

NSF 24-559: Mathematical Foundations of Digital Twins

Program Solicitation

Document Information

Document History

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National Science Foundation

Directorate for Mathematical and Physical Sciences

Division of Mathematical Sciences

Directorate for Engineering

Division of Civil, Mechanical and Manufacturing Innovation



Air Force Office of Scientific Research

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

June 20, 2024

March 17, 2025

March 15, Annually Thereafter



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Important Information And Revision Notes

Any proposal submitted in response to this solicitation should be submitted in accordance with the *NSF Proposal & Award Policies & Procedures Guide (PAPPG)* that is in effect for the relevant due date to which the proposal is being submitted. The NSF PAPPG is regularly revised and it is the responsibility of the proposer to ensure that the proposal meets the requirements specified in this solicitation and the applicable version of the PAPPG. Submitting a proposal prior to a specified deadline does not negate this requirement.

Summary Of Program Requirements

General Information

Program Title:

Mathematical Foundations of Digital Twins (MATH-DT)

Synopsis of Program:

The Division of Mathematical Sciences (DMS) in the Directorate for Mathematical and Physical Sciences (MPS) at the National Science Foundation (NSF) and the Air Force Office of Scientific Research (AFOSR) plan to jointly support foundational mathematical and statistical research on Digital Twins in applied sciences. Recent years have witnessed a significant increase in the demand and interest in applications that involve collaborative teams developing and analyzing Digital Twins to support decision making in various fields, including science, engineering, medicine, urban planning, and more. Both agencies recognize the need to promote research aiming to stimulate an interplay between mathematics/statistics/computation and practical applications in the realm of Digital Twins. This program encourages new collaborative efforts within the realm of Digital Twins, aiming at stimulating fundamental research innovation, pushing, and expanding the boundaries of knowledge, and exploring new frontiers in mathematics and computation for Digital Twin development, and its applications. By leveraging this synergy, the program aims to harness science, technology, and innovation to address some of our Society's most pressing challenges.

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.

- Yuliya Gorb, Program Officer, MPS/DMS, telephone: (703) 292-2113, email: ygorb@nsf.gov
- Jodi Mead, Program Officer, MPS/DMS, telephone: (703) 292-7212, email: jmead@nsf.gov
- Fariba Fahroo, Program Officer, AFOSR/RTA2, telephone: (571) 230-6634, email: fariba.fahroo@us.af.mil
- Yulia Gel, Program Officer, MPS/DMS, telephone: (703) 292-7888, email: ygel@nsf.gov
- Dmitry Golovaty, Program Officer, MPS/DMS, telephone: (703) 292-2117, email: dgolov@nsf.gov
- Daan Liang, Program Officer, ENG/CMMI, telephone: (703) 292-2441, email: dliang@nsf.gov
- Siqian Shen, Program Officer, ENG/CMMI, telephone: (703) 292-7048, email: siqshen@nsf.gov

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

- 12.800 --- Air Force Office of Scientific Research
- 47.041 --- Engineering
- 47.049 --- Mathematical and Physical Sciences

Award Information

Anticipated Type of Award: Standard Grant

Estimated Number of Awards: 6 to 10

Awards are for collaborations involving at least two PIs or co-PIs for 36 months.

Anticipated Funding Amount: \$5,000,000

Estimated program budget and number of awards are subject to the availability of funds and receipt of competitive proposals.

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 laboratories, professional societies and similar organizations located in the U.S. that are directly associated with educational or research activities.
- Tribal Nations: An American Indian or Alaska Native tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges as a federally recognized tribe pursuant to the Federally Recognized Indian Tribe List Act of 1994, 25 U.S.C. §§ 5130-5131.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

Because of the level of commitment expected from senior/key personnel, none can be part of more than one proposal or award at a time as a PI or co-PI.

Proposals involving investigators from more than one organization are allowed and separately submitted collaborative proposals are encouraged. See the NSF PAPPG for guidance on the simultaneous submission of proposals from different organizations.

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 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:**

Not Applicable

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitting organization's local time):
 - June 20, 2024
 - March 17, 2025
 - March 15, Annually Thereafter

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:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

I. Introduction

In recent years, there has been a remarkable upsurge in the demand and interest surrounding applications that necessitate the development of Digital Twins (DTs). A Digital Twin is a representation of a real-world object, process, or system that changes over time as it is updated with data and models. This dynamic digital counterpart serves as a powerful tool that enables us to gain insights, test strategies, and make predictions about real-world behavior. The scope of applications for Digital Twins is exceptionally broad, encompassing fields as diverse as manufacturing, engineering, healthcare, urban planning, and more. What is driving the growth in this area is the significant advancements made in a range of fields, including artificial intelligence and scientific machine learning, numerical partial differential equations, imaging techniques, inverse methods, data assimilation, uncertainty quantification, control, optimization methods, high performance computing, experimental design, and various others. These advancements are poised to accelerate the development and the impact of Digital Twins across multiple domains.

Recognizing the inherently interdisciplinary nature of Digital Twins and the synergistic relationship between Digital Twin applications and mathematical innovation, the Division of Mathematical Sciences (DMS) within the Directorate for Mathematical and Physical Sciences (MPS) at the National Science Foundation (NSF) has forged a strategic partnership with the Air Force Office of Scientific Research (AFOSR). This partnership effort is geared towards mathematical and statistical advancements that can enhance the accuracy, reliability, robustness, efficiency, and effectiveness of Digital Twins in applications, ultimately leading to improved decision-making and policy design for various practical applications. This pilot program, jointly launched by DMS and AFOSR, calls for proposals that aim to expand the boundaries of both mathematics and applications. Through this partnership, the NSF and AFOSR aim at driving research and innovation in the burgeoning field of Digital Twins, setting the stage for transformative breakthroughs in the future.

II. Program Description

MATH-DT is a pilot program designed to foster new and existing collaborative research that innovatively addresses critical mathematical and statistical challenges arise in the development of Digital Twins. The primary objective of the MATH-DT program is to facilitate innovative research that tackles overarching problems characterized by substantial complexity and challenges, such as those involving multi-scale, multi-physics, or high-dimensional components, rather than concentrating on specific application domains. The MATH-DT program seeks proposals that address one or both aspects of the two-directional relationship between mathematics/statistics and Digital Twins within practical applications. In one direction, mathematics/statistics plays a pivotal role in guiding the creation of intricate Digital Twin models and methods for their evaluation while also serving as a problem-solving tool. In the other direction, application domain experts can introduce constraints and objectives that necessitate the development of new mathematical, computational, and statistical approaches for Digital Twins.

The MATH-DT program will provide support for collaborative efforts involving research teams consisting of at least two Principal Investigators (PIs). At least one of the PIs will assume a lead role in addressing the emerging mathematical or statistical challenges of the project, while at least one other PI should be specialized in modeling or have access to data directly related or relevant to practical Digital Twin applications. Some examples of application problems with significant mathematical challenges encompass areas such as design monitoring, operations of civil infrastructure systems, emergency response to disasters, and complex system prediction and control. Mathematical challenges such as these

often include, but are not limited to, (i) the integration of models and data across various scales and levels of fidelity, (ii) the quantification of uncertainty to assess model inadequacy when dealing with limited and noisy data, and (iii) the comprehensive evaluation of computational costs and scalability within the overarching framework.

Successful proposals are expected to demonstrate substantial innovation within the field of mathematics, computation and/or statistics, and clear evidence of Digital Twins' potential to address real-world problems and issues. These two critical aspects should be prominently featured in the project summary and further elaborated upon in the project description. The MATH-DT program anticipates that the Digital Twins development will capitalize on and be transformed by the synergistic relationship between Digital Twin applications and mathematical/statistical innovations. The program, however, does not impose specific requirements on applications, offering flexibility to advance the foundations of Digital Twins.

The MATH-DT program aims to stimulate a dynamic interaction between mathematics/statistics, application, and the linkage between the two in the realm of Digital Twins. By supporting projects that address the closed loop interaction between the physical and the Digital Twin, the program seeks to catalyze innovation, push, and expand the boundaries of knowledge, and chart new frontiers in both the realms of mathematical theory and its practical application. The MATH-DT program expects that Digital Twin development will capitalize on, and be transformed by, the synergistic relationship between application domain knowledge and the related mathematical innovations. The program strives to advance the development of Digital Twins and their transformative impact across various scientific and engineering domains through the collaborative synergy between foundational research and practical applications.

The MATH-DT program welcomes the submission of proposals to this funding opportunity that include the participation of the full spectrum of diverse talent in STEM, e.g., as PI, co-PI, senior personnel, postdoctoral scholars, graduate or undergraduate students or trainees. This includes historically under-represented or under-served populations. It also includes diverse institutions including [Minority-Serving Institutions](#) (MSIs), Primarily Undergraduate Institutions (PUIs), and two-year colleges, as well as major research institutions. Proposals from EPSCoR jurisdictions are especially encouraged.

III. Award Information

Anticipated Type of Award: Standard Grant

Estimated Number of Awards: 6 to 10

Awards are for collaborations involving at least two PIs or co-PIs for 36 months.

Anticipated Funding Amount: \$5,000,000

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.
- Non-profit, non-academic organizations: Independent museums, observatories, research laboratories, professional societies and similar organizations located in the U.S. that are directly

associated with educational or research activities.

- Tribal Nations: An American Indian or Alaska Native tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges as a federally recognized tribe pursuant to the Federally Recognized Indian Tribe List Act of 1994, 25 U.S.C. §§ 5130-5131.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

Because of the level of commitment expected from senior/key personnel, none can be part of more than one proposal or award at a time as a PI or co-PI.

Proposals involving investigators from more than one organization are allowed and separately submitted collaborative proposals are encouraged. See the NSF PAPPG for guidance on the simultaneous submission of proposals from different organizations.

Additional Eligibility Info:

A minimum of two PIs must be named on a proposal. At least one of them will assume a lead role in addressing the emerging mathematical or statistical challenges of the project, while at least one other PI should be specialized in modeling or have access to data directly related or relevant to practical Digital Twin applications.

AFRL and its staff are ineligible to be involved in any proposals submitted to this funding opportunity, including as unfunded collaborators, via letters of collaboration or support, or via any other means.

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 Research.gov or Grants.gov.

- 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.

In determining which method to utilize in the electronic preparation and submission of the proposal, please note the following:

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via Research.gov. PAPPG Chapter II.E.3 provides additional information on collaborative proposals.

See PAPPG Chapter II.D.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.

Title. To facilitate timely processing, the title of the proposed project should begin with "MATH-DT". When you submit a proposal as part of a set of collaborative proposals, the title of the proposal should begin with "Collaborative Research: MATH-DT". Please note that if submitting via Research.gov, the system will automatically insert the prepended title "Collaborative Research" when the collaborative set of proposals is created. All proposals in a group of separately submitted collaborative proposals should have the same title and should be submitted to the Computational Mathematics program.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

C. Due Dates

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

June 20, 2024

March 17, 2025

March 15, Annually Thereafter

D. Research.gov/Grants.gov Requirements

For Proposals Submitted Via Research.gov:

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/ProposalPreparation

For Research.gov user support, call the Research.gov Help Desk at 1-800-381-1532 or e-mail rgov@nsf.gov.

The Research.gov Help Desk answers general technical questions related to the use of the Research.gov system. 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 Research.gov for further processing.

The NSF [Grants.gov Proposal Processing in Research.gov informational page](#) provides submission guidance to applicants and links to helpful resources including the NSF [Grants.gov Application Guide](#), [Grants.gov Proposal Processing in Research.gov how-to guide](#), and [Grants.gov Submitted Proposals Frequently Asked Questions](#). Grants.gov proposals must pass all NSF pre-check and post-check validations in order to be accepted by Research.gov at NSF.

When submitting via Grants.gov, NSF strongly recommends applicants initiate proposal submission at least five business days in advance of a deadline to allow adequate time to address NSF compliance errors and resubmissions by 5:00 p.m. submitting organization's local time on the deadline. Please note that some errors cannot be corrected in Grants.gov. Once a proposal passes pre-checks but fails any post-check, an applicant can only correct and submit the in-progress proposal in Research.gov.

Proposers that submitted via 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 [Leading the World in Discovery and Innovation, STEM Talent Development and the Delivery of Benefits from Research - NSF Strategic Plan for Fiscal Years \(FY\) 2022 - 2026](#). 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.D.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.D.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 other underrepresented groups 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 and Sharing Plan and the Mentoring Plan, as appropriate.

Additional Solicitation Specific Review Criteria

In addition to the National Science Board merit review criteria, reviewers will be asked to review how well the proposal addresses the following aspects:

- To what extent do the proposed activities explore the synergistic relationship between Digital Twin applications and mathematical/statistical innovation?
- To what extent do the proposed activities address one or both aspects of the two-directional relationship between mathematics and Digital Twins in the context of practical applications? In one direction, mathematics serves as a guide for creating intricate Digital Twin models and methods to evaluate them, while also functioning as a problem-solving tool. In the other direction, application domain experts can introduce constraints and objectives that necessitate development of new mathematical, computational, and statistical approaches for Digital Twins.
- To what extent does at least one PI or co-PI serve as lead in the emerging mathematical or statistical challenges of the project, and at least one other serve as the expert in modeling or data relevant to the practical Digital Twin application?

B. Review and Selection Process

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

NSF will coordinate and manage the review of proposals jointly with AFOSR. AFOSR-designated Program Officer(s) may attend NSF review panels as observers. Relevant information about proposals and reviews of proposals will be shared with designated AFOSR Program Officers as appropriate.

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 proposers whether their proposals have been declined or recommended for funding within six months. Large or particularly complex proposals or proposals from new recipients 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 or the Division of Acquisition and Cooperative Support 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 an NSF Grants and Agreements Officer. 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.

Administrative and National Policy Requirements

Build America, Buy America

As expressed in Executive Order 14005, [Ensuring the Future is Made in All of America by All of America's Workers](#) (86 FR 7475), it is the policy of the executive branch to use terms and conditions of Federal financial assistance awards to maximize, consistent with law, the use of goods, products, and materials produced in, and services offered in, the United States.

Consistent with the requirements of the Build America, Buy America Act (Pub. L. 117-58, Division G, Title IX, Subtitle A, November 15, 2021), no funding made available through this funding opportunity may be obligated for an award unless all iron, steel, manufactured products, and construction materials used in the project are produced in the United States. For additional information, visit NSF's [Build America, Buy America](#) webpage.

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 annual project report, and a project outcomes report for the general public.

Failure to provide the required annual or final annual 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 annual 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:

- Yuliya Gorb, Program Officer, MPS/DMS, telephone: (703) 292-2113, email: ygorb@nsf.gov
- Jodi Mead, Program Officer, MPS/DMS, telephone: (703) 292-7212, email: jmead@nsf.gov

- Fariba Fahroo, Program Officer, AFOSR/RTA2, telephone: (571) 230-6634, email: fariba.fahroo@us.af.mil
- Yulia Gel, Program Officer, MPS/DMS, telephone: (703) 292-7888, email: ygel@nsf.gov
- Dmitry Golovaty, Program Officer, MPS/DMS, telephone: (703) 292-2117, email: dgolovat@nsf.gov
- Daan Liang, Program Officer, ENG/CMMI, telephone: (703) 292-2441, email: dliang@nsf.gov
- Siqian Shen, Program Officer, ENG/CMMI, telephone: (703) 292-7048, email: siqshen@nsf.gov

For questions related to the use of NSF systems contact:

- NSF Help Desk: 1-800-381-1532
- 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 (FASED) 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.F.7 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** (NSF Information Center): (703) 292-5111
- **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 proposers 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 proposers 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](#), "Principal Investigator/Proposal File and Associated Records," and [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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National Science Foundation, 2415 Eisenhower Ave Alexandria, VA 22314
Tel: [\(703\) 292-5111](tel:(703)292-5111),