

Understanding the Rules of Life: Emergent Networks (URoL:EN)

Predicting Transformation of Living Systems in Evolving Environments

PROGRAM SOLICITATION

NSF 21-560



National Science Foundation

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

May 10, 2021

IMPORTANT INFORMATION AND REVISION NOTES

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPP) ([NSF 20-1](#)), which is effective for proposals submitted, or due, on or after June 1, 2020.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Understanding the Rules of Life: Emergent Networks (URoL:EN)
Predicting Transformation of Living Systems in Evolving Environments

Synopsis of Program:

In 2016, the National Science Foundation (NSF) unveiled a set of "Big Ideas," 10 bold, long-term research and process ideas that identify areas for future investment at the frontiers of science and engineering (see https://www.nsf.gov/news/special_reports/big_ideas/index.jsp). The Big Ideas represent unique opportunities to position our Nation at the cutting edge of global science and engineering by bringing together diverse disciplinary perspectives to support convergence research. As such, when responding to this solicitation, even though proposals must be submitted to the Division of Emerging Frontiers in the Directorate for Biological Sciences (BIO/EF), once received, the proposals will be managed by a cross-disciplinary team of NSF Program Directors.

The *Understanding the Rules of Life: Predicting Phenotype* "Big Idea" is based on developing a predictive understanding of how key properties of living systems emerge from interactions of factors such as genomes, phenotypes, and evolving environments. This activity has launched a series of new research programs designed to elucidate "minimal rules" (building a synthetic cell), "rules of complexity" (epigenetics), and "rules of interaction" (microbiome). A list of *Understanding the Rules of Life* awards made thus far can be found on the [NSF Awards Search](#).

This *Understanding the Rules of Life: Emergent Networks* (URoL:EN) solicitation adds to those previous foundational activities to now understand "rules of emergence" for networks of living systems and their environments. Emergent networks describe the interactions among organismal, environmental, social, and human-engineered systems that are complex and often unexpected given the behaviors of these systems when observed in isolation. The behavior of emergent networks of living systems depend on, but are not wholly predicted by, chemical and physical principles and unit-level biological properties (molecule/cell/organism/population), as well as communication and information flows among nodes in the network. Networks of living systems are reciprocally coupled with natural, built, and social environments in ways that are complex and difficult to predict. The often-unanticipated outcomes of these interactions can be both wide-ranging and enormously impactful. Prediction is further hampered by accelerating perturbations within evolving environments and the associated increase in the frequency of previously rare or extreme events. Determining the emergent properties of these networks, which arise from complex and nonlinear interactions among the different systems that in isolation do not exhibit such properties, is a critical and unsolved problem. One of many examples of this could include the emerging network of interactions across scales that arose from the arrival of the nonnative pathogen, *Cryphonectria parasitica*, or Chestnut blight, introduced with nursery stock. This pathogen effectively eliminated a dominant overstory tree species, American chestnut (*Castanea dentata*), across North America and had concomitant impacts on and feedbacks between biotic, abiotic, and social networks. For example, the economic impacts of this pathogen ranged from local agricultural and social impacts to global scale impacts on the timber industry.

Successful projects of the URoL:EN program are expected to use convergent approaches that explore emergent network properties of living systems across various levels of organizational scale and, ultimately, contribute to understanding the rules of life through new theories and reliable predictions about the impact of specific environmental changes on behaviors of complex living systems, or engineerable interventions and technologies based on a rule of life to address associated outcomes for societal benefit.

The convergent scope of URoL:EN projects also provides unique STEM education and outreach possibilities to train the next generation of scientists in a diversity of approaches and to engage society more generally. Hence, the URoL:EN program encourages research projects that integrate training and outreach activities in their research plan, provide convergent training opportunities for researchers and students, develop novel teaching modules, and broaden participation of under-represented groups in science.

The URoL:EN Program will support projects with a total budget of up to \$3,000,000 and an award duration of up to 5 years.

Cognizant Program Officer(s):

Please note that the following information is current at the time of publishing. See program website for any updates to the points of contact.

- Betsy von Holle, BIO, telephone: (703) 292-4974, email: e-networks@nsf.gov
- Mitra Basu, CISE, telephone: (703) 292-8649, email: e-networks@nsf.gov
- Jeremy Guinn, EHR, telephone: (703) 292-8193, email: e-networks@nsf.gov
- Grace M. Hwang, ENG, telephone: (703) 292-4271, email: e-networks@nsf.gov
- Dena M. Smith-Nufio, GEO, telephone: (703) 292-7431, email: e-networks@nsf.gov
- Trisha Van Zandt, SBE, telephone: (703) 292-7437, email: e-networks@nsf.gov
- Junping Wang, MPS, telephone: (703) 292-4488, email: e-networks@nsf.gov

Applicable Catalog of Federal Domestic Assistance (CFDA) Number(s):

- 47.041 --- Engineering
- 47.049 --- Mathematical and Physical Sciences
- 47.050 --- Geosciences
- 47.070 --- Computer and Information Science and Engineering
- 47.074 --- Biological Sciences
- 47.075 --- Social Behavioral and Economic Sciences
- 47.076 --- Education and Human Resources
- 47.079 --- Office of International Science and Engineering
- 47.083 --- Office of Integrative Activities (OIA)

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 5 to 10

Anticipated Funding Amount: \$15,000,000

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.
- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.

Who May Serve as PI:

A minimum of one PI and one co-PI must be named on a proposal, representing expertise in different disciplines pertinent to at least two of the following directorates: Biological Sciences (BIO), Computer and Information Science and Engineering (CISE), Education and Human Resources (EHR), Engineering (ENG), Geosciences (GEO), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE), at the National Science Foundation.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may appear as Principal Investigator (PI) or co-PI on only one proposal per annual cycle submitted in response this solicitation. **If an individual is listed as PI or co-PI on more than one proposal to this solicitation, all proposals in excess of the limit for any person will be returned without review in the reverse order received.**

Proposals submitted in response to this solicitation cannot be duplicates of proposals to any other Federal agency for simultaneous consideration.

If a proposal involves multiple organizations, it must be submitted as a single proposal with subawards; **separately submitted collaborative**

proposals are not permitted and will be returned without review.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposal Submission:** Not required
- **Full Proposals:**
 - Full Proposals submitted via FastLane: *NSF Proposal and Award Policies and Procedures Guide* (PAPPG) guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
 - Full Proposals submitted via Research.gov: *NSF Proposal and Award Policies and Procedures Guide* (PAPPG) guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
 - Full Proposals submitted via Grants.gov: *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov* guidelines apply (Note: The *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide).

B. Budgetary Information

- **Cost Sharing Requirements:**

Inclusion of voluntary committed cost sharing is prohibited.
- **Indirect Cost (F&A) Limitations:**

Not Applicable
- **Other Budgetary Limitations:**

Other budgetary limitations apply. Please see the full text of this solicitation for further information.

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

May 10, 2021

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria. Additional merit review criteria apply. Please see the full text of this solicitation for further information.

Award Administration Information

Award Conditions:

Additional award conditions apply. Please see the full text of this solicitation for further information.

Reporting Requirements:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

The 21st century is becoming the "century of biology", enabled by major advances in understanding the molecular basis of life. In the past fifty years, revolutions in biology have included advances in genomics, modeling, and bioinformatics, among others. A critical dimension of this century of biology will be the further integration of life sciences with other disciplines. The URoL:EN program is a cross-directorate program of the National Science Foundation that aims to develop a predictive understanding of how key properties of living systems emerge from interactions of factors such as genomes, phenotypes, and environments and how emerging networks of organismal, natural, social, and human-engineered systems respond to and/or influence evolving environments. The URoL:EN program supports projects that take interdisciplinary approaches to better understand emergent networks and their mechanisms, emphasizing projects that cross multiple levels of complexity and/or temporal scales in taxa from anywhere within the tree of life. The program's required interdisciplinary focus presents excellent opportunities for the exploration of novel experimental and comparative approaches, leveraging existing large data sets and analytics, predictive modeling, engineerable interventions, new mathematical, computational and data science approaches, and for integrated multi-disciplinary education and outreach activities.

Investigators wishing to inquire about the suitability of potential projects for URoL:EN are encouraged to email a one-page summary to e-networks@nsf.gov.

II. PROGRAM DESCRIPTION

Emergent networks describe interactions among organismal, environmental, social, and human-engineered systems that are unexpected given the behaviors of these systems when observed in isolation. Networks of living systems are reciprocally coupled with natural, built, and social environments in ways that are complex and often unpredictable. The often-unanticipated outcomes of these interactions can be both wide-ranging and enormously impactful. The URoL:EN Program is focused on understanding and determining the emergent properties of complex networks whereby environmental changes and variabilities result in significant effects on networks of living systems and their interaction with natural and human engineered systems. The URoL:EN program includes participation from the Directorates for Biological Sciences (BIO), Computer and Information Science and Engineering (CISE), Education and Human Resources (EHR), Engineering (ENG), Geosciences (GEO), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE) at the National Science Foundation.

The goal of the URoL:EN program is to foster crosscutting convergent research that integrates perspectives and research approaches from more than one scientific discipline. Convergence research is generally inspired by the need to address a specific challenge or opportunity, whether it arises from deep scientific questions or pressing societal needs. Successful projects will be built across the intersection of a variety of disciplines. As experts from different disciplines pursue common research challenges, their knowledge, theories, methods, data, research communities and languages become increasingly intermingled or integrated. New frameworks, paradigms or even disciplines can form sustained interactions across multiple communities. Proposals submitted to this program are expected to address significant scientific questions in emergent networks of living systems that can be answered by integrating perspectives and approaches from different disciplines relevant to two or more NSF Directorates. Successful projects must address the specific nature of the integration and how it is essential for achievement of the overarching goal. The synergy among the integrated strategies and efforts must be made explicit in the proposal. Projects should show strong connections between the contributing disciplines, while demonstrating innovation in the integrated research approaches which is characteristic of a successful convergent project.

There are many basic research opportunities for new understanding about emerging networks of interactions among organisms, Earth, human, natural, and human-engineered systems in evolving environments. Environments can evolve in response to biotic or abiotic drivers, and evolution can occur on a variety of spatial and temporal scales, impacting various levels of organization. URoL:EN projects may involve, but are not limited to involving, aspects of one or more of the following themes:

- Prediction of emergent properties of complex organismal, Earth, social, and human-engineered systems operating under conditions of evolving environments over timescales that allow for societal response.
- Determination of tipping points, thresholds, and/or state changes in interacting networks of living systems with Earth, social, natural, and human-engineered systems within evolving environments, determination of systems' underlying mechanisms, and associated timescales.
- Establishment of general theories of emergent properties of networks of living systems with Earth, social, and human-engineered systems that are influenced by evolving environments, as well as their associated feedbacks.
- Exploration of potential adaptations to, and methods for mitigation of, networks of living systems with Earth, social, and human-engineered systems due to environmental variability based on a Rule of Life, which can include how past organismal changes over the history of the Earth have contributed to adaptation, or a Rule of Life based on any other biological discipline.
- Development of novel mathematical and computational methodologies that examine relationships between networks of systems, describing complex systems and their nonlinear interactions at multiple levels and along heterogeneous dimensions, with the goal of developing new models that broaden our understanding of emergent properties of living systems within other complex systems.
- Discovery and integration of the theoretical principles of one or more Rules of Life from different scientific fields — including paleobiology, biology, neuroscience, computer science, engineering, mathematics, chemistry and physics, social science, materials science, among others — to create new frameworks for transformative technologies, e.g., multi-scale sensing, communication, information processing, robotics, and AI-systems that cooperate to confer nontrivial decision-making ability and efficiently adapt to uncertain dynamic environments.

Projects may be laboratory, field, and/or simulation and theory based and may include a focus on terrestrial, aquatic, marine or polar organisms and ecosystems. Projects are encouraged to extend laboratory, experimental, theoretical, or other research approaches beyond well-established model systems, individual populations, and controlled environments, and should address how the networks under study characterize the interactions of living systems with Earth, social and/or human-engineered systems, as well as explain and predict their emergent responses to proposed interventions.

The need for effective and sustainable new training paradigms that are inclusive and prepare the next generations of scientists to navigate diverse scientific fields is also relevant to this solicitation. Students and postdoctoral scholars need training to address barriers posed by language and cultural differences between fields and among people, to interpret a variety of data types with rigor, and to interrogate hypotheses that transcend narrow systems or sub-disciplines. The next generations of scholars and educators must reflect the diversity of peoples and cultures in the nation, and they will need working knowledge of not just experimental approaches, but also theory, computation, and modeling, to name a few critical skills. At the same time, it is imperative that such integrative training does not replace or diminish in-depth disciplinary training. The URoL:EN Program encourages research projects that integrate training and outreach activities in their research plan, provide interdisciplinary training opportunities for researchers and students, develop novel teaching strategies, and/or provide explicit plans to integrate primarily undergraduate institutions and broaden participation of under-represented groups in science.

Investigators are encouraged to develop collaborations with researchers with complementary expertise where necessary to facilitate an interdisciplinary approach to address the overarching research question(s).

Outreach activities that successfully penetrate societal communication barriers are encouraged. Efforts could include, for example, educating the general public about the research, developing citizen science activities, etc., as driven by the team's expertise and interests, and the needs of the community. Plans to assess the success of such efforts should be included.

URoL:EN provides support for projects with a total budget (including indirect costs) of up to \$3,000,000 and award duration of up to 5 years.

International collaborators are encouraged to seek support from their respective funding organizations. Funding guidelines for involving international collaborators allow the following expenses to be included in the NSF budget:

- Travel expenses for US-based scientists and students participating in exchange visits integral to the project.
- Project-related expenses for international partners to engage in research activities while in the U.S. as project participants.
- Project-related expenses for US-based participants to engage in research activities while abroad.

III. AWARD INFORMATION

The Program estimates an FY2021 budget of \$15,000,000 and expects to make 5-10 awards.

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.
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If a proposal involves multiple organizations, it must be submitted as a single proposal with subawards; **separately submitted collaborative proposals are not permitted and will be returned without review.**

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via FastLane, Research.gov, or Grants.gov.

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.
- Full Proposals submitted via Research.gov: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal and Award Policies and Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov. The Prepare New Proposal setup will prompt you for the program solicitation number.
- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov*. The complete text of the *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov.

See PAPPG Chapter II.C.2 for guidance on the required sections of a full research proposal submitted to NSF. Please note that the proposal preparation instructions provided in this program solicitation may deviate from the PAPPG instructions.

Special instructions for submitting to this Big Idea solicitation

FastLane Users: Proposers are reminded to identify the program solicitation number (located on the first page of this document) in the first block on the NSF Cover Sheet. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Please note that even though proposals must be submitted to BIO/EF, once received the proposals will be managed by a cross-disciplinary team of NSF Program Directors.

Research.gov Users: The Prepare New Proposal setup will prompt you for the program solicitation number (located on the first page of this document). Compliance with this requirement is critical to determining the relevant proposal processing guidelines. As stated previously, even though proposals must be submitted to BIO/EF, once received the proposals will be managed by a cross-disciplinary team of NSF Program Directors.

Grants.gov Users: The program solicitation number will be pre-populated by Grants.gov on the NSF Grant Application Cover Page, however you will need to locate the Division Code, Program Code, Division Name, and Program Name for the specific solicitation you are applying to by visiting <https://www.fastlane.nsf.gov/pgmannounce.jsp>. As stated previously, even though proposals must be submitted to BIO/EF, once received the proposals will be managed by a cross-disciplinary team of NSF Program Directors.

Proposal Preparation Instructions

Proposal Title: Titles of proposals should begin with "URoL:EN" followed by a substantive title.

Project Description (up to 15 pages): For all proposals, the project description must include:

- The proposal or identification of a rule(s) of life around which the proposed research is oriented or to which the research is applied.
- Convergent research plan:
 - The proposed research plan must tackle critical, cross-cutting questions that are larger in scope than typical proposals to NSF Core Programs.
 - A description of two or more diverse and complementary disciplines involved and how the project integrates them via interdisciplinary research and analytical approaches to identify critical properties of emergent networks of organisms, Earth, human, natural, and human-engineered systems within evolving environments.
 - The proposed research should include a range of objectives and research approaches that are clearly integrated under a coordinated vision. Convergent research requires an open and inclusive culture, and for practitioners to become conversant across disciplines and common set of concepts and metrics and understanding of goals. Proposals should include an explicit plan for integration across disciplines and articulate how the proposed research questions will lead to the integration of those researchers and scientific disciplines.
 - Proposals must convincingly articulate the approaches from more than one research discipline (e.g., biological science, neuroscience, chemistry, computer science, complex systems, engineering, geology, mathematics, chemistry, physics, behavioral and social sciences, among others) employed to understand and determine the critical properties of emergent networks associated with evolving environments.
- Broader Impacts: Follow the standard NSF format, as described in the PAPPG.
- Results from Prior NSF Support: Follow the standard NSF format, as described in the PAPPG.

Budget: Proposals Requiring Research Facilities: Budgets should include all costs charged to the project for platforms and facilities supporting the proposed research, except those facilities separately supported by NSF (e.g., research aircraft or field equipment). PIs are responsible for filing the appropriate requests for major research platforms; a copy of the request must be included as a supplementary document.

Special Information and Supplementary Documentation: Provide information such as letters of collaboration, data management plan, postdoctoral researcher mentoring plan, and other allowed items as applicable as noted in the current issuance of the PAPPG and as described below.

Data Management Plan (up to two pages): Each proposal must include, as a Supplementary Document, a data management section with the specific details of data standards, accessibility, electronic dissemination, and preservation. Public access and timely release of project results should be clear and routine.

Materials, data products, and other resources generated by the project should be fully released within a reasonable time frame, consistent with NSF and community standards. These include, for example, sequences of all types, materials, tools, images, software, publications, videos and other media, and teaching curricula. Of particular importance (where applicable) are: plans for data collection and analysis; plans for dissemination of data and archiving, including a named time for when data will become publicly available; details of collaborative efforts; information about necessary permits; and information about access to resources that are not immediately under the investigator's control (e.g., museum collections, research sites, computing facilities). The data management plan must not exceed two pages. Further information about Data Management Plans can be found in the PAPPG (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg).

Letters of Collaboration: If the project involves collaborative arrangements of significance, these arrangements should be documented through letters of collaboration. Letters of collaboration should be limited to stating the intent to collaborate and should not contain endorsements or evaluation of the proposed project. Letters of collaboration should follow the single-sentence format:

"If the proposal submitted by Dr. [insert the full name of the Principal Investigator] entitled [insert the proposal title] is selected for funding by the NSF, it is my intent to collaborate and/or commit resources as detailed in the Project Description or the Facilities, Equipment or Other Resources section of the proposal."

Requests for letters of collaboration should be made by the PI well in advance of the proposal submission deadline, because they must be included at the time of submission. **Please note that letters of recommendation for the PI or other letters of support for the project are not permitted.**

Project Management Plan and Role of Project Personnel (*up to five pages*): Proposals **must include** a separate supplementary document, titled "Management Plan", that specifies how the disciplines are integrated in their research approach. Key individuals who are associated with each of the selected disciplines must be identified. A clear description of the role and expertise of each investigator, what each person brings to the project leadership team, reporting relationships, means of communication and interaction among the members of the project team, oversight and accountability mechanisms, and metrics to evaluate the success of the project.

Project team criteria:

- The project team should be diverse. Teams and their leadership should include a diversity of types of participants, including individuals from a variety of career stages and members of underrepresented groups such as women, minorities, and those with disabilities.
- Expertise can be demonstrated by earned degrees from disciplines, current departmental and center affiliations, or experience, details of which can be included in the relevant section of the Project Description, and the Biographical Sketches.
- The role of each team member must be clearly described and justified in the management plan. Team members may be from a single organization or multiple organizations. A collaborative culture that values and benefits from shared research and multidisciplinary training is highly encouraged. Teams should be designed to achieve the goals of the proposed work.
- The research team must provide evidence that it is ready to engage in convergence research. This evidence may include specialized knowledge residing in the research team that is pertinent to the problem, previous project collaborations, joint publications of the PIs and co-PIs, and/or co-development of research infrastructure.

Student Training Plan (*up to two pages, if applicable*): The URoL:EN Program encourages the development of a diverse, interdisciplinary, globally engaged, scientific workforce capable of communicating and transforming our understanding of the emergent networks and other general principles regulating life on Earth. The future of science is highly interdisciplinary and as such, any URoL:EN proposals that involve funded or unfunded student participation should train those students in broad research competencies. Training should promote intellectual and methodological cross-fertilization and encourage a systems/integrative perspective towards understanding networks of living or complex systems.

If students are involved in the project, the proposal must include a robust, integrated education and training component. Research ideas and endeavors are rejuvenated by new participants. Training that enables individuals to overcome disciplinary barriers and succeed in cross-disciplinary research should be fully integrated into the project, as needed. A plan to evaluate training outcomes should be included.

Projects are encouraged to provide new learning and research experiences for undergraduate students, graduate students, and/or postdocs that would prepare them to become the next generation of convergence researchers. The proposal should use best practices in training STEM practitioners to contribute to Emergent Networks convergent research.

Projects that involve students should demonstrate a collaborative effort aimed at enhancing the contributions of individuals from groups that have been historically underrepresented and under-served in STEM. Communities (both public and professional) from which underrepresented students will be recruited should be described. The proposal should include explicit plans or strategies for addressing or accommodating the specific interests, community or cultural perspectives and the educational needs of students of the identified underrepresented groups.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Other Budgetary Limitations:

Please see the full text of this solicitation for further information.

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

May 10, 2021

D. FastLane/Research.gov/Grants.gov Requirements

For Proposals Submitted Via FastLane or Research.gov:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: <https://www.fastlane.nsf.gov/a1/newstan.htm>. To prepare and submit a proposal via Research.gov, see detailed technical instructions available at: https://www.research.gov/research-portal/appmanager/base/desktop?_nfpb=true&_pageLabel=research_node_display&_nodePath=/researchGov/Service/Desktop/ProposalPreparationandSubmission.html. For FastLane or Research.gov user support, call the FastLane and Research.gov Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov or rgov@nsf.gov. The FastLane and Research.gov Help Desk answers general technical questions related to the use of the FastLane and Research.gov systems. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

For Proposals Submitted Via Grants.gov:

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. Comprehensive information about using Grants.gov is available on the Grants.gov Applicant Resources webpage: <https://www.grants.gov/web/grants/applicants.html>. In addition, the NSF Grants.gov Application Guide (see link in Section V.A) provides instructions regarding the technical preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: support@grants.gov. The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

Submitting the Proposal: Once all documents have been completed, the Authorized Organizational Representative (AOR) must submit the application to Grants.gov and verify the desired funding opportunity and agency to which the application is submitted. The AOR must then sign and submit the application to Grants.gov. The completed application will be transferred to the NSF FastLane system for further processing.

Proposers that submitted via FastLane or Research.gov may use Research.gov to verify the status of their submission to NSF. For proposers that submitted via Grants.gov, until an application has been received and validated by NSF, the Authorized Organizational Representative may check the status of an application on Grants.gov. After proposers have received an e-mail notification from NSF, Research.gov should be used to check the status of an application.

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program for acknowledgement and, if they meet NSF requirements, for review. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF either as *ad hoc* reviewers, panelists, or both, who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts of interest with the proposal. In addition, Program Officers may obtain comments from site visits before recommending final action on proposals. Senior NSF staff further review recommendations for awards. A flowchart that depicts the entire NSF proposal and award process (and associated timeline) is included in PAPPG Exhibit III-1.

A comprehensive description of the Foundation's merit review process is available on the NSF website at: https://www.nsf.gov/bfa/dias/policy/merit_review/.

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in *Building the Future: Investing in Discovery and Innovation - NSF Strategic Plan for Fiscal Years (FY) 2018 – 2022*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

One of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions must recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy. NSF's contribution to the national innovation ecosystem is to provide cutting-edge research under the guidance of the Nation's most creative scientists and engineers. NSF also supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning.

NSF's mission calls for the broadening of opportunities and expanding participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines, which is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

A. Merit Review Principles and Criteria

The National Science Foundation strives to invest in a robust and diverse portfolio of projects that creates new knowledge and enables breakthroughs in understanding across all areas of science and engineering research and education. To identify which projects to support, NSF relies on a merit review process that incorporates consideration of both the technical aspects of a proposed project and its potential to contribute more broadly to advancing NSF's mission "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF makes every effort to conduct a fair, competitive, transparent merit review process for the selection of projects.

1. Merit Review Principles

These principles are to be given due diligence by PIs and organizations when preparing proposals and managing projects, by reviewers when reading and evaluating proposals, and by NSF program staff when determining whether or not to recommend proposals for funding and while overseeing awards. Given that NSF is the primary federal agency charged with nurturing and supporting excellence in basic research and education, the following three principles apply:

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the

research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. The project activities may be based on previously established and/or innovative methods and approaches, but in either case must be well justified.

- Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher, more aggregated, level than the individual project.

With respect to the third principle, even if assessment of Broader Impacts outcomes for particular projects is done at an aggregated level, PIs are expected to be accountable for carrying out the activities described in the funded project. Thus, individual projects should include clearly stated goals, specific descriptions of the activities that the PI intends to do, and a plan in place to document the outputs of those activities.

These three merit review principles provide the basis for the merit review criteria, as well as a context within which the users of the criteria can better understand their intent.

2. Merit Review Criteria

All NSF proposals are evaluated through use of the two National Science Board approved merit review criteria. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two merit review criteria are listed below. **Both** criteria are to be given **full consideration** during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Therefore, proposers must fully address both criteria. (PAPPG Chapter II.C.2.d(i). contains additional information for use by proposers in development of the Project Description section of the proposal). Reviewers are strongly encouraged to review the criteria, including PAPPG Chapter II.C.2.d(i), prior to the review of a proposal.

When evaluating NSF proposals, reviewers will be asked to consider what the proposers want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful. These issues apply both to the technical aspects of the proposal and the way in which the project may make broader contributions. To that end, reviewers will be asked to evaluate all proposals against two criteria:

- **Intellectual Merit:** The Intellectual Merit criterion encompasses the potential to advance knowledge; and
- **Broader Impacts:** The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

The following elements should be considered in the review for both criteria:

1. What is the potential for the proposed activity to
 - a. Advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and
 - b. Benefit society or advance desired societal outcomes (Broader Impacts)?
2. To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?
3. Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?
4. How well qualified is the individual, team, or organization to conduct the proposed activities?
5. Are there adequate resources available to the PI (either at the home organization or through collaborations) to carry out the proposed activities?

Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. NSF values the advancement of scientific knowledge and activities that contribute to achievement of societally relevant outcomes. Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education.

Proposers are reminded that reviewers will also be asked to review the Data Management Plan and the Postdoctoral Researcher Mentoring Plan, as appropriate.

Additional Solicitation Specific Review Criteria

In addition to the two standard review criteria established by the National Science Board, reviewers will evaluate URoL Emerging Network proposals for:

1. The proposal or identification of a rule(s) of life around which the proposed research is oriented or to which the research is applied.
2. A compelling convergence research plan with deep integration across disciplines.
3. A basic research approach to investigate a new understanding of emerging networks of interactions among organisms, Earth, human, natural, and human-engineered systems in evolving environments.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review.

Reviewers will be asked to evaluate proposals using two National Science Board approved merit review criteria and, if applicable, additional program specific criteria. A summary rating and accompanying narrative will generally be completed and submitted by each reviewer and/or panel. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF strives to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. Large or particularly complex proposals or proposals from new awardees may require additional review and processing time. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director acts upon the Program Officer's recommendation.

After programmatic approval has been obtained, the proposals recommended for funding will be forwarded to the Division of Grants and Agreements for review of business, financial, and policy implications. After an administrative review has occurred, Grants and Agreements Officers perform the processing and issuance of a grant or other agreement. Proposers are cautioned that only a Grants and Agreements Officer may make commitments, obligations or awards on behalf of NSF or authorize the expenditure of funds. No commitment on the part of NSF should be inferred from technical or budgetary discussions with a NSF Program Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement signed by the NSF Grants and Agreements Officer does so at their own risk.

Once an award or declination decision has been made, Principal Investigators are provided feedback about their proposals. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers or any reviewer-identifying information, are sent to the Principal Investigator/Project Director by the Program Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

Notification of the award is made to *the submitting organization* by a Grants Officer in the Division of Grants and Agreements. Organizations whose proposals are declined will be advised as promptly as possible by the cognizant NSF Program administering the program. Verbatim copies of reviews, not including the identity of the reviewer, will be provided automatically to the Principal Investigator. (See Section VI.B. for additional information on the review process.)

B. Award Conditions

An NSF award consists of: (1) the award notice, which includes any special provisions applicable to the award and any numbered amendments thereto; (2) the budget, which indicates the amounts, by categories of expense, on which NSF has based its support (or otherwise communicates any specific approvals or disapprovals of proposed expenditures); (3) the proposal referenced in the award notice; (4) the applicable award conditions, such as Grant General Conditions (GC-1)*; or Research Terms and Conditions* and (5) any announcement or other NSF issuance that may be incorporated by reference in the award notice. Cooperative agreements also are administered in accordance with NSF Cooperative Agreement Financial and Administrative Terms and Conditions (CA-FATC) and the applicable Programmatic Terms and Conditions. NSF awards are electronically signed by an NSF Grants and Agreements Officer and transmitted electronically to the organization via e-mail.

*These documents may be accessed electronically on NSF's Website at https://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov.

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

Special Award Conditions:

Grantees will be required to include appropriate acknowledgment of NSF support in any publication (including World Wide Web pages) for any material based on or developed under the project, in the following terms: "This material is based upon work supported by the National Science Foundation Understanding the Rules of Life Big Idea under Grant No. (Grantee enters NSF grant number)."

Grantees also will be required to orally acknowledge NSF support using the language specified above during all news media interviews, including popular media such as radio, television and news magazines.

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer no later than 90 days prior to the end of the current budget period. (Some programs or awards require submission of more frequent project reports). No later than 120 days following expiration of a grant, the PI also is required to submit a final project report, and a project outcomes report for the general public.

Failure to provide the required annual or final project reports, or the project outcomes report, will delay NSF review and processing of any future funding increments as well as any pending proposals for all identified PIs and co-PIs on a given award. PIs should examine the formats of the required reports in advance to assure availability of required data.

PIs are required to use NSF's electronic project-reporting system, available through Research.gov, for preparation and submission of annual and final project reports. Such reports provide information on accomplishments, project participants (individual and organizational), publications, and other specific products and impacts of the project. Submission of the report via Research.gov constitutes certification by the PI that the contents of the report are accurate and complete. The project outcomes report also must be prepared and submitted using Research.gov. This report serves as a brief summary, prepared specifically for the public, of the nature and outcomes of the project. This report will be posted on the NSF website exactly as it is submitted by the PI.

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

VIII. AGENCY CONTACTS

Please note that the program contact information is current at the time of publishing. See program website for any updates to the points of contact.

General inquiries regarding this program should be made to:

- Betsy von Holle, BIO, telephone: (703) 292-4974, email: e-networks@nsf.gov
- Mitra Basu, CISE, telephone: (703) 292-8649, email: e-networks@nsf.gov
- Jeremy Guinn, EHR, telephone: (703) 292-8193, email: e-networks@nsf.gov
- Grace M. Hwang, ENG, telephone: (703) 292-4271, email: e-networks@nsf.gov
- Dena M. Smith-Nufio, GEO, telephone: (703) 292-7431, email: e-networks@nsf.gov
- Trisha Van Zandt, SBE, telephone: (703) 292-7437, email: e-networks@nsf.gov
- Junping Wang, MPS, telephone: (703) 292-4488, email: e-networks@nsf.gov

For questions related to the use of FastLane or Research.gov, contact:

- FastLane and Research.gov Help Desk: 1-800-673-6188
- FastLane Help Desk e-mail: fastlane@nsf.gov
- Research.gov Help Desk e-mail: rgov@nsf.gov.

For questions relating to Grants.gov contact:

- Grants.gov Contact Center: If the Authorized Organizational Representatives (AOR) has not received a confirmation message from Grants.gov within 48 hours of submission of application, please contact via telephone: 1-800-518-4726; e-mail: support@grants.gov.

IX. OTHER INFORMATION

The NSF website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this website by potential proposers is strongly encouraged. In addition, "NSF Update" is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF [Grants Conferences](#). Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. "NSF Update" also is available on [NSF's website](#).

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this mechanism. Further information on Grants.gov may be obtained at <https://www.grants.gov>.

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent Federal agency created by the National Science Foundation Act of 1950, as amended (42 USC 1861-75). The Act states the purpose of the NSF is "to promote the progress of science; [and] to advance the national health, prosperity, and welfare by supporting research and education in all fields of science and engineering."

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000 colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

NSF receives approximately 55,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Arctic and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities (FASSED) provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See the *NSF Proposal & Award Policies & Procedures Guide* Chapter II.E.6 for instructions regarding preparation of these types of proposals.

The National Science Foundation has Telephonic Device for the Deaf (TDD) and Federal Information Relay Service (FIRS) capabilities that enable individuals with hearing impairments to communicate with the Foundation about NSF programs, employment or general information. TDD may be accessed at (703) 292-5090 and (800) 281-8749, FIRS at (800) 877-8339.

The National Science Foundation Information Center may be reached at (703) 292-5111.

The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at <https://www.nsf.gov>

- **Location:** 2415 Eisenhower Avenue, Alexandria, VA 22314
- **For General Information** (703) 292-5111

(NSF Information Center):

• **TDD (for the hearing-impaired):** (703) 292-5090

• **To Order Publications or Forms:**

Send an e-mail to: nsfpubs@nsf.gov

or telephone: (703) 292-8134

• **To Locate NSF Employees:** (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

The information requested on proposal forms and project reports is solicited under the authority of the National Science Foundation Act of 1950, as amended. The information on proposal forms will be used in connection with the selection of qualified proposals; and project reports submitted by awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff assistants as part of the proposal review process; to proposer institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; and to another Federal agency, court, or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See [System of Record Notices, NSF-50](#)NSF-50, "Principal Investigator/Proposal File and Associated Records," and [NSF-51](#)NSF-51, "Reviewer/Proposal File and Associated Records." Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

An agency may not conduct or sponsor, and a person is not required to respond to, an information collection unless it displays a valid Office of Management and Budget (OMB) control number. The OMB control number for this collection is 3145-0058. Public reporting burden for this collection of information is estimated to average 120 hours per response, including the time for reviewing instructions. Send comments regarding the burden estimate and any other aspect of this collection of information, including suggestions for reducing this burden, to:

Suzanne H. Plimpton
Reports Clearance Officer
Policy Office, Division of Institution and Award Support
Office of Budget, Finance, and Award Management
National Science Foundation
Alexandria, VA 22314

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