ERC for Hybrid Autonomous Manufacturing Moving from Evolution to Revolution (HAMMER)

The Ohio State University (lead institution)

Revolutionizing US manufacturing by pioneering and implementing hybrid processes to develop intelligent autonomous manufacturing systems

HAMMER ERC

A National Science Foundation Engineering Research Center since 2022

Partner Institutions:

- ***Case Western Reserve University***
- ***North Carolina Agricultural and Technical State University***
- ***Northwestern University***
- ***University of Tennessee-Knoxville***

Vision

HAMMER will lead the development and deployment of Hybrid Autonomous Manufacturing, revolutionizing American production supply chains. This will provide the societal benefits of fulfilling jobs, reducing carbon emissions, strengthening supply-chain robustness, and speeding local innovation.

Objectives

HAMMER will create a multi-process, intelligent, autonomous approach to local manufacturing that is unified and inclusive based on the following research benchmarks and objectives that require collective effort across the Center to achieve:

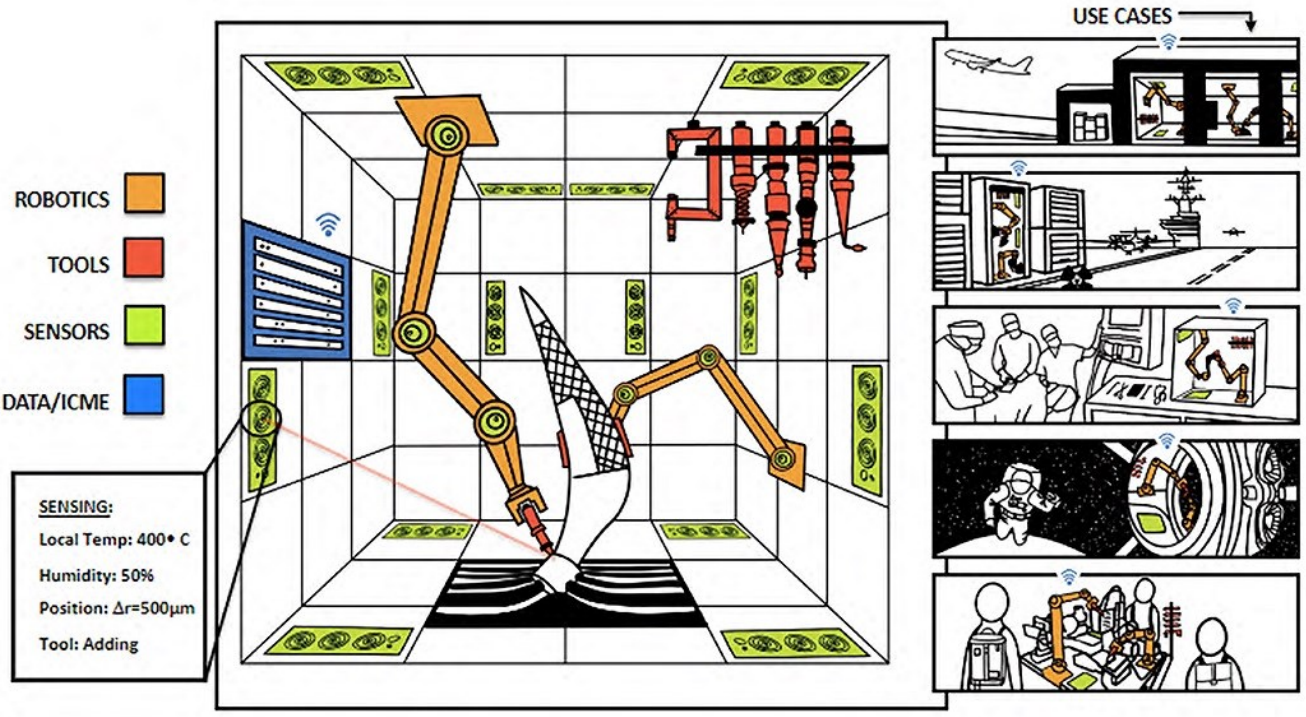
1. *Concurrently design products and manufacturing processes.*
2. *Develop and integrate new approaches for workholding and tooling for numerically controlled deformation processing (e.g. robotic blacksmithing) so that components can easily be transferred to/ from other processes (e.g. CNC machining), enabling new types of hybrid manufacturing.*
3. *A unified modeling approach focused on material state and evolution that integrates multiple manufacturing processes which, when properly validated through experiment, can serve as the basis for certification and quality assurance.*
4. *Develop Artificial Intelligence (AI) enhanced control methods that will allow robots to control currently high-touch processes, assess multiple possible process plans for manufacturing a product, and select options on the Pareto front. AI systems will learn, improve, and share insights among Autonomous Factory/ Artisan Boxes (Auto-FABs).*
5. *Deploy hands-on learning tools, including PET-FABs (Physical Education and Training Factory/ Artisan Boxes) for training & educating to community colleges, workforce development centers, and universities, with a focus on including underrepresented groups.*

Achieving this vision will enable Manufacturing for Design (i.e., design of the fabrication work path to ensure design-required or custom functionality)—a revolutionary shift in distributed manufacturing, with a new generation of equipment, new business models, and new methods of quality control. These will enable a much more responsive, robust, and secure industrial base that will empower the United States to (re)capture a large share of the world market for fabricated structural components and related products.

RESEARCH

HAMMER will perform fundamental engineering research to create the new knowledge needed to achieve hybrid autonomous manufacturing. The research will be focused in four major thrust areas with specific objectives/milestones in each thrust. The research thrusts will largely be aligned with and supported by the NSF ERC Program investment. Testbeds are aligned with industry, focused on specific opportunities. Issues raised in the testbeds will often become topics for the more formal research agenda.

Thrust 1—Design: Led by Northwestern University (NU), this thrust will develop a comprehensive system-level design method that can concurrently design material, topology, and flexible manufacturing process sequences.



AutoFab – Autonomous Factory/Artisan box; multi-tool operations, sensing, control and learning. (Credit: HAMMER)

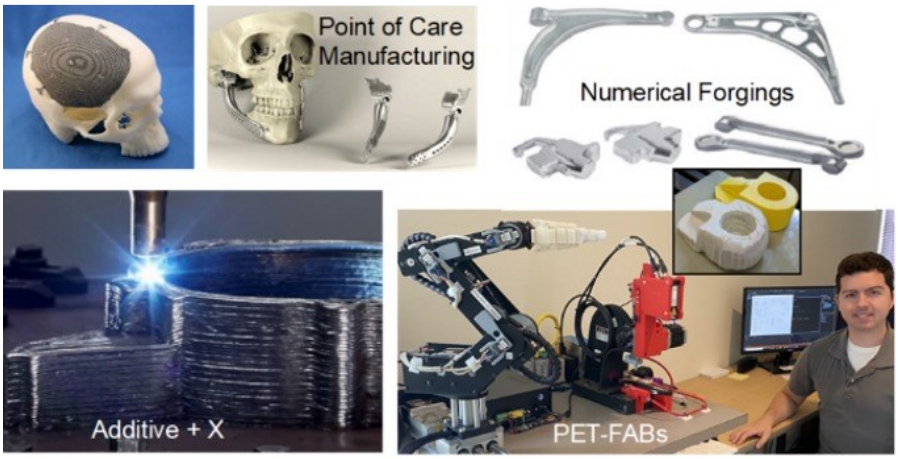
Thrust 2—Tools and Process Convergence: Led by University of Tennessee-Knoxville (UTK), this thrust will develop the underlying framework for design of novel machines and control strategies for individual processes and the sequencing and transfer from one process to another.

Thrust 3—Materials State Awareness: Led by Ohio State University (OSU), this thrust will develop materials modeling capabilities, calculate and manage expected values and uncertainty in the materials properties and response of the manufactured part, and develop regulatory and quality control strategies for autonomous manufacturing.

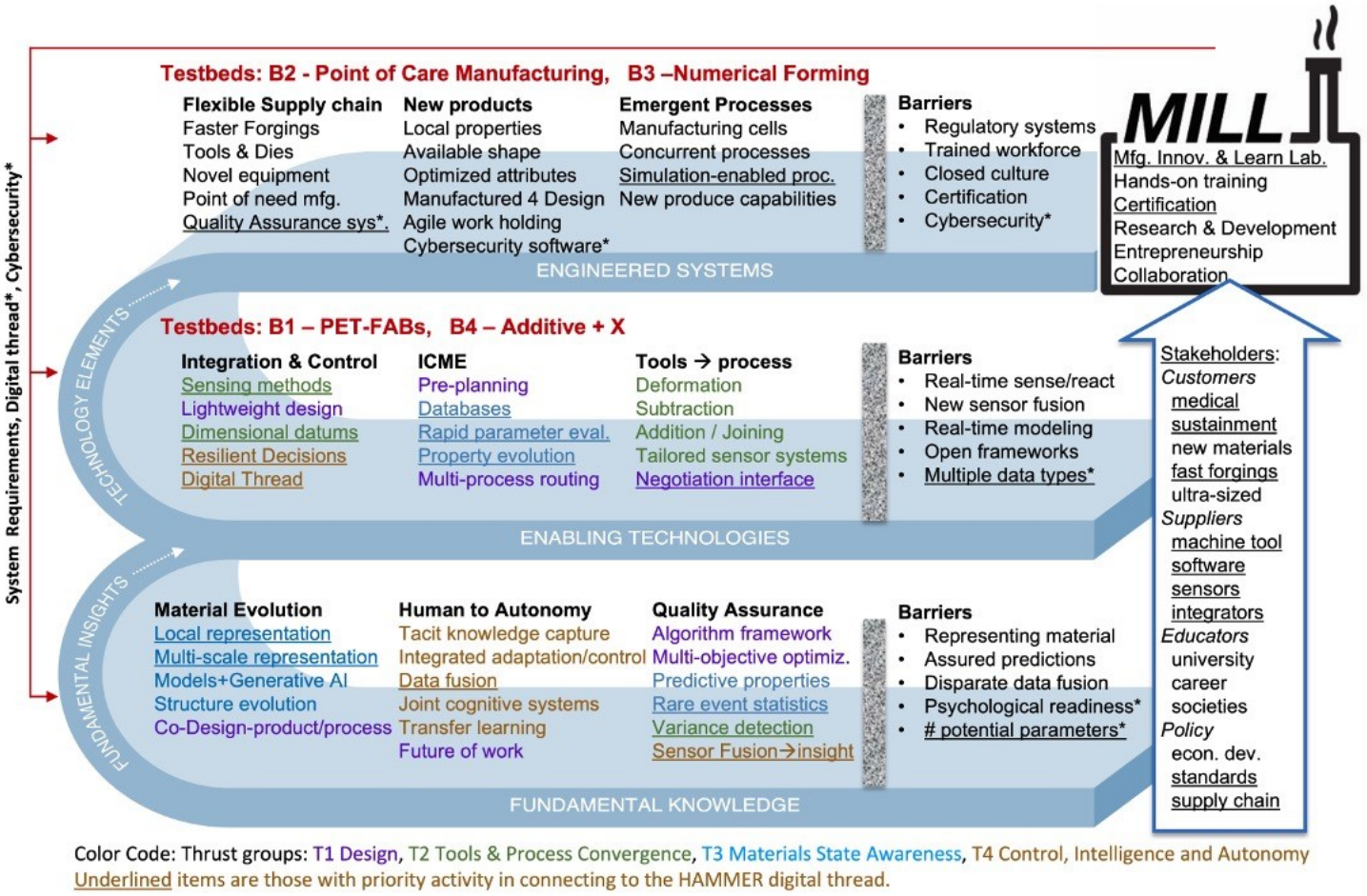
Thrust 4—Control, Intelligence, and Autonomy: Led by Case Western Reserve University (CWRU), this thrust will improve process intelligence to enable autonomous control of a diverse set of complex manufacturing processes that include self-correcting strategies for realizing the target shape, material properties, and functions.

HAMMER Testbeds will have four initial foci:

Testbed 1—PET-FABs (Physical Exploration and Training Factory/Artisan Boxes): Led by North Carolina A&T State University (NCA&T), PETFABs are minimally viable, low-cost manufacturing cells incorporating robots, dimensional and temperature field sensing, Programmable Logic Controllers (PLCs), and computation with a modular design to easily add new process modules. Primary uses are for education and to prototype new features emerging from research. Development of the PET-FAB platform is an essential early focus.



HAMMER Testbeds, emphasizing near-term impact (Credit: HAMMER)



3-Plane Diagram showing breadth of Convergent Research program (Credit: HAMMER)

Testbed 2—Point-of-Care Manufacturing (POCM): Led by OSU, the POCM testbed will focus on manufacturing personalized medical devices and implants (such as metal skeletal fixation plates used in reconstructive surgery). Starting with simpler operations such as numerically bending homogeneous skeletal fixation plate preforms, the work will progress to increasingly complex fabrication techniques including additive manufacturing coupled with deformation and machining.

Testbed 3—Numerical Forming: Led by CWRU, this testbed will use advanced incremental forming to produce three-dimensional structures that meet location-specific material properties and performance metrics. Processes will include thermal energy and multiple modes of forming, such as English wheels and local stretchers.

Testbed 4—Additive + X: Led by UTK, this testbed will combine spatial control of chemistry and structure in additive processes with use of thermomechanical processing to refine, align, and densify material to create components with unprecedented combinations of local properties.

EDUCATION

HAMMER's strategy for workforce development is multi-faceted. First, PET-FABs serve as low-cost platforms for project-based student training. Second, Manufacturing Innovation and Learning Laboratories (MILLs) will be created to showcase emerging technologies, engage researchers, students, and practitioners, and spur private investment. Third, asynchronous modules will be developed for training and certification of community/vocational college instructors in a concerted effort to train trainers. Fourth, programs and for K-14 educators will be developed and broadly disseminated. Finally, new university-level courses and specializations will emerge from the research program.

DIVERSITY AND CULTURE OF INCLUSION

In all of its activities—R&D, workforce development, technology commercialization, etc.—HAMMER will aggressively attract participation of Underrepresented Minorities (URMs). NCA&T, an HBCU, will play a key role in providing a pipeline of minority engineers, technicians, and computer scientists. HAMMER will work closely with the national GEM Consortium to increase participation of URMs in HAMMER's research at the masters and doctoral levels. HAMMER will use training and leadership by example to ensure that a culture of diversity and inclusion is developed and maintained. Active recruitment and mentoring of new minority faculty, with opportunities to move into leadership roles at HAMMER, will be used to ensure continued diversity and a culture of inclusion.

INNOVATION ECOSYSTEM

A culture of collaboration between partners on research and testbeds will build an effective innovation ecosystem that engages all the necessary disciplines. HAMMER has a multi-tiered engagement model: at the most open level, anyone with interest can see many of the results through publications, participation in HAMMER-Time and other open events. Low-cost memberships will allow participation in live meetings and interaction with students and the ecosystem. The Technology Leader membership level gives companies direct influence in project selection and a favored position for intellectual property (IP) licensing. This group of companies will comprise the Industry Advisory Board.

At the deepest level of engagement, an allied 501(c)(3) is being established for technology de-risking and diffusion. It will develop a coordinated portfolio of related technologies and will have a mandate to cement hybrid autonomous manufacturing technologies in the United States. This business model will allow agile decision making and maximize the value and use of collective invention of the HAMMER technical team.

FACILITIES

HAMMER's core facilities are in the heart of OSU's innovation District, Carmenton.

Each of the partners has committed to making relevant facilities available through the HAMMER MILL programs. Other Ohio State University facilities include: The Artificially Intelligent The Focal point at Ohio State is the Center for Design and Manufacturing Excellence (CDME) at OSU houses over $12M worth of manufacturing equipment which can be used by HAMMER members. Other OSU assets include: the Artificially Intelligent Manufacturing System (AIMS) Lab; NSF I/UCRC: Manufacturing & Materials Joining Innovation Center (Ma2JIC); Center for Electron Microscopy and Analysis (CEMAS); and the Nanotech West Labs.

CWRU is home to The Institute of Smart, Secure and Connected Systems (ISSACS), Advanced Manufacturing and Mechanical Center (AMMRC), and Think[box].

NCA&T is home to the graduated NSF ERC Revolutionizing Metallic Biomaterials which built world class facilities for the production, processing (casting, extrusion, shear rolling, etc.) characterization (microscopy, corrosion, microtomography) and testing of biomedical materials.

NU is home to the Advanced Manufacturing Processes Laboratory (AMPL), Advanced Intelligent Manufacturing Laboratory (AIML), CHiMaD Metals Processing Facility, NUANCE Center, Metrology Laboratory, The Metallography and Material Mechanical Properties Characterization Facilities and the Jerome B. Cohen X-ray Diffraction Facility. NU houses many open-architecture and in-house designed flexible metal forming instruments and metal additive manufacturing.

UTK has access to the Oak Ridge National Laboratory Manufacturing Demonstration Facility and is home to the Innovation Collaboration Studio (ICS), Engineering Services (ESF) Fibers and Composites Manufacturing Facility (FCMF), Institute for Advanced Materials and Manufacturing (IAMM), Machine Tool Research Center, Polymer Printing Lab, The CNC machining capabilities, MABE Advanced Welding Laboratory, Mechanical Aerospace and Biomedical Engineering (MABE) Maker Lab.

CENTER CONFIGURATION, LEADERSHIP, TEAM STRUCTURE

HAMMER is led by Ohio State University in close collaboration with Case Western Reserve University, North Carolina A&T University, Northwestern University, and the University of Tennessee–Knoxville. The team contains recognized world leaders in the fields of materials science, mechanical engineering, industrial systems engineering, welding engineering, statistics, and sociology. HAMMERS's faculty will also engage closely with graduate students, undergraduate students, and post-docs to cultivate and build the next generation of leaders in their fields.

CENTER HEADQUARTERS

273 Bevis Hall
1080 Carmack Road
Columbus, Ohio 43210
Ph: 614-292-0767

hammer@osu.edu

HAMMER NSF ERC Director
Prof. Glenn S. Daehn • daehn.1@osu.edu

HAMMER NSF ERC Associate Director
Prof. Steve Niezgoda • niezgoda.6@osu.edu

HAMMER NSF ERC Administrative Director
Ms. Kathleen Babusci • babusci.5@osu.edu

https://hammer.osu.edu/