

## Request for Proposals – Fall 2021

### I. Proposal Objectives

Carnegie Mellon University's Manufacturing Futures Institute (MFI) is requesting research proposals from teams of two or more faculty members that align with the MFI mission to inspire, engineer and lead technological and workforce advances for agile, intelligent, efficient, resilient and sustainable manufacturing.<sup>1,2</sup> MFI seeks to support research projects and associated infrastructure that will advance the digital transformation of manufacturing and enhance the requisite human workforce. Projects should address technical challenges, need for informed policy, future workforce issues and opportunities or combinations of these. Such complex problem spaces benefit from convergent research where knowledge, methods and expertise are pulled from different disciplines within the team. The appropriate infusion of modern-era information technologies into manufacturing environments holds the potential to create new paradigms and policies when merged with advanced manufacturing technologies. Simultaneously, this digital transformation of manufacturing disrupts conventional manufacturing career pathways and creates both issues and opportunities.

Via an annual Request for Proposals (RFP), the research program seeks to achieve overarching strategic objectives that center on the growth and long-term sustainability of the institute. These strategic objectives are 1) to achieve critical mass in strategic priority research areas, 2) to seed future innovation, 3) to converge and leverage CMU's strengths, 4) to externally partner for relevance and 5) to activate the Mill 19 facility.

*Achieve Critical Mass in Strategic Priority Research Areas:* CMU is not large enough to be excellent in every aspect of every discipline, and instead has established both excellence and relevance by maintaining the cultural agility to make big bets in areas that matter. Cultivating CMU MFI as a leading academic organization for advanced manufacturing discovery and innovation dictates an objective to build convergent research communities with a critical mass of activity in strategic priority areas. Project concepts should fall into one or more of the current MFI strategic priority research areas listed in Section II. While certain strategic areas, such as additive manufacturing, already enjoy critical mass of activity, there is room for cross-fertilization with other areas to grow overall impact. Other strategic areas are beginning to emerge at CMU, such as the digital twin/digital thread. Still other strategic areas, such as intelligent robotics, have a large base of activity at the university, but relatively little overlap with manufacturing needs and applications. The areas are quite broad in scope. Specific project ideas, for example, manufacturing process

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<sup>1</sup> More information on the mission and long-term outcomes of the institute are provided in Section VII.

<sup>2</sup> Background information on MFI and its programs is found on the institute's website, <https://engineering.cmu.edu/mfi/>.

development or policy studies, may fall into one or more of these areas by linking to aspects that apply to the process innovation or to the policy study.

*Seed Future Innovation:* The MFI strategic priority research areas create top-down guidance across relatively broad thematic areas. In concert, CMU is known for its organic bottom-up culture of innovation and discovery. MFI's intent is to have these forces be synergistic with an objective to seed the future of advanced manufacturing with new ideas and cross-cutting teaming that fuel innovation and attract future investments. Proposers may want to consider, for example, how to fuse academic strengths and concepts in strategic priority research areas in new and creative ways. Ideas may be so compelling as to seed new efforts in advanced manufacturing that do not neatly fall into any of the strategic priority research areas. Those proposals are also solicited and considered.

*Converge and Leverage CMU's Strengths:* Manufacturing is a broad application area in current, albeit slow, transformation to embrace a full merger of manufacturing technologies, information technologies and the human workforce. An objective is to incentivize CMU researchers across all disciplines to form teams that address the problems and opportunity spaces in advanced manufacturing. In particular, an objective is to connect to CMU strengths in artificial intelligence (AI), machine learning, robotics, additive manufacturing, autonomy, internet of things, cybersecurity, technology-informed policy, learning science, economics, and future of work. This list is by no means an exhaustive list of CMU strengths, but rather is meant to be descriptive. These strengths drive innovation within the framework of the MFI strategic priority research areas and these academic strengths tend to cut across all of the areas.

*Externally Partner for Relevance:* A key component of MFI is to connect the research efforts with industry-relevant outcomes. Across all MFI programs, partnerships with organizations outside of the university will hone the societal impact of the research and will help in identifying problems having industry relevance. Therefore, an objective is to establish and grow relationships and partnerships with industry, government agencies, the Advanced Robotics for Manufacturing (ARM) Institute and other Manufacturing USA institutes, and Catalyst Connection and other economic development organizations focused on advanced manufacturing.

*Activate the Mill 19 Facility:* CMU has invested in Mill 19 at Hazelwood Green, an off-campus advanced manufacturing research facility. An objective of this funding program is to activate Mill 19 by having research leverage the existing facilities, by adding or augmenting shared research capabilities, and by enabling side-by-side partnerships with external organizations that better enable the research. The facility space includes high bay area, large contiguous and agile project cell spaces, space for large manufacturing equipment, embedded personnel dedicated work space, dedicated collaborative project space, and a shared infrastructure incubation space and conferencing space. The opportunities exist to collaborate side-by-side with industry on sponsored research projects, to showcase innovations (e.g. technologies and equipment), to de-risk technology through maturation, to integrate technologies with partners such as the ARM Institute, and to provide advanced workforce training opportunities with partners such as Catalyst Connection.

Projects are intended to seed and initiate exciting research collaborations that address the MFI objectives described above, when considered as one part of the portfolio of projects. Proposed research must demonstrate a clear fit with most, if not all, of these strategic objectives. Selected projects are expected to evolve into efforts that lead to convergent research clustering and where this short-term investment from MFI helps increase the investigators' prospects of winning subsequent externally sponsored awards. Proposals connected to research areas already having critical mass and large-scale external funding may benefit from a connection to adjacent strategic priority research areas poised for growth to be competitive

for this current opportunity. Proposals that are simply requesting funding to continue an existing and/or mature line of work will receive lower priority.

Preference will be given to proposals that involve multiple investigators and multidisciplinary interactions (cross-college and/or interdepartmental). Partnering with industry or relevant non-profit organizations such as Manufacturing USA institutes (e.g. the ARM Institute) or with regional economic development organizations (e.g. Catalyst Connection) in the form of direct or in-kind support or other collaboration will be considered. Cooperation and coordination across one or more MFI project proposals or existing synergistic projects will be considered when it increases the likelihood of meeting the strategic objectives.

## **II. MFI Strategic Priority Research Areas**

The current MFI strategic priority research areas are described below. Example project areas are also given. Please note that the examples are not intended to make up an exhaustive list nor be interpreted as endorsement for selectability.

*Advanced Additive Manufacturing:* Additive manufacturing is a successful cluster area of research, led by the NextManufacturing Center with significant funding from the NASA University Leadership Initiative (ULI) and the Army Research Laboratory “AI Enabled Additive Manufacturing” program with a strong focus on additive manufacturing of metal parts, as well as funding from NSF and other sources supporting 3D printing of soft and biological materials. Proposed projects associated with additive manufacturing should focus on new aspects not covered by other funding sources, including advancing fusion with other strategic priority research areas as motivated by innovative outcomes. Projects that exploit the unique capabilities of the additive manufacturing facility at Mill 19 are also encouraged. Example new aspects might include robotic process development for scale, safety, quality and/or yield; digital twinning of additive equipment for factory-level AI exploitation; new methods to integrate electronics additive with metal or polymer additive manufactured parts; and mixed reality environments for additive part inspection.

*Intelligent Robotics for Manufacturing:* Robotics is one of the largest research fields at CMU and is recognized internationally for excellence. However, relatively little robotics research at CMU is currently directed toward manufacturing applications and corresponding industry-relevant challenges and inclusive of manufacturing processes, product assembly, inspection, logistics and manufacturing for sustainability. CMU is well positioned to make robots more intelligent in such manufacturing applications. Example new aspects might include robots that robustly handle uncertainty in industrial manufacturing application(s); safe, efficient, and robust human-robot or multi-robot cooperation in manufacturing; and robot learning for rapid setup and/or adaptation. Projects that include partnering with ARM consortium members toward competitive future ARM proposals or other external funding are encouraged. Projects that propose partnering with the ARM Institute through research engagement with their AI Data Foundry infrastructure are also in scope (see separate download for additional information).

*Manufacturing Digital Twins and Digital Threads:* Digital twins and digital threads act as a basis for application of AI to improve broad aspects of manufacturing, yet the concepts have not yet gained extensive traction in academic research. CMU with its strengths in most aspects of digital twin systems is well positioned to lead in this area. “The Digital Twin is meant as the virtual and computerized counterpart of a physical system that can be used to simulate it for various purposes, exploiting a real-time synchronization

of the sensed data coming from the field.”<sup>3</sup> The digital twin construct may apply to a part, a product, a process, equipment, a factory, or even a supply chain. A digital twin system, when paired with the physical twin including industrial internet-of-things (IIoT) and networking for data capture, is one example of a cyber-physical system. “Digital thread is a mechanism for correlating information across multiple dimensions of the virtual representation, where the dimensions include (but are not limited to) time or lifecycle stage (including design intent), kind-of- model, and configuration history .”<sup>4</sup> *Product digital twins* may, for example, generate insights for next-generation product design and better position products in the market. *Production digital twins* may, for example, optimize production scheduling routing and asset operation, and can be used for virtual commissioning of manufacturing systems. *Operation (or service) digital twins* may monitor, troubleshoot, diagnose, detect and isolate faults and failures, may predict maintenance scheduling, and may trace issues for security and legal compliance. *Sustainability digital twins* may optimize pathways for product disassembly, disposal and recycling. While there exists substantial marketing in industry on these topics, research opportunities abound, with some potential examples being methodologies for easier creation of digital twins, digital twin interoperability, application of IIoT, edge computing and networking for low-latency data capture and feedback, deployment of augmented/mixed reality systems as real-time factory interfaces, and cybersecurity of the increased attack aperture in advanced manufacturing environments.

*Generative Manufacturing:* The concept of generative manufacturing is analogous to generative design, which is an iterative exploration process driven by AI to generate design solutions. Generative manufacturing aims to evolve this process further by the automated synthesis of optimal manufacturing options based on user requirements and real-time business requirements and constraints, along with automated and resilient manufacturing execution with human workers. As an example of one conceptual vision, an adaptive factory compiler instructs, orchestrates and coordinates workers and machines with just-in-time guidance, while adapting real-time to feedback from digital twin systems of the workers, machines and factory. Research challenges, for example, may include generative manufacturing methodologies and practical demonstrations, general, readily extensible, frameworks for automated orchestration of machines and workers, along with the overlapping challenges in developing the underlying digital twin systems.

*Future of the Manufacturing Workforce:* Advanced manufacturing technologies, particularly the expected growth in adoption of robotics, artificial intelligence and additive manufacturing, are creating new jobs in new career pathways and driving new sets of building blocks as part of necessary skillsets for the corresponding manufacturing workforce of the future. The increased adoption of automated and autonomous technologies will displace many manufacturing tasks currently being performed by workers. Example research on meeting the challenges related to the future manufacturing workforce may include studies to uncover the causes for the relatively low pipeline of workers in training for high-paying manufacturing skills under high demand (e.g. welding), to identify future career pathways and skillsets for new manufacturing jobs (e.g. additive manufacturing, AI, digital twinning), and to assess the impact of adoption of advanced manufacturing technologies on workforce diversity, equity and inclusion. Large-scale manufacturing research opportunities funded through NSF generally require a convergent research approach that incorporates consideration of workforce implications; projects that develop such convergent

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<sup>3</sup> Elisa Negri et al., “A review of the roles of Digital Twin in CPS-based production systems,” *Procedia Manufacturing* 11 ( 2017 ) 939 – 948 (Politecnico di Milano), <https://doi.org/10.1016/j.promfg.2017.07.198>

<sup>4</sup> Digital Twin Consortium, <https://www.digitaltwinconsortium.org/glossary>

research teaming in advance of these opportunities are encouraged. Along with internal CMU collaborations across disciplines, partnering with organizations such as the ARM Institute who are developing these career pathways, with small and medium manufacturing service providers such as Catalyst Connection, with community colleges who provide vocational training, and/or directly with manufacturers may be appropriate to inform and ensure real-world relevance of proposed research.

### **III. Expected Funding Amount, Period of Performance, and Eligibility**

MFI is seeking research project proposals that are one-year in duration and has plans to fund 8-12 projects with a combined program budget of up to \$1.0 M. The funding amounts represent the total amount available to projects (without administrative or F&A burden). MFI reserves the right to select fewer projects and commit less than the projected funding level, dependent on the number of proposals meeting objectives and availability of funds.

Additional funds are available for shared research testbeds that augment the proposed effort. Such testbeds are required to be located at Mill 19, and are expected to be extensible, modular, and flexible with the aim of catalyzing integrative research involving projects that cut across strategic thrust areas. Proposals that request testbed funding should include letters of support from faculty outside of the core project to indicate and gauge the potential for effective shared use. Coordination of testbed capabilities across proposed projects and/or existing externally funded projects is allowable and exploration of such opportunities are encouraged.

This solicitation is open to all CMU faculty members. For informational purposes, a listing of faculty members currently affiliated with MFI can be found on the MFI website People page:

<https://engineering.cmu.edu/mfi/directory>.

Research projects previously funded by MFI can be viewed on the MFI website Research page:

<https://engineering.cmu.edu/mfi/research>.

### **IV. Application Process and Timeline**

Investigators must prepare proposals using the format and templates provided. Submissions as Principal Investigator (PI) are limited to one per person (not precluding participation on other proposals).

Proposals are due by 5:00 pm on Friday, November 19, 2021 and awards are expected to be announced by Friday, January 14, 2022. Proposals must be submitted at [this link](#).

MFI will convene an [informational session via Zoom on Thursday, October 21, 2021 at 4:30 pm](#) to describe this request for proposals opportunity and to field questions. We cannot a priori answer “is my project idea good”, however we will provide guidance on project concepts being within the MFI scope and mission and their potential for alignment to thematic areas. Please send questions to [CMU-MFI@andrew.cmu.edu](mailto:CMU-MFI@andrew.cmu.edu). We will post frequently asked questions and responses on the [MFI RFP website](#).

Proposal Format:

- Technical section must use the template provided and comprise a one-page cover sheet and a technical narrative that is four pages maximum, including all tables and figures.
  - Use 1 inch margins on all sides.
  - Font is 11-point Times Roman type or equivalent, no less than single spaced.
  - Fonts on tables and figures are no smaller than 10-point Times Roman type or equivalent. Figure captions should not be used to skirt text format constraints.

- Budget must use the template provided and does not count toward the technical page count.
- Support letters from external partners and/or from CMU investigators that are collaborating or otherwise benefit from the project (does not count to page count; however each support letter is limited to one page).

The Technical Proposal Template is available at the application link and includes the following:

**Cover Sheet** (one page)

**Proposal Title**

**PI:** name, department

**Co-PI(s):** name(s), department(s)

**Business Manager(s):** name, department(s)

**Research Area(s):** Specify from list of strategic priority research area(s) or “Other” (describe)

**Partner Organization(s):** List partner organizations, if any

**Total Requested Budget:** \$00,000

**Project Description:** Provide a description of the proposed activity that outlines the concept to be explored and/or problem to be addressed. Summarize innovative claims to the research. Explain why the project is important to the mission of MFI and relevant to the future of advanced manufacturing. The description must include clear project objectives and the plan with quarterly target milestones to achieve those objectives. Briefly outline other related, applicable work and explain what is different and new about the proposed project.

**Outputs and Metrics:** List the expected outputs (e.g. specific direct results, software, data sets, methodologies, testbeds, demonstrations, human subject studies) and corresponding metrics to measure success. Explain how the expected outputs demonstrate concept viability and/or advance technology readiness for further maturation when addressing industry-relevant problems.

**Intended Societal/Economic Impact (Outcomes):** Describe the downstream outcomes or changes you intend to achieve from a successful project, and how the outputs from the project support those outcomes. Describe the project’s potential for social and economic impact, e.g. broadly for U.S. manufacturing and, if applicable, for the Greater Pittsburgh Region. Explain who will ultimately benefit from the project outcomes and why they benefit.

**MFI Strategic Impact:** Describe how the project contributes to one or more of the MFI strategic priority research areas or otherwise seeds a new area with potential for significant multi-investigator activity and long-term growth and contributions in the future. Explain how the results from the project act as part of a larger foundation of knowledge within the chosen strategic priority research area(s). Describe, if applicable, how the project leads to expanded follow-on research activity and attracts further investigators or partners to the area.

**Teaming and Expertise:** Describe the partitioning of work among the team aligned to and justified by specific expertise. Include identification of cross-college and/or cross-department collaboration and any partnering with organizations outside the university. (Use of MFI funding for effort from outside organizations is not permitted).

**Leverage of CMU Strengths and Partnering:** Describe how the effort taps into CMU's strengths in particular relevant academic areas. Describe the closest related work currently underway at CMU by the team (clarifying the uniqueness of the proposed project). Also, describe the prospects for matching or in-kind support that can amplify the impact of the grant. Disclose other pending proposals, internal or external. Discuss what specific sources may be sought for future support.

**Activation at Mill 19:** If applicable, describe what aspects of your proposed project positively impact and/or leverage potential activities and/or capabilities at Mill 19. If applicable, describe any proposed new or augmented facilities or capabilities at Mill 19 (e.g. a shared testbed), how the project benefits, and how these facilities help meet the overall program objectives.

**Budget (not part of technical section page count and using separate budget template):** Provide a budget and justification appropriate for the proposed scope of work using the provided budget template to be uploaded separately. The period of performance should be no more than one year and start on/after February 1, 2022 and end by January 31, 2023. Describe any committed cost share from partners (e.g., industry) if applicable.

**Support Letter(s) (not part of technical section page count):** If applicable, include support letters from any collaborative external partners and/or CMU principal investigators of synergistic projects, confirming their engagement in the proposed project. (Do not include letters from co-investigators on your MFI proposal.) If applicable, include support letters from partners and/or CMU principal investigators of other projects that would benefit from the proposed new or augmented facilities or capabilities. Letters from external partners should specify direct or in-kind cost share, if any, being contributed toward the project. Support letters should not include information about the proposed technical project, aside from confirmation of content in the proposal, so as to not skirt the technical section page count.

## **V. Proposal Evaluation**

Proposals will be evaluated by ad-hoc reviewers, primarily CMU faculty members without a conflict of interest. Final approval of grant awardees will be made by MFI Leadership.

While all proposals will be treated as confidential with respect to protecting investigator ideas, we reserve the right to be proactive with facilitating development. For example, depending on the ideas we receive, we may approach investigators to explore possible alternative or additional collaborations when it might add valuable new perspectives to a project. We may ask investigators to revise proposals prior to funding, based on reviewer feedback. We may request to bundle two or more projects as part of a larger coherent thematic thrust.

The review scoring criteria is multi-faceted. It is likely that proposals will score highly on some criteria and lower on other criteria due to the limited scope and funding of the proposals. Review scoring is based on the extent to which the project meets the following criteria:

- *Mission alignment (10 %):* The project aligns with the MFI mission to inspire, engineer and lead technological and workforce advances for agile, intelligent, efficient, resilient and sustainable manufacturing.
- *Achieves critical mass in strategic priority research areas (15 %):* The project helps to achieve critical mass in one or more of the MFI strategic priority research areas, including e.g. creating linkages between other projects that may seed research clustering. The project helps as a building block in competing in the future for larger external funding.

- *Seeds future innovation (15 %)*: The project seeds future innovation with new ideas and cross-cutting teaming that fuel innovation and attract future investments. e.g. by investigating new manufacturing-relevant areas of discovery, and by addressing industry-relevant problem(s).
- *Converges and leverages CMU's strengths (15 %)*: The project leverages CMU's academic strengths and converges disciplines through teaming and partnering and/or augments conditions that lead to construction of convergent research teams. Involvement of at least two investigators interacting across different disciplines (cross-college and/or interdepartmental) is required.
- *Partnering for relevance (15 %)*: The project team partners with external industry and/or other organizations toward manufacturing-relevant outcomes and/or augments conditions that lead to future external partnering.
- *Activating Mill 19 (15 %)*: The project results will activate the Mill 19 facility, e.g. by leveraging capabilities, and/or by developing and using new capabilities and/or testbeds, and/or through collaborative partnering with the ARM Institute or Catalyst Connection. If applicable, proposed testbed development is extensible, modular, and/or flexible to be useful to other/related MFI research.
- *Management Plan (5 %)*: The project will result in tangible expected outputs, e.g. demonstration of concept viability, with clear plan, milestones and timeline.
- *Expertise (5 %)*: The expertise of the team has the fit and quality to lead to project success.
- *Budget (5 %)*: Budget reasonableness (e.g., the proposed work and outcomes can be accomplished within the budget).

## VI. Awarded Project Requirements

If accepting an award, PI award recipients will be required to:

- Request team members attend monthly MFI meetings, when available
- Ensure team leadership is participating in MFI technical thrust meetings, when applicable
- Submit quarterly reports outlining the progress of the project and its financial status
- Include a project overview Power Point slide at the time of award and with each quarterly report. This slide highlights the project aspects and major results
- Present project progress and status once every six months at MFI project review meetings
- Provide summary and presentation information upon occasional request for reporting to the Richard King Mellon Foundation
- Present project progress to the MFI community in a rotating basis at MFI monthly meetings, working into schedule and availability (no more than once a semester)
- PIs may be called upon to present their work on an as-needed basis throughout the year. For example, we plan to hold the Manufacturing Futures Forum annually where MFI thematic areas, project results and demonstrations will be highlighted. PIs may also be called upon to present or demonstrate their project(s) at MFI events involving industry executives and government leaders.

Intellectual property (IP) developed under the projects remains under the default, standard terms of the university, unless otherwise waived by the university.

## VII. MFI Mission and Long-Term Outcomes

**Mission:** The mission of the Manufacturing Futures Institute (MFI) at Carnegie Mellon University is to inspire, engineer and lead technological and workforce advances for agile, intelligent, efficient, resilient and sustainable manufacturing. We own a culture of collaboration and activate across disciplines to create



and conduct groundbreaking research, to educate manufacturing innovators and leaders, to accelerate research translation into industry relevant applications, and to engage and partner with our communities.

**Long-term Outcomes:** MFI is funded through a generous grant by the Richard King Mellon Foundation. The long-term outcomes (3-10 years) expected of the institute through this grant are mapped into general categories as follows:

*Partnering for Impact:*

Raised visibility and awareness of the new Institute increases engagement in MFI opportunities and broad participation of faculty, research staff and students across departments and colleges at CMU.

A growing number of collaborative projects with industry, ARM and Manufacturing USA Institutes to transition research to commercialization increases the regional and national impact of MFI.

Demonstration of unique manufacturing advancements and of MFI's unique capabilities in collaborative and integrative research, stemming from research testbed(s) supporting the integration of advanced manufacturing technologies, feeds the reputation for MFI and Mill 19 and aids competitiveness for sustaining further advances.

*Mill 19 Activation:*

MFI seeded facilities, research projects and related activities attract industry partners to Mill 19 and provide the collateral to build relationships through direct industry contact and interaction with members of the ARM consortium.

Increased density of research projects, researchers and partners at Mill 19 – committed to take advantage of the unique facilities, equipment, and environment to accelerate discovery and demonstration – acts as a foundation for growth.

Growth of industry and government collaborations increases the external investment in Mill 19, promoting a positive investment climate in Hazelwood Green.

*Education and Workforce Development:*

Awareness of manufacturing technologies and opportunities among K-12 students, teachers and the lay public increase as evidenced from participation in events and programs.

New pathways for education, workforce development and career development emerge and are defined for the advanced manufacturing technologies and factories of the future.

Advanced manufacturing test cells, projects, and demonstrations at Mill 19 attract an increasing number of students to manufacturing careers and an increasing number of manufacturing professionals to executive education offerings.

*Innovation:*

Research partnerships develop specific opportunities for spin-off companies and startups and MFI is nurturing their potential for success.

*Institute Sustainability:*

The world-class personnel and facilities within MFI, backed by its demonstrable success, provides the foundation for sustainability of the Institute and its mission.