

Enabling Quantum Leap: Quantum Interconnect Challenges for Transformational Advances in Quantum Systems (QuIC-TAQS)

PROGRAM SOLICITATION

NSF 21-553

REPLACES DOCUMENT(S):

NSF 19-532



National Science Foundation

Preliminary Proposal Due Date(s) (required) (due by 5 p.m. submitter's local time):

April 12, 2021

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

June 14, 2021

IMPORTANT INFORMATION AND REVISION NOTES

There are several revisions to [NSF 19-532](#):

- The specific focus of the current solicitation is on quantum interconnects.
- The requirement for a letter of intent has been removed.
- There is a limitation on the number of proposals that may be submitted by one institution.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) ([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:

Enabling Quantum Leap: Quantum Interconnect Challenges for Transformational Advances in Quantum Systems (QuIC-TAQS)

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 leadership 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 Directorate for Mathematical & Physical Sciences/Office of Multidisciplinary Activities (MPS/OMA), once received, the proposals will be managed by a cross-disciplinary team of NSF Program Directors.

One of these ideas was 'Quantum Leap' – exploiting the quantum properties to produce the next-generation quantum-enabled science and technology for sensing, information processing, communicating and computing. NSF has funded a range of programs in this area. The importance of this area has been recognized more broadly. On December 21, 2018 the National Quantum Initiative Act (<https://www.congress.gov/115/plaws/publ368/PLAW-115publ368.pdf>) was signed into law. The purpose of this act was to ensure the continued leadership of the United States in quantum information science and its technology applications. This provided a coordinated Federal program to accelerate research in this area. A framework for this can be found in the Quantum Frontiers report: <https://www.quantum.gov/wp-content/uploads/2020/10/QuantumFrontiers.pdf>

The **Quantum Interconnect Challenges for Transformational Advances in Quantum Systems (QuIC - TAQS)** program is designed to support interdisciplinary teams that will explore highly innovative, original, and potentially transformative ideas for developing and applying quantum science, quantum computing, and quantum engineering in the specific area of quantum interconnects. Quantum interconnects are an

integral part of all aspects of quantum information science. Proposals should have the potential to deliver new concepts, new platforms, and/or new approaches that will implement the transfer of quantum states efficiently across platforms and over large length scales. Progress in the area of quantum interconnects will enable breakthroughs in quantum sensing, quantum communications, quantum simulations, and quantum computing systems. This Quantum Interconnect Challenges solicitation will support the process of translating such ideas into reality.

This solicitation calls for proposals focused on interdisciplinary research that enhances the development of quantum interconnects (QulC) that would allow the transfer of quantum states between different physical states and/or different physical systems. Proposals must articulate how the project leverages and/or promotes advances in quantum interconnects. Proposals should be innovative and must focus on quantum functionality and must result in experimental demonstrations and/or transformative advances towards quantum systems and/or proof-of-concept validations. Competitive proposals will come from an interdisciplinary research team led by at least three investigators who collectively contribute synergistic expertise from a subset of the following domains: engineering, mathematics, computational science, computer/information science, physical, chemical, biological, material science. Proposals will be judged on how likely the integrated effort is to lead to transformative advances in quantum interconnection.

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.

- Quantum Interconnects, telephone: (703) 292-2980, email: quic@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: 10 to 12

The final number of awards will depend on the availability of funds and the quality of the proposals.

Anticipated Funding Amount: \$25,000,000

Anticipated funding amount is pending availability of funds. Each project team may receive support of up to a total of \$2,500,000 over the project duration of 4 years. It is not expected that all awards will receive the maximum amount; the size of awards will depend upon the type of research program proposed. The budget must be commensurate with the scope of the project and thoroughly justified in the proposal.

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.

Who May Serve as PI:

The Principal Investigator (PI) must be a faculty member employed by the submitting organization. A minimum of one PI and **two** co-PIs must participate.

Limit on Number of Proposals per Organization: 1

Only one preliminary proposal may be submitted per lead institution

Limit on Number of Proposals per PI or Co-PI: 2

No individual may appear as Senior Personnel (Principal Investigator, Co-PI, and Faculty Associate or equivalent) on more than two QulC - TAQS preliminary proposals. In the event that any individual exceeds this limit, any preliminary proposal submitted to this solicitation with this individual listed as PI, co-PI, or Senior Personnel after the first two preliminary proposals are received at NSF will be returned without review. No exceptions will be made.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposals:** Submission of Preliminary Proposals is required. Please see the full text of this solicitation for further information.
- **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 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

- **Preliminary Proposal Due Date(s) (required)** (due by 5 p.m. submitter's local time):

April 12, 2021
- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

June 14, 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:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

The "Quantum Leap: Leading the Next Quantum Revolution" is one of NSF's "10 Big Ideas" that aims to empower U.S. researchers to propel the science and engineering of quantum phenomena through high-risk, high-payoff projects. In 2019, NSF held a workshop to identify the scientific challenges in the development of quantum interconnects for the next-generation of information technologies. This workshop highlighted the need for focused convergent research in quantum interconnects to enable progress in quantum information science. The findings of the workshop were summarized in <https://arxiv.org/abs/1912.06642>. Although this report represents a view of the current needs in this area, it highlights examples of areas of research that is non-prescriptive. In addition to those topics and ideas presented in the workshop, this solicitation welcomes ideas and topics in the area of quantum interconnects that were not covered by the workshop.

As a part of the Quantum Leap, QuIC-TAQS research efforts are expected to explore highly innovative, original, and potentially transformative ideas for developing and applying quantum science, quantum computing, and quantum engineering in the specific area of quantum interconnects. In addition, these efforts will contribute to training the next generation of a highly skilled workforce. The program serves to support the process for bringing these ideas into reality.

The challenge in achieving quantum connected modules requires advancing basic principles and developing devices with controls and protocols. Proposed activities should explore new concepts involving quantum methods, algorithms, and/or materials that exploit quantum phenomena and enable novel efficient devices, circuits, and/or system architectures. The activities should be designed to accelerate fundamental understanding of the physical, chemical, biological, computational, or information-theoretic mechanisms that underlay the transfer of quantum information. To achieve these goals, a variety of approaches for generation, processing, communication with, and sensing of quantum states could be considered, including modeling, analysis, and computational simulations. Where appropriate, the proposed activities should include validation and verification through measurement, experimentation, and/or device demonstration.

Research topics of interest include all aspects of quantum interconnects. These range from quantum interconnects for modular quantum processors and computers, the quantum internet, quantum enhanced interconnected sensors and integrated quantum photonic platforms. In addition, research into quantum interconnects between various quantum systems and atomic/photonic, atomic/atomic and photonic/photonic interconnects is of interest.

The education of scientists and engineers with expertise in quantum technologies and advanced cyberinfrastructure who are able to work collaboratively with researchers on science and engineering topics, spanning both theoretical tools as well as experimental approaches, platforms, and testbeds, is crucially important for bringing new ideas into reality. Creative and novel approaches to K-12 and informal education tools as well as training of a new generation of teachers are needed to secure the continuing supply of talent. Reaching out and establishing impactful collaborations with underrepresented groups including collaborations with Minority Serving Institutions and Historically Black Colleges and Universities provides means of growing the pool of US Science, Technology, Engineering and Math (STEM) talent. We encourage proposals that include educational and workforce development components that address these goals.

II. PROGRAM DESCRIPTION

Competitive proposals are expected to present a collaborative, integrated approach and make a compelling case for how the selected topics are unified to potentially deliver a breakthrough in quantum interconnect technologies.

Potential Research Areas:

Interconnected quantum systems, whether the interconnection is between quantum interfaces, chip-to-chip, or across continent-scale distances, rely on a set of common quantum communication elements. To fully realize the potential of quantum interconnection, significant [convergent research](#) by an interdisciplinary team is required, to advance areas such as:

- Quantum memory and/or quantum repeaters with error correction ability
- High rate quantum entanglement sources, memory buffers and detectors
- Spatial-temporal encoding for high bit rates
- Efficient multiplexing and demultiplexing technology
- Transduction from optical and telecommunications regimes to quantum computer and quantum-sensor relevant domains

Diverse and innovative ideas that fit with the scope of quantum interconnects are encouraged. A discussion of examples of application specific challenges follows in the sections below.

Quantum enhanced Interconnected sensors

In order to realize the goal of interconnected quantum sensors in real-world applications, research must go beyond current sensor capabilities and create new devices and architectures that can not only detect but create a quantum sensing platform integrated into a quantum network for long distance entangled distribution. Most existing quantum-enhanced sensing demonstrations leverage non-classical resources to improve the measurement performance at a single sensor, but many real-world applications rest upon a network of sensors that work collectively to undertake measurement tasks. Recent theoretical works on quantum-enhanced sensing based on multipartite entanglement show that interconnecting distributed quantum sensors can form an entangled sensor network that can probe global parameters at the Heisenberg limit. Several research and technical challenges must be addressed for the construction of entangled quantum sensor network, which include but are not limited to

- High-efficiency quantum transducers to convert the physical information contained in the microwave, mechanical, or magnetic domains into modulations on the photonic quantum states at each quantum sensor node.

- Entanglement-enhanced sensing in local registers (e.g., multi-nuclear or electron-nuclear spin entanglement around or within a color center).
- Scaling up entangled photonic sensors in an integrated platform.

Quantum Interconnects for modular quantum processors and scalable computers

Modern classical computing systems connect thousands of distributed computers, memories and storage to carry out large-scale calculations. The comparable modular quantum computer system would incorporate quantum processors via a quantum network using quantum interconnects. Challenges in this area include:

- improving quantum interfaces, including between heterogeneous platforms
- integration of modules and interfaces,
- hybrid architectures
- hybrid interfaces
- design and operation of control systems across modules
- control and tracking of the quantum phase in the modules

Research is also needed in distributing tasks across a quantum modular system efficiently, especially since the functionality of the modules and interconnects may vary affecting performance.

Integrated quantum photonic platforms

The development of scalable integrated quantum photonic platforms for QuIC is needed to achieve efficient matter-photon or photon-photon qubit connections. This research requires cross disciplinary efforts. It includes all aspects of such development such as:

- The synthesis of emerging quantum materials for efficient frequency conversion with elucidation of noise sources and mechanisms,
- Fast reconfigurable switches,
- Development of novel ultra-low loss optical waveguides,
- Fabrication and packaging of hybrid-integrated quantum photonic device platforms.

Quantum internet

A Quantum Internet enables the exchange of quantum information between a large number of nodes across potentially global distances at high bit rates. Enabling a system of this scale with high throughput requires addressing major research challenges (beyond those listed above) which include, but are not limited to:

- Robust, scalable quantum repeaters with error correction capability.
- Long-lived, stable and scalable quantum memories
- Efficient quantum non-demolition measurements
- Methods for control and efficient measurement of quantum states
- Highly efficient frequency conversion for frequency translation across system interfaces
- Low loss scalable optical switches

The Quantum Internet must also be able to route information from any point to any other point in the network, through multiple nodes and for multiple information flows simultaneously. Associated systems-level research challenges include but are not limited to:

- Scalable Quantum Internet network architectures
- Protocols and algorithms for achieving any-to-any communication at acceptable performance levels.

QuIC-TAQS Programmatic Considerations:

Among the programmatic considerations, the following features are deemed important under this QuIC-TAQS research solicitation in order to realize the promise of this field over the coming years:

- **Interdisciplinary and convergence:** Progress in this field will benefit tremendously from research that draws on multiple disciplines including physics, chemistry, biology, mathematics, computer sciences and engineering, and thus it is natural to enable scientists and engineers to work together more effectively in research teams involving theory, modeling, design, characterization, and/or device fabrication and testing. More diverse topics and approaches are encouraged.
- **Quantum functionality:** It is expected that proposed research will focus on quantum functionality by assessing aspects relevant to both fundamental and application concepts.
- **Experimental demonstration:** Examples of demonstrations include, but are not limited to quantum-device properties characterization or demonstration in a system, proof-of-concept of novel quantum functionalities, algorithms demonstration of quantum hardware, demonstration of quantum programming systems and/or software stacks, etc. Proposals in which experimental demonstration is not appropriate should clearly explain why this is the case and how the proposal is exceptionally strong in the other programmatic considerations.

The QuIC - TAQS program also encourages other activities with the potential to increase the impact of projects:

- **Educational and Training Initiatives:** Proposals that address the educational and training needs of K-12, undergraduate and graduate students or teachers, and/or the development of a diverse workforce, in all areas of quantum science and engineering are encouraged.
- **Partnerships:** Creation of academia-industry or academia-National Lab partnerships may be critical in the development of new concepts and platforms, in scaling-up, and subsequent commercialization of technologies based on QuIC - TAQS concepts. Such partnerships are therefore encouraged where appropriate. Leveraging unique facilities at National Labs and other agencies is also welcome.
- **International Collaboration and Student Mobility:** We encourage collaboration with international scientific teams, from like-minded countries, who are leaders in the field. Travel support for principal investigators, research personnel and students may be considered under the proposal application, or through travel supplements during the award period. Opportunities for student mobility are encouraged in order to develop a globally engaged workforce in this nascent technology sector.

III. AWARD INFORMATION

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds. The estimated program budget is \$25,000,000 with 10 -12 awards expected. Each project team may receive support of up to a total of \$2,500,000 over the project duration of 4 years. It is not expected that all awards will receive the maximum amount; the size of awards will depend upon the type of research program proposed. The budget must be commensurate with the scope of the project and thoroughly justified in the proposal.

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.

Who May Serve as PI:

The Principal Investigator (PI) must be a faculty member employed by the submitting organization. A minimum of one PI and **two** co-PIs must participate.

Limit on Number of Proposals per Organization: 1

Only one preliminary proposal may be submitted per lead institution

Limit on Number of Proposals per PI or Co-PI: 2

No individual may appear as Senior Personnel (Principal Investigator, Co-PI, and Faculty Associate or equivalent) on more than two QuIC - TAQS preliminary proposals. In the event that any individual exceeds this limit, any preliminary proposal submitted to this solicitation with this individual listed as PI, co-PI, or Senior Personnel after the first two preliminary proposals are received at NSF will be returned without review. No exceptions will be made.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Preliminary Proposals (required): Preliminary proposals are required and must be submitted via the NSF FastLane system, even if full proposals will be submitted via Grants.gov.

Preliminary proposals must be submitted via FastLane in accordance with the instructions below. Preliminary proposals that are not compliant with this solicitation will be returned without review. It is the submitting organization's responsibility to ensure that the proposal is compliant with all applicable requirements. If there are multiple universities involved in a preliminary proposal, it must be submitted as a single proposal with subawards and not as separately submitted collaborative proposals. Preliminary proposals must contain the items listed below and strictly adhere to the specified page limitations. No additional information may be provided as an appendix or by links to web pages. Figures and tables must be included within the applicable page limit. Preliminary proposals must meet all formatting requirements specified in the NSF PAPPG https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg..

Unlike full proposals, preliminary proposals must **ONLY** include the following items:

Cover Sheet: Select the QuIC - TAQS program solicitation number from the pull-down list. Check the box indicated for preliminary proposal. A minimum of three senior personnel must participate.

Title of Proposed Project: The title for the proposed QuIC - TAQS project must begin with "**QuIC - TAQS Preliminary Proposal:**".

Project Summary: The project summary may not be more than one page in length and must consist of three parts:

- In the Overview section, include the title of the project, the name of the PI and the lead institution, and a list of co-PIs and senior personnel along with their institutions;
- Provide a succinct summary of the **intellectual merit** of the proposed project. This should also articulate how the project leverages and/or promotes advances in quantum interconnects; and
- Describe the **broader impacts** of the proposed work, including the potential long-term impact on national needs.

Proposals that do not separately address in the project summary both intellectual merit and broader impacts will be returned without review.

Project Description: The project description of the preliminary proposal is limited to **five pages** and must include the following subsections:

- **Vision and Goals:** Describe the vision and specific goals of the proposed research, explicitly addressing how the different PIs and research topics

mesh together to achieve the research goals

- **Approach and Methodology:** Describe the approach and methodology that will be used to achieve the research vision and goals
- **Relevance to Quantum Interconnects:** Describe how the project leverages and/or promotes advances in quantum interconnects

References Cited: Indicate with an asterisk any cited publications that resulted from prior research funded by NSF for the PI, or co-PI (s).

Biographical Sketches: The standard NSF two-page biographical sketches must be prepared for the PI, co-PIs, and other senior personnel listed on the project summary page.

Budget: The preliminary proposal will include a budget for each of the proposed years. FastLane will automatically provide a cumulative budget. Preliminary proposal budgets should not include detailed subaward budgets. However, the budget justification should include planned levels for subawards to any partner institution. Enter the anticipated total level of subaward support on line G5, Subawards.

Single Copy Documents: *Collaborators and Other Affiliations Information:* Proposers should follow the guidance specified in the PAPPG Chapter II.C.1e for details. This information will be used by NSF to help manage reviewer selection.

In the **Supplementary Documentation** section, include the following:

- List of **key personnel involved** (maximum one page), with a succinct description of what each person uniquely brings to the project and how they are integrated to produce positive synergies.

Review of Preliminary Proposals and Invitation to Submit a Full Proposal: The preliminary proposals will be reviewed by panels of external experts. Based on the reviews, a limited number of preliminary proposal teams will be invited to submit full proposals. By mid-May 2021, PIs should expect to receive a message from the QuIC - TAQS program, indicating whether or not a full proposal is invited for the project. Such an invitation is required for submission of a full proposal; full proposals submitted without an invitation will be returned without review.

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via FastLane 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 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.

Based on the review of preliminary proposals, a limited number of PIs will be invited to submit a full proposal. Such an invitation is required for submission of a full proposal; full proposals submitted without an invitation will be returned without review.

If multiple universities are involved in an invited full proposal, it must be submitted as a single full proposal with subawards, and not as separately submitted collaborative proposals.

The full proposals will be reviewed by panels of outside experts. Both standard criteria (Intellectual Merit and Broader Impact), as well as Additional Solicitation Specific Review Criteria, will be given full consideration during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Please consider all the details described in Section VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES.

Special instructions for submitting to this 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 the Directorate for Mathematical & Physical Sciences/Office of Multidisciplinary Activities, 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 the Directorate for Mathematical & Physical Sciences/Office of Multidisciplinary Activities, once received the proposals will be managed by a cross-disciplinary team of NSF Program Directors.

The following instructions supplement the guidance in the PAPPG and Grants.gov Application Guide.

Cover Sheet: Select the QuIC - TAQS program solicitation number from the pull-down list. Check the box indicated for full proposal. A minimum of three senior personnel must participate.

Title of Proposed Project: The title for the proposed QuIC - TAQS project must begin with "QuIC - TAQS:".

Project Description (maximum 15 pages) must include the following subsections:

- **Vision and Goals:** Describe the vision and specific goals of the proposed research, explicitly addressing how the different PIs and research topics mesh together to achieve the research goals.

- **Approach and Methodology:** Describe the approach and methodology that will be used to achieve the research vision and goals.
- **Proposed Research:** Describe the research topics that will be explored by the project and identify the associated QuIC - TAQS research areas as delineated in Section II Program Description.
- **Thrust Area(s):** Describe the activities envisioned and the expected outcome(s), as well as possible inter-relation and/or feedback between the different efforts/topics.
- **Relevance to Quantum Interconnects:** Describe how the project leverages and/or promotes advances in quantum interconnects
- **Broader Impacts:** Describe how the proposed project has long-term potential for significant impact on national needs. The proposal should also discuss effective ways in which education, outreach, and broadening participation activities are to be integrated within the research program to achieve societal impacts.
- **Management Plan:** Provide details on planned means of communication, data tracking, management of personnel within the project group, management of intellectual property resulting from the project, and timeline of activities.
- **Results from Prior NSF Support:** Please follow the guidance provided in the NSF Proposal & Award Policies & Procedures Guide (PAPPG) for reporting results from prior NSF support. Please also describe the prior research of each PI or co-PI funded by NSF that is directly relevant to the proposed project.

Supplementary Documents: Include the following:

- A list of **key personnel involved** (maximum one page), with a succinct description of what each person uniquely brings to the project and how their expertise is to be integrated to produce positive synergies.
- **Means of sharing the outcome** (optional) of the research with the rest of the scientific community, e.g. publications, tool sets, models, designs, code, tutorials, websites and significant data bases, etc. (maximum two pages). The description should be specific and describe what, how, and when the community would have access to the outcome of the project. This is particularly important for the projects that will produce tangible research tools and resources; and
- **Broadening Participation Plan** (optional) You may include additional detail about plans to broaden participation as a supplementary document (maximum two pages).

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

C. Due Dates

- **Preliminary Proposal Due Date(s) (required)** (due by 5 p.m. submitter's local time):
April 12, 2021
- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):
June 14, 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 NSF review criteria (intellectual merit and broader impacts), additional criteria will be used in the review of both QuIC - TAQS preliminary and full proposals:

- **Interdisciplinary:** Does the proposed research involve the convergence of diverse fields of expertise to address an important topic?
- **Experimental Demonstration:** Does the proposed research include a plan for experimental demonstration, when appropriate? Examples of demonstrations include, but are not limited to, quantum devices characterization or demonstration in a system, proof-of-concept of novel quantum functionalities, algorithms demonstration on quantum hardware, etc.
- **Relevance to Quantum Interconnects:** Does the project focus on quantum functionality and leverage and/or promote advances in quantum interconnects?
- **Educational Potential:** Consideration will be given to interesting education plans/curriculum development that would contribute to an increased convergent and diverse quantum research community, including active involvement of underrepresented communities.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by 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.

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:

- Quantum Interconnects, telephone: (703) 292-2980, email: quic@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** (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 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, "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
Office of the General Counsel
National Science Foundation
Alexandria, VA 22314

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