NATIONAL SCIENCE FOUNDATION
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NSF 16-042

Dear Colleague Letter: Mathematical Sciences Funding Opportunities in Sustainable Infrastructure

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Dear Colleagues:

Growth of the global population, improved standards of living, and long-term changes in climate are placing ever-increasing stresses on the interconnected resources that support society. There is an urgent need to better understand, model, design, and manage the system of natural, social, and human-built components on which human society depends for a sustainable future.

Mathematicians and statisticians have much to contribute to the development of solutions to the pressing resource problems facing society. The Division of Mathematical Sciences (DMS) participates in the array of National Science Foundation programs supporting fundamental research that aims to advance knowledge and to create tools for strengthening sustainable infrastructure. A natural way for mathematicians and statisticians to become involved in such work is by lending mathematical sciences expertise to interdisciplinary teams of researchers engaging in collaborative research projects in these important areas.

The Division encourages mathematical scientists to investigate the funding opportunities noted below and to participate when appropriate in the multidisciplinary research teams investigating the complex, dynamic, coupled systems that are critical to maintaining and increasing humanity's well-being in a sustainable way. The following synopses highlight some NSF funding opportunities of interest in this direction. Links to the various opportunities can be found on the web page for the Mathematical Sciences Innovation Incubator (MSII).

INNOVATIONS AT THE NEXUS OF FOOD, ENERGY, AND WATER SYSTEMS

Innovations at the Nexus of Food, Energy, and Water Systems (**INFEWS**) is a partnership between NSF and the United States Department of Agriculture's National Institute of Food and Agriculture to support research that aims to understand, design, and model the interconnected food, energy, and water infrastructure through an interdisciplinary research effort that addresses the natural, social, and human-built factors involved. The need for this research is increasingly urgent, as growing demand for food, changes in land use, and increasing geographic and seasonal variability in precipitation patterns are placing an ever-increasing stress on these critical resources. INFEWS supports research on the fundamental science and engineering questions at the food, energy, water (FEW) nexus and training of the next generation of researchers in this interdisciplinary area. The program seeks proposals from groups of researchers on interdisciplinary efforts using systems methodology.

INFEWS proposals are to be submitted to one of four distinct tracks, each reflecting a different objective:

Track 1: FEW System Modeling: "The goal is to define and understand the couplings/linkages, feedback mechanisms and processes among the FEW systems components and to elucidate the factors that influence resilience, thresholds and criticalities. [...] [INFEWS] projects should enable innovative perspectives and advances in understanding and modeling complex systems processes. Development of advanced computational methods and effective means for incorporation of large quantities of disparate data, as implemented in new and novel software and tools, is also appropriate."

Additional key phrases of interest to mathematical scientists in the Track 1 description include: "define/quantify spatially heterogeneous FEW systems responses to various internal and external driving factors that occur on both short and long timescales," "evaluate minimization-of-risk with respect to FEW services, [...] and the impact of mitigation and adaptation with respect to minimization-of-risk."

Track 2: Visualization and Decision Support for Cyber-Human-Physical Systems at the FEW Nexus: "[...] seeks to develop the core system science needed to understand the interactions between these diverse but closely coupled components that operate at multiple temporal and spatial scales.[...] Research challenges include, but are not limited to new methods, and data science algorithms for integrating multiple, heterogeneous, and high-volume FEW data from physical, ecological, engineered, and social sources, [...] modeling approaches and algorithms that can capture FEW component interactions at multiple temporal and spatial scales and support cyber- human-physical system resource management."

Track 3: Research to Enable Innovative System Solutions: "Sustainability solutions might incorporate physical sciences, biological sciences, computer sciences, institutional, economic, behavioral, and technical components."

Track 4: Education and Workforce Development: Seeks "... to develop a cadre of citizens, scientists and engineers capable of thinking across FEW disciplines and systems. [...] NSF (principally, but not exclusively) plans to make a limited number of Track 4 awards to support virtual resource centers. The students affiliated with the resource centers will engage in interdisciplinary research while developing expertise in their primary fields."

RISK AND RESILIENCE

The nation's increasing dependence on infrastructure services, including transportation, energy, water, and communications, has increased the potential impact of adverse events that cause these systems to fail, with associated consequences for economic competiveness and societal well-being. Risks include extreme natural events, malicious attack, and technological failure. NSF supports research aimed toward improving predictability, assessing risk, and increasing resilience in order to reduce the impact of extreme events on society. NSF investments focus on fundamental science and engineering issues, such as understanding the dynamical processes that produce extreme events, how people respond to extreme events, and how to engineer resilient infrastructure.

The complex set of interdependencies between the components of an interconnected set of critical infrastructures presents significant challenges to conceptualize, understand, model, design, and manage. The **Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP)** program supports fundamental research that addresses this complex, interdependent system of infrastructure services. CRISP aims to: (1) foster an interdisciplinary research community of engineers, computer and computational scientists, and social and behavioral scientists in design and operation of infrastructure processes and services; (2) enhance understanding and design of Interdependent Critical Infrastructure systems (ICIs) that provide essential goods and services despite disruptions and failures;

(3) create the knowledge for innovation in ICIs to safely, securely, and effectively expand the range of goods and services they enable; and (4) improve the effectiveness and efficiency with which ICIs deliver existing goods and services.

Natural disasters cause thousands of deaths and billions of dollars in damage annually. Improved fundamental scientific understanding of natural processes underlying natural hazards and extreme events, together with improved quantitative models and qualitative research, can enhance societal preparedness and resilience against such events. The **Prediction of and Resilience against Extreme Events (PREEVENTS)** program aims to (1) enhance understanding of the fundamental processes underlying geohazards and extreme events on various spatial and temporal scales, as well as the variability inherent in such hazards and events; (2) improve models of geohazards, extreme events, and their impacts on natural, social, and economic systems; and (3) develop new tools to enhance societal preparedness and resilience against such impacts.

GLOBAL CHANGE AND EARTH SYSTEMS MODELING

NSF provides support for a broad range of fundamental research activities that provide deeper understanding of climate science issues, including those that form the scientific basis for climate-related policy. High priorities include: data assimilation and analysis; predictability at different temporal and spatial scales; improved understanding of Earth system processes and of feedbacks between ecosystems and the physical climate; and the development of advanced analytic research methods for observations and for models. Understanding climate change and how it will affect the Earth requires the development and application of next-generation Earth System Models that include coupled and interactive representations of such components as ocean and atmospheric circulation, agricultural working lands and forests, biogeochemistry, atmospheric chemistry, the water cycle, and land ice.

Disciplinary programs in the NSF Directorate for Geosciences and the Division of Mathematical Sciences remain interested in new proposals that address the above aims, and queries should be directed to appropriate program directors. Other NSF programs supporting research in these areas include Long-Term Ecological Research (LTER) as well as others featured on the Mathematical Sciences Innovation Incubator (MSII) web page listed previously.

For the most recent information on many of these and other programs, please see the funding opportunities listed under "Clean Energy," "Earth Observations," "Global Climate Change," and "Research and Development for Informed Policy-Making and Management" on the aforementioned web page for the Mathematical Sciences Innovation Incubator (MSII) activity. Investigators with questions about these programs are encouraged to contact the DMS program directors listed below.

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- INFEWS: Frederi Viens, telephone: (703) 292-2858, email: fviens@nsf.gov
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- Global Change and Earth Systems Modeling: Michael Steuerwalt, telephone: (703) 292-4860, email: msteuerw@nsf.gov
- Other programs featured via the MSII activity:
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