark participation of Women, URM, Hispanic or Latino, and Persons with Disabilities against national engineering averages. These data are further disaggregated by citizenship status (U.S. Citizens or Permanent Residents, Foreign, or Citizenship not Reported). It should be noted that in ERCWeb-produced tables and figures, the acronym URM refers to underrepresented *racial* minorities and thus includes individuals who identify as Black or African American, American Indian or Alaska Native, and/or Native Hawaiian or Other Pacific Islander.

7.6.2 Site Visits

The NSF Site Visit represents an opportunity for the ERC to receive valuable feedback. There will likely be at least one Site Visit Team member who is specifically responsible for reviewing the ERC's DCI programs, though multiple Site Visit Team members may ask questions and contribute to the written Site Visit report comments. It is the Site Visit Team's job to identify both strengths and weaknesses of the ERC's programs, and offer constructive criticism.

DCI appears several times within Site Visit presentations. As specified in the Annual Site Visit guidelines, NSF expects the following:

- the ERC Director and Deputy Director will include DCI goals, strategy, and accomplishments within the Overview of the Center presentation;
- the Engineering Workforce Development team will discuss the role of education programs in strengthening the diversity of the ERC; and
- the DCI Director will "present an overview of the ERC's strategy to increase the diversity of the ERC's leadership, faculty, and student teams, actions taken, results to date benchmarked on national averages in engineering, the diversity climate of the center and the ERC's impact on diversity, and plans for the future."

DCI Directors should review the most recent Site Visit guidelines for any changes to NSF requirements. It is helpful for DCI Directors to prepare their presentations with the appropriate Gen-3 or Gen-4 performance criteria in mind.

Most Site Visits include overnight written questions that the Site Visit Team presents to the ERC leadership team at the conclusion of Site Visit presentations. These overnight written questions from the Site Visit Team are answered the following day by the leadership team in a final presentation to the Site Visit Team. The DCI Director should be prepared to remain with the

ERC team into the evening to draft responses to any questions that pertain to the ERC's DCI programs.

A few tips for more successful Site Visit experiences include:

- Anticipate potential challenging questions from the Site Visit Team based on your own assessment of your ERC's DCI weaknesses and practice responding to them.
- Prepare with your ERC Director and EWD leaders so they are familiar with your evaluation of DCI programming or any relevant contextual data or information and can help support you.
- Anticipate that the Site Visit Team will direct some DCI-related questions to partner institutions.
- Explore including DCI highlights or accomplishments in non-DCI Site Visit presentations such as in the ERC overview or research presentations. This gives all ERC participants a chance to discuss their contribution to DCI and shows the integration of DCI efforts throughout the ERC.
- Review the backgrounds of NSF Site Visit Team members--in particular those focused on DCI programs--to gain perspective on their DCI experience, their institution's DCI programming or focus, etc., in order to anticipate questions.
- If possible, sit next to the Site Visit Team member to allow for side conversations about DCI and enlist them as a partner in achieving the ERC's DCI goals.

7.7 SUSTAINING A CULTURE OF INCLUSION POST-ERC GRADUATION

An ERC is expected to have a 10+ year lifespan, as depicted in Figure 2-2 from the ERC History. It is never too early to start planning sustainability efforts to ensure that gains in DCI made over the course of the ERC live on beyond the end of NSF funding (termed "graduation"). Newer Gen-3 and Gen-4 ERCs should consider sustainability as they prepare materials for their fourth-year renewal review. Conversations about DCI program sustainability should be held at the leadership team level, and indeed at the institutional level, as part of larger-scale conversations about ERC sustainability. Potential avenues for DCI program sustainability are somewhat dependent on the long-term vision for ERC sustainability. If the ERC plans to remain a fully sustained entity post-graduation, the DCI Director can advocate for a continued budget and plan for a continuation of programs similar to those that operated during the ERC's NSF-funded period. If the ERC plans to transition to a different operating model post-graduation, DCI Program sustainability could be compromised.

It is also useful to understand the ever-changing landscape of DCI both within the ERC and within the contexts of the ERC partner institutions. This allows insights into potential available resources, institutional priorities, and leveraging opportunities. Additionally, communicating the impact of successful ERC DCI programming to ERC partner institution leadership can be important for possible long-term institutionalization of the programs.

Considerations and possible solutions for sustainability of DCI programs post-graduation include:

- Collaborating with offices and programs of partner institutions that might absorb and continue ERC DCI programming, partner on funding that might lead to inclusion in annual budgets, or support institutionalization of programming

- Seeking internal or external funding opportunities to continue programming, including exploring a corporate partnership model, looking into Deans' alumni development priorities, or identifying annual sponsors
- Utilizing technology solutions such as web-based toolkits and resources, video libraries or playlists, online courses, and other systems for open access to program content.

Sustainability of diversity programs has not been tracked for Gen-1 and Gen-2 ERCs, and only a few of the Gen-3 ERCs have graduated from the program as of the time of writing; thus the sustainability discourse and strategy is somewhat limited in practice. Examples of sustainability practices include the following:

- ReNUWIt's student/postdoc DCI committee researched and prepared a report on Evidence-Based Practices for Systematic Holistic Review in Graduate Engineering Admissions. Several of the recommended strategies have been piloted in Civil & Environmental Engineering Departments at the ERC's partner institutions.
- CURENT faculty, staff, and students joined a committee at the University of Tennessee to help craft the college's Diversity Action Plan.
- NASCENT's strategy for Bias Busting workshops and DCI-focused icebreakers as part of graduate student onboarding has been adopted by other research groups and programs on The University of Texas at Austin campus.
- POETS's Young Scholars program was institutionalized by the University of Illinois College of Engineering, which will allow the program to be fully funded and staffed beyond the ERC. The College uses it as a strategy to recruit undergraduates that contribute to the diversity of its undergraduate population.

7.8 LESSONS LEARNED

Lessons learned and promising practices have been presented throughout this chapter. Examples used are drawn from ERC experiences as documented in Annual Reports and/or shared within the DCI Community of Practice. Key lessons learned that rose to the top during chapter preparation include the following:

- DCI goals and a culture of inclusion cannot be achieved without committed ERC leadership and faculty participation.
- It is essential that the DCI Director and associated staff are dedicated DCI professionals with experience and commitment to DCI who are allocated sufficient time and resources to make meaningful contributions to the ERC.
- A successful DCI Program cannot operate in isolation; it must be integrated within the research, education, workforce development, innovation ecosystem, and all other operations at all levels of the ERC and must be actively supported by ERC leadership and aligned with institutional DCI activities.
- DCI programs must meaningfully engage and serve participants at all levels across all ERC partner institutions.
- Design and implementation of DCI assessment and evaluation should be overseen by an evaluation expert, with adequate funding and support.
- DCI work is ongoing and never complete; it is hard, emotionally demanding, often uncomfortable, and incredibly necessary work that challenges the individual, the institution, and the systems in which the ERC operates.

- Positioning DCI programs for sustainability is a challenging endeavor that requires deep engagement and advocacy by ERC leaders.

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Chapter 8: Student Leadership Councils

8.1 Executive Summary

The Student Leadership Council (SLC) is a vital part of every NSF-funded Engineering Research Center (ERC). Required by NSF, it serves as a voice for the students and a vehicle for many of their activities in the center. The SLC chapter of the ERC Best Practices Manual is a guidebook for SLCs, both new and preexisting, that provides useful ideas and principles for starting and operating an SLC to obtain the highest possible benefit for the students and the center. This online edition of the SLC Best Practices chapter was first posted in October 2014 and is a thorough update of the original chapter. It is updateable online by SLC students on a continuing basis, ensuring that it will remain current.

This Executive Summary will briefly summarize the main points of the chapter, section by section. The authors encourage all SLC members to read the entire chapter, as it is a rich resource for detailed tips and suggestions that will make SLC membership and the ERC experience as a whole more beneficial and enjoyable.

SLC Formation and Purpose

The SLC consists of students, undergraduate as well as graduate, who have a leadership position as students in the ERC--including the leaders of the SLC itself and others with specific roles and responsibilities such as outreach, industry liaison, and communication. Its primary mission is to organize student activities. An SLC should establish its mission and organizational structure to best suit its particular ERC's research, the universities it represents, and the size and nature of its student body.

Main elements of the SLC's mission are:

- Representation of the students and communication with the students, center administration, and industrial partners
- Service to the ERC and students
- Broadening the overall experience of ERC students
- Organizing to represent students and carry out the SLC's activities
- Providing opportunities to develop leadership skills and experience.

Planning, Administration, and Development

One role of the SLC is to work closely with center administrators, and in particular, the education director(s) to plan and help organize center activities that involve the SLC and/or ERC students generally, such as workshops and seminars. Scheduling regular meetings of the SLC with center administrators is a good idea, as is attending some of each others' meetings as appropriate. The center director in particular should be kept informed regarding student activities and opinions, either through direct communication with the SLC or via reports from the education director(s).

The SLC can be an excellent medium for the "onboarding" of new students joining the ERC, especially given the multi-institutional nature of these centers. Orientations, a website, and lists of pertinent information such as industrial partners all help speed the integration of new students into the ERC.

Organizational Structure

The way an SLC is structured is key to how well it can meet its goals and carry out its mission. While a few SLCs are open to all ERC students as members, most comprise volunteers representing about 10% of the ERC student body, with members from each of the university partners. A strong effort is usually made to include undergraduate students in the SLC. In most cases, all members have titles and specific responsibilities such as outreach, social activities, communications, etc. Several ERCs have bylaws that govern their structure and operations. This is not required, but in general, those SLCs that have bylaws tend to function especially well.

Generating and Maintaining Interest

There are three guiding principles that allow an SLC to hold the interest of it members: value, respect, and ownership. The SLC must be seen as offering benefits for membership that allow it to be seen as a valuable association for a student to hold. Second, the SLC must respect its member students, and especially their time, in order to maintain their willing participation. If the first two principles are consistently observed, the students will begin to feel a sense of ownership of the SLC. If students think of the SLC as *their* own group instead of an external organization, as their way to interact with the center administration and the NSF, they will be interested in it and will participate actively.

Communication

SLCs serve as a liaison between the student community and the center administration, and as a facilitator of communication between staff, students, the NSF, and industry partners on center research, organization, and function, as well as with students outside the center. Thus, effective communication is an essential requirement for a successful SLC.

Today there are many routes to communication through email, meetings, websites, social media, and traditional publications. Good communication involves a mixture of "mass" media and individual and in-person contacts. Some SLCs maintain intranets to provide communication of various kinds with a variety of internal audiences within the center. This can be particularly effective in maintaining good communication across various university partners in an ERC. SLCs also have a role in recruiting new students into the ERC.

Outreach

Outreach—to undergraduates, precollege teachers and students, and the general public—is an integral part of the SLC mission. It is an ERC-wide activity in which the SLCs often have an active role in planning and implementation. Participating in these activities benefits the SLC members through building mentoring and leadership skills.

It is important to begin planning the center's outreach activities at the beginning of the semester or academic year. Most SLCs have an outreach student coordinator or student committee as the focal point for these activities. In order to maintain the interest of student volunteers, it is important to add new activities on a regular basis and to recognize publicly the contributions of individual students. Also, keep the activities local to the center students. SLCs should facilitate the planning of outreach activities independently at each ERC partner institution.

SWOT Survey and Analysis

Every SLC is required to conduct and annual Strengths-Weaknesses-Threats-Opportunities (SWOT) analysis involving a survey of all students in their ERC. This analysis benefits the SLCs and NSF alike by giving a clear picture of the condition of the ERC student body, including its demographics. Follow-up to address areas of concern identified in the SWOT is an important part of this process.

Site Visits

A key role for SLCs is to represent the ERC student body to center administrators and guests. This is particularly important prior to and during site visits. In most centers, (SLCs) provide considerable assistance in the preparation and execution of the annual site-visit reviews of the ERC by NSF. The SLC role can include the preparation of posters, poster competitions, and other presentations, as well as the student SWOT.

The SLC often assists center administration is gaining the ful participation of students during site visits. It is important to maintain good communication among students from all ERC partner institutions and to include viewpoints from all partners within the SWOT results. Finally, the

SLC is the conduit for any student issues or concerns that might arise regarding the site visit (scheduling, agendas, etc.)

Industry Meetings

In conjunction with the SLC's role of providing student perspectives and facilitating communication between students and other stakeholders in the center, student contributions and input regarding industry meetings are valuable to the center and to industry. The SLC can also plan events that give ERC students opportunities to network with industrial visitors to identify employment and internship opportunities. Some SLCs host industry seminars in which companies come and present on the company or on their industry. Another popular activity is workshops in which industry representatives teach useful skills to the students. Finally, compiling a student resume book can be an effective way to market students to industry.

To ensure effective communication with industry and "advertising" of industry-related programs, the SLC should dedicate a student or even a committee specifically tasked with maintaining student-industry relations.

Building a Student Community

Social activities enhance student life, build community, and add to the center experience. Students at ERCs should benefit from a broader range of experiences than typical university research assistants, including multi-disciplinary interactions and opportunities to network with a wide variety of industry professionals. Social activities are generally planned by the SLC, but they are sometimes assisted by the Education Director or other center staff members.

It is important to involve the ERC's partner institutions in these activities, to the extent possible. An annual (or even more frequent) retreat is one traditional way to do this. Each partner institution's SLC rep(s) should be responsible for organizing social events on their campus as well.

One popular type of event is "Student Day," a 2-3 day event held at each partner university in which students from all the ERC's participating institutions attend. The center-side "Perfect Pitch" competition is often held during this event. It is best to survey the ERC's students as to which types of activities they prefer, and to advertise the events thoroughly and persistently.

Facilities

The SLC has a vested interest on the part of the ERC's students in the facilities in which and with which they will work. These include general facilities, computers and other technical equipment, and the student area. Ideally, a facilities management plan can be put into effect by a joint effort of students and center administration. The most important objective here is to ensure that the students have access to the technology they need to be productive. Generally, maintenance and services are left to the university staff.

8.2 Introduction and Overview

8.2.1 Overview

The Student Leadership Council (SLC) Chapter of the ERC Best Practices Manual contains best practices and recommendations that should be useful for all SLCs that operate in an Engineering Research Center. The original chapter was written in 2002 and was updated in 2014 to produce this edition. All sections were revised and in some cases rewritten. In certain sections, survey data incorporated in the original chapter was kept where appropriate and still applicable.

8.2.2 Methodology for Writing the Chapter

8.2.2.1 Original 2002 Edition

The Student Leadership Council of the NSF Engineering Research Center for Reconfigurable Manufacturing Systems (ERC/RMS) at the University of Michigan volunteered to conduct a study of the role played by SLCs at various centers across the country with the goal of identifying "best practices." Toward this end, a comprehensive survey was sent to SLCs. The survey addressed issues in key areas generally relevant to all SLCs, such as organizational structure, communication with students, faculty, and industry, social and outreach activities, site visit preparations, and facilities management. Specific questions were also included to address the special features of ERCs that span multiple universities. The respondents were also given a chance to share their ideas on issues that were not addressed in the survey, and also given an opportunity to evaluate their performance in various areas

Responses to the survey were analyzed to produce a set of recommendations and best practices for SLCs. These were organized into the 2002 edition of the SLC Chapter of the Best Practices Manual.

8.2.2.2 Current 2014 Edition

The 2014 edition of the SLC Best Practices chapter started with a student retreat at the 2012 ERC Program's Annual Meeting, in which students from all 17 of the active ERCs at the time formed into teams to discuss best practices about a particular function of the SLC. These teams then generated a set of recommended best practices and designated writers to be responsible for chapter sections. Further work was delayed until 2014 due to web developer turnover, as the erc-assoc.org website was undergoing a complete redesign at the time. Once a new plan for updating the chapter was devised, additional writers were selected from among active SLCs to augment the writing teams and they then built on the 2012 work to produce the new chapter.

8.2.3 Organization of Chapter

The chapter is organized as follows:

Sections 8.2 and 8.3 provide an introduction and overview, outline the objectives of the chapter, describe the 2002 survey methodology and the methodology of the 2014 update, and discuss the reasons for forming a Student Leadership Council.

Section 8.4 discusses SLC planning, administration, and development strategies, along with the onboarding of new students so that ERC information and related policies and procedures can be passed on to the next generation of students.

Sections 8.5 through 8.13 cover the various SLC functional areas addressed in the survey - namely, organizational structure, communication, outreach efforts, site visits, industry meetings, social activities, and facilities management. Each of these sections addresses the importance of the functional area, summarizes the survey findings, discusses any special aspects relevant to multi-university centers (which all current ERCs are), and identifies the best practices. In Section 8.14 we present conclusions and possible future directions.

8.2.4 Contributors

A list of contributors for this chapter from the 2014 update and after can be found at http://erc-assoc.org/content/subsequent-contributors-new-chapters-and-updates. The chapter is set up for easy updating online by authorized SLC members as circumstances and best practices for SLCs change over time. Contact the webmaster (see bottom of screen) to obtain authorization.

In addition, the authors of this study are grateful to Courtland Lewis, NSF consultant, for his encouragement and valuable advice regarding both the original and updated editions. We also acknowledge the work of Dr. Michael Nolan, graduate of Iowa State University and the CBiRC ERC and President of WebChemi LLC, for serving as coordinator of the update effort and for developing the online updating utility.

8.3 SLC Formation and Purpose

8.3.1 Forming the SLC

The formation of a Student Leadership Council is required by NSF's Cooperative Agreement with all ERCs. In most centers, this council must be comprised of representatives from both undergraduate and graduate programs. SLC members are thus a subset of the entire ERC student body, but one with an important role in the center. The SLC consists of students who have a leadership position as students in the ERC--including the leaders of the SLC itself and others with specific roles and responsibilities. A typical SLC consists of the following positions (although these vary): President, Vice President, Education & Outreach Coordinator, Industrial Liaison, and SLC rep (one for each partner institution who oversees activities at that university). Sometimes chair positions are created for major ongoing tasks to be handled by the ERC--for example, Web Chair or Seminar/Lectures Chair.

SLC members are usually students who volunteer for these positions. If no one volunteers for a role that is needed, then the ERC's Education and Outreach Director typically will reach out to students who are deemed to be a good fit. Usually these are students who are active in the center and have demonstrated a willingness to take on extracurricular activities in addition to research.

Contractually, the primary responsibility of an SLC is for the organization of student activities. Further, they are responsible for carrying out a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and communicating the results to the center director and leadership team, and to the NSF site visit team. Communication of SWOT results to the NSF site visit team is conducted in a private session. However, most SLCs see their role as broader than what is contractually specified.

NSF does not specify guidelines for the organizational structure or required activities of an SLC, except for the SWOT analysis. Therefore, it is important that an SLC establish its mission and organizational structure to best suit the research being conducted by its center, the university or universities it represents, the size of its student body, and the age of its center. Further, the manner in which the center is organized may influence the organization of the SLC. Developing SLC bylaws or an organizational charter is an excellent mechanism for tailoring the SLC to meet the organizational needs of center students.

8.3.2 Mission

A previous survey of SLCs indicated that they see their primary mission as (in order of frequency):

- *Representation and Communication* - The SLC is seen as a liaison between the student community and the center administration, and should facilitate communication among staff, students, the NSF, faculty, and industry partners on center research, organization, and function. Further, the SLC is seen as a vehicle to promote communication outside the center and provide an entry point for students wishing to get involved in the center.
- *Service* - The SLC is seen as a formal mechanism for students to contribute to the center above and beyond their research, activities facilitating outreach activities with students outside the center, such as entertaining and educational projects to excite K-12 students in engineering, and undergraduate recruitment to graduate programs.
- *Broaden the Student Experience* - The SLC is seen as providing a well-rounded experience for students through seminars/workshops, outreach, and social functions. This includes facilitation of engineering education beyond traditional methods; providing a social setting (social club) in which students from different disciplines and backgrounds within the center can network, collaborate, and build friendships with people outside individual labs; and providing an opportunity for students to have presentations and papers reviewed by their peers.
- *Organization* - The SLC is seen as a governmental entity that facilitates the organization of students working within a center to plan, coordinate, and execute activities that reflect student interests. While noted specifically as a mission, this is a really a means for performing the other missions.

- *Leadership*- The SLC is seen as providing students with a unique opportunity to develop leadership and management skills that may not be part of their curriculum.

The survey indicated that SLCs see one or more of the following as what their main functions are or should be in fulfilling their primary mission.

Representation and Communication -

- Communication with the center administration concerning student needs and perspectives on the academic and work environment, research, curricula, and outreach development.
- Facilitate the interaction between faculty and student members of the center.
- Sponsor events such as meetings, seminars, and networking opportunities with industrial affiliates and center visitors.

Service -

- Promote engineering education outreach through support of the center's education director or coordinator and participation in educational events to encourage an interest in science and technology.
- Serve as mentors for undergraduate students selected into the summer research programs through the center.
- Assist in student recruitment for the university, the center, and the SLC.
- Promote awareness of the center (what it is and how to get involved).

Broaden the Student Experience -

- Encourage social interaction among center students through planned events. Usually, there is one "team-building" event planned for each major multi-institution meeting.
- Encourage students to initiate collaborations with students from other universities by providing travel grants.

Organization -

- Aid in the development and administration of planned responsibilities of center students, including social and professional activities.

Leadership -

- Provide a student government entity where leadership experience can be obtained.
- In many centers a student's tenure on the SLC is limited to a year to ensure that there is turnover and that the maximum number of students benefit from holding a leadership position.
- Act as an advisory council for input to major center and faculty decisions.

8.3.3 Bylaws
SLC bylaws or an organizational charter can play a significant role in good SLC practice. While there seems to be a strong positive correlation between having bylaws and a good organizational structure, the lack of bylaws does not necessarily imply the absence of an efficient SLC organization.

Based on the survey, bylaws typically provide officers with guidelines on the mission of the SLC, roles and responsibilities of the officers, membership rules, voting rights and procedures, meetings, and amendments.

Examples of bylaws are provided in 8.15.1 Appendix A: Bylaws of Selected SLCs.

8.4 Planning, Administration, and Development

8.4.1 Collaboration with Staff, Administration, and Faculty

The SLC should work closely with center administrators, and in particular, the education director(s) in planning, administration, and development of center activities that involve the SLC and/or ERC students generally. The administration will appreciate student leaders who are willing to help organize activities and make preparations for lab reviews, among other tasks. All the ERC students will benefit from the improved work environment and better center policies that result when student perspectives are effectively communicated to the administration.

One successful method for good communication between the SLC and center administrators is to schedule regular meetings. For example, if the SLC meets once a week or once a month, the education director(s) could be invited to attend a portion of each meeting, or every other meeting. Alternatively, correspondents from the SLC (e.g. president and/or vice president) may wish to attend faculty meetings on a periodic basis to facilitate communication and report student issues as they arise. In keeping with this idea, members of the SLC may also wish to allocate part of their regular meeting time to hear from attending students wishing to voice questions and concerns. This will help to make SLC/faculty interactions as efficient as possible.

The center director should also be well-informed regarding student activities and opinions, either through direct communication with the SLC or via reports from the education director(s). Finally, establishing email distribution lists can greatly facilitate communication among SLC members and between SLC members and administrators. In this manner, when issues arise where administrators require student input, they do not need to wait until the next scheduled meeting. This is especially important when students do not work regular hours or are geographically distributed around the lead university campus and partner university campuses.

Research-related work such as presentations and demonstrations are generally coordinated by individual faculty members or research scientists, who direct the activities of their own graduate and undergraduate researchers. At times, however, faculty members may require assistance from the SLC in order to communicate expectations, requests, and deadlines to the general ERC student body.

8.4.2 Leadership and Professional Development

Being part of an NSF-sponsored research center should provide students with additional opportunities for leadership and development beyond their degree program requirements. The SLC can assist administrators in encouraging students to further develop their skills by helping to plan workshops or seminars and by recognizing students who have made specific achievements.

In 2002, the SLCs then in operation were surveyed as to whether they or their centers presented awards or recognition to graduates. While half of the SLCs reported they do nothing formal, the following recognitions were noted among those who did:

<u>Awards</u>

- Best Poster
- Best Presentation
- Best Undergraduate Research Paper
- Outstanding Students/Teams/ Leadership
- Certificate of Recognition for Service
- Certificate for Course Completion

<u>Graduate Recognition</u>

- Graduation Parties/Receptions
- Banquet
- Certification (associated with program)
- Guest speaker after graduation

A similar range of awards and recognitions are still employed today.

It is very important to publicly recognize students who assist with center-related work that is beyond the scope of their research – for example, those who volunteer to help with site visit preparations, plan social events, and help with outreach activities. Widely attended social events such as end-of-year banquets and receptions, or welcome picnics and orientations, provide good opportunities for such recognition. Another option would be to recognize such achievements in periodic student newsletters, which could be authored by the SLC with additional help from the center administrators and/or education director(s).

While most centers conduct workshops and seminars for the students, in most cases SLCs are not involved with their planning or execution. One exception is that some SLCs sponsor graduate student research seminars. While the great majority of the seminars are research oriented, other seminars/workshops hosted by centers include:

- Resume Writing
- Preparing a Curriculum Vitae
- Managing Thesis as Project
- Team Building
- Presentation and Communication Skills
- Assessment & Evaluation
- Mentoring
- Educational Techniques
- “What is [this center]?”
- MD Seminar (on reallife work experiences)

- LIFE Seminar (Learn about Industry From the Experts)
- Ethics
- Job Negotiation Strategies
- Career Preparation
    - Transitioning from Grad School to Industry: IAB-hosted Q&A forum
    - Mock/Practice Interview Sessions: Hosted by IAB members or faculty
- Patent Research/Writing and Intellectual Property
- Starting Your Own Business.

8.4.3 Onboarding of New Students

New graduate and undergraduate students join universities, and thus ERCs, each academic semester. It can prove challenging for a new student to receive all pertinent information regarding the ERC, which typically spans several institutions. The SLC can be an excellent medium for the onboarding of these new students. Onboarding refers to the mechanism or methods through which new ERC students and/or SLC members acquire the necessary knowledge, skills, and behaviors to become effective organizational members. Several strategies include:

- Beginning of the semester orientations -- Current SLC officers/members can host a meeting or series of meetings which provide a semester outline of the SLC's functions, e.g., typical events hosted, upcoming goals of each SLC committee or officer, available involvement positions, etc.
- Website or documentation which provides:
    - An overview of the ERC's main Thrusts and/or testbed projects
    - Video interviews or write-ups from the Thrust or Testbed leads (faculty) can be incorporated into these overviews (uploaded to Youtube if the ERC website is unavailable for this purpose)
    - A directory providing all faculty, staff, and student contact information
        - May also include a short bio of each person containing their ERC Thrust or Testbed project involvement and their institution affiliation
- A list of all industrial partners working with the ERC
    - Due to intellectual property rights or non-disclosure agreements, details of each company's involvement in an ERC's Thrust(s), Testbed(s), or projects may vary
- A comprehensive list of equipment available to the ERC researchers, including name and contact information of each tool or software program owner
    - Google Drive provides ease of accessibility and security (e.g., "Only those with link") and allows multiple users to continuously update and edit this list
    - Troubleshooting advice, tips, or questions can be a subset of this list such that owners of the same or similar tools can readily discuss best practices in a documentable manner
- Formal/informal gatherings at conferences highly attended by large percentages of faculty, staff, students, and industry partners of the ERC
    - Schedules of talks, presentations, and poster sessions specifically of ERC members can be distributed to allow greater interaction and exposure for new students to projects spanning the ERC

- ERC-sponsored luncheons at these conferences

Note: ***If a website is utilized to provide the above information--especially bullets #3 and #4--it is highly recommended that a login process is required so that this information is not publicly available***.

8.5 Organizational Structure

8.5.1 Motivation

The organizational structure of an SLC is often an excellent pointer to its activities. The way an SLC is structured provides important information on how it is equipped to meet the mission and goals outlined in its charter, and whether it is able to meet those goals.

8.5.2 Different SLC Types

SLCs may be broadly classified into two categories. A few schools have open membership in the SLC for the entire ERC student body. Such membership may be either mandatory or voluntary. Subsequently, SLC leadership councils and committees may be formed to provide direction to the students, and to provide the impetus for various activities. The more traditional type of SLC is one in which a small percentage of ERC students are elected or volunteer to serve on a leadership council to represent the interests of the students.

8.5.3 More about SLCs

The size of SLCs varies greatly. In a couple of centers, the entire ERC student body is automatically part of the SLC, while in most centers, they are made up of about 5-10 members representing an overall ERC student body of 50-100. SInce an ERC involves participation from different universities, the SLC should be formed such that there is a proportionate representation from different schools.

The motivation for SLC membership can be in the form of monetary incentive, in the form of an increase in salary to serve on the SLC, bookstore gift certificates, or even reimbursement for travel. In most cases, however, recognition and appreciation and greater involvement in the center are what motivates people to serve.

Most of the well-established centers are making special efforts to encourage undergraduate participation on the SLC. In some centers, it is a requirement of the administration or their bylaws that some undergraduates be members of the SLC. Some centers could be constrained by their relatively small student body, or even the fact that undergraduate students are present only during the summer, making them unavailable to serve in a leadership role. But most places seem to make a sincere effort to recruit undergraduates to the SLC.

Most of the SLCs hold elections for SLC officers. In smaller or newer centers with fewer overall students, members tend to be appointed or volunteered, while the more established centers with a sizeable study body hold elections. If elections are held, then this is done by email, voice vote, or secret ballot. Nomination periods range from 1 week to 1 day. In the case where elections are conducted, the nominees can be asked to share their details and their plan of action for the SLC in the year with the entire ERC student body. This approach can help the students choose their representatives.

Most SLCs have titles and specific responsibilities for their officers, but in some cases, officers simply get together on various projects on an as-needed basis. In some other cases, officers are elected for each research thrust area in addition to holding other positions such as social activities, outreach efforts, etc. Nearly all SLCs have a designated person or committee to focus on outreach efforts. There might be cases where responsibilities could also be shared if two people are assigned to each role/committee.

In centers where the entire student body constitutes the SLC, meetings are held only a few times a term, though the leadership meets more often. In other centers, the SLC meets weekly, every two weeks, or monthly. Since the SLC has members from different universities, the meetings could be conducted via Skype, telecon, Webex, etc. Most SLCs have a meeting at the start of the term, in which they decide what they need to accomplish that term. Most centers have someone from administration attending SLC meetings, by invitation.

Several SLCs have bylaws that govern their SLC's functioning. There seems to be no correlation between having bylaws and having a good organizational structure. But in general, those centers that do have bylaws tend to have a strong SLC organization. See Appendix A for sample SLC bylaws.

Communication between the SLC and the rest of the ERC student body could be via a variety of methods: email, questionnaires, mass meetings, newsletters, etc Some SLCs also have their Linkedin and Facebook pages to keep everyone informed about upcoming events, research and development activities, and upcoming seminars and conferences. At a few ERCs, the SLC also undertakes the task of updating the ERC website.

8.5.4 Best Practices and Conclusions

Create bylaws and follow them in both letter and spirit

The absence of bylaws does not necessarily imply a weak organizational structure, but the converse is invariably true: Bylaws give structure to an organization's activities and lend weight and substance to its decision-making process. Bylaws may typically include (but are not limited to) information on officers' roles and responsibilities, membership rules, voting rights (if elections are held), amendments, and meetings.

Have an outreach coordinator

Most ERCs have an outreach coordinator on their SLC. This appears to be a very desirable practice. Experience has shown that outreach efforts are usually very challenging in terms of time, logistics, and the effort involved in motivating students to participate. Given the importance of outreach activities to the center, it is an excellent idea to designate an SLC officer to handle all outreach activities and to liaise with the center leadership in all such efforts.

Invite center leadership to SLC meetings

Inviting a representative from the center's administration, such as the education director, to SLC meetings is a desirable practice. The presence of such a person provides an opportunity for better communication between the students and the administration, avoids potential communication gaps, can provide information about money matters and budget allocation, and expedites decision-making.

Other suggestions

Some SLCs reported that they do not assign roles for their officers, but rather allow them to work on projects they are interested in, as this motivates them to do a better job. While this practice may work in some cases, another idea may be to pair up officers in committees, so that they may motivate each other and share the responsibilities.

8.6 Generating and Maintaining Interest

The best methods for generating and maintaining interest in the Student Leadership Council are going to be different for each center. However, in all cases those methods should be guided by three intertwining principles: value, respect, and ownership.

- **Value**
  For students to have interest in their SLC, they have to see the SLC as something that benefits them. The easiest way to provide value to students initially is of course by giving them free food, and an SLC event without free food is a poorly attended one. However, other methods are required for encouraging more than just attendance.

  In general, greater participation deserves greater rewards. A student who has contributed time and effort to the SLC and is overall having a positive impact on the whole center should be given more rewards and opportunities than a student who shows up to an SLC event twice a year. These rewards can take any form that the SLC sees fit, from gift cards to travel awards to project funding. If students see that being on the leadership council is a lot of hard work with little appreciation, they will take their talents and energies elsewhere.

  However, this philosophy does not mean ignoring uninvolved students. The SLC must also represent and advocate for all of the ERC's students. When any student has a complaint concerning the center, the SLC has an obligation to investigate and respond. A single voice is easily silenced, but the power of the SLC is the unity of its members. Therefore, an SLC that neglects its responsibilities is worthless to its members and to the other ERC students. This same principle holds on the positive side as well; the SLC can be instrumental in communicating positive features of the ERC to engineering students, including those already involved in the ERC and those who are not.

- **Respect**
  Students are people too; and of all organizations, the SLC is one that cannot afford to forget this. Students are the fundamental building blocks of each ERC, and disgruntled students weaken the whole center. The SLC must respect their member students, and especially their students' time. Graduate students are a busy lot, and if they perceive that the SLC is wasting their valuable time, they will disregard it as a trivial distraction at best, or a dreary requirement at worst.

  Therefore, the SLC must take care of how it presents itself. Should an activity be mandatory, or should it be an optional opportunity for the member students? Students respond more favorably to events that are beneficial but optional than to mandatory events of dubious value, so the number of events that are absolutely required for each student should be minimized. If turnout remains low, the SLC should re-evaluate those events: Is this what the students want, and if not, what do they want?

- **Ownership**
  The natural continuation of the previous two principles is that, if they are consistently observed, students will begin to feel a sense of ownership over the SLC. The SLC member students must feel that this organization is *their* SLC for it to flourish. If students think of the SLC as *their* own group instead of an external organization--as *their* interface with the center administration and the NSF, and as a reflection and representation of *themselves*, they will be interested in the SLC and will participate actively.

  As such, each student must be free to voice their thoughts about the SLC. They should not find the SLC disorganized or chaotic; established bylaws should lend structure and purpose. The center administration should treat the SLC in a hands-off manner, but it is still up to the students to make the SLC theirs.

At this point, it must be stressed that these ideas are nothing if the average student never hears about them. Communication is essential, from the leadership council to the ERC students and vice versa. Center administration does not always communicate the center's goals and philosophies to the students. It is often up to the leadership council to give the center's students a sense of cohesion and direction. How this communication should be conducted can be coordinated with the center leadership to avoid mixed messages and redundant efforts. It is also a good opportunity for the SLC to recruit members of the council from among the ERC students.

Special care must be taken for centers that are spread out over multiple campuses. When a large number of students are at one campus, it becomes logistically simpler to tailor events to that main campus. However, this practice excludes students at the branch campuses. Each campus must have a campus representative who will organize local events at their respective campuses. These representatives will ensure that their local peers are receiving a fair share of the SLC's benefits, creating and sustaining a local ERC community, so that no student will feel that, "The SLC is just for those other students." (See the following section 8.7 for more discussion of this topic.) Ultimately, when the SLC is useful to all of its members and treats them with respect, the students will be interested and active in their organization.

8.7 Communication

8.7.1 Motivation
An important aspect of the SLC's role is that of a liaison between the student community and the center administration, and as a facilitator of communication between staff, students, the NSF, and industry partners on center research, organization, and function. Further, the SLC is seen as a vehicle to promote communication outside of the center and provides an entry point for students wishing to get involved in the center as well as a vehicle for reaching out to pre-college students to interest them in engineering. Thus, communication is a vital aspect of a successful SLC and is addressed in this section to identify best practices for this area.

8.7.2 Communication Best Practices
The center leadership can communicate with the students through email lists, meetings, flyers, websites, in-person communication, newsletters, and through the students' advisors. Communication from the SLC to the students (SLC members and others) can occur through email lists, texts and Twitter, meetings, websites, and in-person communication.

Given the inherent challenge of communicating within any large organization consisting of disparate locations and various disciplines, such as an ERC, such organizations often employ an internal-facing website (intranet) to help solve this challenge. The SLC can easily develop and host an intranet that contains information of common interest to all students (see example below). Such information may include: events calendar; time zones by location; key contact information for the SLC, ERC leadership, and liaisons by partner university; links to the ERC's online presence such as their homepage, LinkedIn page, Facebook page, etc.; links to various shared Google docs wherein a variety of information may be shared and updated; and links to the websites of and contact information for industry partners. The code for the intranet itself need not be complex in nature and could even be as simple as a single HTML file with information formatted in simple HTML tables and links to other websites and hosted images. A screenshot is given below as an example of such a website, including multiple tabs at the top which display examples of some of the content mentioned above.

If ERC students have any concerns they wish to relate to the center administrators or staff, they can raise them through personal communication or e-mail with the administrators or discuss them with the SLC, which acts as a liaison. Students can voice concerns to the SLC and other students through weekly/biweekly/monthly student meetings, the SWOT analysis, or social events. SLC meetings should be open to all center participants so that they can voice concerns there.

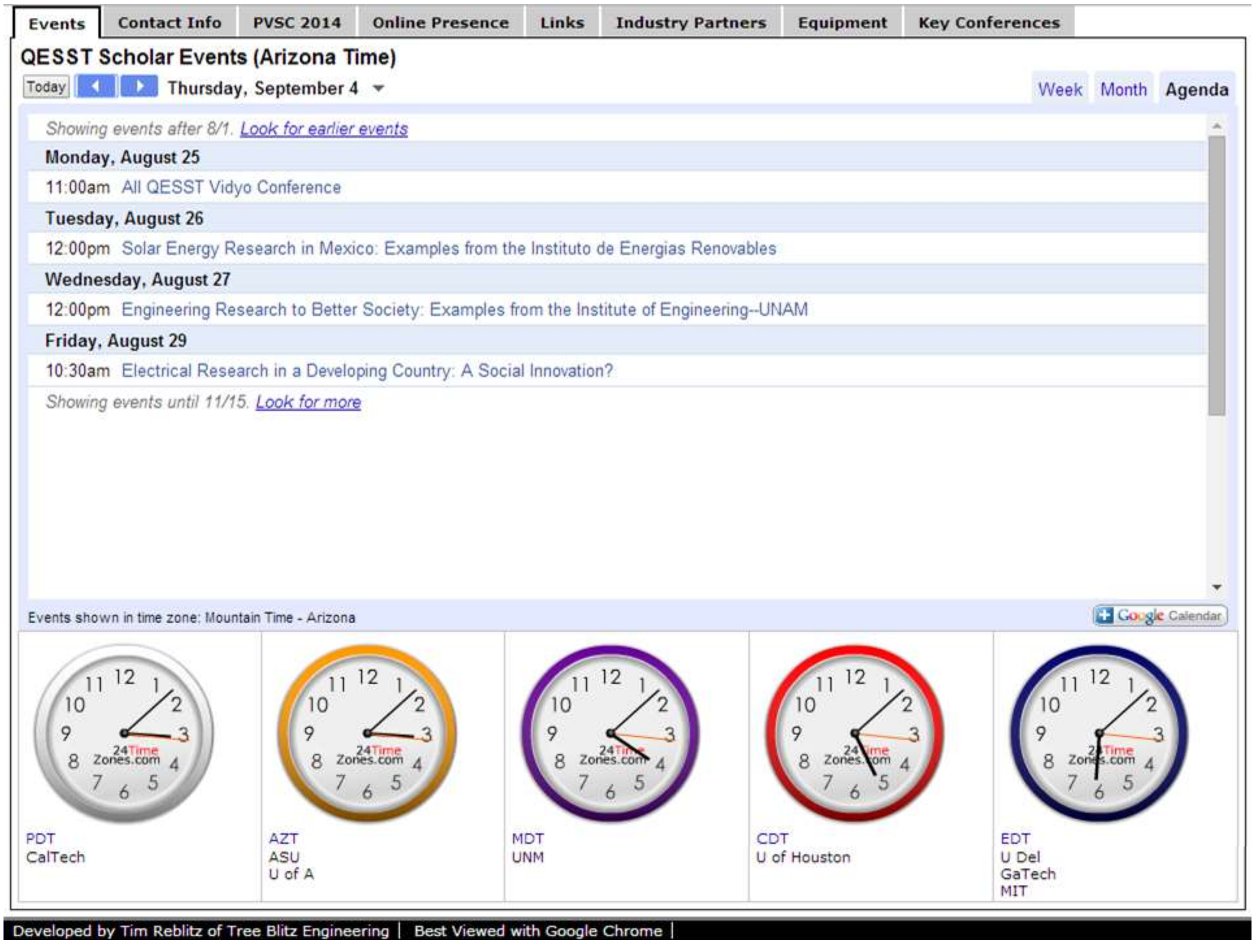
Students can learn about other research being conducted in the center through meetings. The best practice is a weekly SLC meeting where the students presenting their research are evaluated by the other students in order to improve their public speaking skills.

If students need to express confidential concerns such as conflicts with faculty or harassment while they are working at the center, they can report to the SLC, administrators, or the ERC's Education Director. If the student is leaving the center, these concerns could be expressed through an exit interview or questionnaire.

SLCs can communicate openings for new undergraduates with the ERC primarily through advertising and undergraduate programs. Advertising can take the form of email, flyers, ads at campus employment offices, and website postings.

Communication between the ERC students or the SLC and industry partners occurs mostly at meetings where industry partners visit, or through students' advisors. Students and industry partners can meet in the form of table discussion or working lunch without the presence of faculty.The best practice to promote communication between ERC students and the NSF is through the annual site visit and the SWOT. The Student Retreat at the ERC Program's Biennial Meeting can also be a good connection to the NSF.

The ERC Association website (www.erc-assoc.org) is potentially a useful means of communication among SLCs and between SLCs and other groups such as industry partners and potential ERC or SLC student recruits. For example, the "Student Portal" area contains contact information as well as resources for use by all SLCs. The Portal main page also lists all current SLCs and the addresses to their web page.



8.8 Outreach

8.8.1 Overview

Outreach is one of the important objectives of the ERCs, and is an integral part of the SLC mission. Active participation in outreach mutually benefits both the students who are volunteering and the community they are serving. This also enhances the leadership, communication, and networking skills of the students involved.

The planning for ERC outreach activities and the involvement of SLCs in those activities is generally overseen by the education director(s) of the ERC. Most SLCs also have an outreach student coordinator or a student committee who help and are involved in the planning and implementation of the activities. Outreach activities can be implemented that cater to students of different ages and specializations.

ERC outreach activities typically encompass some or all of the following:

- Summer internship for undergraduates – Research Experiences for Undergraduates (REU)

- Summer internship for high school teachers – Research Experiences for Teachers (RET)
- Summer internship for high school students – Young Scholars Program (YS)
- Science club and science fair activities for middle school/high school students
- Volunteering at on-campus "ERC open house" days
- Volunteering at science museums to explain science and technology projects
- Participating in university-wide outreach activities
- Designing activity kits and in-class demonstrations for middle school/high school students.

8.8.2 Outreach Activities Planning

Planning the center's outreach activities at the beginning of the semester/academic year is one of the crucial steps to ensure successful outreach participation of the center and the SLC. During the planning, it is important to take into account the diversity and the variety of activities being considered. For instance, a student might be interested in volunteering to teach science to middle school students and a different student might be interested in designing an activity kit for middle school students. Although the above two activities are targeted to reach the same community, they are quite different in implementation and both may need additional student volunteers to help the primary organizer. Considering the above factors when planning the activities increases the student participation.

8.8.3 Best Practices

It is important for the SLC to be actively involved in outreach, as the center's student body is critical in supporting those activities. The benefits of volunteering for these activities, to both the students and the center, should be discussed and emphasized with the students. Benefits like broadening mentorship and leadership skills and the importance of these skills in advancing their career should be discussed.

Beware of lagging interest

One of the biggest problems in implementing outreach activities is gaining and maintaining the interest of the volunteering student. Most students get busy with their academic/research activities and do not find time to be involved with outreach activities. Also, in older centers, students might have a "been there, done that" sentiment which discourages them from participating further. This problem can be avoided by keeping the activities diverse and ensuring that fresh activities are added regularly.

SLC outreach coordinator or committee

This feature provides a focal point for the SLC to organize outreach activities and support the ERC's education outreach director. The SLC outreach coordinator can also work closely with the ERC student body and know their personal opinion about the outreach activities. This viewpoint could serve as a feedback mechanism during the design of new activities.

Recognize your participants

Because SLCs rely heavily on volunteers for their outreach activities, it is critical to publicly recognize their involvement. Center wide email “thank-you’s”, certificates of recognition, or banquets are several suggestions. Incentives such as t-shirts, giveaway merchandise (like water bottles, etc), and free food may also be helpful.

Keep activities in scope and distribute the leadership roles

Many volunteer activities fail due to their sheer magnitude. Keep activities within a manageable size for the size of your student body. Distributing leadership roles for an outreach project beyond the SLC not only makes it more manageable, but also provides more opportunities to develop leadership skills while potentially helpping with recruitment of more students into the SLC.

Design a student expectation chart for the students of the center

Designing a chart that lists the expectations of students working in a center will be helpful, to both the center and the students, in planning their activities ahead of time. This practice is not only limited to help with outreach involvement, but will also serve as a guide for the overall planning of the student. For example, the NASCENT ERC suggests that a student be involved for at least 6 hours of outreach per semester. Although this is still entirely voluntary, providing an expectation seems to increase the student involvement.

Find effective communication channels

Volunteers do not participate in outreach activities when they are not informed about an event in a timely fashion. Direct email, listservs, posting on an SLC Facebook page and/or an SLC page on the ERC's website are all communication mechanisms that can be used. Don't forget the effectiveness of one-on-one in-person communication.

Encourage local schoolteacher involvement

Many outreach activities involve secondary and primary school children. The effectiveness of these programs is dependent on the support received from their schoolteachers. Encourage teachers to involve themselves in the development of these outreach activities.

Keep it local

For maximum participation in an outreach activity, keep it local to the center students. SLCs in multi-university centers should facilitate the planning of outreach activities independently at each partner institution.

8.9 SWOT Survey and Analysis

SLCs are responsible for conducting an annual survey of all students within their ERC regarding center Strengths, Weaknesses, Opportunities, and Threats. The information gathered in this SWOT analysis is intended to help SLCs identify center strengths to be capitalized upon, identify needed areas of improvement, and plan for future opportunities and threats. The SWOT analysis also aids the NSF in assessing student life and the students' views regarding the center.

The SWOT analysis is carried out once per year, and the results and planned follow-up are discussed with the NSF in a closed meeting between the NSF, SLC and, in some centers, the entire ERC student body.

8.9.1 Generating Questions

Most SLCs generate questions and issues to include on the SWOT survey through brainstorming sessions and discussions. This can be achieved at meetings of either the SLC leadership or the general student body, over email, or through social media and online forums such as reddit. Some centers review the results from the previous year, or even simply revise the old survey, but this might not effectively address all new issues affecting students in the center. The recommended best practice is to gather student input ahead of the SWOT survey in order to get recommendations for new questions or issues that arise. To aid in maximum survey participation and completion, survey questions should not be too numerous. Depending on the section, a maximum of 15-20 questions is appropriate, and similar questions should be merged.

Since the goal for the SWOT survey is to get a clear picture of the condition of the student body, questions on student demographics should be gathered. Demographics include information such as a student's university, core or associated status, thrust/section/testbed affiliation (the term varies by ERC), and years in their graduate/undergraduate career. This information is necessary for analysis of the results, which will be discussed in Section 8.9.3 below.

Regarding the questions, responses should follow a Likert Scale (1 to 5, with 1 being strong disagreement and 5 being strong agreement), and may also include a response about the student's awareness of an issue (such as "not aware"). Questions should be phrased so that the meaning of agreement or disagreement is very clear, and it is best if one or two members of the SLC who had a lesser role in developing the survey complete the survey first to get an impression of how the questions will be interpreted. Short answer responses may also be gathered, and if so, comments should be solicited at the end of each of the four sections of the SWOT survey so that a student does not forget his or her comment(s) about that section.

8.9.2 Conducting the Survey

Different centers conduct the SWOT survey through a wide variety of methods: SurveyMonkey, paper-and-pencil, email, and verbal responses have all been used. Some centers have an initial discussion and then use follow-up emails or surveys to generate responses from a greater percentage of the ERC student body. Response rates vary from 20% to almost 100%. There is little correlation between the response rate and the center's size, age, or strength. In fact, some of the largest centers are able to achieve the highest participation rates. Centers with a large number of partner institutions, however, seem to have lower response rates for SWOT surveys.

Successful methods for gaining a high response rate have included incentives (such as a drawing for prizes), timing the survey with a student event that has large student participation, or creating a paper-and-pencil survey that is physically given to all students. With all current ERCs consisting of two or more partner institutions, web-based surveys typically have very low student participation unless the SLC assigns a champion for each university, who contacts other ERC students on their campus.

8.9.3 Analyzing Results

Proper analysis of the SWOT survey results can be a powerful tool for getting a snapshot of the condition of students across an ERC. At least a week should be set aside for analysis of results, as responses should be measured not only in aggregate, but also by demographics. For example, a weakness with a 60% agreement rate may be composed of 50% from one demographic and 10% from another, pointing to issues such as a lack of engagement for new students or for students at a particular university. Since drilling down on questions can be time consuming, priority should be given to survey responses that merit action items.

SLCs from mature centers may come across repeating problems, which have not been resolved despite numerous efforts by the SLC. In these cases, studying the demographics of the response can often point to the source of the issue (such as new students being unaware of resources) but after this, it may also be helpful to append additional questions to the survey or gather more detailed student feedback. One center was able to identify, for example, that its inability to resolve a complaint about internships came mainly from newer students being unaware that the center provided internships.

Proper analysis of the SWOT survey can also help generate better questions in future years.

8.9.4 Forming an Action Plan

Surveying students for the sake of presenting results to administrators or NSF evaluators is not enough. The SLC should be responsible for following-up on the results of the SWOT analysis. Some SLCs assign specific individuals to areas of concern. Others make recommendations to center administrators regarding how problems might be resolved or student life improved. For instance, when computers, notebooks, and tablets were found to be inefficiently distributed at one center, action was taken in the subsequent year to allocate resources appropriately. In another case, when the judging procedure for site visit poster contests was not working well, it was later revised. The Site Visit Team looks not only for action plans for the current SWOT survey, but also for success with action plans for previous surveys.

8.10 Site Visits

8.10.1 Motivation

Site visits are, of course, a necessary component of all NSF-sponsored centers. In most centers, Student Leadership Councils (SLCs) significantly assist in the preparation and execution of these reviews. Site visits provide students with opportunities to showcase their research efforts and achievements, as well as network with visiting scholars. Providing the student perspective is critical at these reviews, and the SLC should facilitate this process and help organize the student body of the center.

8.10.2 Summary

Almost all centers have poster exhibitions or competitions and other presentations and demonstrations in conjunction with the site visit. In most cases, the SLC plays some role in the preparation of these presentations. Examples of assistance include providing poster guidelines, templates, materials, and printing facilities. They also play a major role in organizing the poster session and competition, when applicable. Preparations begin anywhere from a few weeks to a few months in advance. Students may only be required to attend a small portion of the site visit, but are strongly encouraged to attend as much as possible in most centers, particularly technical sessions and those which are most closely related to their research. During the site visit at some centers, students also help with other volunteer or assigned jobs such as poster session set-up, transportation, and lab tours.
The other key component of the site visit, from an SLC perspective, is the presentation of SWOT survey results to the NSF and the written SWOT report, which was discussed in Section 8.9.

8.10.3 Multi-University Centers

With regard to site visits, the most significant difference for centers that span several universities is that there seems to be lower participation from partner institutions. Holding events and retreats that bring together students from all institutions garners camaraderie and increased cross-institutional collaborations. It is important to maintain good communication among students from all partners in multi-university centers and be sure to include viewpoints from all institutions within the SWOT document/presentation.

8.10.4 Best Practices and Conclusions

One role of all SLCs is to represent the student body to center administrators and guests. This is particularly important prior to and during site visits. In addition, the SLC needs to assist the entire student body as they prepare for and carry out their duties during the visit.

Preparation
The SLC should work with the administration to determine what is needed and expected from

students well in advance of the site visit. Then, the SLC must communicate these expectations to the students and assist them however necessary. Work related to the site visit itself can take a significant amount of time for students and they must account for this in their schedule. The SLC can help by distributing the work as evenly as possible and minimizing the time required to prepare. The SLC should organize the poster session, which is an important opportunity for students to directly present themselves and their work to NSF visitors. Students should be provided with specific instructions on how posters should be designed, what electronic templates or samples are available, and how posters should be printed and mounted. The timeline for reviews and submission deadlines of posters, presentations, and demonstrations should be communicated to the entire student body. SLC leaders should generate and conduct the SWOT survey more than one month in advance of the site visit, so that there is sufficient time to develop a presentation that fully represents the student perspective for the closed-door session with the NSF during the site visit.

Student Participation
Encouraging full participation of students during site visit events can be challenging in many centers and the SLC often assists the administration in this regard. Where students must help with specific tasks and jobs, many centers first ask for volunteers. If volunteer positions are not filled, the SLC can help in assigning remaining jobs. Incentives such as food are often used to encourage participation. In addition, some centers mandate participation as a condition of funding, to varying levels of success. Advisors and administrators encourage participation with repeated reminders and sometimes by verifying attendance. One more positive method that has been used to increase student participation is to organize the poster session and/or meals with visitors in a manner that is conducive to networking.

Student Input
Another best practice is for the SLC members and other students to be advocates for student concerns during site visits. For instance, student input regarding scheduling, agendas, session locations, and other issues is important. Advance notification of visitor names, research interests, and affiliations can help students be better prepared for questions they may encounter. It is important for students to be well informed about results from previous site visit reports as well as overall objectives and research thrusts of the center. Having effective communication channels throughout the year is the best way to prepare for site visit reviews. Many centers accomplish this through seminars and lunches that expose students to research areas beyond

8.11 Industry Meetings

8.11.1 Motivation

One of an SLC's primary missions is to provide student perspectives and to facilitate communication between students, center staff, industry partners, and the NSF. Student contributions and input regarding industry meetings are valuable to the center and to industry. Another function of the SLC is to plan social and professional events that provide students with opportunities to network with center alumni and visitors from industry and academia. Meetings with industrial partners are an ideal opportunity to fulfill these objectives. Students can find potential future employers and also broaden their educational experience through practical applications of their research via internships and other collaborations with industrial partners.

8.11.2 Current Practices Within Active ERCs

Industry/Working Meetings

Center-wide industry meetings are typically held between one and four times per year. Other industry meetings at a project level can occur much more frequently at some centers. As with site visits, students are generally expected to participate in a poster session and other presentations and demonstrations during industry meetings. However, most of the preparation work is conducted through center administrators and faculty advisors on a more individual basis. Industry meetings seem to be an area where SLC and center students are less involved or less successful in their involvement, despite the fact that student involvement with industry relates directly to several of the stated SLC missions and functions as well as to those of the ERC. This is an area where students, working with faculty and center administration, could begin to have greater input over time.

Industry Committee

One center's SLC has an Industry Committee that focuses on activities and events related to industry. For instance, they organize seminars where industry members teach current industry practice to the students on a regular basis and compile lists of current journal publications from the center to distribute to industry.

Industry Seminars

Some SLCs host student-oriented industry seminars, in which companies come and present on the company itself or on their industry in general. Another popular activity is to host workshops in which industry or ERC representatives teach a useful skill to the students. The primary challenge identified with industry seminars is maintaining sufficient student attendence to keep the interest of industry speakers; this is a responsibility of the SLC's leaders. Other possibilities for student-led industry interactions include:

1. Informal Luncheons at conferences attended by students of the ERC and industry members partnered with the ERC Industry
2. Career Panels, where a panel of 3 or more industry members answer questions from students in the ERC relating to internships, future career paths, and general advice for transitioning from a graduate school environment to industry.
3. Mock Interview Sessions where industry representatives and/or faculty hold in-person or via video (Skype, Gchat, Vidyo, etc.) interviews for a fabricated job position with students. These can be one-on-one or multiple-on-one (multiple interviewer-to- one interviewee) interview sessions

Foundry Programs

Entrepreneurial students at some ERCs are taking part in ERC Foundry-type programs, which give such students training and support at the earliest stages of company formation. Examples of Foundries can be found here:

http://erc-assoc.org/achievements/qolt-booth-hit-consumer-electronics-show

http://erc-assoc.org/achievements/erc%E2%80%99s-world-innovation-and-technology-led-entrepreneurship-continues-evolve

Typically, an SLC's role is to maintain contact with an ERC's foundry program and to promote opportunities to students.

Resume book

Finally, some ERCs currently collect resumes of students seeking jobs and internships and compile them into a physical and digital book for distribution to IAB members.

8.11.3 Best Practices and Conclusions

Again, one main function of an SLC is to represent the student body to center administrators and guests--especially industry sponsors. Industry meetings provide an excellent opportunity for students to network and socialize with industry executives. The SLC can facilitate this process by:

- Maintaining a dedicated SLC position to oversee relationships with the ERC's Industrial Advisory Board (IAB), Foundry program (if available), and students; this position may be called the IAB Chair or SLC/Industry Coordinator
- Helping to organize events such as luncheons or private sessions with industry
- Contributing to resume books and student/company matching programs for internships and full-time positions after graduation.

Conclusion: In order to ensure effective communication with industry and timely promotion of programs, the SLC should dedicate a student specifically to maintaining student-industry relations. It may be necessary to create a committee of students. For these students, primary tasks include gathering student requests for industry interaction and professional development, planning industry seminars, and creating the student resume book. An additional task may be to maintain industry contacts in order to disseminate job and internship information.

8.12 Building a Student Community

8.12.1 Motivation

Social activities relate to several motivations and goals of SLCs. One of the main missions of SLCs is to represent the student body. In order to do this effectively, the SLC must frequently interact with members of the student body in social settings. In addition, the SLC should facilitate communication between students, faculty, staff, NSF reviewers, and industry partners of the center. Social activities also enhance student life, build community, and add to the center experience. Students at NSF-sponsored centers should benefit from a broader range of experiences than typical university research assistants, including multi-disciplinary interactions and opportunities to network with a wide variety of science and engineering professionals. Finally, NSF-sponsored centers have service obligations to educate the public and the next generation of engineers with regard to the research they conduct. This service function can be fulfilled through outreach activities that are also enjoyable for center students who participate.

8.12.2 Overview of Social Activities

In addition to helping to fulfill some of the main mission elements of SLCs, social activities provide a wide variety of benefits for students, including:

- Provide a forum for multi-disciplinary interaction
- Encourage informal interaction between individuals in different center roles (undergraduates, graduate students, faculty, staff, etc.)
- Enhance research relationships
- Build community and a sense of belonging
- Reward students and staff
- Provide a fun break from work.

The type and frequency of social events at different centers varies widely. Based on results of a suvey of SLCs taken in 2002, most centers have between four and six events per year. Activities include:

Activity Type	**# of Centers Approx**	**# of Participants**
Barbeques and picnics	5	45
Banquets	2	93
Meals with visitors	2	8
Food-based socials (holiday parties, ice cream socials)	4	45
Activity-based socials (bowling, trivia/games, Halloween)	4	45
Sports outings or intramural teams (does not count large #s of non-center students)	4	20
Research or outreach-based field trips	2	12
Seminars	4	35

Some centers use weekly or bi-weekly social meetings and lunches to share specific areas of research with students and staff from throughout the center. This helps everyone to be more informed about everything that is going on at the center, but falls more into the realm of communication than purely social activities.

Other idea for events and activities include:

- Going out to lunch
- Holiday themed parties
- Seminars followed by potlucks
- University partner-specific events vs whole-center events

Social activities are generally planned by the SLC, but they are sometimes assisted by the Education Director or other staff members. There are also opportunities to partner with other research groups or professional organizations at the university. Almost all centers fund their social activities through the SLC or Education budgets. Another possible funding source is through the university. One center chartered itself as a university organization in order to qualify for reimbursement through departments or groups such as student government. This typically involves paperwork and annual renewal forms, but often these groups have more money to distribute than what is requested by student organizations. Restrictions may exist on the type of activities that can be funded in this way (such as not paying for food or events where alcohol is served, etc.). Students can be asked to pay all or a portion of the costs for certain types of events, particularly tickets to sports events or events where non-center students are also invited to participate. This may discourage some students from attending.

8.12.3 Involving Partner Institutions of Multi-University Centers

All ERCs encompass one or more core partner institutions in addition to the lead institution. Social activities are especially important for bringing together students, faculty, and staff from multi-university centers whose participating institutions are located in different geographic regions. Depending on the proximity of the participating institutions, these centers might have relatively few cross-center events during the year. It is customary that centers without major geographical restrictions schedule at least one annual retreat, during which high attendance rates are expected. However, centers in which the participating institutions are located in widely dispersed geographic regions should plan quarterly or bi-annual events to foster enhanced communication among researchers within the center. The responsibility of hosting these events should also be alternated among the participating institutions. An additional cost of social events at multi-university centers is travel, which must be budgeted for and funded.

Suggestions on how to more effectively organize events are:

- Keep location in mind
    - Certain locations can be more appealing to students
    - Alternate locations for different events
    - Pick an activity that is relevant to the location
- Have each school's SLC reps organize local events
- Plan whole center events around the center's annual meeting

   - Team building events: scavenger hunt, outdoor education (zip-lining, rock-climbing)
   - Interactive seminar or training sessions (public speaking, diversity); “alternative teaching”

"Student Day" -- The Student Day retreat, a 2-3 day event held annually or bi-annually at each major ERC partner university, can provide ERC students with opportunities to:

- Visit labs at other ERC campuses
- Get up to speed on projects outside of their major research focus
- Network with other ERC students and faculty
- Instill a sense of pride in being an ERC student
- Participate in and lead professional development efforts
- Conduct the "Perfect Pitch" Contest to select a center-wide winner to represent the center at the ERC Program's biennial meeting
- Exercise skills in leadership by defining and organizing the event activities
- Perform the center SWOT analysis

The Student Day can be further used to conduct a poster session (where every student presents their research in the form of a poster) as well as to provide time for different SLCleadership teams to work on other ERC initiativese.g. ERC Newsletter, outreach strategies, the SLC's website, and professional development opportunities.

At the end of every Student Day, SLC leadership surveys the participants to make sure that each Student Day is better than the last. The biggest impact of these events comes from the friendships and professional relationships that are forged among the students; Partnerships emerge across universities at the student level, students become aware of the big picture, and they feel accountable for the success of the center.

8.12.4 Best Practices and Conclusions

Personal interaction and interpersonal communication is one of the best ways to understand student concerns, perspectives, and desires. When the SLC plans social events, several best practices will help to ensure success:

- Survey students for ideas on the types of activities they prefer and which previous activities they enjoyed most.
- Advertise well in advance of the event, through a variety of methods (email, text and Twitter; flyers in the workspace, particularly near doors and elevators; the SLC website).
- Personally invite students, faculty, and staff through word-of-mouth, including announcements at meetings.
- Send multiple reminders as the date of the event approaches.
- Require or recommend an RSVP, particularly when resources such as expensive meals or advance-sale tickets are required.
- Provide incentives to increase participation, such as food, prizes, entertaining activities, or the price of admission to special events.

- Even when RSVPs are used, expect more participants than just those who respond, including last-minute requests to attend.
- Enlist the help of staff members or administrators such as the Education Director, when needed.
- Always thank everyone who participates and publicly recognize volunteers who help to plan social events or other center activities.
- Help organize transportation such as car-pooling (use dropbox or google docs to facilitate), provide public transportation, or allocate additional travel expense.

8.13 Facilities

8.13.1 Motivation

Facilities management encompasses a broad spectrum of areas that are rooted in the needs and wants of the student body. Since any SLC is formed with the intention of representing the students, it is natural that the SLC should be concerned with the facilities and environment where the students work. Knowing that not all student requests and inputs will be included in a final decision should not take away from the fact that a facilities management plan put into effect by a joint effort of students and administration could benefit both sides of the table. The administration and faculty will receive organized feedback, and the students will be able to express concerns in a fashion that increases the effectiveness of the response.

8.13.2 Facilities Issues

Issues regarding facilities can be divided into three main categories: general facilities; computers and other available technology; and the student area. A student area is simply where each respective lab or center has assigned student desks and/or workstations.

8.13.2.1 General Facilities

Many of the centers allow students similar full-access privileges to the "core facility," a library, and perhaps a separate computer lab, with no restriction of scheduled hours. While student groups are generally not charged with maintenance of the areas they are permitted access to, it is reasonable to expect that students will "leave it as you found it." The same holds true for a snack area for students, if there is one.

Recycling is also a task that most centers leave to the university, except for one. In this instance, the SLC designates one person to handle recycling and puts the money earned from bottles and cans back into a student-run store.

8.13.2.2 Computers and Technology

Computers and technology are perhaps the most important area in facilities management, since they are the focal point of much of the work that gets done in any research center. Quite commonly, a center will have a given number of computers allotted for individual assignment as well as a set designated for general usage. Usually, the SLC has little or no input into the computer assignment process; it is done by the center administration. Seniority and degree pursued are typically used as a criterion for computer assignment, which commonly leaves the undergraduate students sharing computers. Some centers do not assign undergraduates to a computer at all. Perhaps it is surprising, then, that SLCs generally report that their computer resources are sufficient. Part of the reason undoubtedly is that every student has their own laptop, notebook, or tablet for autonomous computing and later connection to the network.

When it comes to computer updates and maintenance, the SLC is only marginally involved in the upgrading of their individual center-owned computers, while network and university computers are left to the administration. To ensure that student computing needs are accommodated, the SLC should offer to provide input to the center administration on as "as needed" basis and make the student body aware that the SLC can communicate needs to the ERC's leadership team.

Available peripheral devices and technology typically consist of printers, scanners/copiers/faxes, digital cameras and videocameras, LCD projectors, and video editing equipment. The selection of peripheral devices for student use is in the hands of the administration, although SLC input is sometimes requested by the administration. Some centers have a Facilities Director/Network Support Specialist who is in charge of such decisions and will sometimes ask for the input of the SLC.

8.13.2.3 Information Exchange

Also included under facilities is the issue of information exchange among the center students, faculty, administration, and industry partners. Email (including listservs such as Google Groups) and a website are the most common means. Most SLCs maintain their own web page within the ERC's main website. Some have a dedicated Facebook page for news and networking.

8.13.2.4 Student Area Environment

The final major facilities issue concerns the areas where students typically spend a majority of their time in the ERC. This itself varies greatly across the centers. Some schools have one general area where students have their desks and computers; but others have several such areas, and on separate campuses. That being said, this discussion will apply to each individual area or lab, rather than to the center as a whole.

Most centers put the students' office space together, or in close proximity to each other. The responsibility for desk space and arrangement of lab area workspace varies across the centers. In some ERCs this varies according to department; some centers allow the students to decide, or at least solicit SLC input; in others this varies per faculty member and in others the students have no involvement.

Some ERCs have student offices spread out through their respective departments but designate a large space for collaboration with labs, lounge areas, and conference/meeting rooms with multimedia display options such as desktop sharing to enable communication across campuses or other locations. SLC/Student input should be heavily considered in the design and furnishing of this space since it is primarily for the students. Recreation and lounge areas are important for community building within the center.

Many centers have a phone system that assigns anywhere from 2 to 10 people per phone in a student area. This type of system requires a method for making sure that people get their messages when they are not personally able to answer the phone. Some centers have given each phone a voice mailbox for taking messages, thus eliminating the responsibility and culpability for message delivery, or lack thereof. Perhaps the more common approach relies on a note or email to the person for whom the phone call was intended. Most centers reported that their methods worked satisfactorily. Obviously in the era of ubiquitous cell-phones, the center phone system is less important than it was in the past, although there is a still a role for the traditional wired phone system.

Aside from email, one of the most common document exchange methods is online, via Dropbox or Google Docs or other file-sharing system. This can be accommodated at the SLC level or the ERC level. Ftp is rarely used nowadays, as are faxes.

Meetings and presentations are quite commonplace in almost any center; therefore, reserving conference rooms is an important task. Most schools centers rely on a web-based sign-up scheduler such as Outlook or contact a center administrative staff member, who will note the reservation and set the room and audio-visual equipment as resources for the meeting. Connectivity options for meetings spanning several campuses or other locations including webcams and some desktop sharing software such as WebEx can also be very useful.

8.13.3 Best Practices and Conclusions

General Facilities
There does not appear to be a best practice here, unless it is the common practice of leaving maintenance and services in the hands of the university.

Computers and Technology
It is universally true that obtaining the best results from one's hard work and effort requires that one use the right tools for the job. It is a given in any center that access to adequate technology is necessary for students to be productive in the lab. Any SLC and any administration will concede this point willingly; the problem arises with the definition of "adequate." Few people will know what the students need better than the students, but among those few would perhaps be the select

group of administrators and faculty members involved in the center. It is a good idea for these two groups to discuss together what is needed to maintain or improve the work coming out of their center, rather than having one group dictate these decisions.

Information Exchange

It seems that, especially with all ERCs being multi-university centers, a website or file server, or in some cases a dedicated SLC Facebook page, might be the simplest form of mass information exchange. Using a file server or website eliminates the delay associated with waiting for someone to check their email, and creates an easily accessible and convenient method of information storage-if properly indexed, of course. In conjunction with Smartphones, Facebook posts can be useful; and for brief messages, Twitter can be employed.

Student Area Environment

Students must be able to achieve a reasonable comfort level within the center if they are to be expected to work and be productive there. Students who don't find this "comfort zone" may become disconnected from the center, which then creates other problems. The student area environment, then, must be conducive to getting work done and must be somewhat malleable to meet the needs of the students. This may be primarily a function of student seating arrangements, which appears to be quite similar from center to center. Locating people according to project or department seems to be working very well for each center, except in cases where the center is widely dispersed across campus.

Mediating issues that arise between students may be something in which SLCs should not get involved. Instances where judgment and decision may leave some or all of the parties involved feeling slighted or resentful is not something that any center wants or needs for its students. The administration is the most impartial and probably the best source for resolution of conflicts that arise between students. However, there may be a role for the SLC here, which could be determined by each SLC as they see fit. This is a matter of quality of student life within the center, and as such the SLC should have some - even if limited - involvement and attention.

While there is no best ratio of telephones to students, the size of the student body within the center and character of the center should be a consideration when setting up the message system. If center students make and receive important phone calls, voicemail may be the best way to relieve people of the pressure of delivering someone's "very important and urgent message" and then making sure someone gets that message. With regard to the use of cell-phones in labs and classrooms, standard phone etiquette prevails and should be adhered to and made clear to individuals who tend to violate these standards.

Conference rooms are always in demand, and it may the case that they are quickly booked when found to be available. Even if this is not the case, making a conference room's schedule of events easily accessible, either by website or Microsoft Outlook online scheduler, makes planning and coordinating meetings, conferences, and presentations much easier.

Overall Facilities Conclusion

One of the primary responsibilities of each SLC, as noted in Section 8.3.1, is to represent the student body to the administration, and in doing so to communicate the needs and concerns of the students. Allowing the SLC to have some voice in facilities management ensures that they carry out another facet of this responsibility. The most important objective is to ensure that the students at least have access to the necessary technology to be productive. However, one should not discount the other issues raised here, as all hold relevance to student life in their respective center.

8.14 Conclusions

The Student Leadership Council, as an entity, generally becomes more active over the life of its center and plays an increasingly important role in representing students and solving their problems. Its focus on establishing itself as a student representative body evolves over time to operate more effectively and to live up to students' expectations. The number of students in a center can substantially increase over the years, usually from a handful at inception to over 100 at maturity; therefore, the importance of the SLC grows accordingly. In many cases, the SLC meetings that were once a month later become a weekly event. In the process, the SLC emerges as more dynamic and more actively involved in the student body.

Although the primary responsibility of an SLC is to attend to the basic needs of the students, a successful SLC does not restrict itself just to this. An active SLC coordinates a variety of activities, including outreach and social events. These activities not only entertain the ERC's students, but also improve student cohesion while generating interest and involvement in the SLC, the ERC, and engineering in general on the part of students at the partner institutions and elsewhere, including pre-college students. Social activities such as Students' Day, barbeques, potlucks, etc., along with outreach activities such as peer review, mentoring Research Experiences for Undergraduates students, organizing middle-school LEGO competitions, etc., have become part of the tradition of many SLCs. Various committees are established periodically by or within the SLC to address specific interests. For example, the industry committee at one center organizes LIFE (Learn Industry From the Experts) courses for students and has individual student liaisons assigned to each industry partner. Similarly, the poster committees at many centers assist students in displaying their accomplishments in poster format, while public relations or social committees are responsible for planning social events and maintaining external communications.

SLCs have been generally successful in fulfilling their responsibilities, although along the way some initiatives are not as successful as hoped. However, following best practices such as holding an annual SWOT survey, having student representation from all partner universities, and developing clear role and responsibility assigments aids SLCs in identifying and resolving issues quickly. Further, these and other best practices make it easier to develop and evaluate successful SLC programs.

Throughout this chapter-updating project, we have attempted to ascertain the "best practices" of SLCs from as many centers as possible. Overall, nine SLCs from a diverse set of centers (in terms of ERC age and subject matter) came together for this project, leading to a truly collaborative effort. We believe we have put together a comprehensive document that summarizes the important activities of SLCs and identifies best practices in several key areas.

We hope that this chapter will benefit not only new centers, as a kind of "how-to" guide for nascent SLCs and an orientation guide for new members of all SLCs, but also will give mature SLCs an opportunity to borrow ideas that have been tried and successfully tested elsewhere. We hope that this will be an ongoing process, with new findings being periodically added to update what will be a living document.

8.15.1 Appendix A: Example SLC Bylaws

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8.13.2.1

Bylaws of the
Pacific Earthquake Engineering Research Center
Students Association

As amended through October 14, 1999

Article I. Identity

This organization shall be known as the Pacific Earthquake Engineering Research Center Students Associaton, PEER Students Association, or PSA.

Article II. Purpose

The purpose of this organization is to provide a forum for collaboration of students engaged in study and/or research in fields related to earthquake activity. These areas include, but are not limited to, Engineering, Seismology, Geology, Public policy, Technology impact, Urban planning, and Disaster risk analysis and hazard mitigation.

Article III. Membership

1. Active membership. An active member shall be a student at a recognized postsecondary educational institution studying or performing

research in an earthquake-related field. Active members shall be able to vote, but only students at a core PEER institution may hold senior offices on the Student Leadership Council (q.v.). It shall be the obligation of each active member to inform the Secretary of his current mailing address.

2. Advisory membership. An advisory member shall be an advisor as defined in Article IV. Advisory members shall have all rights and privileges of active membership except those of voting or holding office in the Association, other than the Chairman of the Advisory Committee. It shall be the obligation of each advisory member to inform the Secretary of his current mailing address.
3. Alumni membership. An alumni member shall be anyone who has left the Association, having been at one time a member.
4. Suspension. A member shall be liable for suspension upon the written petition of a majority of the active members. The Secretary shall notify the member in question of the charges against him at least thirty days prior to the suspension proceeding. All of the active and advisory members shall be notified of the proceedings at least thirty (30) days prior to the proceedings. These proceedings shall be at a regularly scheduled Association meeting at which a majority of the active members are present at the time of the proceedings. For due cause and after just deliberation, a member may be suspended from the Association by an affirmative vote of two-thirds of the active members present at the proceedings. The Chairman of the Advisory Committee shall preside over the suspension proceedings.
5. Honorary Association membership. Honorary Association membership may be conferred at a regularly scheduled Association meeting upon those persons who have contributed significantly to the ideals and purposes of the PEER Students Association by a three-quarters vote of the entire active membership. Honorary Association membership may not be conferred upon members who are still eligible for active membership in the association.
6. Association life membership. Association life membership may be conferred upon any member by a unanimous vote of the active members present at a regularly scheduled Association meeting. An Association life member shall be entitled to all the rights and privileges of active membership. He shall not count towards a quorum, or hold an office other than Chairman of the Advisory Committee, unless he is granted these rights under another classification of membership.

Article IV. Officers

1.

1. Officers. The officers of this Chapter shall be the President, Secretary, Mentoring Coordinator, Outreach Coordinator, and Newsletter Editor. All offices shall be held by active members who are students at a core PEER
institution.
2. Appointed Officers. The President shall appoint the following positions by the end of the second week of his term: Sergeant at Arms/Parlimentarian and Alumni Liason.
3. Junior Officers. The junior officers of this Association shall be the Internet Coordinator and Historian. All junior offices shall be held by active members.
4. Student Leadership Council Representatives. One Student Leadership Council Representative shall be appointed by each core PEER university. This person may also serve as an office or the Association. In no case, however, may any member have more than one vote on an individual motion, regardless of the number of positions he holds on the Student Leadership Council.
5. Term of office. Each officer shall serve from the time of his installation until the installation of his successor. An elected officer may succeed himself only once.
6. Vacancies. If a vacancy occurs among the officers or junior officers of the Chapter, the President shall appoint an active member to temporarily fill the vacancy, except the case of a vacancy in the office of President, the Mentoring Coordinator shall assume his duties until the election of a successor. The Secretary shall immediately notify all active and associate members that a vacancy has occurred. At the first regularly scheduled Association meeting occurring after this notification, nomination shall be made and elections held to fill the vacant office and any offices vacated as a result thereof.
7. Removal from office. An officer shall be liable for removal from office upon written petition of a majority of the active members of the Association. Written charges must be sent to the officer under consideration at least thirty days prior to the removal proceedings, and the officer shall at that time be suspended from performing further duties of the office. The Student Leadership Council shall appoint an active member to fill the office for the duration of the proceedings and shall submit a written report to the Association before a vote is taken. The removal proceedings shall be held at a regularly scheduled Association

meeting at which a majority of the active members are present at the time of the proceedings. All of the active and associate members shall be notified of the proceedings, at least seven days prior to the proceedings. For due cause and after just deliberation, an officer may be removed by an affirmative vote of two-thirds of the active members present at the proceedings. The Chairman of the Advisory Committee shall preside over the proceedings.

Article V. Duties of Officers

1.

1. President. The President shall plan the agenda and preside at all meetings of the Association and the Student Leadership Council, and shall be an ex-officio member of all committees. He shall coordinate the functions of all Association officers and committees. He shall appoint any committees necessary for expediency in carrying out the Association program. He shall serve as a member of the Advisory Committee, and arrange for the participation of Advisors at Association activities. He shall be responsible for the external relations of the Association except as otherwise provided by the Association or these bylaws. He shall give supervision to the Association and its officers, and shall see that its constitutional duties, both local and national, are fulfilled.
2. Mentoring Coordinator. The Mentoring Coordinator shall perform all functions of the President in the absence of the President. He shall be responsible for the operation and coordination of all Association mentoring programs and shall chair the Mentoring committee.
3. Outreach Coordinator. The Outreach Coordinator shall be responsible for activities relating to member-ship enlargement and retention. He shall serve as chairman of the Membership Committee. He shall be responsible for maintaining the permanent membership records of the Association and for seeing that all related responsibilities are fulfilled. At the beginning of each Pacific Earthquake Engineering Research Center funding period, he shall be responsible for contacting the central office and obtaining a list of the current.
4. Secretary. The Secretary shall coordinate the internal affairs of the Association. He shall be responsible for keeping the active and advisory members informed of all matters pertaining to the Association, and for overseeing the administrative details of the Association. He shall assure that the attendance and minutes of each Association and Student Leadership Council meeting are recorded, and see that these minutes are

placed in the Association archives and made available for the members' inspection. He shall keep up-to-date the copy of these bylaws on file with the Pacific Earthquake Engineering Research Center, and shall submit to them the names of all members elected to any office in the Association immediately upon their assuming office.

5. Newsletter Editor. The Newsletter Editor shall be responsible for the regular publication and distribution of the Association newsletter.
6. Internet Coordinator. The Internet Coordinator shall maintain the electronic mailing lists, homepage, and other Internet-related resources of the Association.
7. Historian. The Historian shall keep historical records by archiving photographs, keeping scrapbooks, and archiving the Association newsletter. He shall serve as chairman of the Archives Committee.
8. Student Leadership Council Representatives. Student Leadership Council Representatives shall be re-sponsible for attending all Student Leadership Council meetings. In addition, he shall serve as the first point of contact for students at his university regarding activities of the PEER Students Association. He shall also perform active promotion of the PEER Students Association as appropriate at his university, and represent the PEER students Association and Student Leadership Council to the public whenever necessary or appropriate.
9. Duties of all Officers. Each officer shall, at the end of his term of office, instruct his successor in the duties of his office and shall see that all files and records of his office are placed in the Association archives. He shall perform any other duties the Association may direct.

Article VI. Advisors and Advisory Duties

1.

   1. Advisory Committee. There shall be three or more Faculty Advisors, and as many Service and Industry Advisors as the Association deems necessary. They, with the Association President and the past Presidents of the Association shall constitute the Advisory Committee of the Association.
   2. Faculty Advisors. The Faculty Advisors shall encourage the development of high fraternal and scholastic standards. They shall assist the Association in planning and executing campus projects. They shall attend association meetings as regularly as possible, and shall serve as personal advisors and counselors on Association matters at all times.
   3. Service Advisors. The Service Advisors shall give counsel and advice to the Association when they deem appropriate. They shall encourage a

high standard of excellence in the Association and its service program. They shall attend Association meetings as regularly as possible.

4. Industry Advisors. The Industry Advisors shall assist and advise the Association in matters related to interaction with the professional industry. Industry advisors from all areas of earthquake-related practice are strongly encouraged, including both private and public agencies.
5. Chairman of the Advisory Committee. The Chairman of the Advisory Committee shall call and preside over all meetings of the Advisory Committee. He shall attend Association meetings regularly and shall serve as advisor and counselor at all times to the Association, its members, and its officers. He shall serve as presiding officer at any suspension or removal proceedings of the Association.
6. Duties of the Advisory Committee. The Advisory Committee shall, if necessary, give leadership in starting the Association's program at the beginning of the academic year. They shall meet, when necessary, for the purpose of advising the Association on its program and administration.

Article VII. Student Leadership Council

1.

1. Membership. The Student Leadership Council of the Association shall consist of the officers of the Association, the Chairman of the Advisory Committee, and the Junior Officers. The President shall serve as chairman. At least one representative from each core university shall be a member of the Student Leadership Council, with full voting rights. The other Association members and advisors may attend the meetings of the Student Leadership Council and have floor privileges, but shall not have voting rights. No member of the Student Leadership Council shall have more than one vote.
2. Meetings. The Student Leadership Council shall meet at least quarterly. Special meetings of the Student Leadership Council may be held upon the call of the President, or upon written request of one-third of the members of the Student Leadership Council.
3. Duties of the Student Leadership Council. The duties of the Student Leadership Council shall be:
   1. To exercise, when necessary, all the powers of the Association during the interval between Association meetings.
   2. To be responsible for carrying out the resolutions, policies, and activities of the Association.
   3. To refer to the Association such legislation as it may desire.

4. To advise the President in the coordination of all Association affairs.
5. To analyze the past projects of the Association, weigh their value, and determine the advisability of their continuance.
6. To analyze any particular problems of the Association pertaining to its program or administration, and plan for their solution.
7. To perform all other duties as directed by the Articles of Association, these bylaws, or the Association.

4. Quorum. A Quorum of the Student Leadership Council shall be a majority of the voting members of the Student Leadership Council.

Article VIII. Committees

1.

1. Standing Committees. The standing committees of this Association shall be the Mentoring Committee, the Membership Committee, and the Archives Committee. The chairman of each committee shall be responsible for seeing that its duties are fulfilled.
2. Mentoring Committee. The Mentoring Coordinator shall serve as chairman of the Mentoring Committee. The duties of this committee shall be:
   1. To make plans for carrying out the traditional Association mentoring programs.
   2. To work with the Faculty and Industry Advisors to determine the need for additional educational programs of various types.
   3. To work in cooperation with the local community leaders, the Service Advisors, Faculty Advisors, and Industry Advisors to determine the need for additional projects of a community nature.
   4. To present definite plans for each service project to a meeting of the Student Leadership Council for its approval, well in advance of the time the project is to take place, and to secure the cooperation of the entire membership in making each project a success.
   5. To assist in the formation and continuance of other service organizations.
   6. To submit to the Pacific Earthquake Engineering Research Center at the end of each term, a complete report on the mentoring program of the Association for that term.
   7. To make a full report to the succeeding committee which shall include both reports on the individual mentoring projects and an evaluation of the entire term's mentoring program.
3. Membership Committee. The Outreach Coordinator shall serve as chairman of the Membership Committee. The duties of this committee

shall be:
1. To inform students who are eligible for membership in the Association of the activities of the Association and their opportunity to join.
2. To hold open meetings of the Association at frequent intervals to which prospective members will be invited.
3. To check the qualifications and eligibility of prospective members and to recommend them for membership.
4. To plan and carry out membership campaigns and work toward definite membership goals.
5. To make a full report to the succeeding committee which shall include an evaluation of the entire outreach program.

4. Archive Committee. The Historian shall serve as chairman of the Archives Committee. The duties of this committee shall be:
   1. To establish standards for the archiving of historical materials.
   2. To maintain archives of minutes, newsletters, event reports, photographs, and other historical materials.
   3. To maintain the scrapbooks and the picture board.
   4. To ensure that adequate supplies of film and other archival materials are maintained in the Historian's supplies.
   5. To make a full report to the succeeding committee which shall include both reports on the individual policies and procedures and an evaluation of the entire term's accomplishments.

Article IX. Meetings

1.

   1. Regularly scheduled Association meetings. The Association shall meet at least annually at the Pacific
   Earthquake Engineering Research Center Annual Meeting. Additional meetings may be scheduled upon a majority vote of the active members of the Association.
   2. Place and Time. There shall be at least one regularly scheduled Association meeting during each year. These meetings shall be held in such places as the Student Leadership Council shall direct.
   3. Special Association Meetings. Special Association meetings may be called by the President or the Student Leadership Council on their own initiative, or upon the written request of one-fourth of the active members of the Association. The President shall call a special Association meeting to be held within three weeks after the presentation of such a request; if the President does not comply with the request

within the required time, a request in writing of one third of the active members may be presented to the Chairman of the Advisory Committee, who shall immediately call and preside over a special Association meeting. All active and advisory members shall be notified in advance of each special Association meeting. This notification shall include either a statement of the purpose of the special Association meeting or of the special business to be transacted.

4. Quorum. A quorum at all regularly scheduled and special Association meetings shall be one-third of the active members, unless otherwise provided in these bylaws.
5. Written Motions. All main motions, resolutions, and amendments of greater than ten words length shall be submitted to the chair in writing before discussion is in order on the proposal.
6. Closed Meetings. A meeting may be closed either to include only active members or to include only active and advisory members by a majority vote of the active members present.
7. Voting. Only active members shall be able to vote. Voting by proxy shall not be allowed on any Association business or during any Association elections.
8. Parliamentary Authority. For all questions of parliamentary procedure not covered by the Articles of Association or these bylaws, the current edition of Robert's Rules of Order shall be considered authoritative.
9. Floor Privileges. All persons present at a meeting shall have the right to speak. Only active members shall have the right to introduce or second a motion or resolution.

Article X. Elections

1.

   1. Advisors. At the second regularly scheduled Association meeting of the academic year, the Student Leader-ship Council shall submit a list of advisors to the Association for its approval. At this meeting the Association shall elect the Chairman of the Advisory Committee by plurality vote. Advisors may be added to this list at any regularly scheduled Association meeting.
   2. Officers. The Association shall conduct an election of officers at the Pacific Earthquake Engineering Re-search Center Annual Meeting. Only active members shall be eligible to hold office. At least twenty-eight days prior to this meeting, the President shall appoint a nominating committee, which shall present its report at the Association

meeting prior to commencing the election. Nominations from the floor may be made at the meeting prior to the beginning of the vote for the office in question, or any time between Annual meetings upon notification of the President. Election shall be by a preferential balloting procedure, and each office shall be voted on separately, from the highest to the lowest as listed in Article II, sections 1 and 3 of these bylaws.

3. Election Procedures. All elections shall be by secret ballot. Only those candidates who have accepted nomination can be candidates in a Association election.
4. Holding Offices. Each Officer or Junior Officer Position may be held by only one person at a time.
5. Assessments. An assessment may be levied on all active members upon the affirmative vote of three-fourths of the active members present at a regularly scheduled Association meeting at which a quorum prevails, provided that:
   1. At least fourteen days prior to the voting the proposed assessment shall be read, entered upon the minutes, and discussion opportunity provided via an approved medium.
   2. All active and advisory members shall be notified, at least seven days prior to the voting, of the proposed assessment.

Article XI. Amendments and Bylaws Interpretation

1.

1. Amendment Procedure. The bylaws may be amended upon the affirmative vote of two-thirds of the active members present at a regularly scheduled Association meeting at which a special quorum of one-half the active members prevails, provided that:
   1. The proposed amendment has had the consideration of the Student Leadership Council at least twenty days prior to the voting.
   2. Each proposed amendment has been submitted to the Student Leadership Council in the form of a petition signed by one-fourth of the active members.
   3. At least fourteen days prior to the voting, the proposed amendment has been read, entered upon the minutes, and discussed in an approved forum.
   4. All active and advisory members have been notified, at least seven days prior to the voting, of the contents of the proposed amendment.
   5. Before the vote is taken, a copy of the proposed amendment and the recommendations of the Student Leadership Council has been distributed to all present.

2. Approval. Each amendment shall be submitted to the Pacific Earthquake Engineering Research Center when it becomes effective.
3. Bylaws Interpretation. Questions involving the interpretation of these bylaws shall be decided by the President. The President's decision may be changed by a two-thirds majority vote of the active members present at any regularly scheduled Association meeting.
4. Discussion Requirement. All changes to the Bylaws, Standing Policies, or other governing documents or procedures of the Association must be discussed at a meeting of the Student Leadership Council before being in order for discussion at a meeting of the Association.

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8.13.2.2

STUDENT LEADERSHIP COUNCIL

Engineering Research Center for Reconfigurable Machining Systems
The University of Michigan

BYLAWS

Article I: Aims

The Student Leadership Council (henceforth referred to as "SLC") aims to:

1. Provide leadership for the undergraduate and graduate students (henceforth referred to as "students") of the Engineering Research Center for Reconfigurable Machining Systems (henceforth referred to as "ERC").
2. Act as representatives of the students in all discussions with the ERC administration concerning their general well being.
3. Actively encourage and promote cooperation and camaraderie among the students.

Article II: Officers of the SLC

Officers shall consist of a President, a Social Activities Coordinator, a TAC Meeting/Site Visit Coordinator, a Facilities Coordinator, a Communications Coordinator, and an undergraduate member, all holding office for a term of one (1) year. At least one of the officers shall be an undergraduate student.

A. The President shall:

1.
    1. Convene and preside at SLC meetings.
    2. Represent the SLC and the students in all discussions with members of the ERC administration.
    3. Maintain and manage the SLC budget.

B. The Social Activities Coordinator shall:

1.
    1. Organize social activities such as picnics, parties, and sporting events to enhance interaction among the students, and report expenses arising from such activities to the President.
    2. Preside over the bi-weekly student meetings.
    3. Assist the President in organizing the annual ERC banquet.
    4. Maintain and update a list of significant dates (such as birthdays, weddings, and bereavements) and make arrangements to suitably mark such occasions.

C. The TAC Meeting/Site Visit Coordinator shall:

1.
    1. Assist the ERC administration in organizing the TAC meetings and site visits.
    2. Work with the administration to assign duties to students during these events.
    3. Initiate and conduct the annual SWOT analysis.

D. The Facilities Coordinator shall:

1.
    1. Ensure that ERC facilities are generally clean and well maintained, and that all computer equipment is in working condition.
    2. Coordinate the distribution and return of ERC-owned student laptops with the administration.
    3. Assist in the administration of the ERC store, including coordinating its recycling efforts and report accounts to the President.

E. The Communications Coordinator shall:

1.

1. Convene and decide the agenda for bi-weekly student meetings, including student presentations and announcements.
2. Maintain attendance records at bi-weekly student meetings.
3. Keep minutes of all SLC and bi-weekly student meetings and disseminate them to the appropriate audience.
4. Arrange food for bi-weekly student meetings.

F. The Undergraduate Member shall:

1.
    1. Represent the students at the annual ERC conference in Washington, D.C.
    2. Attend all SLC meetings on a regular basis.
    3. Assist other SLC members in the discharge of their responsibilities.

Article III: Voting Rights and Elections

1. All students who are currently on the payroll of the ERC shall have the right to vote in the election of SLC officers.
2. Elections shall normally be held annually in April during the last bi-weekly student meeting of the academic year.
3. Any student of the ERC who will continue on the payroll of the ERC for at least one term during the forthcoming academic year shall be eligible to be a candidate for a position on the SLC.
4. The outgoing SLC shall appoint a responsible person to serve as Election Officer.
5. Students interested in being candidates should file their nominations with the Election Officer at least one week prior to the date of the election. No write-in candidates shall be allowed.
6. Following the deadline for filing nominations, the Election Officer shall create a ballot in sufficient quantities for use in the election.
7. Each student who has the right to vote shall be eligible to cast one vote each for six (6) candidates (for 6 positions on the SLC).
8. Elections shall be conducted by secret ballot.
9. Ballots with more votes than the number of available positions on the SLC shall be deemed invalid.
10. The six candidates with the highest number of valid votes (including at least one undergraduate) shall be deemed elected as members of the SLC by the Election Officer.

11. In the absence of any undergraduate on the ballot, only five (5) members shall be elected. The vacant position shall be filled by a suitable undergraduate student as soon as possible, either by appointment or by invitation.
12. Following the election, the newly elected members of the SLC shall elect a new President. This shall be done by consensus, or by simple majority of the entire SLC.
13. Other roles and responsibilities on the SLC shall also be assigned after the election.
14. The term of the SLC shall be one (1) year.
15. Midterm vacancies on the SLC, if any, shall be filled by nomination or by invitation.

Article IV: Meetings

1. Student meetings shall be held on a bi-weekly basis during the academic year at a time convenient to the majority of the students. Food and drink shall be provided. The purpose of such meetings shall be to foster a spirit of interaction among the students by holding student research presentations, making key announcements, and generally providing an atmosphere that stimulates discussion. Students shall make every effort to attend these meetings.
2. The SLC shall normally meet on a weekly basis during the academic year, at a time convenient to all SLC members. The purpose of such meetings shall be to discuss student concerns and make decisions in the interests of the students, and to propose and discuss new ideas for the betterment of the students. Members shall also use this opportunity to update each other on their respective activities.

Article V: Amendments and Ratification

1. Any amendments to this document shall be ratified by the students before taking effect. Information regarding proposed amendments shall be posted at least one week in advance of the bi-weekly student meeting.
2. Any amendment shall require a quorum of 25 students before being proposed for ratification.
3. Ratification of each proposed amendment shall require a simple majority of the quorum.

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WIMS Students Association
[Bylaws of the Center for Wireless Integrated MicroSystems,
University of Michigan]

1. The WIMS Student Association (WIMS-SA) is formed to discuss activities and ideas relating to the WIMS ERC and its students.
2. The WIMS Student Association exists to advance the development and interest in Wireless Integrated MicroSystems among the students of the WIMS ERC.
3. WIMS-SA Structure - The WIMS Student Association has a president, a vice-president, and a University of Michigan Engineering Council representative. There are also 3 subcommittees, each having one chair.

3.1. Committees and Leadership Responsibilities:

3.1.1. Student Leadership Council (SLC): This is comprised of the president, vice-president, UMEC representative, and the three committee chairs. This council serves as the steering committee for WIMS-SA.

3.1.1.1. *President* is responsible for: (1) planning SLC and Student Association meetings, (2) facilitating the activities of the committees, (3) providing interaction with the WIMS ERC director, (4) providing direct feedback to the NSF, and (5) updating the database of WIMS-SA students.
3.1.1.2. *Vice President* is responsible for (1) the yearly budget planning, (2) planning the SLC and Student Association meetings.
3.1.1.3. *UMEC Representative* provides interaction the University of Michigan Engineering Council.
3.1.1.4. *Committee chair* responsibilities are listed below.

3.1.2. Education Committee: Primarily responsible for organizing activities that encourage those outside of the WIMS ERC, especially pre-college and undergraduate students, to learn more about Wireless Integrated MicroSystems as well as the mathematics, science, and technology in general.

3.1.2.1. *Education Committee Chair:* Responsible for organizing and overseeing Education committee meetings, encouraging student participation in Education activities, and coordinating interaction with the ERC Educational Outreach Liaison.

3.1.3. Social committee: Primarily responsible for fostering interaction amongst all members of the WIMS ERC, thus facilitating an more personal level between all that are involved in the ERC

3.1.3.1. *Social Committee Chair:* Responsible for planning social activities for the WIMS Student Association

3.1.4. Industrial committee: Primarily responsible for organizing activities related to interacting with industrial members in the field of MEMS, especially those connected directly to the WIMS ERC. Responsible for developing ways to better share information between industrial members of the ERC and its students.

3.1.4.1. *Industrial Committee Chair:* Responsible for (1) interaction between the student association Industrial Advisory Board members as well as planning and communication with the Industrial Outreach Liaison, (2) planning Industrial Committee meetings, and (3) exploring possible student internship opportunities

4. WIMS-SA By-Laws

4.1. Membership: WIMS-SA is open to all interested students at the institutions participating in the WIMS ERC. This can include non-ERC Students1. A student becomes a member by contacting the President directly or through another SLC member.
4.2. Participation in Events: Most WIMS-SA events are open to the following: WIMS-SA members, faculty and staff of the WIMS ERC, industrial members of the WIMS ERC, and personal friends and family thereof. Exceptions:

4.2.1. For WIMS-SA student mass meetings, only WIMS-SA members and invited speakers shall attend.
4.2.2. For SLC planning meetings, only the SLC members will attend.

4.3. Funding of Events: Decisions regarding the funding of activities and events will be made by the SLC, with the option of final approval being reserved by the WIMS ERC Director.

4.3.1. Generally, WIMS-SA may pay funds for activities toward ERC students1 only. Unless otherwise specified, funding will be provided given that (1) the activity has participating ERC Students1, and (2) the activity was formed as part of WIMS-SA.
4.3.2. Funding may be decided in 2 ways:

4.3.2.1. The amount of money contributed toward these activities will reflect the percentage of ERC students participating. Examples include (but are not limited to): site visits to companies, conferences, and IM sports.
4.3.2.2. As part of its outreach to the public, WIMS-SA may schedule activities (e.g. barbeques) where non-ERC students1, and non-WIMS-SA members can attend.

WIMS-SA may pay for any portion of the expenses of these gatherings. This portion will be decided upon by the Student Leadership Council and must be within reason.

4.4. Elections will be held once a year, at the first WIMS-SA mass meeting held each January.

4.4.1. Only ERC students1 may run for an office.
4.4.2. The committee chairs, UMEC representative, and the vice-president are elected by a simple majority vote from all present WIMS-SA members.
4.4.3. The vice-president automatically becomes the president for the following year.
4.4.4. Only one office may be held by a member at any given time.
4.4.5. If any elected officer becomes unable to fulfill his/her duties during their term, an interim officer will be appointed by the SLC by a simple majority vote from the remaining members. This officer will serve out the remainder of the term until new elections are held.

4.5. Amendments to the WIMS-SA bylaws may be suggested by any WIMS-SA member, and will be enacted by a unanimous vote of the SLC members.

4.5.1 Appendix
[1] The term "ERC Students" refers to: directly funded students, partially funded students, and students on associated contracts only. This is not to be confused with WIMS-SA members, who may be any student regardless of funding.

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8.13.2.4

Charter of the Biotechnology and Bioengineering Student Council [MIT]

Mission

The Biotechnology Process Engineering Center (BPEC) and Biotechnology Training Program (BTP) Student Council has a general mission of promoting interdisciplinary interactions among trainees supported by the NSF-funded BPEC and the NIH-funded Biotechnology Training Program, and participating in outreach to the larger community, including MIT, other academic institutions, government and industry.

Background and Context

BPEC and BTP both support interdisciplinary training with an emphasis on the interfaces between engineering, biology, and chemistry. Among academic institutions, MIT plays a unique role in promoting the interface between biology and engineering, setting the pace for an emerging new discipline. "Bioengineering" as it is evolving at MIT is rooted in the now-established molecular science of biology and thus has become a new fundamental discipline in engineering, with a wide spectrum of applications, including medicine among others, in a manner analogous to the emergence of chemical engineering from the molecular science of chemistry early in the 20th century. The department-level academic structure, the Biological Engineering Division (BE) is charged with creating educational curricula in bioengineering, as well as environmental health, so it joined the departments of Biology, Chemistry, and Chemical Engineering as a major partner in the BPEC and BTP programs and serve as the academic home for bioengineering degree programs. Since many of the issues in the areas we have traditionally viewed as "bioprocess engineering" and "biomedical engineering" at MIT have merged, it makes great sense to take advantage of the synergy offered by joining many activities supported by BPEC and the BTP. Coordination is facilitated by Douglas A. Lauffenburger's positions as Co-Director of BE, Executive Director of BPEC, and BTP Steering Committee Member. Linda G. Griffith, in her capacity as BPEC's Executive Director of Education and BTP Steering Committee Member, coordinates the activities of the BPEC/BTP Student Council on a day-to-day basis.

Composition of the Student Council

The Student Council comprises trainees drawn from the participating Departments of Biology, Chemistry, Chemical Engineering and the Division of Bioengineering and Environmental Health. The Graduate and Postgraduate Student Council has at least 6 member, 2 from each department. The Undergraduate Student Council has at least 6 members, one from each department.

Responsibilities of the Student Council

1. Meet monthly with Professor Griffith to discuss current issues, provide suggestions about improvements in training or operations, and update any changes in the responsibility list.
2. Organize a seminar series which meets on a weekly basis in which trainees present current work. Each trainee should present at least 4 times per year. Students will decide the format of the seminar series and organize a list of speakers, with assistance from Professor Griffith. BPEC administrative staff will ensure the series is advertised. Professor Griffith will be responsible for encouraging faculty attendance.

3. Provide input to the content of the BPEC and BE Websites. A formal representative from the Council will be listed with the BPEC administration as the contact person for student input.
4. Provide lab tours for visitors from other academic institutions (including middle and high school teachers and students), government, and industry. Lab tours are arranged on an ad-hoc basis, initiated by calls from the outside to BPEC, and thus rotating assignment of trainees who would be available each month as suggested. The Student Council will be responsible for providing the BPEC administration with a pair of trainees capable of giving tours each month.
5. Representatives of the Student Council will participate in site visits by NSF and NIH. While most such meetings are held at MIT, some travel to NSF may be required.

The Student Council will perform a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of BPEC and prepare a report for the NSF. BPEC staff will assist in organizing and running this analysis and preparing the report, while students will provide the intellectual input.

8.15.2 Appendix B: Contact Information

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Chapter 9: Multi-University Centers

9.1 INTRODUCTION AND OVERVIEW

Since 1998, NSF has funded only *multi-institution* Engineering Research Centers (ERCs) for two reasons: in order to gain the broadest possible impact in research and education, and to maximize the capabilities of research teams without limiting the Center's vision. This requirement means that to all of the day-to-day challenges of operating an industry-oriented, multidisciplinary Center on a university campus are added the extra dimensions—geographic, logistical, administrative, legal, cultural, and psychological—of requiring separate institutions to collaborate closely. This chapter focuses on the issues, challenges, and best practices that are unique to the multi-institution Center. Thus, it overlays and augments the other chapters of the Best Practices Manual, cutting across all the functional and program areas described there.

Loosely paralleling the structure of the Best Practices Manual as a whole, this chapter addresses the following topics. Links take the reader to that section.

2. Organizational Structure and Center Management
3. Administrative Management
4. Research Program Management
5. Education Program Management
6. Industrial Collaboration and Technology Transfer

The chapter was written by a task group of ERC staff members:

- Dr. Michael Silevitch *(chair)*, Director, Center for Subsurface Sensing and Imaging Systems (CenSSIS)
- Ms. Jacqueline Wheeler, then Administrative Director, CenSSIS
- Ms. Janiece Harrison, Assistant Director, VaNTH ERC for Bioengineering Educational Technologies
- Dr. Fred Lee, Director, Center for Power Electronics Systems (CPES), with Ann Craig, CPES Administrative Director and Beth Tranter, CPES Administrative Director, Education and Outreach Director

- Dr. Amr Elnashai, Director, Mid-America Earthquake Center
- Ms. Sally Clement, then Education Coordinator, Center for Environmentally Benign Semiconductor Manufacturing
- Ms. Teresa Shaw, Industrial Liaison, CPES

The effort was coordinated by Mr. John Beaty, Program Manager at CenSSIS, with NSF consultant Courtland Lewis as overall project director. Please direct comments and questions regarding the chapter contents to Mr. Lewis at clewis@nsf.gov.399

9.2 ORGANIZATIONAL STRUCTURE AND CENTER MANAGEMENT

The Center Director faces a number of challenges at the start of an Engineering Research Centerâ ™s life cycle. Initial task delegation and staffing decisions are vitally important to smooth operation and sustained success. The Director must determine which management and operations functions to delegate during the planning stages and through the start-up phase of the ERC, as well as the level of delegation. A multi-university ERC Director also encounters the significant challenges of delegating responsibilities for campus-level activity coordination. The initial decisions regarding the fundamental operating structure of the ERC are crucial to determining its success and ensuring active collaboration among programs, thrust areas, and institutions.

9.2.1 Identifying and Forming the Center Leadership Team

At its inception, an ERC is often strongly reflective of the Directorâ ™s personal vision. The Director usually has initiated the effort and recruited the key researchers. Often, the Director brings a strong background of experience in leading large, well-funded research efforts such as a single campus-based research group. When making the transition to a newly-funded ERC, the Director must be willing and able to integrate personal goals with the Center concept, and to delegate responsibilities within the Center as it begins to progress toward the first important National Science Foundation (NSF) review. Three pivotal decisions faced by a new ERC Director include: selection and cultivation of the leadership team, delegation of various responsibilities to the leadership team, and distribution of leadership responsibilities across campuses.

During the ERC proposal process, it is critical that the senior-level university administration be recruited first, so as to ensure commitment, entice career-minded individuals to participate, and develop the support structure for partnership in all facets of the Center. Strong relationships between the Center and the lead university administration are also important to ensure establishment of similar support structures on partner campuses. As this process occurs, it is important to aggregate administration supporters under a common governing or advisory organization so that the support is nurtured and maintained throughout the life of the Center. This governing body should also be actively engaged in responding to issues and challenges raised by industry or through the NSF review process, so that resources particular to individual institutions are appropriately leveraged and concerns are addressed across institutional boundaries. Throughout its lifetime, the ERC should be envisioned and promoted as a permanent part of the participating universities and their individual strategic plans.

When forming the leadership team, the Director must consider the long-term Center life cycle, assessing the commitment of individuals to the success of the *Center* rather than to their individual goals, as well as the ability of those individuals to collaborate effectively over the long-term. Leadership roles for individuals geographically separate from the lead institution should be clearly enumerated, documented, and periodically reviewed to ensure effective management and collaboration. The Director must also recognize that the original leadership group will affect the future nature of the Center and the evolution of the strategic plan. As part of the long-term view of the Center, the Director must consider the eventual transition of top leadership and cultivate, throughout the life of the Center, an environment and synergy in which this transition can be made successfully.
As part of the recruitment and selection process, the Director must seek out specific talents and personality characteristics that are essential for the success of the team. An informed Director will recruit individuals with a team mind-set, a reputation for successful relationship-building with colleagues and university administration, and an established reputation for research leadership. Individuals with unique talents and who are prepared to be a part of the team top the list of recruits and can serve as catalysts for recruiting others, both in their home institutions and Center-wide. Recruiting talented individuals also requires the ability to balance â œlone rangersâ • and talented team players, realizing that personality characteristics are deeply ingrained and ultimately will affect the productivity and overall success of the Center. The Director must be mindful that diversity in the leadership team is essential and best seeded early. It is also essential that all leadership team members understand that the

likelihood of organizational and personnel changes during the life span of the Center is quite high, and that the concept of the Center must be sufficiently broad to incorporate these changes.
The role of the Deputy Director in a multi-university ERC leadership team is vital to the success of the Director and the Center. The Deputy Director should augment the expertise of the Director in terms of the core research thrusts of the Center. The two primary authors of the center need to build the breadth and depth of the Centerâ ™s focus. Ideally the Deputy is a senior faculty member, often at a different partner institution. Such an arrangement cements the involvement of both institutions in the Center. The ERC will function more effectively if the Deputy can step in for the Director when needed. The more credible the Deputy is as a leader, the more flexible the management structure can be. If the Deputy can manage, lead, and be responsible for several key strategic goals of the Center, the Center can move forward more effectively with its strategic plan.

CASE STUDY:, Bahaa Saleh is the Deputy Director for CenSSIS. He is a senior faculty member at BostonUniversity (BU), while the Center is led by NortheasternUniversity. Prof. Saleh is the leader of one of the fundamental science research thrusts dealing with advanced sensing concepts. He is also responsible for overseeing the development of a unifying framework for subsurface sensing and imaging systems. This framework is a key long-range system-level strategic research deliverable for the Center. Moreover, he is leading the development of an undergraduate textbook on subsurface sensing and imaging concepts. This is a key education deliverable of the Center. As the Chair of BUâ ™s Electrical and Computer Engineering Department, Prof. Saleh has significant administrative experience and the seniority to provide leadership to the center when the Director is unable to do so.

9.2.2 Establishing Institutional Partnerships

In a multi-institution ERC, it is essential to develop and foster strong administrative relationships within and among the cooperating colleges and departments of the partner institutions so that the vision and the strategic research and diversity plans can be implemented and can evolve as needed. Therefore, successful commitment from partner universities throughout the lifetime of the ERC is key to institutionalization and is essential for the survival of the Center after graduation from the ERC program.

As keeper of the ERC vision, the Director is best suited to promote the Centerâ ™s driving concepts and to garner support for external institutions as partners. The intimate involvement of other academic departments within the lead university and partner universities at inception is vital, building toward critical reviews. Senior administrative support of the lead and partner institutions is necessary for establishing long-term institutional partnerships, and an intercampus Governing Board (GB) or similar organization can be quite useful in engaging these constituencies to sustain the Center. Such a Board can and should play an important role in establishing a common set of practices and procedures to maintain intercampus research and education endeavors, including intellectual property (IP), distance learning, and student and faculty exchange. In such cases, working relationship agreements should be formalized, signed by all parties, and recorded. The resulting agreements should be accessible and reviewed periodically as a group.

CASE STUDY: *The Center for Power Electronics Systems (CPES) Memorandum of Understanding (MOU) established a pool of industrial funds from which to select and apply for patents.*

As the number of new technologies generated by CPES grew, it became apparent that the established IP evaluation process was cumbersome and inefficient. Missed deadlines resulted in valuable technologies becoming part of the public domain. After considerable exploration and negotiation, Dr. Fred Lee, CPES Director, proposed a potential remedy to industry and officials at the partner universities. The essence of the idea was to streamline the IP review procedure and expedite the IP protection process by utilizing pooled resources from participants. The idea evolved into an agreement for implementation of a system to pool resources for the protection of selected technologies and is now known as the Intellectual Property Protection Fund (IPPF). An IPPF agreement offers participants the undisputed IP advantage of a nonexclusive, nontransferable, royalty-free license after a two-year exclusivity period. Companies that choose not to participate in the IPPF option continue to follow the standard procedure to gain access to CPES technologies. If IPPF pool participants and non-IPPF participants are interested in protecting the same technology, the cost is equally shared. Since the implementation of IPPF, 20 companies have participated to provide protection for 24 CPES technologies.

Examples of basic agreements and other organizational documents include: Strategic Plan, Operations Policies and Procedures manuals, Industry Consortium Agreements, Intellectual Property Agreements, Curriculum Cross-Listing Agreements, Student/Faculty Exchange Program Agreements, Course Credit Earnings/Transfer Agreements, and a Student Leadership Council Constitution. Examples of these documents can be found in other chapters of the Best Practices Manual or obtained from other ERCs.

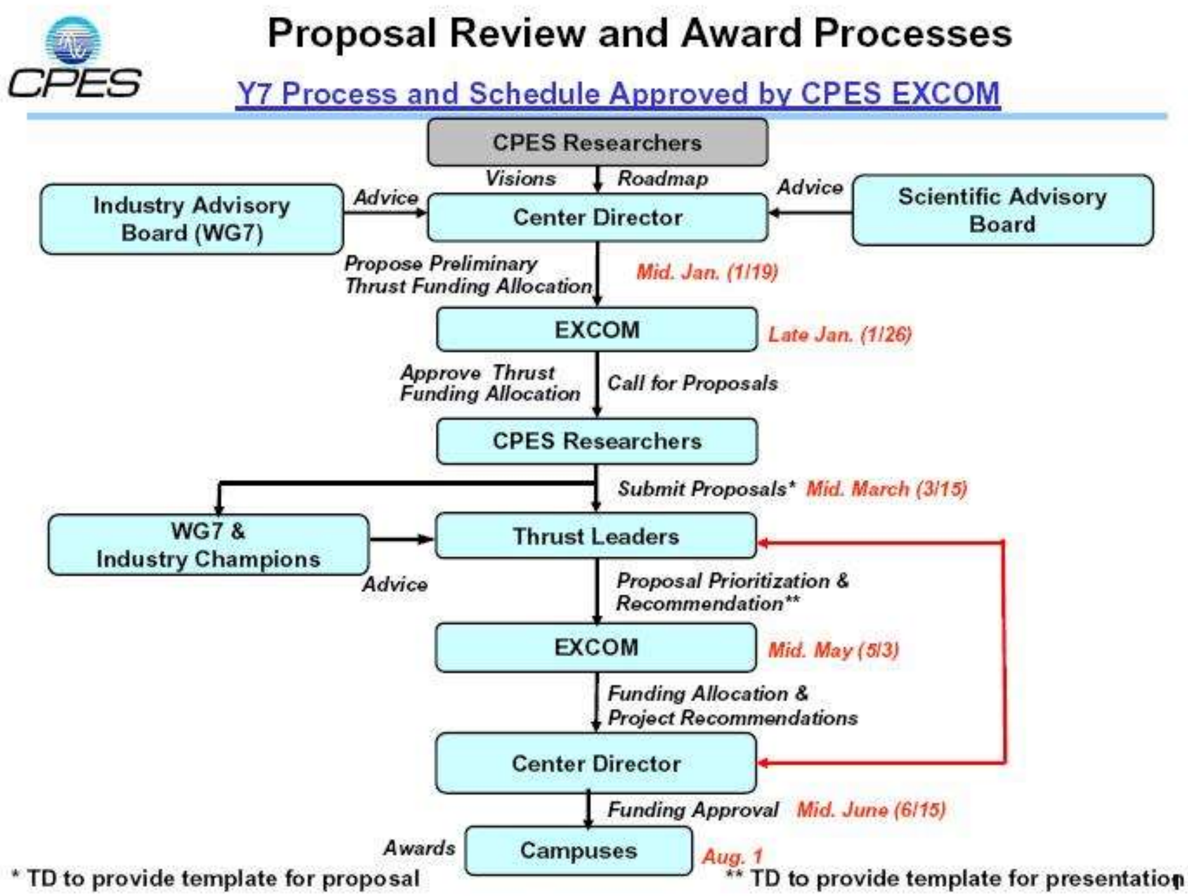
9.2.3 Initial Strategic Planning: Organizational Considerations

A first task of the newly-assembled leadership team is to review, develop, and refine the initial strategic plan to address the research, education, outreach, and diversity missions of the ERC. The initial strategic plan is usually the result of a collaborative effort and a democratic process. During this process, the Center leadership team must ensure that the plan maintains a systems focus and addresses development of all programmatic components, focusing particular attention on those areas that will be benchmarked as a part of the Centerâ ™s reviews by NSF and industry. In a multi-institution Center, the process may involve discussion and input from faculty and staff, advisory groups, and ultimately, review by representatives from each participating institution prior to submission to NSF for approval. A facilitator or consultant might be useful in this process. The Centerâ ™s organizational structure could also include a Research or Technical Director who can assist the Center Director in review and implementation of the research strategic plan.

The strategic plan should be viewed as a living document and updated regularly to reflect changing priorities during the Centerâ ™s life cycle. The Director develops a systematic plan to revisit the strategic plan with the leadership team and Center Principal Investigators (PIs) on a regular basis, so that input from review panels and advisory bodies can be incorporated as appropriate. The Center may also form new outreach initiatives with academic institutions and/or government laboratories. These relationships will likely provide an opportunity to incorporate new expertise into the Centerâ ™s programs, including the strategic plan. It is therefore essential to develop a well-defined mechanism to review the progress of programs, individual projects, and thrust areas as part of the funding allocation process, and to review and revise the strategic plan to reflect the evolution of the Centerâ ™s work and inter-institutional connectivity over time. Factors for consideration include the channels and means of collecting internal input, as well as engaging Center faculty, thrust and program leaders, and industry and scientific advisory groups.

In managing a large multi-disciplinary research program, it is very important that each team member in each task/thrust/program understands the integrated system goals and is able to relate individual research activities to the overall Center research objectives. Each individual is a part of the ongoing communication effort that must occur to ensure that there is a mutual understanding among all participants, from the malleable student to the seasoned researcher.

Case Study: CPES uses many tools to facilitate an integrated culture. The development of an all-encompassing roadmap that clearly delineates the interdependencies among the thrusts and is supported by milestones and benchmarks at each thrust level is the single most powerful tool. This roadmap is reviewed, discussed, and updated as part of an annual CPES Research Retreat that involves all *faculty research leaders from all the partner campuses. Further, weekly project meetings attended by all faculty and students involved provide an opportunity for the students to reinforce understanding of the overall activities and to foster team collaboration. The key to success is frequent and productive communication and interaction among all Center members, using telephone and web conferencing tools. These interactions establish a basis for individual appreciation of outcomes that are achievable when acting as part of the team.*



9.2.4 Allocation of Funds

Establishing budgets/funding allocations is a major process that must be addressed at the Center Executive Committee level and requires time to refine. Funding cannot be allocated on either a pro forma or entitlement basis. In addition to the concerns of allocations across programs, disciplines, and research thrust areas, multi-university Centers also face the unique challenge of reviewing and allocating budgets across institutions. Cost-sharing commitments must be made and met at each institution, while remaining balanced against expected and actual outcomes. In a multi-university environment, it is therefore necessary to develop a process which addresses all internal parties such as thrust leaders, campus directors, program directors, and PIs, while also reflecting the input of the Industrial Advisory Board (IAB) and the Scientific Advisory Board (SAB), as well as other applicable external consultants or stakeholders. The Directorâ ™s role is critical to ensure that the process and outcomes reflect the multi-institutional nature of the ERC. In particular, the Directorâ ™s perspective is instrumental in ensuring that the research review process considers not only technical connectivity within and among projects and thrusts, but also supports ongoing intercampus connectivity.

Fig. 9.2.1 Sample Research Review Process Flow Chart

Figure 9.2.1 shows the research proposal review and funding process at CPES. The timeline allows for input from the five campuses of this Center and their representatives on the Centerâ ™s Executive Committee (ExCom).

9.2.5 Principles and Practices for Managing the Multi-university Center

Overcoming geographic, institutional, and cultural distances within a multi-university Center requires open and regular communication at all levels. The cultivation and maintenance of relationships is a priority throughout the life of the Center. Achieving collaboration toward a common goal (and suppressing unproductive competition) is largely dependent on the Director and is a task that grows exponentially with the number of involved individuals. While the Director should avoid processes that are excessively democratic, consensus decision-making methods and implementation are fundamental to fostering an open and constructive environment within the Center. Essential staff members can play a vital role in supporting this environment by their responsiveness and flexibility.

From Center inception, the Director should be mindful that participation in an ERC will require attitude adjustments and a deep level of personal commitment from all participants. Key faculty must commit to a substantial administrative load, including strategic planning, cross-campus project coordination and reporting, as well as administration of their own research projects. Given the administrative complexities and the need to develop programs and relationships consistently over time, long-term commitment of these faculty members is essential to Center success. Commitment to long-range planning and outcomes is required of participants at all levels. For participating faculty, transformation of the individual PI mindset to one of interdisciplinary team play is a challenge. In multi-university ERCs, participation is as a Center partner, rather than an as a separate institution involved in a Center. Being an ERC partner is a cultivated behavior.

Data collection, interpretation, presentation, and access pose significant challenges in multi-institution ERCs. The lead institution should be prepared to provide technical infrastructure to facilitate this information exchange; to interpret and clarify reporting guidelines for individuals and offices at lead, core partner, and outreach institutions; and to identify common platforms for intercampus communication. Scheduling across time zones and multiple faculty class schedules is often challenging. For this reason, it is best to establish in advance long-range schedules for critical meetings.

9.2.6 Planning and Delivering on Diversity Goals

From the establishment of a Center, gender equity and ethnic diversity need to be embedded in the education and outreach goals as well as the faculty and staff recruitment goals. During the first year the Diversity Coordinator needs to convene an Education and Diversity Advisory Board (EDAB) (or the equivalent) representing the Centerâ ™s partner institutions and strategic corporate partners, and supplemented by nationally recognized experts in these fields. The EDAB or a subset needs to develop a strategic plan for diversity across all the partner institutions and to integrate key elements of the plan into strategic planning discussions of the Centerâ ™s Executive Committee.

During the second year, the EDAB or subset should develop a strategic planning process to help the Director set realistic goals and workable strategies for significantly increasing diversity in Center laboratories and classrooms. The core of the process is the development of a Strategic Plan for Diversity. Key elements of this plan are:

Get accurate baseline data and set realistic five-year diversity goals for increases in the percentage of females and racial and ethnic minorities represented among the Centerâ ™s faculty, graduate students, and undergraduate students

- Designate strategic activities that will assist in reaching established goals
- Provide sufficient resources to adequately fund designated activities
- Develop a flexible funding strategy for efficient deployment of resources
- Establish specific patterns of responsibility and accountability
- Collect accurate annual data (separately by partner institution, and totals for the ERC)

- Supplement annual data-gathering with interim reporting requirements as needed
- Create a mechanism for the diversity program to report to key stakeholders at both lead and partner institutions, such as the Governing Board or Advisory Board.
- Leverage existing institution-level initiatives at lead, core partner, and outreach institutions
- Engage in continuing project evaluation.

CASE STUDY: *The CenSSIS six-year results demonstrate that if a strategic planning process is applied to increasing the numbers of females and minorities in an ERC, increasing diversity is possible. For example:*

- *The number of female faculty increased from 6 (13%) in Year One to 18 (30%) in Year Six. The number of minority faculty increased from 7 (12%) in Year One to 19 (31%) in Year Six.*
- *The number of female graduate students increased from 9 (23%) in Year One to 34 in Year Six. The number of minority graduate students increased from 10 (8%) in Year Four to 31 (28%) in Year Six.*
- *The number of female undergraduate students increased from 37 (41%) in Year 5 to 38 (41%) in Year Six.*

9.3 ADMINISTRATIVE MANAGEMENT

Administrating a multi-institution Engineering Research Center (ERC) involves several special challenges. Paramount among them is building and maintaining a strong relationship among the academic, strategic, and industrial partners.

Effective communication is the key to maintaining a cohesive and focused Center. The management teams—Governing Board, the IAB, the SAB, research managers, education program directors, outreach coordinators, industrial liaisons, and administrators—need to understand their roles and objectives in the changing environment typical of the ERC. Weekly management team meetings, composed of members of all the groups within the ERC, keep everyone on the same page. Regular meetings of the GB, IAB, and SAB tune the strategic focus.

The ERC events (IAB meetings, Center-wide research symposia, Retreat, NSF ERC program annual meeting, NSF Annual Report, and Site Visit) are coordinated efforts that require the cooperation of academic, strategic, and industrial partners. The administrative and financial infrastructure must be designed to be flexible and robust.

9.3.1 Administrative Challenges Unique to Multi-Institution ERCs

The challenges for multi-institution ERCs are obvious. They are more intricate organizations, composed of many institutions with different systems, complex administrations, and varied financial needs and accounting systems. Getting things done requires cooperation, communication, and talented administration.

9.31.1. Increased Complexity of Multi-institution Centers

There are many aspects of this greater complexity:

- There are additional stakeholders and layers with differing priorities, agendas, and institutional cultures.
- There is an increased need to manage expectations when there are competing demands for resources, i.e., balancing the Center's core work of producing research results and educating a diverse future engineering workforce with creating and maintaining the management and administrative infrastructure needed to accomplish both that work and NSF deliverables.
- Process- and consensus-building takes more time, effort, and shepherding at all levels, but is critical to achieving the collegiality and cohesion needed to think and work as a Center, versus with an institution-specific mindset.
- The cost of doing business (e.g., administration, operations, marketing expense) is higher and requires a larger percentage of funding. Managing a geographically distributed enterprise with multiple partners requires a more sophisticated administrative structure and additional resources. For example:
- Administrative overhead/infrastructure funds for administrative personnel, facilities, and information technology support are needed (at least part-time) at each campus.
- There are substantial travel-related costs (hotels, airfare, and meals) for Center-wide events such as NSF Annual/Renewal Site Visits and IAB Meetings, the NSF ERC Annual Meeting in Washington, D.C., and periodic Center operating meetings such as Retreats and Executive Committee Meetings.

<u>CASE STUDY:</u> Each core partner institution of the Center for Subsurface Sensing and Imaging Systems (CenSSIS) is usually represented by approximately 20-25 faculty researchers, students, and senior administration personnel at its annual NSF Site Visit and annual Research and Industrial Collaboration Conference; smaller groups meet in person at other times during the year.

<u>CASE STUDY:</u> At CPES, the NSF Site Visit is held in conjunction with the Center's Annual Conference and review by industry. The Annual Conference, which includes tutorials, invited presentations, technical sessions, a poster session, and industry-student forum, is organized by a multi-institutional committee of students. The CPES Annual Conference typically attracts approximately 250 attendees per year from around the world. In recent years, this annual event also provides a forum for strategic planning workshops involving industry as well as faculty and students from lead, core partner and outreach institutions.

Tip: Consider scheduling IAB meetings and NSF Site Visits back-to-back to minimize travel-related and other costs. Since Site Visits may be conducted at the partner institutions, rotate the fall IAB meeting among partners to spread the burden and maximize industrial members' familiarity with the Center's "branches."

- Telephone conference calls needed to conduct the Center's administrative business, research, and technology transfer increase the cost of doing business.
- Infrastructure at the university level for administrative/operating support can vary greatly from institution to institution. Expect the Center to build, buy, or outsource solutions for Center operations to meet NSF deliverables, which are unique and complex.

9.3.1.2 Agreements Between and Among the Partner Institutions

At a minimum, the lead institution will enter into a subcontract with each of the partner institutions to provide them with their NSF ERC and industrial funds and bind them to the requirements of the Cooperative Agreement with NSF.
Many multi-institution ERCs also execute a Memorandum of Understanding (MOU) among all the partners. This agreement can address a range of issues but almost always includes a statement about how the Center's intellectual property (IP) will be handled.
The lead and partner institutions also need to agree on how the industrial partnership agreements between the Center and an industrial partner will be handled. Typically, these agreements are signed by the lead institution on behalf of all the partners but the policy needs to be clarified and documented by mutual agreement among the partners.

<u>CASE STUDY</u>: CenSSIS established an Academic Partnership Agreement from the onset that was executed by the lead partner and the other three partner institutions; the CenSSIS Academic Partnership Agreement points to the Center's Industrial Partnership Agreement that is executed with member companies. A separate Intellectual Property Agreement was drawn up by the ERC's Industrial Liaison

Officer and the lead university's Technology Transfer Office after substantial discussion with all the partner institutions.

CASE STUDY: CPES established intercampus agreements for Distance Access of Courses and Exchange of Graduate Students. In preparation for graduation from the NSF ERC program, CPES also established an intercampus agreement for continued post-award collaboration of the lead and core partner campuses.

9.3.1.3 Effective Communication Is Key to Achieving Multi-institution ERC Cohesiveness and Focus

Multi-institutional weekly meetings via teleconference or videoconference are critical to operational success. Timeliness and frequency of meetings are important considerations. It is best to establish a consistent time and place, where appropriate, so meetings become routine.

CASE STUDY: CenSSIS has a weekly management meeting accessible via a toll-free call-in number that is open to a broad constituency. The Director is highly involved in shepherding these meetings and personally emails out the agenda in advance and the meeting minutes afterwards. He often contacts key personnel beforehand to encourage meeting participation by remote attendees.

Tips:

- Encourage participation by key people.
- Prepare and follow an agenda that is sent out in advance.
- Follow up with minutes and action items.

Face-to-face meetings throughout the year in addition to those required by NSF increase the quality of communication.

CASE STUDY: The CenSSIS Executive Committee meets two to three times annually to make funding allocation and other high-level, Center-wide decisions. One of these meetings is the Strategic Planning Retreat attended by the Center's Senior Management, key researchers, and BOD (composed of partner deans and strategic industrial/government partner members).

CASE STUDY: CPES conducts a weekly management meeting which involves all key personnel within the leadership team. The CPES Executive Committee, which includes all leadership team members, campus directors and thrust leaders, meets on *a monthly basis. Discussion topics include: upcoming events, annual reporting, funding allocations, strategic planning issues within the Center's research, education, and industry collaboration programs, and other Center-wide decisions. Each November, a retreat is conducted for all Center PIs to discuss strategic planning within the research program.*

Information technology is the tool that the local and distant partners use to generate, communicate, and store their information. The local area networks (LAN), Internet, and the associated administrative staff are indispensable to a multi-institution ERC.

Electronic media—email, internet, file transfer protocol (FTP) and WebEx—are timely, inexpensive, and useful to expedite communication.

CASE STUDY: *At CenSSIS, email is the predominant means of communication among academic, strategic, and industrial partners, used to announce events and transmit the CenSSIS newsletter.*

The Internet and the CenSSIS website are used to keep partners and interested parties aware of the work being done and informed about the calendar of events. The Internet is also used to obtain data (registration and personnel information) and distribute it (forms and documents).

The FTP site is used to obtain and send large files between CenSSIS partners. WebEx is used for sharing documents in real time, distance learning, seminars, and video conferences.

CASE STUDY: *Beginning approximately a calendar quarter prior to the NSF Annual Report due date, CPES has a weekly conference call for administrators only, as a forum for discussion about data collection, documentation, and reporting.*

Tips:

- Explore and use appropriate tools and technology to facilitate administrative communication.
- The Administrative Director should participate in the meetings related to formulation and review of the Annual Report.
- The Administrative Director should become familiar with the NSF ERC library (part of the ERC website operated by NSF contractor QRC), enhancing access to and consideration of NSF-ERC outputs, including Annual Report guidelines and the ERC database.

9.3.1.4 Multi-institution ERC Activities Are Complex

ERC activities (Retreat, Site Visit, Center-wide conferences, Annual Report preparation, and IAB, SAB and GB meetings) occur during the academic year (September through May). The ERC's calendar should be created two to three months before the beginning of the academic year. It is important to schedule the ERC's activities so that (if possible) the ERC is not conducting more than one activity at a time. Further, it is important to avoid institutional event conflicts.

Creating a multi-institution ERC calendar can be a challenging process.

Tips:

- Establish calendar dates for events and deliverables as early as possible in the year and make the event timing as consistent as possible from year to year. Cementing mutually agreeable dates can be difficult to accomplish with multiple institutions and different academic calendars.
- Institute mechanisms and timelines to report data (via QRC, the NSF database contractor) and in print form) to NSF centrally by lead partner, but with input and supporting documentation from partner institutions. Personnel activities can be more difficult to track with multiple contributing institutions, particularly for students and more ancillary Center contributors.

CASE STUDY:To prepare for Annual Report data submission, CPES disseminates to all contributors a complete copy of the report and indicator table guidelines as soon as the final versions are received from NSF. This provides an electronic template and detailed instructions for data submission based on NSF expectations. Each partner university is asked to submit the required data PLUS back-up documentation for each item to a centrally-administered ftp site that is established specifically for this purpose. Contributors and advisors have access to the FTP site and can provide input or suggestions for refinement throughout the development of the report document. The back-up documentation is required for file record and to ensure that the data submitted has been thoroughly reviewed by the submitting institution for applicability and correctness. Approximately six weeks prior to the Annual Report deadline, the CPES Executive Committee meets to jointly review and discuss the data and text submissions, both as component parts and as a whole. In the six weeks following this review meeting, CPES centrally gleans each partner institution's data submission, checking for errors, duplication, or inconsistencies with current or previously gathered information. Communication with the partner institutions during this period is via any and all means available, frequent, and quite detailed to ensure accurate reporting of the activity, both during the reporting period and cumulatively. Finally, *the data are finalized in the indicators database and submissions are merged by CPES central into the final NSF-prescribed format.*

CASE STUDY: *At the VaNTH ERC, partner institutions begin working on data submission approximately four months prior to the Annual Report deadline. Templates and instructions for the tables required for the indicators database and the Annual Report are developed and provided to each partner institution at approximately two-week intervals. In particular, the instructions emphasize the reporting periods for financial and non-financial data. Individual deadlines are established for each of the tables and data for a particular table are analyzed and verified before the template for the next table is provided to the partner institution. As tables are completed, the Administrative Director atVanderbiltUniversity (the lead institution) accumulates the data in linked Excel spreadsheets for each of the VaNTH institutions into the combined table that is required for the indicated database.*

9.3.1.5 Multi-Institutional Education Programs, Diversity Programs, and Financial Systems

Education programs at a multi-institution ERC can be difficult to establish and operate. Institutions may be on semester or quarter calendars. Course set-up is similar to that at single-institution ERCs, but agreeing on course credits, registration process, course calendar, and course execution can be challenging. Agreeing on a lecture forum (real-time webcast, videotape, etc.) can be an issue, as can implementing the forum.
Establishing a diversity program can vary in difficulty across ERCs, depending on the maturity of the diversity programs at each institution and institutional support of the effort.

Developing a financial system for a multi-institution ERC is difficult. The various institutions and NSF all have different accounting, reporting, and calendar systems and treat overhead, fringe, capital, expense, and travel differently. Each institution typically provides different information in a different form from a different software program. The NSF calendar and reporting period often do not coincide with those of the institutions and may change during the life of the grant. In a multi-institution ERC, receiving relevant information on schedule is also problematic. Finally, inputting the financial information from the multiple institutions into the NSF annual reporting system is difficult.

9.3.2 Structure and Roles of the Administrative Staff

An administrator is required at each partner's location to expedite communication and coordinate Center activities. The administrative staff performs a variety of tasks to carry out the Center's business. The same tasks continue during the life of the Center, but the amount of effort needed in each area varies and the staffing level required to complete the tasks varies accordingly.

9.3.2.1 Functional Elements

A mature multi-institution ERC needs sufficient staff to carry out the following administrative tasks, programs, and activities:

- General Office Management and Administration
- Conference and Events Planning and Management
- Information Technology Planning, Development, and Management
- Database Planning, Development, and Management
- Accounting/Financial Planning, Development, and Management
- Program Grant/Contract Administrator
- Graphic Arts Support

9.3.2.2 Lead Institution Staffing

Normally this comprises at minimum two full-time administrators at the lead institution (and often more). Dedicated (at least part-time) administrative support and grant/contract personnel are necessary at the lead institution to administer the NSF contract and assist with the budget/accounting.

9.3.2.3 Administrative Staff at Partner Institutions

There should be an administrative staff member at each partner institution to expedite the necessary financial, personnel, and other data for the Annual Report; assist with event planning; and provide a central point of contact for ERC faculty, staff, and students. Without such administrative support, partner faculty will need to provide a wide range of data and services to support the ERC activities.

CASE STUDY:When the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) became an ERC in 2003, the University of Puerto Rico at Mayagüez (UPRM), a CASA core partner, established a central ERC office that supports not only CASA, but also UPRM's three other ERCs, CPES, CenSSIS, and the ERC for Structured Organic Composites at Rutgers. This enables highly beneficial teaming and sharing of knowledge and approaches.

9.3.2.4 Staffing for Center Life Cycle Stages

Start-up Stage: Minimal staff, analogous to a business venture start-up. Start staffing up and establish systems early, optimally before NSF ERC funding begins, so that the Center is positioned to get off to a good start and hit the ground running. This can help preclude complicated, time-consuming problems later.

Ramp-up Stage: Period of Center growth and specialization of administrative job functions. Particularly needs to be well staffed by the end of years one and two as the Center moves toward year three renewal, a major Center milestone.

Steady State: Begins at approximately year four, as work proceeds towards year six renewal through approximately year eight.

Ramp-down Stage: At about years eight through ten and beyond, preparation for self-sufficiency intensifies in anticipation of NSF's phase-down of support and graduation after year 10. Administrative support must meet the NSF deliverables contract. The needs at this stage tend to center on financial/accounting, personnel management, and information technology functions. Ideally, the Center begins to enter a new enterprise stage—e.g., a spin-off company, receipt of support from a new source—during which the administrative structure will need to be assessed and adapted.

9.3.3 Center-wide Systems, Procedures, and Operations

Established systems and procedures are needed to conduct the IAB meetings, major research symposia, Retreats, and the Annual Reports and Site Visits. Establishing a reasonable and achievable calendar is a first step.

The most time-consuming administrative event is the Annual Report. To effectively manage the Annual Report preparation process:

- Develop a database and data entry system for the personnel database.
- Develop a system for obtaining the accounting data from partner institutions.
- Develop a procedure for obtaining the project reports.

The Site Visit is the next most demanding administrative event, and arguably the most important. The renewal year visits, the third and sixth years, are crucial. The Site Visit and industry research symposium require a comparable level of administrative effort. These events require clear communication with Center partners (academic, strategic, and industrial) via effective communications media. Phone calls, teleconferences, email, websites, and ftp sites are the primary media. An important administrative function is to keep the media up and running and easy to use. Face-to-face meetings can also be important.

9.3.3.1 Annual Report Systems

The most important points and suggestions are as follows:

- Thoroughly review the current Annual Report Guidelines.
- Data collection for NSF reporting is complex and may require an individualized system at each Center. Developing a personnel database is difficult and costly. Review the Annual Report data collection system to understand the demographic and financial data requirements.
- Links to the most current versions of the Annual Reporting Guidelines and the Database Guidelines can be found on the ERC Library website at https://www.erc-reports.org/
- Detailed timelines for each part of the Annual Report, including individual project reports, proposals, and thrust reports, must be publicized well in advance. Timelines should contain deadlines for submitting initial and revised reports, and should provide adequate time for the review and selection of proposals to submit as part of the next annual funding request.
- Templates for both the project report and proposal are strongly suggested. In addition, the Center should develop a standard questionnaire for each project Principal Investigator to complete. Create a system to collect and assemble report materials by email, ftp site, snail mail, etc.

9.3.3.2 Site Visit Planning Logistics

The Site Visit usually is the one event of the year that the NSF attends. It occurs five weeks after the delivery of the Annual Report. The administrative priority is to ensure that the event runs seamlessly. The two events, Annual Report and Site Visit, form the peak of administrative activity in the year.

Arranging and preparing the written materials for the Site Visit is not difficult, because they are excerpted from the Annual Report. Every third year is a funding renewal year; hence, it is especially important for these meetings to run exceptionally well.

Practicing the Site Visit presentations with some reviewers external to the ERC is highly recommended. Commit several days to the review that can be used to strategize, practice, and edit presentations from the partners. Coming together at a single location and running through the presentations from beginning to end can be helpful, as can a Red Team (composed of the IAB and SAB) review of these presentations.

Careful attention must be given to communicating details about technical set-up (audiovisual, etc.) so that the presentations run smoothly. Make sure that presentation format requirements are well understood by all participants in advance.

Collecting presentations for printing the required Briefing Book means advanced coordination, since many participants are likely to be traveling on the day the materials are in production.

9.3.4 Maintaining Strong Relationships Among Partner Institutions

Developing and maintaining strong relationships within the multi-institution ERC is necessary to accomplish the groups' activities and goals. Communication among the partner institutions on a weekly basis maintains focus and helps to develop a multi-institutional culture.
A Center culture and orientation versus an institutional orientation must start at the Director and senior levels and permeate the organization, so that the administrative activities are carried out seamlessly throughout the consortium.

The Center needs to invest in occasional in-person opportunities for Center personnel to interact, such as Center-wide retreats and conferences, to help form relationships that will expedite day-to-day activities. This approach can be taken for smaller subsets of the ERC faculty and staff as well. For example, CPES holds quarterly campus meetings of its five Campus Directors.

The administrative staff carries out the Customer Service function for all of the partner institutions to accomplish the groups' activities. Dedicated customer service is particularly needed for a distributed Center where the partners are geographically distant and most Center business is done remotely.

Each ERC institution should have a "go-to" person who gets things done and provides administrative support. This person acts as a conduit for communicating and providing materials to the other ERC participants in the institution and to the other partner institutions.

Tips:

- Rotate the location of Center meetings among partner institutions.
- Include Administrative and Grants and Contracts personnel from partner institutions at occasional meetings to ensure that the administrative staff is acquainted with all ERC institution members.

<u>CASE STUDY:</u> CPES representation at Administrative Directors' Summer Retreats has included the AD from CPES's partner institution, Virginia Polytechnic Institute, and the Administrative Coordinator from partner institution Rensselaer Polytechnic Institute.

<u>CASE STUDY:</u> CenSSIS invited Grants and Contracts personnel to planning meetings from all partner institutions; joint Center Retreats have been held near partner institutions RPI and UPRM, as well as Woods Hole Oceanographic Institution. These Retreats include the Senior Management Group and its Board of Directors.

9.3.5 Financial Management

Creating a common financial calendar can be a multi-institutional administrative issue. It is important to recognize that there may be several different financial calendars among the partners. Institutions might be on a government, academic, or annual calendar.

Establishing the chart of Accounts and Budget Account Management Structure is critical to Center operations. It is critical that the lead institution and all of the partners understand the financial reporting requirements for the Annual Report at the outset. Each partner will have to account for funds on a project-by-project basis as well as accumulate costs to the appropriate research thrust or program as required. It may not be possible for the partner institutions to establish the same kind of accounting system as the lead institution, so the partners may need to consider an appropriate "shadow" system. This system should be reflected in the partner's invoices so that the lead can determine costs by task/thrust/program.

Cost-sharing and industrial memberships must be certified for the entire Center by the lead institution, which is the legally responsible entity for the ERC; partner institutions are considered to be subcontractors. While recognizing that partner institutions may not meet deadlines, the requirements and schedule for invoicing should still be tight; timeliness is paramount. Monthly invoicing using a standard invoice template that includes cost-sharing by task/thrust/program and line item is recommended, certified through signature of an authorized organizational representative. This serves the dual purpose of: (1) enabling monitoring and follow-up that cost-sharing expenditures are occurring throughout the year to meet cost-sharing commitments at each institution, and therefore as a Center; and (2) facilitating reconciliation of fiscal information for the Annual Report, thereby streamlining the required annual certification of cost-sharing by the lead institution.

There are subcontract management and invoice timing implications for the Annual Report tables. It is important that the lead institution understand the requirements for reporting expenditure data in the Annual Report. The lead institution, for example, has not actually expended any funds until it has paid a partner's invoice. Therefore, if subcontractors are tardy in submitting their invoices, expenditure data for the lead will lag and cause concerns at NSF. It is important that the subcontract include language requiring timely submission of invoices.

The lead institution should work closely with the office on campus responsible for writing and issuing the subcontracts to the partner institutions. The subcontract language will help clarify the requirements that each subcontractor must fulfill, and ensure that data and certifications are available for the Annual Report. The lead institution should decide, for example, whether the subcontracts will include detailed individual task orders for each project at the partner institution or whether the partner institution will receive a lump sum to allocate to individual projects.

9.4 RESEARCH PROGRAM MANAGEMENT

An Engineering Research Center's research program is at the core of its purpose and activities. Creating a strategic research plan is vital to the Center's success. The research plan is a central part of the ERC's overall strategic plan, which also includes education, diversity, and industrial interaction elements.

Equally as important as developing, revising, and monitoring the strategic research plan is establishing the infrastructure to select and review appropriate research projects. Integrating resources and facilities to build teams whose contributions are greater than the sum of their parts also is an important part of the research effort. The testbeds around which the ERC research thrusts are crystallized provide an important focus for research, education, industrial collaboration, and technology transfer.

Chapter 4 of the *ERC Best Practices Manual* addresses research program management for ERCs in general. This subsection of Chapter 9 focuses on research management for multi-institution ERCs.

9.4.1 The Strategic Research Plan: Development and Evolution

The plan starts with an understanding of the state-of-the-art of research in the academic disciplines that converge on the engineered systems that are the focus of the ERC. It is developed in recognition of the fact that the plan will evolve. The plan is built on established organizing principles (NSF's three-plane chart, various conventional flow charts) and several leadership levels (Center Director, an overall Research Leader, and Thrust Leaders). It is important for the academic participants to recognize the correlation between changes in the plan and its funding as well as the fact that program components may be completed or phased out.

9.4.1.1 State-of-the-Art Analysis

The first step in developing the strategic research plan is to assess the state-of-the-art in the field. This analysis should be updated continually and the Center's contributions documented, resulting in a comprehensive history of contributions in the field. The dynamic state-of-the-art analysis should cover national and international developments, and both disciplinary and interdisciplinary literature.

This initial analysis step is part of the Center's proposal development process and defines the potential contribution that a subsequent award might provide. Continuing analyses of the state-of-the-art and the impact of the ERC's work on the field must be formally coordinated and then documented through comparisons in the Annual Report submitted to NSF. Speculation about the state-of-the-art in the field and the ERC's role in its evolution is insufficient to support continued NSF funding. Sourced references and documentation are required to justify the expectation that the ERC is not operating in a vacuum toward insular goals that may have little or no application in the global environment. A multi-institution ERC may acquire information or documentation from multiple sources and perspectives, requiring joint discussions to reach a consensus about how the Center can be optimally integrated to achieve the maximum impact—and what impact it is having.

<u>CASE STUDY:</u> The Mid-America Earthquake (MAE) Center, which is focused on earthquake risk only, reviews all literature in the risk arena in which tools and data may be available that apply directly to earthquake risk. Developments all over the world are reviewed continuously, even though the exposed societal systems might be different than those in the US.

9.4.1.2 Nature of the Research Plan

The ERC strategic research plan is focused on both addressing fundamental, technical, and system-level barriers that must be overcome to advance the field—as defined by the current state-of-the-art assessment—and serving as a potential catalyst in the development of a new field and/or industry

CASE STUDY: The state-of-the-art in power electronic systems at the inception of Virginia Tech's Center for Power Electronic Systems (CPES) was delimited by numerous disjunctions among the many components that comprise such a system. The CPES strategic plan laid out a roadmap that would provide the Center with the capabilities to become a world leader in power electronics through a multidisciplinary, multi-university, and multi-industrial partnership program extending over a ten-year period. The program was based on an integrated systems approach to standardize power electronics components and packaging techniques in the form of highly Integrated Power Electronics Modules (IPEM). The IPEM approach makes possible increased levels of integration in the components that encompass a power electronic system– devices, circuits, controls, sensors, and actuators. It was a new approach that took power electronics to a new level of performance.

The level of definition of the plan will vary, depending on the field and the specific Center circumstances. For example, "The primary research goals of the Center are as follows . . ." and "The baseline for progress assessment is or will be established by . . .", followed by enough detailed information to clarify the specific areas of the field to be addressed as well as the approach for achieving success in those areas utilizing the proposed Center configuration, with special attention to the advantages gained through partnering with other institutions/disciplines and industry partners. The relationship between the primary goals and the partner institutions should be articulated and future expansion and refocusing should be discussed with regard to possible changes in the makeup of the ERC where new alliances might be sought to optimize the talents needed to achieve the research goals.

9.4.1.3 Plan Organization

Deliverables take many forms and should be identified and scheduled in the research strategy development.

A PERT chart, Gantt flow chart, or equivalent schedule of planned milestones with an anticipated target date for completion can be used to summarize the plan and its deliverables. Including details for reaching the charted milestones in the strategic document is considered optional. Anticipated barriers should be identified, specifically to facilitate incremental progress, assessment and documentation. NSF has developed a "three-plane chart" that is a useful tool for organizing and visualizing the interconnections between the fundamental research, technology demonstration, and technology/system integration levels of an ERC's work. This chart can be customized to reflect the strategic research plan in detail. It is important to have the chosen organizational tool detailed at the Project, Thrust, and Center levels with clear relationships among the three levels, both top-down and bottom-up. All ERC researchers should be committed to the deliverables and have a full appreciation of where they fit within the grand plan. The effort has to be balanced among the three planes.

9.4.1.4 Research Leader

Many multi-institution Centers find that designating a single research leader whose purview spans all the research thrusts is integral to the research plan's successful realization and evolution. This optional (but recommended) position can have a variety of titles, for example, Associate Director for Research, Deputy Director, Technical Program Director, or Chief Scientist.

The administrative burden on a single-institution ERC Director is quite heavy and increases exponentially in a multi-institution ERC. Although the Center Director might be tempted to control the research program personally, it is advisable to assign another individual to the task. There are many reasons to do so, not the least of which is preservation of the Director's sanity. These include the Director's need to maintain a macroscopic view, while the research leader is immersed in the program details; the need for a single individual who is well-versed in the program to interact directly with the Thrust Leaders and facilitate research integration at a hands-on level; and the need to continually assess progress and failure, to coordinate reporting out, and to coordinate revisions to the plans in a thorough and progressive manner. Additionally, this individual may provide a higher degree of accessibility and linkage to partner university programs and Thrust Leaders, thus expediting forward progress.

9.4.1.5 Thrust Leaders

Thrust Leaders lead in planning and executing a thrust-level strategic research plan. They can provide the critical perspective that might reveal the gaps or barriers in the plan as well as its potential outcomes or shortcomings. Often Thrust Leaders can also offer preemptive solutions to perceived barriers, thus facilitating planning and implementation strategies. Thrust Leaders serve as the third level of research management, below the Research Director and the Center Director. Their role is critical in translating between researchers and research management to achieve the ERC's deliverables.

9.4.1.6 Annual Plan Review

Visit (and revisit) the strategic research plan and roadmap annually through a group effort involving all key faculty members, Thrust Leaders, the Research Leader, selected stakeholders, advisory boards, and all partner institutions.

CASE STUDY: *At CPES, the Annual Review begins with an annual faculty Retreat. The Retreat agenda includes a review of the Center's vision, goals, technical roadmaps, barriers/challenges, expected outcomes, and a progress assessment. Retreat conclusions are subsequently presented for discussion and/or action through routine meetings of the various advisory boards.*

9.4.1.7 Changes Affect Funding

Project and thrust area funding may be directly affected by changes in the strategic research plan. It is important that all partner institutions be aware of potentially adverse effects on their anticipated future funding levels for research and be prepared to adjust their efforts accordingly.

The documentation resulting from the process of submitting a joint proposal may create expectations for funding in accordance with the original research plan. Since changes in the original research plan are a natural and expected outcome related to the nature of basic research, it is incumbent upon partner institution leaders to ensure that the administrative units within their individual institutions are aware that the dollars included in the originally proposed research plan are not to be interpreted as an entitlement to a specific dollar award in future years and that the actual institutional award will vary commensurate with the research plan's evolution. Setting this expectation requires effective communication as well as changes in the traditional culture of post-award administration. Such administration is institutionally specific because it aligns with the ways that the data included in the original proposal are used within the institution (e.g., reporting of research dollars for an individual faculty member, department, college, or for the university at large; faculty activity and tenure review; and dollars committed in cost sharing or matching support). It is also important that all Center members share responsibility for pursuing alternative funding options for any discontinued projects that have fundamental intellectual merit and/or value in the field, but are outside the scope of the strategic plan. The ERC, mainly through its Director, should spare no effort in stressing to institutional representatives that it is in the interest of all concerned that no culture of entitlement is allowed to develop, even for an institution seen as critical to a successful proposal. Only merit reviews are the basis for continuing funding, and only projects with clear deliverables germane to the Center's should receive funding.

9.4.1.8 Phasing-Out Mechanism

It is advisable to include a phasing-out mechanism as part of an evolving research plan. This will help ensure that the impact on both students and related research projects that results from discontinuing a project or a thrust area is minimized. Phasing out a research area is more complicated in a multi-university Center and requires thorough advance coordination with Campus Directors at partner institutions.

9.4.1.9 Serendipitous Discoveries

As research program assessment occurs, it is likely that some discovery merits further examination and yet does not fall under the strategic plan, even as the strategic plan evolves to encompass changes pertinent to the core research undertaking. In an integrated multi-university environment, the decision to discontinue a particular project or thrust is generally achieved through consensus. Some alternative paths for continuing or using the discovery may be identified in advance so that expectations are limited to realistic possibilities and group harmony is not threatened by the natural evolution of basic research. For example, there may be "seed" or "bridging" funds set aside as part of the industry consortium to temporarily continue research, or the Center may submit a proposal to industry or a government funding agency seeking support for supplemental study in a particular area. Projects that are of a highly fundamental nature should be good candidates for NSF support while those that are of a high application value should be attractive to industrial partners. If such a project falls in neither category, and is not integral to the Center's strategic plan, it is clear that it should not be continued under the aegis of the ERC.

9.4.2 Project Selection and Review

Creating a program, thrusts within a program, and projects within thrusts is fundamental to the research effort. As the program progresses, new barriers and challenges appear, changing the scope and resource allocation. The Center Director is central to the continuous refinement or redefinition of the research program and to determining project approval and funding allocation.

9.4.2.1 Process

As the research program progresses, changes in scope, resource reallocation, and expertise shift will occur. A general process for project selection and review should be established and included in the Center's policies and procedures manual for reference.

The plan and scope of the research are fluid for much of the life of a successful multi-institution ERC, requiring regular review and interactive discussion among various groups of participant institutions. The review process should be balanced to include various Center stakeholders and adequate time for information gathering. Implementing checks and balances to preserve the integrity of the process and minimize stakeholder bias is necessary, yet the process must be simple enough to be practical in terms of time, implementation, and procedural requirements. As the ERC reaches maturity and approaches graduation, less fluidity will be required; hence even the review process itself is not set in stone and should be adapted to the phases an ERC goes through during its life cycle. It is essential that at all stages institutional representatives should act and advise in a Center mode with no bias and no parochialism. Within the established review procedure, the Director's role as the ultimate arbiter is crucial, and therefore her objectivity and judgment should be beyond reproach.

9.4.2.2 Research Program Refinement or Redefinition

The Center Director is crucial to continuous refinement or redefinition of the research program's scope in consultation with research thrust leaders and the Scientific and Industrial Advisory Boards (SAB and IAB). It works best if the selection process is neither entirely bottom-up nor top-down but is highly consultative, with the Center Director as the ultimate decision maker.

Technical leadership and researchers among all partner universities first prioritize research needs and review available program resources in consultation with the IAB and thrust leaders. Although advisory groups provide input to the selection process, Center Directors must be careful to moderate the advisory roles so that special interests do not dictate the Center's research plan to the point that core research becomes fragmented or loses its systems focus. Pressure to support projects that are needed by industry or purported to be needed by industry, within the Center's core research program, should be resisted. Core research is generic in nature and applicable to a wide range of stakeholders, and should not be in service to narrow stakeholder interests. The outcomes of all group discussions regarding research directions should be communicated to the Director in a concise form. The Director may selectively use or disseminate the information in accordance with ongoing consultation with advisory boards or research leaders. In the case of a substantial change in scope, the Center's Governing Board or Leadership Team (if one exists and is different from the IAB) should be involved, offering assistance in composing a revised plan. Failure to keep the Governing Board involved in these processes may result in a lack of commitment from partner institutions, a result that carries a substantial threat to the potential 10-year life of a successful multi-institution Center.

9.4.2.3 Revised Thrust-Level Program

The Center Director approves a revised thrust-level research program plan developed by the Research Director and the Thrust Leaders. This plan includes consideration of related Center objectives (such as education, industrial collaboration, and inter-institutional interactions).

The Center Director can use the input received from the thrust leaders and advisory boards to formulate a proposed preliminary plan and allocation of funds by thrust/program area. This proposal should include consideration for promoting interdisciplinary and intra-institutional collaboration. The Director's thrust/program allocation proposal may then be submitted to the Center Executive Committee, Governing Board, or Leadership Team for evaluation and recommendation. The Center Director is ultimately responsible for defining the research priorities.

9.4.2.4 Project Proposals

Once the scope is defined for an annual funding period, a request for project proposals may be issued, setting forth timetables and deliverables schedules. Potential awardees may then submit project proposals to the respective thrust/program leaders. The thrust leaders may then enlist assistance from industry champions from the IAB in the review, prioritization, and recommendations for project funding, using the approved research plan and preliminary allocation proposal as a basis for discussions. (This is one common procedure. Other mechanisms may be followed.)

9.4.2.5 Project Approval

The Center Director makes the final determination regarding project approval and distribution of resources. In the procedure described above, the Director considers the recommendations of the thrust/program leaders and renders a recommended allocation for incorporation in the final funding allocations. Individual partner institutions may receive more or less than the initial proposal plan sets forth, depending on annual review of assessed progress, future needs, available funds, and the state-of-the-art in the field. Indeed, termination of all projects at a partner institution, if done for clear and identifiable reasons, is legitimate; this allows for new alliances to be established that serve the evolving Center mission. The Director may tap into any or all of the resources available to him/her to facilitate funding decisions.

Partner institutions should be reminded regularly that evolution of the research plan and assessed progress on core initiatives as part of that plan determine continued funding through the Center, which therefore may or may not correspond to the initial multi-year proposal plan. An inwardly focused approach to research challenges and related allocation of resources can threaten an otherwise productive intellectual collaboration. Acknowledgment of this fundamental axiom is necessary to maintain cohesiveness in a multi-institution Center.

9.4.2.6 Continuing Funding

Continued funding for each project is reviewed each year, based on the prior year's progress and the merit of the proposal for the next year.

The Director's top priority in funding decisions is the overall Center health and progress toward long-term goals. Individual institutions are assured of financial support only to the degree that it will be commensurate with the contribution of its Center participants to the overall success of the core program. All communications, calls for proposals, and effort evaluations should reinforce this approach so that administrations for individual partner institutions do not lose sight of the competitive approach to the dissemination of core funds and the continuing need for innovative thinking and approaches to the research.

9.4.3 Research Team Integration

To obtain the benefits derived from an ERC, it is important to integrate the research throughout the organization and achieve collaboration. The collective capabilities and facilities of the Center are more powerful than the individual partners but there must be an organizing principle to achieve the greater capability. A framework to guide the research, points of contact for each activity, good communication within the collaboration, measurable and deliverable objectives, and a certain flexibility to accommodate differences in style are required.

9.4.3.1 Research Integration

Identifying a specific need/purpose for research integration is essential.

Simply obtaining agreement that collaboration is a good idea is not sufficient to bring collaborators from multiple institutions and industries together to actually accomplish the integration of technology. A specific technological advantage to be gained through multi-institutional involvement must be identified in advance of establishing a multi-institution Center. The same principle applies to a renewed Center, where new alliances replace existing ones in the service of the evolving systems vision. Specific methods for achieving integration should be written, along with role assignment for each of the participating institutions. Projects and their integration should be viewed as Center-wide activities, not as institutional activities.

9.4.3.2 Research Program Structure

Structuring a research program that is interdisciplinary in nature and focused on one or more engineered systems is an effective way to promote ERC culture and is necessary to achieve its goals.

As a matter of course, research faculty focus on their chosen discipline. But the expansion of knowledge in ERC systems-based fields requires reaching beyond the chosen discipline, seeking potentials to link and discover beyond known and established boundaries. Connections are made through communication, and initiation is the key. All ERC participants share responsibility for initiating and cultivating interdisciplinary partnerships. A suggested approach is to engage related disciplines in the proposed ERC undertaking early, possibly through a symposium or information gathering that provides an opportunity for other disciplines to be briefed at a summary level and to offer feedback related to the potential for interaction with the ERC plan.

9.4.3.3 Research Capabilities and Facilities

Institutional partner capabilities and facilities pertinent to achievement of the vision, mission, and goals of the Center must be clearly identified and recognized.

As individuals come together to form a Center, participating faculty usually have or gain a general knowledge of the capabilities and facilities of each of the individuals involved. It is important to expand that knowledge to include the specific facilities and capabilities available to the Center and to include potentially related areas as well, as the idea is to broaden the involvement of disciplines, individuals, and technologies in order to explore new paradigms, thus achieving what could not have been achieved without the Center. Education is closely related to research; hence the research plan also provides the basis for the Center's education plan from which uniquely trained individuals emerge.

9.4.3.4 Framework to Guide the Research Process

Roadmaps, testbeds, and benchmarking are essential management tools for integrating faculty research and assessing progress.

Routine communication can be bogged down in individual preferences for certain research aspects, constraining productive use of time and minimizing overall progress. It is advisable to establish a framework to guide the process and assess progress toward meeting Center goals. One of the most effective means of integrating research and determining the criticality of individual projects is capstone projects or testbed applications. Testbeds should be end-to-end applications that bring together many or even all of the tools and knowledge, not *in* a thrust but *across* the thrusts. Planning for testbed applications exposes projects that are not germane to the Center mission.

9.4.3.5 Point of Contact

A central contact should be established for each area of activity.

Communication with the individual best suited to respond is as important as communicating regularly and effectively. Individuals responsible for specific roles and or target areas should be identified and contact information centrally distributed so that communications are direct and channeled appropriately. This is part of the complete management plan of the Center, which should be agreed upon and available to all involved. No activity should be left without a responsible contact individual.

9.4.3.6 Communication is Essential

Frequent and direct group communication is essential to success.

Because there is a growing emphasis on outreach in all Centers, this demands an increased awareness of the need for continuous and effective communication. Communication provides the basis for all actions, interactions, and decision-making in the Center environment. A suggested approach is to establish (as a minimum) a schedule for regular interaction/collaboration of each thrust group, project group, the industry board, the Executive Committee, and each of the advisory boards. Additionally, each partner institution should establish a regular on-site meeting devoted solely to ERC business. This is desirable because Center activities are often a subset of the activities of individual participants. A scheduled meeting forces focus on the activities specifically related to the ERC. Many other opportunities will evolve with the needs of the Center and should be encouraged by senior management. In addition to project, thrust and board integration, it is essential that cross-cutting interactions are instituted in the ERC, whereby 'horizontal groups' cutting across the thrusts meet face-to-face or virtually, and focus on threads that link across thrusts toward Center objectives.

9.4.3.7 Program Measurables: Statement of Work and Period of Performance

Specific task assignments such as Statements of Work (SOWs) and Periods of Performance (POPs) should be established.

Regular monitoring, reporting, and sharing of project progress is especially important in a multi-institution Center due to the geographic dispersion of the participants and the consequently limited ability to observe progress directly. The annual call for proposals, where used, will be most effective in an atmosphere where effort assignments and SOWs for the review period are clearly defined, disseminated, and reinforced through discussion. All projects should have project sheets that articulate milestones and deliverables that are further linked and integrated at the thrust and system levels. Annual coordination of meetings and meetings prior to or after site visits are ideal forums for assessing progress and re-charting the Center's path.

9.4.3.8 Opportunities for New Faculty

Opportunities for new/junior faculty should be apparent.

The expanded opportunity inherent in on-site Center management support is often diluted by the geographic dispersion of the partners and the Center profile may differ among partner institutions. Extra effort may be necessary to ensure that a new/junior faculty member is fully aware of the research underway and the ways in which he may become involved. It is important to train at all levels, including junior faculty, so that the Center will have a lasting influence on the research culture, away from unsolicited proposals and towards the Center's ethos.

9.4.3.9 Industry Research Champions

Engage industry partners to serve as research champions and testbed partners as well as mentors and technology transfer participants.

Collaboration with industry should and will occur in many different ways, especially in the multi-institution environment. It is essential to engage industry in such a way that the flow of ideas, information, and results is continuous and timely. One way to be sure that the Center is receiving and responding to industry interests is to engage industry members as research champions. A research champion serves as a mentor in a particular aspect of development and works closely with Center Thrust Leaders to ensure industry relevance and facilitate direct knowledge transfer. Industrial participants also greatly enhance the educational experience by serving as mentors to young faculty and students; the guidance they provide encompasses research, career choices, and industrial interaction. This model has been very effective at many Centers, enhancing the level, continuity, and quality of industry involvement.

9.4.3.10 Failures Can Occur—Know When to Cut Losses

There is no failsafe mechanism to ensure that all actions, decisions, plans, and policy implementations will result in a model, integrated, multi-institution, productive research undertaking. Incremental failures will almost certainly occur. A plan for acknowledging failure and moving forward in spite of it, while addressing the shortcoming, should be in place. The Center Director and its leadership should not shy away from taking bold decisions.

9.4.4 Role of Testbeds

The boundaries of the knowledge fields addressed by ERCs are virtually unknown. Testbeds provide a means of demonstrating potential and inspiring intellectual exploration beyond the knowledge proven through demonstration.

As the product of the Center's collaboration, testbeds provide a basis for the assessment of research outcomes, a means for integration of research, and a way to demonstrate systems' impact. They are the focal point for collaboration and guide the investigations by offering greater understanding of the issues. They drive modifications to the strategic plan and are the basis for knowledge transfer.

9.4.4.1 Focus for Integration

Testbeds provide a focal point for researchers to rally around and pursue common goals.

A testbed provides a conceptual framework and a tangible way to demonstrate the integration feasibility of a particular tool set. It can be a catalyst for excitement among researchers as well as provide a shared vision for continuing exploration. It also yields results of interest to those supporting the Center; so it is useful—not just a showcase.

CASE STUDY: At the MAECenter, testbeds apply the various tools to a system (transportation networks), a region (city or state) or an organization (national or state emergency management agency). They integrate all products of the projects and thrusts to provide a scenario of the possible consequences of an earthquake on the testbed system, region, or organization.

9.4.4.2 Improved Understanding

Testbeds provide a basis for better understanding of system requirements and barriers.

The visual realization provided by a testbed demonstration may serve as a teaching device for researchers not previously immersed in the concept demonstrated. Concept edification through proof is an effective and powerful tool. In a multi-institution, multi-disciplinary, multi-sponsor environment, demonstration can be the difference between discovery and incremental advances.

9.4.4.3 Driver for Continuing Research

The "proof of concept" achieved through testbeds nearly always serves as a driver for continuing research. The exploration of true knowledge synergy or the compatibility of traditionally separate application areas is enhanced through testbed applications in the context of multidisciplinary cooperation.

The revelations resulting from testbed demonstrations have the potential to turn a skeptic into an advocate or, conversely, terminate exploration along a less-than-promising course. In either case, knowledge is gained and further exploration is seeded. Integration of subsystems, disciplines, and concepts tends to have a unifying effect on the individual researchers involved, spurring broader contemplation and intellectual discussions.

<u>CASE STUDY:</u> Currently, there is relatively limited understanding of the dynamic behavior of power electronics systems or of how the systems may be modeled and controlled. Testbed demonstration of the fundamental nature of system-level issues at CPES is expected to open new opportunities for expanded use of advanced electronic power distribution systems.

9.4.4.4 Driver of Modifications to Research Plan

Ultimately, testbeds may drive modifications to the strategic research plan based on the learning achieved through systems analysis and test results.

One of the bonuses of unplanned discovery is the alternative path(s) presented to the researcher. In the case of a multi-institutional, multidisciplinary Center, the intellectual consideration spurred by an unplanned discovery is often exponentially increased. This may lead to a stronger strategic plan or a modification to the original plan that strengthens the original concept. Many centers set aside "seed" funds to nurture such discoveries.

9.4.4.5 Industry Knowledge Transfer

Testbeds provide a strong basis for the continuing exchanges and knowledge transfers with industry. Through this vehicle, Center research remains pertinent to industry and provides a platform for it to create products or develop technologies.

Historically, testbed demonstrations are well-received by industry; industry representatives typically provide useful feedback stemming from testbed demonstrations. The Center can use this feedback to enhance research and produce additional useful results for industry application. This sharing also complements the dissemination of information that is the common mission for universities and ERC.

9.5 EDUCATION PROGRAM MANAGEMENT

Multi-institution Engineering Research Centers face special challenges in organizing, planning, and administering their education programs. Despite the added complexity, however, a multi-institution Center offers many unique benefits, including opportunities for students to take a wider variety of courses or work on research in more than one university. These students can be exposed to a broader spectrum of research.

9.5.1 Challenges

A fundamental challenge that ERC Education Directors need to address at the outset of the Center is determining the best organizational structure for implementing the multi-campus education program. Early on, the Center management team holds strategic planning sessions to determine the mission and goals for their education program. They then develop a plan, staffing, schedule, and budget to accomplish these goals. Issues to be addressed include:

- What resources (faculty, staff, and infrastructure) are available on different campuses?
- How can multi-campus education committees best be formed?
- Who should be on the committees?
- Will administrative staff be available on each campus?
- Will management of the education program be centralized or distributed?
- Will inter-institutional agreements be necessary?

As a multi-campus Center begins offering education and outreach programs, such as a Research Experience for Undergraduates (REU), Research Experience for Teachers

(RET), outreach programs for precollege teachers and students, Student Leadership Councils (SLC), student exchanges and seminars, the best ways to administer these programs will need to be determined. Questions such as these must be addressed:

- Which campuses will participate?
- Who will coordinate each of these efforts?
- What resources are available?
- How will recruiting for the outreach programs be coordinated?
- Which principal investigators will host students and teachers?
- Where will seminars be held?
- How will communication between participants on the different campuses be facilitated?
- How can video, teleconferences, and the web be best used to promote communication?

As the multi-campus Center develops new courses, course materials, certificates, and degree programs, ways for students on all Center campuses to take advantage of these offerings will need to be arranged. Inter-institutional agreements on credits and fees may require authorization. Mechanisms to offer distance and web courses as well as jointly taught courses may need to be developed.

Similarly, offering multi-institutional continuing education short courses to industry presents challenges. Short courses may be offered either for degree credit or continuing education units (CEU). Mechanisms for receiving credit at different schools and sharing revenues need to be worked out. With Industrial Advisory Board (IAB) input, course topics and instructors will need to be established, as well as mechanisms for delivery (short course, web, or distance course). Finally, the sponsoring university(s) needs to be ascertained. Alternatively, a Center can offer a non-credit short course without any sponsoring university. Subcontracts may be needed to pay speakers, and mechanisms for sharing advertising and administrative costs will need to be determined.

For the secondary-school level and community outreach, strategies for instituting partnerships with schools and organizations in the different communities need to be developed. For example, Center staff can partner with other outreach programs at their university; professional organizations offering precollege outreach, or member-company outreach efforts in various communities. Decisions will need to be made about which campuses can best initiate outreach programs, administer funds, coordinate activities, and provide oversight. For recruiting purposes, partnerships with various minority-serving institutions in different locations can help the Center achieve diversity goals. Here again, decisions about which Center universities, and who at each university, will initiate these partnerships will need to be made.

The following sections will discuss in more detail the challenges and opportunities for multi-institution Centers in:

- organizational structure and strategic planning (5.2)
- developing new curriculum, degrees, and certificates (5.3)
- managing special programs for students (5.4)
- outreach to industry (5.5)
- facilitating collaborations and partnerships with schools and community organizations (5.6).

Each section will also summarize some of the lessons learned in developing multi-institution ERC education programs and illustrate the best practices using case studies.

9.5.2 Organizational Structures and Strategic Planning: Education Director's Role

9.5.2.1 Central vs. Distributed Management

It is important to build a network of communication and an atmosphere of cooperation among participating faculty and universities to address the Center's research and education missions. A common understanding of respective academic procedures must be built so that obstacles to carrying out specific Center-based educational activities can be minimized. This is particularly true for curriculum development activities, which may require departmental approval for a program created by non-host institution faculty. These issues can arise even within a university, if a Center wishes to implement cross-disciplinary courses or modules involving other than engineering disciplines. Regardless of these barriers, inter-institutional, cross-disciplinary knowledge and technology transfer remain a significant element of the National Science Foundation's mission for the ERC program. It is important for Education Directors to involve their Center Directors in exploring avenues to successfully address these issues.

Finding an ideal approach to surmount administrative obstacles can be very time-consuming and may result in an undesirable lag in transferring timely and valuable knowledge derived from research endeavors to students and other potential end-users. If such delays appear likely, it may be that this knowledge can be more effectively communicated by integrating it into existing credit-bearing courses, with CEUs or independent study programs as alternative solutions. It is important to maintain a robust interface between research, education, and the end-user community.

The Education Director may well serve the Center's interests by working with each institution to learn about the structure of course administration, so as to better understand which issues might keep ERC education exchanges between universities from becoming a reality. As educational products are developed, these constraints and ways to address them may be kept at the forefront of consideration.

Remote learning opportunities also have burgeoned in the past decade, making access increasingly easy, affordable, and convenient, and bypassing some of the usual institutional constraints. At the same time, these efforts require oversight and maintenance and must address necessary education standards (whether academic or professional), if credits of any kind are to be awarded. Furthermore, credits earned through online learning programs are not always given equal weight within the discipline or profession.

Overall, it is necessary for the Center Director and Education Director to establish leading guidance and give encouragement to program advocates at each participating university. Without this advocacy and support, extra-institutional commitment to Center-wide programs is not likely to occur and outcomes are less likely to be realized. A Center-based Education Director (with support of the Center Director) can be an important catalyst by establishing proposed activities, budget limits, desired outcomes, and standards, which can be endorsed and promoted to the other institutional participants. The Center Director can provide further incentive by emphasizing to faculty the relative weight of education within the overall Center program. Willingness to advance the education objectives of the Center will then be viewed as having a bearing on funding decisions regarding individual investigators.

On an administrative level, it can be very difficult to extend financial support to other institutions in a timely way, including student stipends, travel funds, etc. This can be an impediment to accomplishing desired tasks, and is an area where Centers can learn and benefit from each others' experiences to improve the funds-exchange mechanisms. For multi-institution Centers, relinquishing funds to other institutions may mean losing control over use of those funds, selection of activities, recruitment of students, etc. In spite of bureaucratic headaches associated with Center management of distributed education funds, it does allow the Center to remain true to its objectives and standards. Center representation at major education functions should involve all participating institutions, yet should always reflect the central vision and leadership.

9.5.2.2 Negotiating Inter-institutional Agreements

Formalized agreements allow Centers to predetermine desired educational goals and outcomes. It may be very difficult for institutions to agree to exchange curricular products as a requirement of their subcontracting agreement. Institutional agreements may instead take the form of something less legally binding, while still demonstrating a mutual agreement between institutions to work toward a common education agenda. A memorandum of understanding may help to achieve this, with clearly stated goals, desired outcomes, and timetable for execution

9.5.2.3 Forming and Using Multi-campus Committees

Some Centers have established multi-institutional committees to direct and achieve their education goals. Often, teaching, research, departmental obligations, and other functions interfere with the faculty participants' dedication to the multi-campus committee activities. It is often necessary for involved faculty to seek released time or other benefits from their institution to devote sufficient time to education committee activities. This will bring an added benefit to the Center, however, as a demonstration of cost sharing.

It is also extremely important for the faculty members to be able to devote their efforts on behalf of the Center, over and above their own individual professional efforts. There must be an exhibited level of commitment to the education vision and mission for this participation to be of optimum value to the Center's education program. In addition, for multi-campus committees, there must be regular interaction (monthly, at minimum) to assure continuity of communication. This is essential to sustain momentum of the activities planned, particularly in view of the continual turnover of participating students and changing demands on faculty. The latter is particularly true for tenure-track faculty.

Rotation of committee members helps infuse enthusiasm. Retaining some long-term members helps to assure that momentum is maintained. The ability of committee members to rely on administrative support and assistance from Center headquarters is also helpful.

If these difficulties can be overcome, a multi-institutional education committee can truly enrich the education experience for those involved. Institutional support and faculty commitment are necessary ingredients in the success of this framework.

9.5.2.4 Setting Program Goals and Objectives

Center program goals are based on the leadership team's determination of its vision and mission, its anticipated outcomes, and the resources (both human and financial) at its disposal. Both goals and objectives need to be shared with all faculty and NSF Program Officers, iterating the process until general consensus is reached on future activities.

9.5.2.5 Allocating Resources

The Center must have clearly defined education activities, objectives, and outcomes when allocating resources. For a multi-institutional activity, the Center must give extensive consideration to fiscal regulations and procedures at its institutions. Unexpected indirect cost recovery, misallocation of costs incurred, and other fees associated with administrative management or education program conduct (e.g., charges for facilities for video/tele/communication activities) can place an unexpected drain on Center funds. A yearly plan that outlines desired activities, costed out at participating institutions, can help to anticipate financial difficulties. While there will always be unanticipated costs, it is incumbent on education leadership to develop an understanding of probable costs and operational issues that may impact the conduct of the program.

Funding of students for special activities such as conferences and study tours is best decided based on a predetermined level of academic standards and expectations. The Center should try to encourage participating institutions to have input into setting benchmarks for spending on various activities, with ultimate decisions to be made by the Center Director and the Education Director.

9.5.2.6 Identify Center Activities

Center-sponsored courses and outreach activities all need to be clearly marked with the Center logo and attributed to the Center, as well as to each of the participating universities. Any press releases issued should also clearly identify the activities as Center sponsored.

<u>CASE STUDY:</u> Multi-institutional Education Committees. The education program at the Pacific Earthquake Engineering Research (PEER) Center is designed to introduce, stimulate, cultivate, and educate undergraduate and graduate students with the knowledge that will enable them to contribute to the earthquake engineering profession from a variety of disciplines and perspectives. PEER's Education Committee, comprised of representatives from all 18 core and affiliated universities, is charged with the planning and implementation of the Education Program.

9.5.3 Developing New Course Curricula and Degrees

Development of new curricula, degree, and certificate programs may be a key output for an ERC, and one of the means by which a Center creates a legacy. Examining core research area curricula, during the proposal and early award, will establish baseline information for the Center's operations and identify strategic planning issues that may be important to intercampus collaboration. This section provides ideas and recommendations for developing new courses; for creating new programs out of these new courses; and for implementing, tracking, and disseminating information relative to this component of the Center's work. Subsections include specific examples pertaining to distance learning, web courses, team teaching, and inter-institution agreements relating to these.

New course development in a Center is a single variable within the larger context of curriculum development, course revision, new course module development, and new program development. Innovations and modifications within individual curricula also provide Centers with a means of addressing their goals within the ERC, such as: promoting visibility of key disciplines within undergraduate and secondary school communities; providing critical resources for industry; and building interdisciplinary bridges within a department and college structures of a university. In addition, multi-campus Centers are organized in order to bring together institutions with diverse strengths, often pairing programs with long histories of contributions to core disciplines and technologies with emerging programs. Consequently, the very organizational structure of the ERC may dictate that the approach to curricular issues be considered at both a campus level and a Center level. Therefore, early consideration of the following key questions should prove useful in the strategic planning phase of education program development.

1. *Creating a common frame of reference for existing courses:*

   - Which courses at each institution form the support structure for the core and associated research areas? Create a reference document with appropriate supporting material that aggregates this information for all partner campuses.
   - Among these courses, which ones are suitable for intercampus cross-listing for student exchange and distance learning purposes?
   - Among these courses, which are currently in distance format? This information should be publicly accessible to students and industry. Course descriptions, registration, deadlines, and contact information should be posted on the Center's web site and updated regularly.

2. *Planning curriculum development:*

   - Based on the Center's research goals and areas of expertise, which courses should receive the highest priority for conversion to distance format? Based on the evolution of the Center's research program over time, research advances in the field, and emerging areas of expertise, this question should be revisited throughout the ERC award period and the strategic plan modified as appropriate.

- What new courses should result from the Center's core research mission and areas of expertise?
- Which existing courses should be modified to include the ERC's latest research results?
- Will the creation of new textbooks (or chapters for existing textbooks) be a priority for the education program development effort? To what extent will this reflect the multi-institutional nature of the research effort?
- Will curricular development extend to the precollege level? If so, have appropriate relationships been established with precollege teachers and other STEM (science, technology, engineering, and mathematics) educators and experts? Will test beds or pilot programs be developed as part of this effort?

3. *Developing new courses within the framework of ERC goals:*

- How does new course development reflect the interdisciplinary nature of the ERC's research?
- How are courses distributed across undergraduate and graduate levels, both within individual institutions and within the Center as a whole? How will new course development support both the need to involve more undergraduates in the Center's core research area and the needs of graduate students who will be working in emerging, interdisciplinary, or nontraditional research areas?
- Will new course modules be developed in support of the ERC's student recruitment and information dissemination priorities? If so, who is the target audience, which concepts are key for presentation, and at what academic levels should they be presented? Which campuses are best suited to undertake the development work? How will this information be disseminated?
- What resources will be needed to support new course development and implementation? What resources will be allocated through the Center's core award for these efforts? How will funding decisions be made? What external sources can be sought for support of these initiatives? To what extent do new courses depend on new facilities/infrastructure within the Center?
- How will the needs of the Center's industrial collaboration program be served through course development? How will needs in this area be determined and addressed?
- How can the collaborative nature of the ERC's research program, as well as the expertise of key faculty and thrust leaders, be cultivated through its education program? Will courses team taught by faculty across partner campuses be a goal?

4. *Addressing the needs of each core partner institution:*

- Do any of the Center's core partner institutions lack key courses that are needed for them to become fully engaged in the research effort? If so, how will this be addressed?
- When reviewing the Center's core curricula from an intercampus perspective, are any course articulation issues apparent? If so, how will these issues be addressed for successful implementation of distance learning and exchange programs?

5. *Repurposing materials to serve constituents:*

- How will the products of curriculum development efforts (courses, modules, etc.) be leveraged? Can sections of new courses be retooled and restructured to form new short courses for industry? Will new course modules be implemented across campuses? Should existing modules be retooled for implementation in different courses?

6. *Developing new programs:*

- How should new and planned courses aggregate to form new programs for options, certificates, and degree programs as well as short courses and workshops?
- How will new certificate, option, and degree programs be distributed across academic levels and Center constituents (precollege, undergraduate, graduate, postdoctoral, and industry)?
- What buy-in is needed from departments, colleges, and universities as well as committees (research area, distance learning, graduate, undergraduate, curriculum) located within these administrative structures? For undergraduate engineering courses, how will these courses address ABET requirements?

7. *Implementing new courses and programs:*

- How will new courses and programs be implemented and disseminated? Who will be responsible for each of these tasks?
- How will new course materials be shared throughout the Center's partner institutions? How will this information be shared outside the ERCs? What format will the shared materials take?
- How will the policies and procedures necessary for the sharing of curriculum-based resources across campuses be developed, approved, and implemented?
- What will be the long-term impact of this education program development and how can it be quantified? How will progress be measured relative to the strategic plan? How will success be measured?

- If a program is to be implemented across campuses, must it take the same form at each institution?
- How will the education program leadership ensure that education program results are disseminated through conferences and journal publications?

The Education Director, in consultation with an intercampus Education Committee, should consider the above questions early in the award period. Since curriculum development is linked with the Center's research focus and reflects its interdisciplinary and multi-institutional nature, it is important that the Education Director and the Education Committee reflect this reality throughout its membership and functions.

It is important to note that the success of curriculum development initiatives depends upon a certain level of buy-in from various constituencies within departments, colleges, and universities. In the case of interdisciplinary course and program development, bridges must be built beyond the level of the individual faculty member and articulation among various degree programs (relative to courses and their prerequisites, as well as degree requirements) may also be warranted. For this reason, the Education Director (or other education program representative) must be prepared to devote a significant level of effort to communication, discussion, and strategic planning with these groups. It is essential to ensure that the education program at each campus includes both the faculty and support personnel necessary to advance the Center's efforts, and to maintain and promote new courses and programs once they have been developed. Often, administrators at partner campuses can assist with this function.

Departments often include support personnel such as undergraduate and graduate academic advising staff, outreach coordinators, and/or enrollment services coordinators. Such offices routinely receive feedback from students that can be helpful in strategic planning relative to curriculum. These offices can also help raise student awareness about these new programs.

It is important to recognize that throughout the life of the ERC, curriculum development initiatives and the Education Strategic Plan as a whole are living documents that are influenced by a variety of factors. For example, through the NSF Site Visit, industry and student SWOT processes, additional opportunities and priorities may be identified. Similarly, initiatives such as certificate, concentration, and degree programs established early in the Center's life cycle must be reviewed and updated at regular intervals to include new and modified courses that are developed under Center leadership. An Education Director of a multi-institution ERC can assist in this process by monitoring administrative changes and progress at all campuses at regular intervals and soliciting assistance from campus administrators to follow up on key issues.

It is important to keep the faculty involved in the education program in general and in curriculum development initiatives in particular. It is useful to solicit input directly from research thrust leaders and other key researchers within the Center at regular intervals to discuss progress vs. plans, strategic planning for out-years of the award, and response to SWOT issues. In this way, barriers can be identified and addressed early in the process, and in an environment that takes advantage of relevant multi-campus expertise issues.

CASE STUDY: At the Center for Power Electronics Systems, a Research Retreat is held on an annual basis for the purposes of long-term strategic planning. Each year, one afternoon and/or evening of the Research Retreat is reserved for an Education and Outreach Program Retreat to which all of the Center's research investigators are invited. This meeting has proved a useful forum for reviewing the work of the Education Committee and soliciting input relative to key implementation issues.

9.5.3.1 Issues in Offering Distance Learning and Web Courses

Distance learning can serve as an important tool for dissemination of Center expertise and resources to partner institutions, to entities external to the core partners, and to industry. Successful implementation of distance learning programs within the context of an ERC depends upon the degree to which courses have been integrated across campuses and the extent to which students view this knowledge as essential to the research that they are conducting within the Center. It is important to understand the distance-learning component of the Center's education program within the context of its research mission, and as a resource for emerging programs within its consortium. Further, it is important to identify and prioritize courses to be converted to distance format as a part of new course-development strategic planning.

Since distance learning programs often are institutionalized through departmental and/or college committees, outreach program offices, or special initiatives offices, it is necessary to determine how decisions related to distance learning courses are made within each partner university, how new course development is prioritized within departments and colleges, how resources are allocated, and who will provide leadership within the committee structure of each university in order to champion the Center's programs and objectives.

In some cases, the Education Director or Coordinator may be responsible for organizing intercampus student input relative to the distance learning course development plan, distance delivery modes, and learning objectives. The Education

Director or Coordinator may also play a role in coordinating logistics for distance learning courses that involve team teaching across institutions.

Intercampus agreements supporting the distance-learning component of the education program should address issues of registration, advising, required approvals, information dissemination, grade assignments, costs, and credits. Depending upon the nature of individual distance learning programs, some partner campuses may rely more heavily on distance access of courses than others. If this is an underlying issue for an education program, the associated cost considerations should be addressed as part of the Center's cooperative agreement.

CASE STUDIES:

Using Distance Learning as a Tool for New Course Development. During a strategic planning meeting at the Center for Power Electronics Systems (CPES), it was discovered that one of the partner campuses lacked a key element within its curriculum. The absence of this course was a barrier to full engagement of that partner institution in the Center's research program. A course that addressed this need was identified within the curriculum of the lead institution. Center resources were then devoted to converting this course to distance format, which was then offered exclusively to students at the partner institution. Office hours were also conducted through distance delivery by graduate student mentors at the lead institution. The following year, the faculty responsible for this course at the lead institution shared all course materials, including lecture notes, projects, and homework assignments, with a faculty member at the partner institution. Videos furnished by the lead institution were then used as the basis for offering the lecture component of the course, while recitation sessions were conducted by faculty at the partner institution. During the third year the course was offered, it was customized to better resonate with the curriculum of the partner campus. The course was then conducted entirely on site at the partner institution, after having been approved as a permanent part of the curriculum. This course development, while not originally a part of the Center's curriculum development plan, had an immediate positive impact on the number of students pursuing power electronics at the undergraduate and graduate levels, and led to increased involvement of the partner campus in the Center's research and academic exchange programs.

Multi-institution Course Credit Agreements. CPES has established two cooperative agreements that support intercampus collaboration in the Educational Outreach program area. During Year One of the ERC award, CPES established a core course listing in the areas of power electronics, packaging, and systems design and integration. At present, more than 80 power electronics and related courses are available through CPES partner campuses, with credits for these classes accepted by each student's home institution. Twenty-seven of these courses are offered for *distance registration. In order to facilitate intercampus course registration, CPES established a Cooperative Agreement for the Distance Access of Courses. This document, signed by officials of each ERC partner institution, establishes a set of common policies and procedures for cross-registration including billing for tuition and fees, payment of incremental costs, recordkeeping, registration, and the terms of distance delivery. The Cooperative Agreement for Exchange of Graduate Students allows Center students access to the portions of the core curriculum that are not offered by distance delivery, while also providing them access to the research facilities at each of the partner institutions. The goal of this agreement is to exploit the diverse technical strengths of each of the Center universities by developing uniform policies and procedures regarding student exchange among the core partner institutions. As part of this agreement, CPES partner universities established policies pertaining to tuition, billing, registration, course curriculum, and reporting of annual statistics to NSF.*

9.5.3.2 Team Teaching Courses in a Multi-Institutional Environment

While distance learning courses shared among campuses can be a useful mechanism for creating synergy within the Center, many are often taught by a single instructor. Multi-institution ERCs provide significant opportunities to expand this model of sharing expertise across institutional boundaries. In some Centers, significant benefits have been derived from introducing team teaching into the ERC's strategic plan for new course development. Models may include new courses, which cross the boundaries of a single departmental and/or discipline; or new courses, taught in distance format, which involve instructors at one or more partner institutions. In the latter case, the Education Director or Coordinator may play a significant role in coordinating the planning, development, and implementation of these courses, and in soliciting feedback in a multi-institutional format.

<u>CASE STUDY:</u> Team Teaching as a Method of Disseminating the ERC Research Vision. The course Power Electronics System Integration (PESI) *is team taught by professors at all CPES campuses, and serves students at each of the five partner campuses. This one-credit seminar course is required for all Center students. The course serves to communicate and reinforce the Center's research vision to upper-level undergraduate and new graduate students. This course involves lectures and intercampus discussion sessions related to the Center vision and each research thrust area. Lectures include introductions to new research foci and breakthroughs, and linkages among CPES research thrust areas. All course materials are freely available on the Center's web site and are revised annually to reflect new research developments as well as the evolution of the Center's research program.*

9.5.4 Cross-institutional Student Opportunities and Organizations

Students in a multi-institution ERC have a somewhat different experience than students in a single-university ERC. For example, the Student Leadership Council at a multi-institution ERC often is composed of students from all of the universities, and students have the opportunity to participate in exchanges with partner institutions. Students are exposed to partner university faculty through distance learning and team teaching, so students graduating from one partner university often go to another partner because they are known and the institutions have similar academic and research foci. The programs and events of the ERC-education, research, symposia, and Site Visit—bring the students from the partner universities in contact with other students, professors, industry professionals, and NSF professionals. The SLC needs a budget to carry out its duties.

9.5.4.1 Multi-institutional Student Internships and Student Exchange Programs

Internships can be very valuable. A central coordinator and budget manager with administrative contacts at participating institutions can help make the educational experience shine. Grant administration of funds to support student internships and exchanges at multiple institutions may vary widely. While a stipend might work at one institution, it might be unacceptable at another. The Education Coordinator needs to explore a wide range of mechanisms that can be employed to support student exchange programs and ensure their success.

9.5.4.2 Multi-institutional Student Leadership Council (SLC)

Students at multi-institution ERCs meet and interact with their peers from partner institutions periodically throughout the year. These meetings may coincide with other ERC activities, such as an annual research colloquium, site visits, the NSF Annual Meeting, etc. Prominent annual technical meetings associated with the field also offer opportunities for the students to meet and work together. Videoconferencing is also very popular, as are web-based communication tools such as Net Meeting. An accurate and up-to-date e-mail listserve helps to mediate communication issues that can arise because of geographical separation. Newsletters and SLC websites also provide a forum for participants.

Recruiting students into the SLC can be problematic. It is imperative that, in addition to the Education Director, an enthusiastic faculty member at each institution champion student participation in the SLC.

9.5.4.3 Recruiting Across Partner Institutions

Regular interaction among members of the Center research teams is instrumental in promoting involvement and recognition of participating students. This may open doors for students to seek professional opportunities at other Center-affiliated institutions. Center management should encourage this exchange, particularly for the matriculating student.

__CASE STUDIES:__

SLC Exchange Program. As a five-university research Center, CPES has been challenged to develop innovative programs supporting a culture of exchange among faculty and students. CPES students have identified novel approaches to traditional programs in order to achieve this goal. In 2002, CPES established Research Experiences for Undergraduates (REU) programs at Virginia Tech (VT) and the University of Puerto Rico-Mayagüez (UPRM). This program complements an existing student-developed initiative to provide short-term exchange opportunities to undergraduate and graduate students interested in performing collaborative work in power electronics. Through the short-term exchange program, CPES is able to invite graduate students for a parallel eight-week summer research experience. During the past two years, CPES has hosted REU and graduate exchange students from the same home campuses, providing undergraduate students who are new to CPES and power electronics with experienced mentors from their home campus as well as the VT campus. The pairing of these two programs has also allowed the Center to maintain closer contact with program participants over time, and has provided opportunities to create a support system for participating students to continue their research after they return to their home campus. Summer exchange students are encouraged to continue their collaboration with host institutions by completing follow-on work through short-term exchange experiences throughout the academic year. Students who have completed undergraduate research exchanges are welcomed back as graduate student mentors in subsequent years. In some cases, students who have been recruited by the host institution for advanced degree work serve as mentors for undergraduates from their former institution. CPES sponsors more than 30 short-term exchanges annually, more than half of which involve underrepresented Hispanic or African-American students.

Weekly Research Teleseminars. The ERC for Environmentally Benign Semiconductor Manufacturing uses weekly teleseminars to update students, PIs, and industrial partners on the current progress of research projects. These teleseminars are an effective tool used to give industry members access to research developments as they occur. The seminars follow a simple but effective format: Visual presentation materials are posted weekly on the Center's website for download in advance. This gives all participants the opportunity to view the presentation materials in advance. At the time of the presentation, Center members, industrial advisors, PIs, and students *dial in to the teleconference from their desks or conference rooms. In a typical one-hour teleconference presentation, a short discussion on one of the active research projects is presented. Instant feedback is obtained from the industry partners and other Center researchers, and all are kept abreast of the status of current research activities. This series is very well received and is an excellent tool for rapid information dissemination to industrial mentors and advisory boards. It is also an excellent means of communication within the Center. Students are involved in the teleconferences. They are given the opportunity to invite and coordinate speakers, present research results, and lead discussions on specific activities, as well as hear the results of the Center's research. This same teleconference format has been used for discussion of other ERC activities and Center-wide planning and discussions. Typically, 40 to 45 teleseminars are held annually.*

Multi-Campus REUs. Because their REU students were located at multiple institutions, the Earthquake ERCs—the Mid-America Earthquake (MAE) Center, the PacificEarthquakeEngineeringCenter (PEER), and theMultidisciplinaryCenter for Earthquake Engineering Research (MCEER)—initially encountered some challenges in implementing REU programs. They have since overcome those difficulties and even learned to cooperate among themselves very successfully in this area. The ready availability of videoconferencing has been very helpful in this regard, along with a multi-Center REU symposium at the end of the summer. Some of the REU activities have led to closer collaboration between graduate students and faculty members. Since their inception, the three ERCs have had many such tri-center projects. While each Center has an REU on its diversified campuses, there is a combined REU symposium for all participants. The three Centers take turns in putting this on. The Centers develop and then share graduate teaching modules on specialized subjects.

- *Networking Multi-institution Centers. Researchers at MCEER, at the University of Buffalo, are leading the initiative to create an electronic network linking its diverse experimental facilities. The object is to overcome geographic limitations and leverage the existing capabilities to share experimental and advanced computational resources and data. The establishment of the network requires developing new procedures and methods, adapting and integrating existing technologies, and developing new methods of communication, storage, and interpretation.*
- *Graduate Student Exchange Program. Virginia Tech's CPES students majoring in electrical engineering may attend classes at all five CPES universities, with credits for classes accepted by each student's home institution. The goal of this program is to provide students with a broader background and allow them to take courses not offered at their home institution. It is designed to maximize interactions among graduate students,*

provide opportunities for students to experience different learning environments, and expose masters-level students from one of the campuses to the possibilities of pursuing a PhD at another campus. It has been necessary to devise collaborative agreements to set forth the policies and procedures governing cross-university programs and student exchanges.

Joint ERC Student Activity: In 2002, PEER initiated a tri-center Earthquake Field Study program. Four graduate research assistants from each Center plus four non-Center graduate students (selected by professional earthquake engineering organizations) compete to spend ten days visiting a recent earthquake site in order to engage in a hands-on field assessment exercise. Each Center may send one advisor to accompany the student team. Funds to cover round-trip travel, participation in the week-long field trip, food, and lodging are provided and industry fellowships are encouraged.

In October 2003, thirteen graduate students, two professors, and a staff member traveled to Italy for a week-long study and tour of earthquake laboratories and field sites. The students were sponsored by the three earthquake centers: MCEER, PEER, and the MAECenter. The mission was organized by MCEER. The trip began with visits to laboratories in the area surrounding Milan. Site visits included the Joint Research Centre's European Laboratory for Structural Assessment (ELSA) at Ispra, University of Pavia, University of Rome, La Sapienza, University of L'Aquila, the devastated village of San Giuliano di Puglia, and Naples.

After their return to the U.S., the students were asked to make at least two presentations during 2003-04 based on what they learned during the trip. One presentation was directed at students or adults without an academic background in engineering or earthquakes—for example, upper-grade high school students or lower-division undergraduate students. The second presentation was a technical seminar for graduate students and professors at the earthquake Centers.

9.5.5 Outreach to Industry

Offering multi-institutional Continuing Education Unit short courses for industry can be challenging. The focus of initial planning is on prospective topics and industrial interest (with IAB input, possibly through a market survey), potential instructors, and mechanisms for delivery (short course, web, or distance course). The originating university(s) needs to be decided. Mechanisms for receiving credit at different schools (academic credit or CEUs) need to be arranged. Or a Center can simply offer a non-credit short course. Mechanisms for sharing advertising and administrative costs as well as formulas for sharing revenues may need to be determined. Procedures to pay the speakers both from industry and universities may need to be established.

9.5.5.1 Planning the Course

Certain questions can arise in the planning process: should the industrial courses be a push (i.e., the ERC wants to offer a course) or a pull (i.e., industry requests a course) activity? Are the administrative and financial resources available for planning and teaching a course? Will the Education Director and/or Coordinator plan the courses using Center administrative resources, or will the activity be decentralized to the course champions at different universities?

Determining course objectives and target markets is very important prior to offering any courses for industry. This may involve adopting a private-sector mentality rather than a traditional academic viewpoint. Market research through industrial members and advisors is key to offering successful industrial courses. A questionnaire distributed via the IAB with potential topics of interest for courses is a fairly easy mechanism used to gauge industrial interest. Industry should also be surveyed for preferences about location, cost, credit, and format.

If a live short course is offered, a venue that is convenient for the target market needs to be selected. It can be either on- or off-campus (e.g., in a hotel or conference center). That decision in turn may affect which university or universities sponsor the course, based on availability of resources and meeting facilities.

9.5.5.2 Choosing and Recruiting Course Instructors

Finding champions—professors and instructors—who want to offer courses geared toward industry interest (as expressed in a market survey) is key to success. Soliciting course ideas and topics from professors and industry instructors is good practice. At times, it may be necessary to recruit professors and/or IAB members to offer a topic requested by industry. But in general it will work better if the instructors are enthusiastic about the idea. It is good to have a mix of professors and industry instructors. The expertise and reputation of the instructors (marketability), their availability, and payment mechanisms need to be addressed. The instructors will need to be paid by the entities collecting the registration fees. It is important for the institutions collecting those fees to determine what financial mechanisms are available to pay the instructors. Subcontracts (as independent contractors) are usually best for industry speakers or professors from other universities, while supplemental compensation may work best for professors at the sponsoring university.

9.5.5.3 Choosing the Delivery Mechanism

The partners involved in offering the course (university and industry) will need to develop marketing materials and mailing lists. Partnering with industrial trade organizations to distribute marketing materials and course publicity is very effective. In addition, targeted mailing lists can be purchased from commercial suppliers. A traditional rule of thumb is to expect a 1% return from a mailing list. If the course is offered via distance learning, the university distance learning departments are also key marketing partners.

For course451 delivery, it is ideal for a Center to have partners. Course books, meals, and breaks will need to be provided for short courses. Finding commercial partners to sponsor breaks or meals can be useful as long as advertising is restrained. For distance courses, mechanisms such as live or satellite video or streaming video can be a daunting challenge. Many ERCs offer distance-learning courses through their institutions' central distance learning or "industrial outreach" program offices, to help minimize such problems.

<u>CASE STUDIES:</u>

Non-credit Short Course. The ERC for Environmentally Benign Semiconductor Manufacturing offered a successful non-credit short course on Chemical Mechanical Planarization (CMP). The course was offered by the Center with SEMATECH (a trade organization) and other industrial co-sponsors. An IAB member who was on sabbatical working at the Center was the driving force behind organizing five Center PIs from four universities to teach the course. The Center paid instructors' travel costs and honoraria. An initial planning meeting was held at the Center's annual retreat meeting, and planning continued via teleconferences. The Center education coordinator organized the course logistics. The Center compiled a mailing list with the help of its industrial members, and also worked with trade organizations in the San FranciscoBay area to publicize the course. In addition, the Center purchased a commercial mailing list and sent flyers to about 8,000 people in the semiconductor industry. The PI instructors also marketed the course through their contacts. Marketing efforts were successful in that 70 people attended the initial 1.5-day course, which was held in a hotel in Palo Alto in 1999. The majority of attendees were engineers or managers, with a significant number from sales. About 50% of the attendees were from the Bay area. The rest came from all over the US and as far away as Korea. This course was offered again in 2000 in Belgium, Japan, Taiwan, and California. For the second California course, the ERC partnered with a private training company, PTI Inc., to offer the course. The foreign courses had organizational partners and sponsors in those countries. Those sponsors handled the local logistics. These and three subsequent offerings of this course have been attended by a total of 280 people from more than 10 countries and representing 72 companies. More recently, the CMP course has been offered via streaming video and audio on the *web, on-demand to enrolled industrial students via a commercial partner, Semizone.com (an affiliate of StanfordUniversity's Center for Professional Development).*

Continuing Education Seminar Series. The Mid-America Earthquake (MAE) Center offers educational programs to the earthquake hazard mitigation community, to emphasize products of the MAE Center's research and to build an audience of professionals in Mid-America interested in earthquake engineering and in the MAE Center's activities in particular. The Center's Continuing Education Advisory Committee identified a need for earthquake seminars with a regional concentration. Accordingly, the Center developed three series of seminars focused on earthquake hazard mitigation in Mid-America.

Speakers were selected to match industry needs with the Center's areas of expertise, as well as representation from stakeholders and practitioners. Seminar locations were selected based on their close proximity to a large number of practicing engineers and engineering organizations that served as cosponsors. The seminars were advertised in cosponsor publications and mass mailings. CEUs were awarded to participants through the University of Illinois Office of Continuing Engineering Education. High-quality notebooks were produced that contained paper and CD copies of speaker presentations, research papers, and notes.

9.5.6 Collaboration and Partnerships (Outreach) with Schools and the Community

The first thing to remember about collaborations and partnerships is "don't reinvent the wheel." Find out what is currently available at each of your member institutions. Do they already have a K-12 component in place? What do they offer? Look at the community. Do you have science and technology museums that have outreach programs? What are the needs of the school systems in your area? What could you offer that might enhance their curriculum in the science and technology/engineering tracks? Diversity is a major issue for all Centers. What departments on your campus are addressing diversity? What minority-serving institutions nearby would mutually benefit from a partnership with your Center? Should your Center apply for a Louis Stokes Alliance for Minority Participation (LSAMP) supplement from NSF? These are all good questions to answer before developing your outreach programs.

9.5.6.1 How Education and Outreach Partners Add Value

Just as an interdisciplinary research team produces outstanding results, having partners and collaborators for your education and outreach components helps develop well-rounded and beneficial programs. Collaborations and partnerships should complement your Center's expertise. Identifying offices, programs, and organizations that complement your education and outreach goals is a place to start. Set up fact-finding meetings with these offices to determine if there are some mutual goals and if collaboration would be beneficial. After that first meeting, you may not feel there is a good match. There is no obligation to take it further. If, however, there are mutual goals, you can determine what all parties could bring to the table. Whereas your Center might bring the engineering component, your collaborators might bring the school systems, the particular age group you want to impact, an industry that uses your technology, etc. For example, The Center for Education Integrating Science, Math, and Computers (CEISMC) on the Georgia Tech campus has as its main focus outreach to the K-12 education community. They were the first office the Georgia Tech/Emory Center for the Engineering of Living Tissues (GTEC) contacted when beginning to plan for K-12 outreach. Not only does CEISMC know the needs of the various school systems in Atlanta, but they had an established teacher program that GTEC could tap into to enhance its Research Experiences for Teachers (RET) program. GTEC offered the research experience the teachers wanted and CEISMC offered the structure to turn the research into lesson plans. It has been a very productive and beneficial partnership.

Having a diverse group of students, faculty, and staff is a major focus for NSF and your Center. It is very important to make connections with offices on each of your campuses that provide assistance to underrepresented populations. Determine what programs are available. Is there a way you could tap into this resource? It is also very beneficial to establish a partnership with minority-serving institutions (MSI). It may be possible to develop a partnership with an MSI at each of your Center's member institutions, or a strong partnership with one or two MSIs could benefit all campuses. It is very important when beginning to establish these partnerships that this be a win-win situation for all concerned. The minority institutions need to see that you are interested in offering their students and faculty valuable experiences. In addition, NSF requires each ERC to develop a partnership with a Louis Stokes Alliance for Minority Participation and an Alliance for the Graduate Education of the Professoriate. The purpose is to engage the broad base of minority students and these alliances. These students usually participate in the ERC's REU program or other research efforts that involve graduate students.

It is important in partnerships like those described below to determine what the Center wants from the collaboration and what the other parties want and need. Coming to an early consensus will help get the project started on a positive note and proceeding productively.

<u>CASE STUDY:</u> The VaNTH ERC for Bioengineering Education Technologies has contracts with the University of Memphis and the University of Texas-Pan American—both minority-serving institutions—and Fisk University, an HBCU (Historically Black Colleges and Universities) in Nashville, TN. In all contracts, it was very important to balance the need for financial, intellectual, and infrastructure support. The needs and the programs may be different at each partnering institution. For example, for all three of these institutions, funding is provided for new seed research projects. At FiskUniversity, there is also the added value of intellectual support for participating Fisk faculty and funding for infrastructure (equipment). There are also student exchanges from all the universities for VaNTH's REU program.

<u>CASE STUDY:</u> GTEC, the Georgia Tech/Emory Center for the Engineering of Living Tissues, has established a partnership with the AtlantaUniversityCenter (AUC), a consortium of five HBCUs in the Metro Atlanta area. GTEC sought the partnership for several reasons. It wants to enhance its biology-based research initiatives and is providing funding for two seed projects for the MorehouseSchool of Medicine for research that is closely aligned with GTECs. The Center will also provide an avenue for undergraduates from Morehouse and SpelmanCollege to do research in the GTEC labs at either Georgia Tech or EmoryUniversity. The last component of the partnership will provide partial summer funding for Morehouse and Spelman science faculty to work in GTEC and MorehouseSchool of Medicine laboratories to experience new techniques, equipment, and applications. This partnership is unique in that GTEC is also partnering with theGeorgia Tech College of Engineering (GT CoE) and their Dual Degree program. This program allows undergraduates to do their first three years at Spelman and MorehouseColleges, and then transfer to Georgia Tech into an engineering curriculum. A program coordinator was hired to work with GTEC, GT CoE, and the AUC to encourage students to participate in the Dual Degree program. Supplemental funding from NSF is making this partnership possible, in addition to the CoE sharing one-half of the cost of the Program Coordinator.

9.5.6.2 Motivating Member Universities to Pursue Collaborations/Partnerships

Working within the Center's multi-campus organizational structure, the essential components of the education and outreach programs need to be decided. Next, determine what is feasible at each campus. Brainstorming on possible partnerships and collaborations will encourage member campuses to initiate contacts. Again, looking to see what is available in the community of each member institution is the best first step. Encourage each campus to think creatively. Other suggestions for motivating member institutions to pursue collaborations might include:

- Ask the Student Leadership Council what they would like to develop and present for outreach. Ownership in the programs greatly increases participation of your graduate and undergraduate students.
- Create a culture of appreciation for education as well as research. Just as your Center funds research projects, you should fund specific ventures that focus on education issues, i.e., curriculum development, precollege educational modules, and involvement of undergraduates in research projects.
- Develop a matrix for the internal review of research projects for the purpose of funding. Projects can be strongly encouraged or required to have an educational component in order to receive funding. Those that do not have an educational component would be less likely to be funded. Collaboration with community organizations can give added weight to a project proposal.

9.6 INDUSTRIAL COLLABORATION AND TECHNOLOGY TRANSFER

During the initial organization and implementation of a multi-institution ERC, extra effort is needed to obtain buy-in for the industrial program from all of the partner institutions. The preexisting industrial relationships among the academic partners need to be recognized, nurtured, and augmented to build a new base of industrial members across the Center. A new membership agreement needs to be created. Intellectual Property (IP), technology transfer, and industrial funding (membership, research funds) need to be discussed, negotiated, and codified into agreements. The Industrial Liaison Officer (ILO), a staff member at the lead university, leads this effort and has the additional task of working with the Principal Investigators (PIs), students, and industrial partners from all of the partner institutions. The structure of a multi-institution ERC is more complex than that of a single-institution Center; the relationships between the partners are more complex; and requirements of the ILO task are more demanding.

As a multi-institution ERC pulls together its dream team of academic and industrial collaborators, it faces several challenges. It must adapt to existing working styles and modes of operation, while accommodating different personalities, campus cultures, and industries. And it must create a viable model to enhance intercampus integration and industrial interactions.

The following paragraphs focus on issues common to multi-institution ERC industrial collaboration. Examples and case studies are provided to illustrate how multi-institution ERCs structure their industrial consortia, secure buy-in, and share resources. Some examples will illustrate how membership agreements and IP policies are established. Other examples will describe what is done to enhance interactions with industry, increase involvement, and motivate all partners. The collective experiences conveyed in these examples should serve as good references for both new and existing multi-institution ERCs.

9.6.1 Getting Started

Before starting the effort to build the Center's industrial program, it is important to recognize the added value of a multi-institutional ERC as it can greatly enrich both industry and university partners. Industry gains multidisciplinary, innovative technologies and resulting IPs; expanded technology transfer opportunities; access to multi-campus graduates as possible employees;, and collaborative possibilities with multi-campus researchers. Participating universities gain additional funding (from industry membership, NSF, multidisciplinary projects) for research and publication, and access to a broader spectrum of industry partners for more R&D and technology transfer opportunities. Recognizing each party's motivation helps in building an infrastructure that will flourish.

9.6.1.1 Securing Buy-in and Commitment

One of the start-up challenges is to secure cooperation and support from university administration on all partner campuses as well as their respective Technology Transfer Offices (TTOs). ERCs that provide industry membership funds to leverage grant-funded research also need to negotiate an overhead rate structure that optimizes both industry membership and research funding.

If a new ERC has pre-existing industry partnership programs at one or more of its partner universities, the Center must establish a membership agreement that incorporates the cultures of all partner institutions, and develop a membership structure that will ensure an easy and transparent transition for existing members. If no such pre-existing industry partnership program is in place, one suggestion for initiating a membership agreement is to request sample agreements from existing multi-university ERCs for reference. Another useful approach for potential partners is to make it clear that three things are expected from/for partners: (1) to contribute to the ERC; (2) to participate actively in the work of the ERC; and (3) to benefit from the ERC. If these goals are articulated early in negotiations, expectations are clear and subsequent unpleasant turns in the relationship can be reduced.

<u>CASE STUDY:</u> Realizing the importance of securing buy-in and commitment from its five core partner universities, the Center for Power Electronics Systems (CPES) began a series of teleconferences with pertinent university officials and TTOs from team universities during the ERC proposal stage. The outcome of these discussions was a draft of a Memorandum of Agreement (MOA) that was eventually refined, approved, and executed by all partner campuses. The MOA helps to clarify the team's agreement regarding membership structure, intellectual property rights, and mechanisms for technology transfer.

<u>CASE STUDY:</u> An existing industry membership organization, the Industry Educational Partners at Georgia Tech, was consulted at the ERC proposal stage for industry input. The industry members, consisting primarily of large medical device companies, strongly suggested the inclusion of EmoryUniversity to gain participation, access, and guidance from clinical groups relevant to the biological systems in the proposal. The industry members thought this partnership would be essential not only to successfully competing for an ERC, but also to the overall, long-term success of the Center. Consequently, the commitment of Emory University was secured and the formation of the Georgia Tech/Emory Center for the Engineering of Living Tissues (GTEC) was proposed for ERC funding, with the Educational Partners Program as a component. The buy-in of the industry members and transfer of the industry program to GTEC was facilitated by including them in the proposal process. They now benefit from the value-added relationships with Emory and Georgia Tech. Because the GTEC industry program was focused on tissue engineering, one member dropped its membership since tissue engineering was not a priority area for the company. With that exception, however, all the other original members have stayed involved and strongly support the Center.

9.6.1.2 Structuring a Program to Benefit All

A multi-institution ERC is usually comprised of a diverse faculty with specialized expertise in complementary areas. Such a multidisciplinary program inevitably attracts industry members with varying interest levels. To serve the needs of a broad spectrum of industry, some ERCs have found that a tiered membership structure is effective because it offers flexibility in terms of financial commitment and collaborative opportunities with the academic institutions.

Although the NSF ERC program prefers that contributions from industrial and practice partners be in cash, to provide maximum operational flexibility for the ERC, in-kind contributions are possible and are welcomed. Companies in financially difficult periods, including start-up, often find it easier and more beneficial to contribute in-kind than in cash. Examples of in-kind contributions include hardware, software, or even support for students under certain conditions. Terms and extent of in-kind contributions must be administered fairly across companies and academic partners; i.e., no favoritism should be shown to a particular company or to a particular industrial or practice partner.

CASE STUDY: The Center for Extreme Ultraviolet Science and Technology (EUV ERC) offers a tiered membership structure with three levels of corporate membership: Full, Associate, and Small Business Corporate Member. The Full Corporate Membership is $50,000 annually, Associate is $25,000 annually, and Small Business (less than 100 employees) is $5,000 annually. Credits for separate contracts which add substantially to the Center's needed infrastructure, equipment, or other valuable resources are given. At a minimum, Full Corporate Members must donate $10,000 in cash annually. The $5,000 annual fee for Small Business has made this level particularly attractive and has brought the EUV ERC a significant amount of industrial participation early in its existence. Companies large and small have joined for a seat at the table, to see the emerging technologies firsthand, meet the faculty and students directly, have potential access to the IP, and in some cases, receive help with simple tasks or components which help them get into the business.

CASE STUDY: CPES offers a tiered membership structure that includes four levels of participation—Principal Plus, Principal, Associate, and Affiliate. Principal Members pay $25,000 per year, and Principal Plus Members pay an additional $25,000 to gain the option of participating in a mini-consortium for focused research or sponsoring a fellowship for exploratory research within the Center's strategic plan. In addition to basic member benefits, Principal-level members also have early access to CPES-developed intellectual properties. Principal Members guide the Center as Industrial Advisory Board (IAB) members and work closely with Center researchers as research champions. Associate Members pay $10,000 per year and have easy access to the Center's research results, CPES researchers, and the state-of-the-art facilities. Affiliate Members include contributing WEMPEC members, small start-ups, and suppliers that are interested in making in-kind contributions to the Center in exchange for access to Center information as well as networking opportunities with Center personnel and other industry partners.

CASE STUDY: At the ERC for Biomimetic MicroElectronic Systems (BMES), Center membership funds are leveraged with sponsored research funds. BMES membership categories include Senior Members and Technology Members. Senior Members commit $50,000 per year for three years, serve on the IAB, and are mentors for technology development. They are in the best position to help define industry needs and influence research direction. They participate in research program reviews, have early access to Center-developed IPs, and are given first licensing opportunities. Technology Members commit $10,000 per year for three years. In addition to receiving the Center's research reports, Technology Members are invited to the ERC *campus once or twice a year to meet-and-greet students for exploring summer internship and employment opportunities.*

<u>CASE STUDY:</u> GTEC has structured their membership fees according to the size of the companies participating. This was done to make the industry membership program accessible to small ($5,000 per year) and mid-sized ($10,000 per year) companies, as tissue engineering is considered an emerging industry with a limited industrial base. Even within large companies ($15,000 annual membership fee), the number of groups working on tissue engineering is limited, and the company might not have tissue-engineered product revenue streams. The fees are kept low to make the program inclusive, since there are a limited number of companies interested in and capable of investing in this emerging industry. Reduced fees for not-for-profit organizations are also considered.

<u>CASE STUDY:</u> The Business and Industry Partnership (BIP) at the Pacific Earthquake Engineering Research Center (PEER) involves industry and government partners that participate in the Center's research and education programs. BIP members are given preferred access to PEER research and products as well as preprinted publications via the PEER website. They have the opportunity to interact with PEER students and faculty and are welcome to attend PEER meetings to provide input on research direction and learn about the latest research findings. Membership contributions vary from $500 to much larger amounts, based on size and participation. Crucial PEER partners, such as the California Department of Transportation, California Energy Commission, and Pacific Gas and Electric Company, are highly involved in defining issues, formulating projects, and funding the specific research.

<u>CASE STUDY:</u> The <u>VaNTHEngineeringResearchCenter</u> in bioengineering educational technologies is unique among ERCs in that its research and development focus is on engineering education and associated learning technologies, not engineering per se. *Several VaNTH partners are leading developers and vendors of engineering education and application software. These companies are encouraged to donate their software for educational purposes; that is, for use in the development of courseware and testing of instructional modules among the student populations of VaNTH research partners. Such contributions have several advantages to both VaNTH and the contributing company: (1) A clientele of users is established among students. If their experience is positive, students who learn to use software during their formal education are more likely to request and continue to use it during their work experience. (2) Instructors who develop educational experiences can provide valuable feedback on product design to software companies. (3) Companies, particularly smaller ones for which cash flow is a problem, can count the value of that*

software and its maintenance (usually discounted by prior agreement with NSF) toward membership requirements.

The importance of partnerships with smaller companies cannot be overemphasized. These companies frequently benefit from advertising their relationship with the academic partners of an ERC, are often involved with cutting-edge technology to which more established partners do not have access, and are flexible enough in organizational structure to be more immediately responsive to ERC initiatives. For example, the VaNTH ERC has profited from many hours donated by a small company specializing in multimedia education to help produce bioengineering learning materials. Another small company, as a result of the VaNTH partnership, has helped develop innovative procedures in engineering design that have been emulated in medical as well as engineering curricula. Still another small company has become the second-largest employer in its home county through, among other strategies, taking advantage of VaNTH students and resources in developing learning materials and production strategies. Finally, it should be noted that small companies that are brought in the door at an affordable level have the potential to grow to higher levels in their involvement with the Center.

9.6.1.3 Incorporating Pre-existing Industrial Consortia

To sustain a robust industrial consortium, an ERC must be successful in recruiting new companies and retaining existing members. For multi-institution ERCs with pre-existing industry partnership programs, it is crucial to provide a seamless and transparent transition for existing members.

<u>CASE STUDY:</u> Two of the five core CPES academic partners have successful pre-existing industrial consortia. The challenge is to develop a strategy to merge these consortia seamlessly into a CPES consortium upon which the Center can build a robust industrial consortium. To achieve this goal, Virginia Tech, the lead institution, folded its pre-existing industrial consortium, VPEC, into CPES, while selected WEMPEC members from the pre-existing UW-Madison consortium who had a relevant interest in the CPES program became CPES Affiliate Members. These members contribute one third of their membership fees to support CPES research activities relevant to the CPES strategic plan.

9.6.1.4 Membership Agreements

A viable membership structure is one that attracts broad-based participation because it provides appropriate benefits to industries with varying needs and interests. Once the structure is agreed upon, membership agreements are reviewed and approved by university and legal counsel officials. For ERCs established at institutions that have pre-existing Centers, the road to securing buy-in and gaining institutional support can be significantly smoother. Using existing working models, the process for establishing multi-university agreements and IP policies can be highly efficient. For ERCs that have pre-existing industry programs, it is also important to clarify the new plan and transitional process for existing industry partners.

CASE STUDY: As the second ERC established at the University of Southern California, the Biomimetic MicroElectronic Systems (BMES) ERC enjoys the advantage of the ERC campus culture shaped by the older Integrated Media Systems Center (IMSC). Based on the IMSC model, BMES was able to streamline the process of setting up its industry membership structure and was successful in implementing a cross-campus IP policy that is stronger than a Memorandum of Understanding (MOU).

CASE STUDY: CPES includes five core academic partners, two of which have pre-existing industrial consortia. Knowing the importance of ensuring that existing industry members are clear about the transition and happy with the program's features, CPES added a special Q&A session during the Center's first annual seminar and invited industry partners to discuss the new program, raise their concerns, and offer feedback and recommendations.

CASE STUDY: At the University of Michigan's Wireless Integrated MicroSystems (WIMS) Center, industry membership agreements are evergreen, allowing automatic membership renewal unless either party opts out. This mechanism has dramatically reduced the burden for corporate champions to obtain executive-level signatures every year.

9.6.1.5 Unique Aspects of Earthquake Engineering Research Centers

The ultimate mission of Earthquake Engineering Research Centers (EERCs) is to save lives and minimize earthquake-induced economic losses. Due to the broad societal impact of earthquakes, both private corporations and government agencies are integral partners of EERCs. At PEER, industrial corporations such as Pacific Gas and Electric Company and state agencies such as the California Department of Transportation and California Energy Commission have strong and long-term relationships with the Center. Utilizing leveraged funding, these government and industry partners work closely with PEER to develop long-term research programs, aiming to achieve the collective goals of addressing seismic issues and problems, reducing loss to human lives, and minimizing damage to the electrical network, highways, buildings, bridges, etc. These Centers are different from other ERCs due to the direct societal nature of the work and the heavy involvement of government agencies from the regional to the local level.

9.6.2 Building a Strong Industrial Constituency Across Multiple Campuses

The ILO needs to recognize the existing links and potential links between companies, Principal Investigators, and students in the ERC. He or she must build or reinforce bridges between the company and the ERC by communicating the benefits of the relationship to both parties.

9.6.2.1 The Industrial Liaison Officer—A Resource for All University Partners

To maintain strong intra-campus connectivity with industry, the ILO must play a central coordination role and serve as the primary point of contact. The ILO should be both people- and detail-oriented, and be well-regarded by both ERC faculty and industry. In addition to recruiting industry members, the ILO also needs to energize effective interactions between researchers and industry champions and act as the liaison between the TTOs on the partner campuses. To enhance effectiveness, each partner university could also designate a campus liaison to support the ILO, as a resident person would better understand the people and infrastructure on his/her respective campus. The ILO should work closely with the Center's research manager(s) and IP offices, act as industry's advocate, and serve as the primary provider of customer service. In short, the ILO must be the "glue" that holds the academic and industrial communities in working harmony.

CASE STUDY: *Keeping all Center constituents (multiple university faculty, students, and administrations; outreach participants, and industry members) informed of activities, special initiatives benefiting industry, and scientific developments is critically important. GTEC publishes an industry newsletter biannually (fall and spring) that highlights faculty/student activities and awards, new publications, patents issued or applications published; introduces new industry members or new faculty; and features short news pieces to keep everyone connected. The newsletter can be distributed to a larger industry community as a PDF file via email or downloaded from GTEC's website to raise the profile of the Center and potentially recruit new member companies. Samples of the Center's* Expressions *newsletter can be found at http://www.gtec.gatech.edu under "Center Publications."*

CASE STUDY: *At VanderbiltUniversity, the VaNTH industrial liaison group has several additional responsibilities that facilitate industrial contact. Dr. Jerry Collins, VaNTH's ILO, is the recipient of an industrial internship award from the Whitaker Foundation. Internship placement with companies, some of which are VaNTH partners, provides feedback on how VaNTH students perform in conditions of adaptive learning (a development goal for VaNTH), as well as suggestions for* *improving the instructional milieu. Dr. Collins has also served as chair of the Interface with Industry Committee of the Biomedical Engineering Society, and is current co-chair of the Education Committee of the Tennessee Biotechnology Association and president of the Tennessee Biomedical Engineering Consortium. This visibility and activity among national and local industrial and professional organizations affords numerous opportunities for development of ERC industrial partnerships.*

Additional partnership opportunities can come from follow-up of summer internship and permanent employment opportunities developed through an active university CareerCenter and Alumni Office. Strong relationships with such offices on every campus of a multi-university ERC should be developed by the ILO and her/his associates.

9.6.2.2 Industry-student Connectivity

To build and maintain a strong industrial collaboration program, ILOs must cultivate connectivity between students and industry. Initially the level of industry connectivity will probably differ from campus to campus, based on prior industry-faculty relationships. As the ERC evolves, it is important to initiate and maintain efforts that will maximize industry-student connections on all campuses.

The natural way to increase connectivity between students and industry are to use the events that bring the industry and academic communities together, such as IAB/SLC meetings, annual symposia and site visit, technical exchange meetings, and hiring opportunities. In planning an ERC symposium or site visit, the ILO and Education Director can arrange for student and industry interactions; for example, a poster session would bring industry representatives and multi-campus students together to meet and discuss research of mutual interest. Industry representatives can be called upon to review and vote on student posters or presentations, leading to an award. The Education Director can compile a student resume booklet to be distributed at the Industrial Advisory Board (IAB) meeting or at the poster session. Graduating students can be invited and introduced at the IAB meetings. Receptions or dinners can be used to encourage networking by pairing students with industry representatives.

When a student's work reaches the intellectual property stage, the ILO can coordinate an effort to bring the student (with mentor and guidance) and appropriate industry partner together to explore commercialization possibilities. Conversely, an industry partner can help a student recognize the commercial potential of some of his or her work and, through the ILO or Education Director, help the student obtain the proper protection (patent, copyright, etc.).

In general, multi-institution ERCs involve students from all partner campuses in annual meetings, workshops, and symposia so they can present their work and interact with industry participants. In addition, some ERCs also engage industry research champions in intra-campus research meetings for technical updates, providing more opportunities for industry-student connectivity. These interactions sometimes lead to students being invited to present their work at the company site, resulting in higher visibility and possibly leading to summer internships and employment opportunities.

CASE STUDY: In the VaNTH ERC, Vanderbilt has a strong undergraduate internship program and NorthwesternUniversity has a strong undergraduate co-op program (undergraduate programs at the University of Texas, a VaNTH research partner, and the University of Memphis, a VaNTH academic partner, are still under development). Placement of bioengineering students in both internship and co-op positions is sought and encouraged by VaNTH. After the training period, co-op students, interns, and industrial mentors are asked to respond to questionnaires patterned after ABET-desired outcomes for accredited educational programs. Assessment of responses provides benchmarks of student performance and VaNTH effectiveness.

CASE STUDY: The GTEC Student Council has developed a short course pertaining to research and development in industry called Learn about Industry from the Experts (LIFE). The LIFE short course assists in preparing students for future industry positions or collaboration. This program draws from the GTEC industrial partners' expertise and enhances student-industry relations. The course introduces students to the events that occur within industry to bring a product through research and development to the market—taking a research idea from the bench and delivering it to a patient in the form of a product. Topics include research and product development in industry, FDA regulatory issues, market-driven research and development, and other topics designed to expose students to the processes involved in commercializing a research idea. Students are provided with notebooks for the course, and those attending 75% or more of the talks are given a certificate of achievement.

CASE STUDY: To improve industry-student connectivity, the CPES IAB's Working Group on Communications invites the Center's Student Leadership Council to join their monthly teleconferences so they can better understand student needs and exchange ideas. As an outcome of these discussions, a dedicated meet-and-greet function became an annual activity for students and industry participants to mingle in an informal setting. In recent years, these interactions evolved into the highly *successful face-to-face IAB/SLC joint meeting held during the annual conference. In these meetings, industry and students openly share issues and concerns and discuss possible means to further improve industry-student connectivity. Another activity that has proven to be of great value to enhancing student experience is that students are given the chance to organize the Center's annual conference by joining the Student Conference Organizing Committee.*

The CPES IPPF plan provides an additional mechanism for direct transfer of knowledge from researchers to industry, as IPPF members are invited to join quarterly telecons to discuss with student researchers the value of their innovative concepts for possible patent protection.

9.6.3 Interacting with Industry Partners in a Multi-University Environment

A multi-university ERC must recognize the research needs of the ERC's industrial partners and, to the extent possible within its strategic plan, guide its research to satisfy its partners' needs. The IAB plays an important role as the voice of the industrial partners by communicating clearly their technological and research needs.

9.6.3.1 Modes of Communication for Intra-campus Collaboration

ERC research direction should be aligned with industry trends and long-term needs, so that the research is relevant for eventual commercialization. To accomplish this objective, ERCs must collaborate closely with industry in technology development and transfer. ILOs are responsible for facilitating this process across the campuses.

<u>*CASE STUDY:*</u> *As the CPES research program matures, the number of cross-campus joint projects increases, allowing more opportunities for multi-campus integration and collaboration. CPES thrust leaders jointly decide on how to group the projects into clusters for team discussions. Student leaders organize the biweekly team teleconferences and invite research champions to join them on a monthly basis for progress updates and industry feedback. In preparation for these meetings, agenda and reference materials are disseminated in advance to industry participants. Those who are unable to participate can retrieve student presentations posted on the Center's password-protected website.*

<u>*CASE STUDY:*</u> *VaNTH has held at least three and as many as four meetings each year at VaNTH research partner sites. IAB meetings are held at two of these (the Austin spring meeting and the Nashville site visit), and Industrial and Practice Partners (IPP) and potential partners are invited to the others as well. When*

appropriate, IPP members give presentations at these meetings. One advantage of distributing the sites of these meetings is that IPP partners can attend meetings in their geographical vicinities with minimal disruption and expense. Regional meetings are also an excellent method for inviting and recruiting potential new partners.

CASE STUDY: To optimize cross-campus collaboration, all partner campuses of the WIMSCenter use the Polycom system as their common mode of communication. This audio/video capability has enabled more effective communication with regard to research collaboration as well as Center administration.

9.6.3.2 Industry Advisory Board

The IAB represents the industrial partners. It meets to review the research of the multi-university ERC, to discuss needs of the industrial partners, to communicate their needs to their university partners, and to carry out the annual industry SWOT (Strengths, Weaknesses, Opportunities, and Threats) analyses for the ERC's and NSF site visit team's reference. Some ERCs open IAB participation to all industry members. However, for multi-institution ERCs with large industry membership, it may be more effective to keep the IAB to a manageable size. Following are examples of how some of the ERCs organize their IAB and related activities.

CASE STUDY: At PEER, selected representatives of the Business and Industry Partnership, plus representatives of key government agencies providing funding for PEER, are members of an Implementation Advisory Board which advises PEER on its strategic plan, research projects, implementation of research results, and new opportunities for funding.

CASE STUDY: CPES Principal-level Members have a stronger interest in closer collaboratin with the Center and demonstrate their commitment by making higher financial contributions. These companies have a guaranteed seat on the IAB. Associate members are mostly interested in basic membership benefits and are offered possible IAB representation by election. In general, the CPES IAB consists of 30 industry representatives.

To enhance its effectiveness, the IAB forms an Executive Committee (ExCom) to filter and identify issues for broader IAB discussion. The IAB ExCom holds monthly teleconferences, while the full IAB meets three times a year—two via telecons and one face-to-face meeting held in conjunction with the Annual Meeting. To provide a forum for all industry partners to interact with each other, the face-to-face IAB meeting is open to all members. Throughout the year, industry partners are given access to program updates posted on the Center's password-protected website, and are kept abreast of IAB activities via the distribution of IAB telecon meeting minutes.

In addition to the IAB ExCom, there is also the IAB "huddle group" that includes the IAB Chair, Co-Chair, Secretary, Center Director/Co-Director, Technical Director, and ILO. IAB Huddle meets on the phone every week for informal updates and dialogue. This tiered model has proven to work very well in ensuring effective communication between CPES and its IAB.

9.6.3.3 IAB Working Groups

When the IAB has identified certain issues and needs industry attention and support, IAB may decide to form a focused working group and charge it with a specific objective. As the working groups carry out their mission, contributing members may go within their own companies to seek help and consult experts, thus allowing the Center to gain expanded support from additional industry advocates and mentors. This model has proven to be quite effective for ERCs that employ it.

9.6.3.4 Industry Champions

Industry champions are advocates of specific research areas and serve as mentors to the Center's researchers. As an added benefit, cross-campus interactive opportunities on technical matters are offered to representatives of Principal-level member firms, as champions who interact closely with ERC researchers can ensure direct technology transfer. Keeping industry champions actively engaged is the collaborative endeavor of ILOs and research thrust leaders. Oftentimes, faculty researchers make the initial connection with industry, and the ILO continues the effort by making follow-up calls, defining champions' role, clarifying expectations, and facilitating communications. ILOs of multi-institution ERCs must make the extra effort to work closely with the various cross-campus research leaders to ensure consistent and active industry involvement.

9.6.4 Intellectual Property and Technology Transfer

Technology transfer is important to all ERCs and can take many forms. However, IP issues vary in importance in different fields. For example, while early IP access is crucial for medical device companies due to the competitive edge it provides, IP is less important to Earthquake ERCs because their business and industry partners are equally interested in minimizing losses and reducing damage resulting from earthquakes.

9.6.4.1 Technology Transfer: Strategies and Mechanisms

The transfer of ideas and technologies from university partners to industrial partners is at the heart of the ERC/partner relationship. Technology can be transferred in many ways (presentations, publications, courses, joint research, student internships, contract and grant support, etc.). The more directly associated the technology is to the compnay's products, the more exclusive and valuable the technology transfer is to the customer. Ideas or technologies derived from sponsored projects and technology jointly developed under joint contracts or grants are generally the most valuable.

- *Joint projects and technology development*—

Working together, industry and universities can be more successful at obtaining government funding for joint research programs. Together they can obtain resources to develop technology needed by both. The transfer of technology then becomes automatic and provides a valuable justification for the ERC partnership and membership dues.

CASE STUDY: The CenSSIS ASHERD Portal Program is a joint development of a nuclear detector for U.S. ports of entry by NortheasternUniversity and Bubble Technology Industries. Initially, it was a program to develop a spectroscopic portal for detection of nuclear materials in vehicles (trucks, cargo containers, cars, and trains). The successful completion of this development effort resulted in the procurement of a third contract between Raytheon, Bubble Technology Industries, and NortheasternUniversity to build portals for U.S. ports of entry.

- *Finding effective models suitable for the diverse university cultures*—

Within a multidisciplinary, multi-university ERC where there may be multiple intra-campus joint projects, ILOs must make sure that industry has an easy way to interact with the various intra-campus project teams, and must also ensure that interactions with industry champions are consistent, efficient, and effective. For industry, the best mechanism for gaining the extra edge on technology transfer is to have company engineers serve as research champions, join IAB working groups, or participate in the Center's industrial residence program and work on-site with the Center's researchers.

- *Educating multi-campus researchers on IP-related issues*—

ERC faculty and student researchers often interact directly with industry. It is thus important to make sure that investigators and their students are fully aware of the Center's IP and non-disclosure agreements. Because jointly conducted research could lead to joint inventions, it is crucial that ERC researchers develop the important habit of documenting innovative concepts in IP lab notebooks as new ideas are conceived so as to support any inventions that may be disclosed under the team effort.

9.6.4.2 Developing an IP Agreement for Multi-university Centers

Multi-institution ERCs face the difficult challenge of developing an all-encompassing IP policy that is fully compatible with existing policies at partner institutions. Meeting with pertinent university officials and technology transfer officers from partner campuses to clarify the parameters, IP rights, and terms and conditions is therefore very important and should occur at the outset. Throughout this process, the ILO must act as the primary facilitator to ensure that the IP agreement serves industry well, while at the same time satisfying the requirements of the university partners. Participating universities should establish an inter-institutional agreement that outlines basic operating policies for the management of IP generated by each university and for collaborative efforts. A lead university may be identified to manage collaborative IP because of its expertise in specific IP categories. These agreements should be put in place early, kept simplified, and used as a guide when managing the Center's IP.

CASE STUDY: *The BMES ERC develops innovative medical devices with application horizons that may take up to 10 years for FDA approval. To justify long-term investments in academic research, most BMES industry supporters are interested in gaining the IP competitive edge. Recognizing that licensing opportunities for Center-developed IP is one of its core appeals, BMES was keen on establishing an IP access mechanism that is streamlined and efficient. With strong institutional support from its partner institutions, BMES was successful in establishing a multi-university IP agreement that allows central management and administration of Center-developed IP at the lead institution, providing the convenience of one-stop shopping for its Senior Members.*

CASE STUDY: *The CPES IP policy allows for a certain degree of flexibility within the framework. It states that if an invention is developed under NSF-funded core research, it will be managed in accordance with the IP policies of the university where the invention is disclosed. In the case of joint inventorship, which would be defined by U.S. patent law and the policies of the respective institutions and/or industry member(s), the home institutions of the joint inventors would decide who would be responsible for the prosecution of the patent and commercialization. In addition, partner institutions have agreed that Principal-level Members will be granted early access to CPES-developed technologies, the option to negotiate a reasonable license fee plus royalties, and the added opportunity for Principal Plus Members to credit annual membership fees towards license fees and royalties. To further streamline the IP protection process, CPES-Virginia Tech offers a novel option called the Intellectual Property Protection Fund (IPPF), a plan that allows Principal-level Members to pool funds for IP protection. IPPF members contribute $5,000 per year, jointly decide which IPs they wish to protect, and are granted a non-exclusive, royalty-free license to use these technologies. Not only has this mechanism* *greatly enhanced the IP advantage for Principal-level Members, it also allows researchers to publish their technical innovations without delay.*

9.6.5 Sharing Industrial Funding Resources

Distribution of resources within a multi-institution ERC is a complex process. Each ERC conducts its distribution differently. Some funds are obtained with restrictions and others are not. Some funds are given to support specific activities at one institution or specific activities at a set of institutions. The distribution of funds and resources is as varied as the variety of sponsors. No matter what scheme for distribution is used, it must strongly support the ERC infrastructure and its technical efforts.

9.6.5.1 Planning and Allocations to Partner Universities

Industrial consortium funds generally are used to directly support industrial collaboration activities coordinated and managed at the lead institution. At times, however, ERCs may find it necessary to earmark a portion of the industry funds to support research or other program enhancement initiatives. In these cases, it is important to make sure that industry and university partners all agree with the purpose of the initiative and understand the funding allocation process.

<u>CASE STUDY:</u> Under certain circumstances, faculty involved with GTEC may prefer to receive a major equipment allocation rather than receive research project support. For instance, faculty receiving most of their funding from the NIH cannot designate major equipment purchases to these grants. Faculty who are securing funding from outside the Center, but whose research <u>clearly falls within GTEC's strategic research plan</u>, may request the purchase of a major piece of equipment directly involved with that research. GTEC has purchased equipment (or provided matching funds) that would be impossible to buy with NIH grants in order to provide key enhancements and added capabilities that directly impact the Center through scientific advancements and collaborative research with other GTEC faculty.

<u>CASE STUDY:</u> To enhance domestic Ph.D. student recruitment and further emphasize basic research, CPES proposed to allocate some industry funds to create special graduate fellowships and fellowship supplements to support these initiatives. After receiving the IAB's endorsement, industry fellowships were established at the lead institution and allocated to specific campuses to fill their needs.

<u>CASE STUDY:</u> In addition to funds, another ERC resource is its students. Some of VaNTH's industrial partners request that they be allowed to hire interns or co-op students as part of their VaNTH commitment. The NSF allows the ERC to do that, partly because VaNTH is an educational ERC and student performance in an internship is an important testbed for the Center. Often, companies request interns from nearby VaNTH partners or from nearby home towns, because they feel their chances of retaining such interns as permanent employees are greater. VaNTH always tries to comply with those requests and coordinates its student searches accordingly.

Appendices

Appendix A: Working Group Members

WORKING GROUP #1--CENTER LEADERSHIP & STRATEGIC DIRECTION

Steven Bishop--Director, Center for Compound Semiconductor Microelectronics, University of Illinois at Champaign-Urbana

J. William Costerton *(Chair)*--Director, Center for Biofilm Engineering, Montana State University

Nino Masnari *(Co-chair)*--Former Director, Center for Advanced Electronic Materials Processing, North Carolina State University (now Dean of Engineering)

Brij Moudgil--Director, Engineering Research Center for Particulate Science and Technology, University of Florida

James Solberg--Director, Center for Collaborative Manufacturing, Purdue University

Daniel I.C. Wang--Director, Bioprocess Engineering Research Center, Massachusetts Institute of Technology

WORKING GROUP #2--RESEARCH MANAGEMENT

David Anderson--Associate Director, Center for Collaborative Manufacturing, Purdue University

James Bryers *(Co-chair)*--then Coordinator of Engineering Research, Biofilm Engineering Research Center, Montana State University

Kristina Johnson *(Chair)*--Director, Center for Optoelectronic Computing Systems, University of Colorado

Brij Moudgil--Director, Particle Engineering Research Center, University of Florida

WORKING GROUP #3--EDUCATION PROGRAMS

Martha Absher *(Co-chair)*--Director of Outreach, Center for Emerging Cardiovascular Technologies, Duke University

Ilesanmi Adesida--Associate Director for Education, Center for Compound Semiconductor Microelectronics, University of Illinois

Marlene Barmish--Special Assistant, Center for Plasma-Aided Manufacturing, University of Wisconsin

Skip Fletcher *(Chair)*--Education Coordinator, Offshore Technology Research Center, Texas A&M University

Anthony Sinskey--Professor of Biology, Bioprocess Engineering Research Center, Massachusetts Institute of Technology

Karl Smith--Associate Director for Education, Center for Interfacial Engineering, University of Minnesota

Darline Wine--Administrative Associate, ERC for Net Shape Manufacturing, Ohio State University

WORKING GROUP #4--INDUSTRIAL COLLABORATION AND TECHNOLOGY TRANSFER

Beth Starbuck *(Co-chair)*--Associate Director of Technology Transfer, Center for Interfacial Engineering, University of Minnesota

James Williams *(Chair)*--Operations Director and Industrial Liaison Officer, Data Storage Systems Center, Carnegie Mellon University

William Michalerya--Manager of Industrial Liaison & Technology Transfer, Center for Advanced Technology for Large Structural Systems, Lehigh University

Nicholas Zelver--Director of Industrial Relations, Biofilm Engineering Research Center, Montana State University

Richard Lucic--Director of External Affairs, Center for Emerging Cardiovascular Technologies, Duke University

Amine Hajji--Senior Technical Staff Member, Storage Systems Division, Servomechanical Development, IBM Corporation

Georgette Demes--then Executive Director for Outreach, Engineering Design Research Center, Carnegie Mellon University

WORKING GROUP #5--ADMINISTRATIVE MANAGEMENT

Bret Chen--then Business Manager, Particle Engineering Research Center, University of Florida

Audrey Jones Childs--Administrative Manager, Center for Biotechnology Process Engineering, Massachusetts Institute of Technology

Darlene Joyce *(Chair)*--Associate Director for Admininstration, Center for Interfacial Engineering, University of Minnesota

Penny LeBourgeois *(Co-chair)*--Assistant Director, Center for Advanced Electronic Materials Processing, North Carolina State University

Sue Lewis--Executive Admininstrative Director, Integrated Media Systems Center, University of Southern California

Susan Price--Operations Manager, Center for Computational Field Simulation, Mississippi State University

Buz Smith--Budget & Financial Officer, Center for Optoelectronic Computing Systems, University of Colorado

Alma Weightman--Operations Manager, Biofilm Engineering Research Center, Montana State University

WORKING GROUP #6--THE NSF/ERC INTERFACE

Jack Bowe--Deputy Director, Center for Advanced Technology for Large Structural Systems, Lehigh University

John Hurt--Program Director, Engineering Education and Centers Division, Directorate for Engineering, National Science Foundation

Lynn Preston *(Chair)*--Deputy Director and ERC Team Leader, Engineering Education and Centers Division, Directorate for Engineering, National Science Foundation

Marianne Hassan Risley *(Co-chair)*--Administrative Director, Center for Emerging Cardiovascular Technologies, Duke University

J. Donald Trotter--Director, Center for Computational Field Simulation, Mississippi State University

Daniel I.C. Wang--Director, Bioprocess Engineering Research Center, Massachusetts Institute of Technology

Appendix B: ERC Program Officers and Staff (in 1999)

ERC Program Leadership:

Ms. Lynn Preston, ERC Team Leader, 1988-92, 1994 to the present (Deputy ERC Program Coordinator, 1984-88)

ERC Program Directors:

Ms. Cheryl Cathey, 1997 to the present

Dr. Lawrence Goldberg, 1999 to present

Dr. Rajinder Khosla, 1999 to present

Dr. Tapan Mukherjee, 1987 to the present

Dr. John Hurt, 1994 to the present

Dr. Joy Pauschke, 1994 to the present

Dr. Deborah Crawford, 1996 to the present

ERC Program Staff

Ms. Mary Poats, Manager Diversity Initiative, 1989 to the present

Dr. Linda Parker, Manager, Evaluation, and consultancies, 1992 to the present

ERC Program Assistants

Ms. Gloria Aguilar, 1998 to the present

Ms. Darlene Suggs, Senior ERC Program Assistant, 1986 to the present

Ms. Sheronda Murphy, 1996 to the present

ERC Program Consultant

Mr. Courtland S. Lewis, Publications and ERC Association, website manager

Subsequent Contributors (new chapters and updates)
