Quantum Sensing Challenges for Transformational Advances in Quantum Systems (QuSeC-TAQS)

PROGRAM SOLICITATION
NSF 22-630

REPLACES DOCUMENT(S):
NSF 21-553

National Science Foundation

Directorate for Biological Sciences

Directorate for Computer and Information Science and Engineering

Directorate for Education and Human Resources

Directorate for Engineering

Directorate for Mathematical and Physical Sciences

Directorate for Technology, Innovation and Partnerships

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

December 16, 2022

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

April 03, 2023

IMPORTANT INFORMATION AND REVISION NOTES

There are several revisions to NSF 21-553:

The specific focus of the current solicitation is on Quantum Sensing.

There are changes on the limitations regarding the number of proposals per lead institution.

This is a crosscutting program with participation from NSF Directorates: BIO, CISE, EHR, ENG, MPS and TIP. This is no longer a "Big Ideas" solicitation because the quantum leap big idea activity is now part of the larger quantum information science and engineering priority area.

Innovating and migrating proposal preparation and submission capabilities from FastLane to Research.gov is part of the ongoing NSF information technology modernization efforts, as described in Important Notice No. 147. In support of these efforts, proposals submitted in response to this program solicitation must be prepared and submitted via Research.gov or via Grants.gov and may not be prepared or submitted via FastLane.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 22-1), which is effective for proposals submitted, or due, on or after October 4, 2021.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Quantum Sensing Challenges for Transformational Advances in Quantum Systems (QuSeC-TAQS)

Synopsis of Program:

The Quantum Sensing Challenges for Transformational Advances in Quantum Systems (QuSeC-TAQS) program supports interdisciplinary teams of three (3) or more investigators to explore highly innovative, original, and potentially transformative research on quantum sensing. The QuSeC-TAQS program supports coordinated efforts to develop and apply quantum sensor systems, with demonstrations resulting in proof of principle or field-testing of concepts and platforms that can benefit society. The QuSeC-TAQS program aligns with recommendations

articulated in the strategy report, *Bringing Quantum Sensors to Fruition*, that was produced by the National Science and Technology Council Subcommittee on Quantum Information Science, under the auspices of the National Quantum Initiative.

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 Sensors, telephone: (703) 292-2980, email: qusec@nsf.gov

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

- 47.041 --- Engineering
- 47.049 --- Mathematical and Physical Sciences
- 47.070 --- Computer and Information Science and Engineering
- 47.074 --- Biological Sciences
- 47.076 --- Education and Human Resources
- 47.084 --- NSF Technology, Innovation and Partnerships

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 (1) PI and two (2) co-PIs** must participate.

Limit on Number of Proposals per Organization: 2

Up to two (2) preliminary proposals and up to two (2) invited full proposals may be submitted per lead institution contingent to the requirement the proposed projects are in substantially different research areas.

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 QuSeC-TAQS preliminary proposals. The same limit applies to invited full proposals. In the event that any individual exceeds this limit, any proposal submitted to this solicitation with this individual listed as PI, co-PI, or Senior Personnel after the first two 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 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

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

  December 16, 2022

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

  April 03, 2023

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 National Quantum Initiative (NQI) Act calls for a coordinated Federal program to accelerate quantum information science (QIS) and technology research in the United States. A framework for implementing the NQI provided in the *National Strategic Overview for QIS*, and additional reports from the Subcommittee augment the Strategic Overview with more detailed recommendations on specific topics. In particular, Bringing Quantum Sensors to Fruition recommends

deliberate collaborations to combine fundamental and applied research on quantum sensors. In alignment with this strategy, the Quantum Sensing Challenges for Transformational Advances in Quantum Systems (QuSeC-TAQS) program will support interdisciplinary teams to explore highly innovative, original, and potentially transformative research on quantum sensing. The QuSeC-TAQS program encourages coordinated efforts to develop and translate ideas for quantum sensors into tangible quantum systems that can benefit society.

QuSeC-TAQS proposals should have the potential to deliver new concepts, new platforms, and/or new approaches to implement and utilize quantum sensors. Proposals must articulate how the project will develop quantum sensing systems that address a particular need, and can demonstrate improved capabilities or performance compared to classical systems. Proposals should be innovative, must focus on quantum functionality, and should result in experimental demonstrations.

Proposals should come from interdisciplinary research teams led by at least three (3) investigators who collectively contribute synergistic expertise from domains such as engineering, computer science, mathematical and physical sciences, biology, or geoscience. This requirement is intended to stimulate collaborations and grow the community of researchers who develop, co-design, and utilize quantum sensors. Some areas where quantum sensors might be applied include, but are not limited to chemical, material, biological, and health sciences, navigation, security, and remote sensing, astronomy, fundamental physics, and the advancement of quantum technologies for revolutionary approaches to computing and networking.

The QuSeC-TAQS program encourages activities with the potential to increase broader impacts of quantum sensors research, for example with educational and training activities, or collaborations and partnerships. Partnerships may include liaisons with industry, National Labs, other Federal Departments or Agencies, and/or international collaborators. In addition to intellectual merit, proposals will be judged on the broader impacts of activities including possible collaborations, partnerships, and training, as well as the potential for these activities to accelerate bringing quantum sensors to fruition.

II. PROGRAM DESCRIPTION

Competitive proposals are expected to present interdisciplinary and collaborative projects that identify a need and describe a sound scientific and engineering approach for developing a novel sensing system with enhanced performance compared to classical technologies. Successful proposals should make a compelling case for how the proposed research project has potential to deliver breakthroughs in quantum sensing technologies that could impact society.

Proposed projects should pursue either or both of the following tracks:

a. Explore new ideas using for enhanced sensing functionalities using quantum information science and engineering principles. Proposals should describe how the project will result in experimental tests or a proof of principle for new concepts, platforms, or approaches for enhanced sensing.
b. Translate quantum information science and engineering discoveries into scalable quantum sensor systems or networks. Proposals should describe how the project will demonstrate advantages for targeted applications as a result of applying fundamentally quantum phenomena.

Competitive proposals will come from interdisciplinary research teams led by at least three (3) investigators who collectively contribute synergistic expertise from domains such as engineering, computer science, mathematical and physical sciences, biology, or geoscience. Competitive proposals should also address the QuSeC-TAQS **programmatic considerations** described below, such as the potential for transformative advances on a targeted quantum sensor technology, the potential for interdisciplinarity and convergence in the research process, plans for experimental demonstration, and the potential for broader impacts such as educational and training opportunities, partnerships, or international collaboration, student mobility and exchanges.

Potential Quantum Sensing research areas:

Innovative proposals on a diverse range of quantum sensors topics are sought. A partial list of quantum sensor topics is provided here. This list is not intended to be comprehensive, nor limiting. Rather, these technical areas are merely presented to illustrate possible considerations. The scientific and engineering communities are strongly encouraged to explore possibilities beyond these examples.

Sensors, in general, consist of devices and systems that interact with the environment and provide a measurable response. Quantum sensors take advantage of quantum mechanical phenomena such as quantum states, quantum spins, matter-wave duality, coherence, superposition, and/or entanglement and quantum correlations to extend sensing capabilities. Importantly, quantum sensors can provide transduction mechanisms to reach beyond the traditional limits of classical sensors in terms of precision, accuracy, bandwidth, speed, or other factors such as size, weight, and power. Sensors using multi-particle entanglement or squeezing have demonstrated progress towards metrology at the Heisenberg limit. Furthermore, networks of quantum sensors have been proposed to enhance the sensitivity of clocks, telescopes, magnetometers, or other instruments.

Quantum sensing has the potential to revolutionize investigation of complex biological systems, where traditional modes of exploration are often limited by studies of microscopic phenomena with macroscopic tools. Creation of new bio-compatible quantum probes and sensing protocols can provide new insights about complex biological systems that cannot be accessed through classical measurements. For example, nanoscale sensors and coherent spectroscopy can reveal correlations and couplings at length and time scales that were previously inaccessible, or gradients in temperature and metabolites that were previously impossible to study. Such advances can potentially provide new knowledge about biological functions and dynamics within cells.

Atomic clocks have made substantial impacts, for example by enabling GPS navigation, high-speed communication networks, and precision measurements. New applications for atomic clocks may come from chip-scale devices, portable systems, and advancements in the state-of-the-art using quantum logic spectroscopy or other forms of quantum control. Improvements in metrology, time-transfer, navigation, very long baseline interferometry, quantum networking, and even geodesy via measurements of gravitational time dilation are just a few of the application areas that have been suggested for next generation atomic clocks. Proposals for collaborative work to realize new applications, or work to improve key components, subsystems, or device functionality is encouraged.

Matter-wave optics such as atom interferometry, neutron interferometry, and electron holography systems provide unique sensitivity to several atomic, molecular, and solid-state properties. Measurements of gravity, inertial displacements (acceleration and rotation) and the index of refraction for de Broglie waves due to various potentials have been mainstays in this field. Collaborative projects to pioneer new applications in disciplines ranging from physics and materials science to geoscience and navigation are encouraged. Well-motivated work on critical subsystems, including chip-scale devices, integrated photonics, and laser systems are also encouraged, as a means to enable targeted applications.

Solid-state and chip-scale methods to detect standards for quantities such as voltage, current, irradiance and temperature benefit from quantum sensors. Since the redefinition of the kilogram in terms of Planck's constant, all the SI base units can now be realized in terms of quantum phenomena, potentially leveraging new quantum sensor modalities.

Magnetometers have diverse applications ranging from remote sensing and navigation to biological and medical research. Quantum sensors may improve magnetoencephalography studies of cognition, cardiology studies in vivo, laboratory measurements of single neurons, and even intracellular studies of biological dynamics. Optical magnetometers with atoms, molecules, or atom-like defects in solids such as nitrogen vacancy centers in diamonds may be further enhanced using quantum effects to increase sensitivity, reliability, and compatibility with various environments. Superconducting systems and magnetometers based on electron and proton spins can be improved too. Related studies of Magnetic Resonance Imaging (MRI) are also encouraged to extend the sensitivity and applicability of MRI systems.

Identification of molecules in samples, for chemical and biological content analysis, e.g. through coherent Raman spectroscopy of rotational and vibrational modes, can be used for understanding biological systems, or for disease diagnosis. Spectroscopy using entangled photons may provide benefits such as enhanced precision, discrimination, or contrast. Benefits may also include lower doses of exposure, or more remote, contactless measurements, and lead to novel platforms for biotechnology and medicine.

Uses of entanglement and many-body quantum states to enable new capabilities such as non-invasive imaging or measurements with precision beyond the standard quantum limit are encouraged. High-efficiency quantum transducers to convert information contained in microwave, mechanical, or magnetic domains into modulations on photonic quantum states are needed. Projects exploring chip-level integration of quantum sensors or engineering of key components and subsystems for quantum sensors are also desirable. Additional examples of possible topics include novel molecular and materials architectures for quantum sensing; improved imaging, entangled-photon microscopy, spectroscopy, or photonic systems using quantum optics; enhancing measurements of electric fields and GHz or THz radiation possibly using Rydberg atomic states and coherent spectroscopy.

QuSeC-TAQS Programmatic Considerations:

The following features are deemed important under this research solicitation:

- **Quantum Sensing**: It is expected that proposed research projects will focus on quantum sensing, leveraging both fundamental understanding of quantum phenomena and novel application concepts. Clear rationale as to the novelty and the potential for enhanced capabilities as compared to classical sensors and systems should be addressed.
- **Interdisciplinarity and Convergence**: Progress in this field may benefit from research that draws upon expertise in multiple disciplines including (but not limited to) physics, chemistry, biology, mathematics, geoscience, computer science, and engineering. Proposals should describe how the project will facilitate scientists and engineers to work together in research teams involving theory, modeling, design, characterization, device fabrication, and testing.
- **Experimental Demonstration**: Proposals should describe how the project will realize a proof-of-concept for novel quantum functionalities, characterize quantum device properties, or system performance in relevant conditions for potential applications.

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

- **Education and Training**: Proposals that in addition to research create education, training, and workforce development opportunities in areas of quantum information science and engineering related to quantum sensing are encouraged.
- **Partnerships**: The creation or development of partnerships with industry, National Laboratories, or other academic institutions can be valuable for developing new concepts and platforms, for scaling up, and subsequently for commercialization of technologies based on quantum sensor concepts. Such partnerships are therefore encouraged where appropriate.
- **International Collaboration and Student Mobility and Exchange**: Collaboration with international scientific teams who are leaders in the field is welcome. Travel support for principal investigators, research personnel and students may be considered. Opportunities for developing student exchange are encouraged in order to develop a globally engaged workforce for QIS technologies.

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 (1) PI and two (2) co-PIs** must participate.

Limit on Number of Proposals per Organization: 2

Up to two (2) preliminary proposals and up to two (2) invited full proposals may be submitted per lead institution contingent to the requirement

the proposed projects are in substantially different research areas.

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 QuSeC-TAQS preliminary proposals. The same limit applies to invited full proposals. In the event that any individual exceeds this limit, any proposal submitted to this solicitation with this individual listed as PI, co-PI, or Senior Personnel after the first two 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 Research.gov, even if full proposals will be submitted via Grants.gov.

Preliminary proposals should provide a brief overview of the project, its scope and expected outcome focusing on its interdisciplinary and transformative aspects. It should include sufficient information to allow assessment of the main ideas, approaches, and the responsiveness of the proposal to the solicitation.

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 IHEs 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.

Submission of a Preliminary Proposal is required to be eligible for an invitation to submit a Full Proposal. **Preliminary Proposals** must be submitted via Research.gov, even if the team plans to submit full proposals via Grants.gov.

Preliminary Proposal Preparation Instructions:

Preliminary Proposal Set-Up: Select "Prepare New Preliminary Proposal" in Research.gov. Search for and select this solicitation title in Step One of the Preliminary Proposal wizard. Select "Single proposal (with or without subawards). Separately submitted collaborative proposals will be returned without review.

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

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

Senior Personnel: A minimum of three senior personnel must participate.

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 sensing; and

Describe the ***broader impacts*** of the proposed work, including the potential long- term impact on national needs.

Project Description: The project description of the preliminary proposal is limited to **five pages** and must include the following separately labeled 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 Sensing:** Describe how the project leverages and/or promotes advances in quantum sensing. Please address the expected performance advantage of the quantum sensor system proposed over classical sensing systems.
- **Broader Impacts:** Describe how the proposed project will benefit society, for example by enabling advances in science and technology in various disciplines, and training individuals to work with quantum technologies.

References Cited: The proposal may indicate with an asterisk any cited publications that resulted from prior research funded by NSF for the PI, or co-PIs and Senior Personnel.

Senior Personnel Documents

- **Biographical Sketch(es):** In accordance with the guidance contained in the PAPPG, a separate biographical sketch must be provided for each individual designated as senior personnel.
- **Current and Pending Support:** Not required for preliminary proposals.
- **Collaborators and Other Affiliations (COA) Information:** COA information must be separately provided for each individual identified as senior personnel on the project.

In the **Other Supplementary Documents** section, include the following:

List of **Senior Personnel** (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 March 2023, PIs should expect to receive a message from the QuSeC-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 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.

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.

If multiple IHEs 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.

Proposal Set-Up: Select "Prepare New Full Proposal" in Research.gov. Search for and select this solicitation title in Step One of the Full Proposal wizard. In the proposal details section, select "Single proposal (with or without subawards). Separately submitted collaborative proposals will be returned without review.

The following instructions supplement the guidance in the PAPPG Application Guide.

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

Senior Personnel: A minimum of three senior personnel must participate.

Cover Sheet: Include the related Preliminary Proposal Number.

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 QuSeC-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 Sensing:** Describe how the project leverages and/or promotes advances in quantum sensing.
- **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, workforce development, partnerships, 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.

Data Management Plan: Research security has been raised as an important issue the National Science and Technology Council report on "Guidance for Implementing National Security Presidential Memorandum 33 (NSPM-33)" and also in National Security Memorandum 10 (NSM-10). This is relevant for QIS R&D given the potential for quantum technologies to impact economic and national security. In alignment with NSPM-33 and NSM-10, proposals should include in the Data Management Plan a description of how any proprietary information or intellectual property will be managed, if these are relevant for the project. This description may include a discussion of how data will be shared with project partners and affiliates, how access to the data will be managed, and how the sensitivity of various data sets will be assessed.

Other Supplementary Documents: Include the following:

- A list of **Senior Personnel** (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.

- **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):

  December 16, 2022

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

  April 03, 2023

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/ProposalPreparationandSubmission.html. For Research.gov user support, call the Research.gov Help Desk at 1-800-673-6188 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 the NSF FastLane system for further processing.

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.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 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 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 QuSeC-TAQS preliminary and full proposals:

- **Relevance to Quantum Sensing:** Does the project focus on quantum functionality and leverage and/or promote advances in quantum sensing?
- **Interdisciplinary:** Does the proposed research involve the convergence of diverse fields of expertise including but not limited to physics, chemistry, biology, mathematics, computer sciences, engineering and education, 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.
- **Educational Potential:** Consideration will be given to innovative plans that would contribute to growing a more diverse, inclusive, and sustainable workforce that possesses the broad range of skills needed by industry, academia, and the U.S. Government.

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 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 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 Sensors, telephone: (703) 292-2980, email: qusec@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 (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.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:

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