NATIONAL SCIENCE FOUNDATION
4201 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22230

NSF 15-061

Dear Colleague Letter: Cybermanufacturing Systems

Dear Colleagues:

With this Dear Colleague letter (DCL), the National Science Foundation (NSF) is announcing its intention to accept EArly-Concept Grants for Exploratory Research (EAGER) proposals in FY 2015 to support researchers who are pursuing novel, early-stage, multi-disciplinary, and high-risk/high-reward research on cybermanufacturing systems. Requests may be for up to $300,000 and of up to two years duration. Approximately 25 EAGER awards will be made in FY 2015. Submission of EAGER proposals is requested by June 1, 2015, but earlier submissions are encouraged and decisions will be made on an ongoing basis until available funds are exhausted.

This DCL strongly encourages collaborative proposals between manufacturing and computer and information science and engineering researchers, and joint review of proposals among complementary NSF programs will be pursued when appropriate. It is anticipated that these collaborations will foster new research directions at the intersection of manufacturing and computer and information science and engineering, paving the way for larger-scale efforts in the future.

Proposers are also especially encouraged to implement, test, and improve the usability of system architectures in teaching environments in which students both use and contribute application software (apps).

BACKGROUND AND CONTEXT

The second major report of the President's Advanced Manufacturing Partnership (AMP), *Accelerating U.S. Advanced Manufacturing*, provides high-level recommendations for U.S. advanced manufacturing strategies, with emphasis on three manufacturing technology areas (MTAs):

- Advanced sensing, controls and platforms for manufacturing;
- Visualization, information, and digital manufacturing; and
- Advanced materials manufacturing.

Detailed information on the recommendations for each MTA can be found in Annexes 1 through 10 of the AMP's report. Also of note are reports from the European Commission[1] and industry[2],[3], which provide descriptions of advances in manufacturing, including leveraging of emerging information technologies.

Consistent with the AMP's report, the evolution of manufacturing technology has arguably been most importantly dependent on the application of increasingly powerful and low-cost computation in manufacturing enterprises. NSF researchers are, and have been, actively engaged in pursuing fundamental advances in design theory and translation; real-time sensing and perception; data capture, representation, and analytics; machine architectures and human interfaces; materials and process

modeling; scheduling and control algorithms; fault detection, analysis, and correction; and coordination of decisions across distributed production facilities that have led to the globally-connected, low-cost, flexible and resilient supply chains, computer-integrated factories, and digital design systems of the modern world. There is a general consensus about the increasingly important role of powerful, low-cost computation in manufacturing.

NSF'S ROLE

NSF anticipates that the research it funds in this area will enable an increasingly wide range of value-added manufacturing services by being:

- Intelligent, precise, predictable, reliable, secure, and adept with fabricating new materials;
- Connected and broadly accessible, with capabilities that are transparent to users;
- Connected to applications (or “apps”) that reside in the cloud and plug into an expansible, interactive architecture;
- Accessible at low cost to innovators and entrepreneurs, including both users and providers of manufacturing services;
- Clean, green, and resource-efficient; and
- Resilient to disruptions.

Current manufacturing software applications are predominantly large, manufacturer-centric, general-purpose software systems with broad applicability. The rapid, bottom-up, evolutionary transformation of service industries has not occurred in manufacturing services. While a primitive, app-based infrastructure for additive manufacturing and other selected manufacturing processes is beginning to emerge, we see an opportunity for academic researchers to pursue research and educational efforts to accelerate the creation of an interoperating, cross-process manufacturing service layer. Such a service layer will in turn allow entrepreneurs and companies to furnish and access manufacturing apps that span the full spectrum from ideation to physical realization, giving rise to an era of cybermanufacturing.

The concept of cybermanufacturing is at the nexus of research advances from the engineering and computer and information science domains. Future manufacturing will increasingly be characterized as complex, networked cyber-physical systems that may be instantiated in one physical location or distributed across many. The physical (mechanical, robotic, chemical, electrical, etc.) components of such systems will be fully interoperable and will be driven by computer interpretable models of product data, systems, and processes. Research from cyber-physical systems including the closely related areas of distributed systems, scheduling, resource allocation, fault tolerance, data analytics, networking, cybersecurity, robotics, human-machine interfaces, and others, will have a significant role in helping to accelerate the transformation to cybermanufacturing. The anticipated transformation requires a service architecture that has the capacity to incorporate and organize the rich and deep semantic elements of manufacturing knowledge, and connect the range and depth of content contributed in the form of isolated manufacturing applications.

One advantage of the bottom-up approach is that it is highly fault-tolerant during the early stages of evolution, with small users willing to explore and tolerate the limitations of early versions. Such efforts seem well suited to incubation in universities, where potential service layer architectures can be prototyped at low cost and tested by student and faculty app developers. Experience with Internet companies suggests that a significant number of university-developed prototype apps have the potential to grow into transformative businesses.

NSF&'s Directorate for Engineering (ENG) and Directorate for Computer and Information Science and Engineering (CISE) are interested in receiving EAGER proposals to existing programs for research to enable the networked integration of manufacturing machines, equipment, and systems into an

increasingly accessible and secure manufacturing service infrastructure. This interest anticipates an accelerating trend towards embedding manufacturing domain knowledge into the networked infrastructure to provide semantic content that assists users in fabricating parts and obtaining a full range of manufacturing services supporting such fabrication. Ideally, the projects proposed will be for elements that can be easily integrated into the network, are testable at small scale, and are extensible to Internet-scale, reflecting the complexity of real-world systems and designs. They may be related to, for example, but are not limited to research on:

- System architectures that are implementable using existing Internet protocols or that aim to identify the specific changes that are needed to existing Internet protocols to improve their effectiveness;
- Innovative computer architectures including cloud-based approaches enabling secure and distributed design and manufacture;
- Methods for safeguarding the security and trustworthiness of cybermanufacturing system elements and integrating them to support end-to-end assurances;
- Methods for establishing and maintaining evidence-based certification and controlled visibility of explicit and implicit assumptions;
- Software, protocols, and semantics for promoting and accommodating user-developed, interoperating manufacturing applications (apps), including hardware computing platforms, operating systems, and middleware;
- Intelligent information processing and flow from product conception to production;
- Software systems for generating and verifying machine instructions and providing guidance in design for manufacturability;
- Product- and domain-focused parametric design apps that model manufacturing resources and capabilities to allow process constraints to be considered at all stages of the product design process;
- Model-based process and machine controls that plug-and-play in a strongly integrated and networked environment;
- Software and associated sensor and perceptual systems for materials selection, processing and quality control/feedback monitoring;
- Novel intelligent robot architectures and representations for productive and adaptive operations in the cybermanufacturing environment;
- Algorithm development for automated parts handing and intelligent assembly automation systems;
- Methods for selecting and efficiently allocating networked manufacturing resources, including the decomposition of designs that optimize the allocation based on multiple criteria;
- Novel machine designs that simplify the user interface, such as additive manufacturing machines;
- Human-machine interfaces that facilitate innovative product design and/or manufacture;
- Potential applications of concepts from Software-Defined Networking (SDN) in the manufacturing flow;
- Methods for coordination of decisions within and across intersecting physical supply chains to create on-demand, low-cost and resilient virtual chains;
- Smart distributed manufacturing that facilitates high-quality but low-cost customization of products to suit local or specialized markets; and
- Hybrid systems that facilitate collaboration among major manufacturing corporations, community-based workshops, and the amateur Maker Movement.

SUBMISSION PROCESS

This is not a special competition or new program. EAGER proposals in response to this Dear Colleague Letter must meet the requirements of NSF's *Grant Proposal Guide* (see Section II.D.2 at http://www.nsf.gov/pubs/policydocs/pappguide/nsf15001/gpg_2.jsp#IID2) and the review criteria of the program to which they are submitted. (As noted in the GPG, EAGER is a funding mechanism for supporting exploratory work in its early stages on untested, but potentially transformative, research ideas

or approaches. This work may be considered especially “high-risk, high-payoff,” for example, in the sense that it involves radically different approaches, applies new expertise, or engages novel disciplinary or interdisciplinary perspectives.)

Please be sure that the title of your proposal starts with “EAGER: Cybermanufacturing:”

Interested investigators are encouraged to contact the program director(s) of the program to which they are considering submitting an EAGER proposal with up to a two-page statement explaining the core idea of their projects. Guidance in selecting the most appropriate program for submission can be sought from:

FOR THE CISE DIRECTORATE

- Dr. David Corman (dcorman@nsf.gov, 703-292-8754), Division of Computer and Network Systems (CNS); and
- Dr. Gregory Chirikjian (gchirikj@nsf.gov, 703-292-7357), Division of Information and Intelligent Systems (IIS).

FOR THE ENG DIRECTORATE

- Dr. Kishan Baheti (rbaheti@nsf.gov, 703-292-8339, Division of Electrical, Communications and Cyber Systems (ECCS);
- Dr. Maria Burka (mburka@nsf.gov, 703-292-7030, Division of Chemical, Bioengineering, Environmental and Transport Systems (CBET);
- Dr. Bruce Kramer (bkramer@nsf.gov, 703-292-5348), Division of Civil, Mechanical and Manufacturing Innovation (CMMI); and
- Dr. Z.J. Pei (zpei@nsf.gov, 703-292-8611), Division of Civil, Mechanical and Manufacturing Innovation (CMMI).

The research areas discussed in this DCL align with multiple NSF programs including, but not limited to, the following:

- Computer Systems Research (CSR);
- Critical Techniques and Technologies for Advancing Big Data Science & Engineering (BIGDATA);
- Cyber-Human Systems (CHS);
- Cyber-Physical Systems (CPS);
- Design of Engineering Materials Systems (DEMS);
- Energy, Power, Control and Networks (EPCN);
- Engineering and Systems Design (ESD);
- Materials Engineering and Processing (MEP);
- Manufacturing Enterprise Systems (MES);
- Manufacturing Machines and Equipment (MME);
- Nanomanufacturing (NM);
- National Robotics Initiative (NRI);
- Networking Technology and Systems (NeTS);
- Process and Reaction Engineering;
- Research in Engineering Education (REE);
- Robust Intelligence (RI); and
- Sensors, Dynamics and Control (SDC).

We are looking forward to receiving your proposals.

Sincerely,

Pramod Khargonekar
Assistant Director for Engineering (ENG)

Jim Kurose
Assistant Director for Computer and Information Science and Engineering (CISE)

[1] *2014 Factories of the Future Roadmap*.

[2] *Industrial Internet: Pushing the Boundaries of Minds and Machines*.

[3] *Building Smarter Manufacturing with the Internet of Things (IoT)*.