

Broad Agency Announcement

Quantum Sensing of Neutrinos (QuSeN)

DEFENSE SCIENCES OFFICE

HR001125S0004

Amendment 3

January 21, 2025

This publication constitutes a Broad Agency Announcement (BAA) as contemplated in Federal Acquisition Regulation (FAR) 6.102(d)(2) and 35.016 and 2 CFR § 200.203. Any resultant award negotiations will follow all pertinent law and regulation, and any negotiations and/or awards for procurement contracts will use procedures under FAR 15.4, Contract Pricing, as specified in the BAA.

OVERVIEW INFORMATION:

- **Federal Agency Name** – Defense Advanced Research Projects Agency (DARPA), Defense Sciences Office
- **Funding Opportunity Title** – Quantum Sensing of Neutrinos (QuSeN)
- **Announcement Type –** Initial Announcement
- **Funding Opportunity Number –** HR001125S0004
- **Assistance Listing Number:** 12.910 Research and Technology Development
- **Dates/Time - All Times are Eastern Time Zone (ET)**
  - Posting Dates:
    - Initial Announcement: November 5, 2024
    - Amendment 1: November 14, 2024
    - Amendment 2: December 5, 2024
    - Amendment 3: January 21, 2025
  - Proposers Day: November 12, 2024
  - Proposal Abstract Due Date: November 25, 2024, at 4:00 p.m.
  - Question Submittal Closed: January 22, 2025, at 4:00 p.m.
  - Proposal Due Date: February 3, 2025, at 4:00 p.m.
- **Anticipated individual awards** - Multiple awards are anticipated, ranging from $1M to $5M per award when justified by the proposed resources needed to meet the program goals and metrics. The period of performance is anticipated to be 30 months.
- **Types of instruments that may be awarded** – Cooperative Agreements, Procurement Contracts, and Other Transaction Agreements for Research. Other Transaction Agreements for Prototype are not permitted as an award instrument.
- **NAICS Code**: **541715**
- **Agency Contact**

  The BAA Coordinator for this effort may be reached at:
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Section I: Funding Opportunity Description

Introduction

The Defense Advanced Research Projects Agency (DARPA) is soliciting proposals for new, high-sensitivity neutrino detectors. Proposed research should investigate innovative approaches that enable revolutionary advances in neutrino detection science, devices, and systems.
The Quantum Sensing of Neutrinos (QuSeN) program aims to develop neutrino detectors with greatly increased performance to detect neutrinos from sources such as nuclear reactors and nuclear materials. Detectors will use neutrino-matter interactions that produce low-energy nuclear recoils and athermal phonons in absorber materials with high neutron numbers at the (multi)-kilogram scale. Specifically excluded is research that primarily results in evolutionary improvements to the existing state of practice.

Background

QuSeN seeks to develop detectors with improved sensitivity to neutrinos in the energy range from below 1 MeV to about 8 MeV. (Anti)-neutrinos produced from nuclear reactors, nuclear materials, and naturally occurring radioisotopes typically have energies ranging from ~0.1 to 8 MeV, with most neutrinos having energies below ~2 MeV. Current neutrino detection methods are relatively insensitive to neutrinos with energies below a few MeV. For example, inverse beta decay (IBD) reactions of (anti)-neutrinos with protons have an energy threshold of 1.8 MeV, making most reactor neutrinos undetectable through IBD.

Coherent elastic neutrino-nucleus scattering (CEvNS) offers a potential path to overcome this limitation. CENNS was first observed in 2017[1] and has a cross-section several orders of magnitude higher than all other known neutrino interaction processes in the MeV range (e.g., $\sim 10^{-40}$ cm^2 at 2 MeV for atoms with relatively high neutron number). However, energy transfers from (sub)-MeV neutrinos to atoms in a detector are relatively small, well below 100 eV, making it challenging to realize the full potential performance benefits of the CENNS process in neutrino detectors.[2]

Using emerging concepts from quantum computing devices and quantum sensors could have potential for measuring small energy transfer signals, such as those from athermal phonons produced by CENNS. If successful, the combination of CENNS and quantum sensing technology could offer unprecedented sensitivity for detecting neutrinos from nuclear reactors and materials.

Program Description and Scope

QuSeN is a 30-month program focused on demonstrating neutrino detection based on quantum sensing of athermal phonons. The QuSeN program has the possibility of program expansion after successful completion of the initial program. The metrics, structure, and schedule of the initial program are shown below.

Assuming a notional combined CENNS and quantum sensing approach, QuSeN seeks to overcome two key challenge areas. The first challenge is sensor development, and the second

[1] D. Akimov et al., "Observation of coherent elastic neutrino-nucleus scattering", Science 357,1123 (2017)
[2] J. Colaresi, et al., "Measurement of Coherent Elastic Neutrino-Nucleus Scattering from Reactor Antineutrinos", Phys. Rev. Lett. 129, 211802 (2022)

challenge is absorber development and scaling. Proposers are expected to address both challenges within a single proposal.

Due to the anticipated sensitivity to sub-eV energy transfers, the detectors must operate at low temperatures (e.g., <0.1 K). Further, athermal phonon sensors must be integrated with absorber materials that can be scaled to several kilograms to increase neutrino detection rates. For such an approach to be successful, absorber materials must be developed and integrated that optimize the interaction cross-section by using atoms with relatively high neutron number (N>40) and that exhibit phonon generation and transport properties that enable efficient sensing of athermal phonons.

In addition, anisotropic phonon-scattering properties that enable extraction of information on the direction of incident neutrinos is highly desirable. This information could be used to suppress background and clutter (e.g., from solar and geoneutrinos) in detectors. Pulse height analysis can help to discriminate neutrino events from signals induced by cosmic rays and radioactive decay processes.

Performers will develop sensors that are sensitive to energy transfers of less than 0.5 eV (energy transfer from neutrinos to nuclear recoils of a given mass and neutron number, N>40) while maintaining signal-to-noise and signal-to-background ratios >1. In parallel, performers will develop and scale suitable absorbers to a mass of 1 kg or larger. Initial program goals constitute proof-of-concept demonstrations of athermal phonon-based neutrino detectors with sensitivity to neutrinos from nuclear reactors and nuclear materials and with energy transfer sensitivity commensurate with the relatively high interaction cross-sections in CEvNS.

To address these challenges, it is anticipated that performers will use theory, modeling, experiments, and testing to develop novel neutrino detectors with increased sensitivity to relatively low energy neutrinos. Given the challenges of the notional approach, integrated teams will be required from the outset of the program. Performers will progress their detector development through a preliminary design review and a critical design review before final fabrication.

Demonstrating neutrino detection is highly desirable but is not a mandatory performance goal within the initial 30-month period of performance. Neutrino detection could be demonstrated at a nuclear reactor or by using a radioactive source.

Toward the end of the initial 30-month period, QuSeN results and accomplishments will be reviewed. Depending on the program results, DARPA may consider expanding the program to further improve sensitivity to small energy transfers in CENNS and to further increase the absorber mass in neutrino detectors.

QuSeN metrics focus on sensitivity to small energy transfers, absorber design (including theoretical analysis and modeling of phonon properties) and achieving high signal-to-noise and signal-to-background (clutter) ratios in detectors (including approaches exploiting directional information).

This solicitation describes exemplar approaches combining CENNS with quantum sensing concepts and associated metrics. However, DARPA encourages the submission of any alternate approach that can meet the overall goal of producing highly sensitive detectors for neutrinos

emitted by nuclear reactors and nuclear materials. Any alternate technical approach must include specific metrics with a level of detail similar to those included in this BAA.

Table 1: QuSeN Program Metrics for the initial 30-month program.

	QuSeN metric	**Goal**
Sensor	Neutrino to nucleus energy transfer sensitivity	<0.5 eV
	Signal to noise, signal to background	>1
Absorber	Mass (with neutron number, N >40)	>1 kg
	Phonon transport and phonon detection efficiencies	>0.5

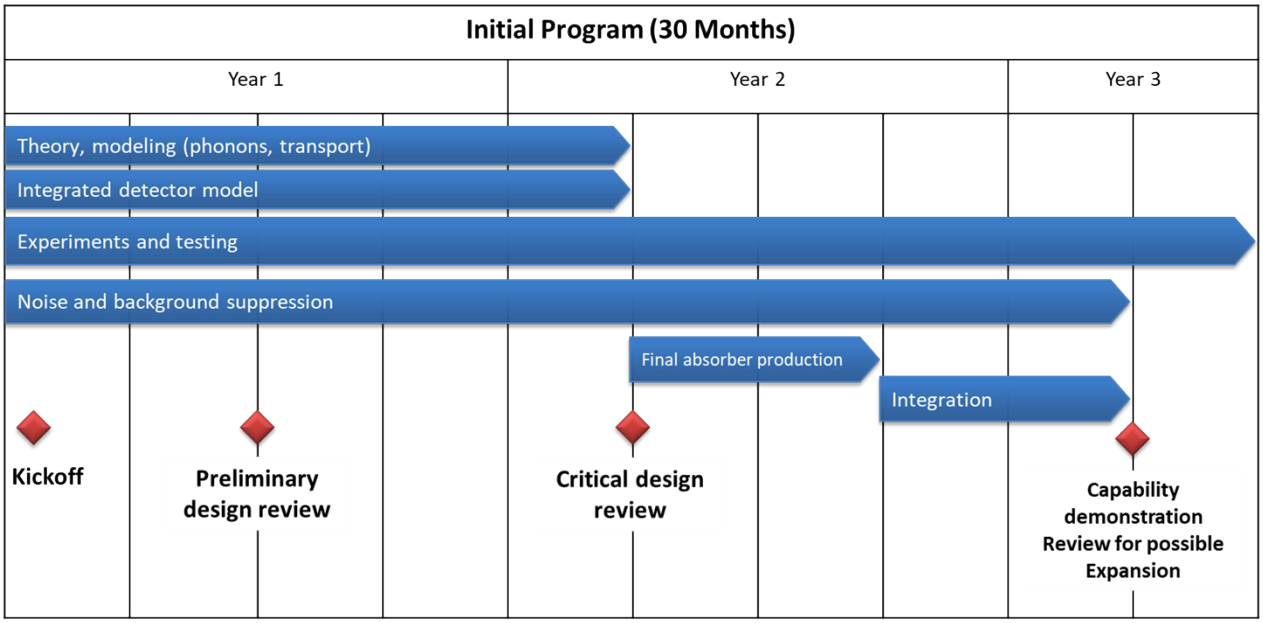


Figure 1. QuSeN program schedule.

Proposals for this solicitation should clearly explain the research and development required to achieve the program goals and how the proposed technologies exceed the state of the art. Proposals should also identify all major risks involved and clearly describe how those risks are mitigated early in the proposed effort. Key risks arise from optimizing sensitivity to progressively smaller energy transfers in detector assemblies with progressively large absorber mass while maintaining high performance (i.e., athermal phonon detection efficiency and signal to noise). Performers can potentially address these risks through cycles of detector design, implementation, and testing, guided by theory and modeling of sensor performance and athermal phonon transport in absorbers. Additional mitigation strategies could include designing and implementing passive and active shielding methods, methods for extracting information on

neutrino directions, and energy pulse height discrimination of signals from solar and other background sources.

The Government will use a phased acquisition approach for the QuSeN program under this BAA. Detailed proposals are solicited addressing both challenge areas, sensors and absorbers, in the initial 30-month period.

A target start date of July 1, 2025, can be assumed for planning and budgeting purposes. A one-day kick-off meeting should be planned for in this time frame.

All proposals must include the following meetings and travel in the proposed schedule and costs:

- An in-person kick-off meeting will be held at the start of the program (dates and location TBD, but for planning purposes a location in the San Francisco Bay Area can be assumed).
- Monthly teleconference meetings will be scheduled with the Government team for progress reporting, problem identification, and mitigation.
- Proposers should anticipate at least one site visit by the DARPA program manager, usually in association with major milestones, during which they will have the opportunity to demonstrate progress towards agreed-upon milestones.
- Annual in-person principal investigator meetings (dates and locations TBD).
- Additional proposed travel should be limited to critical activities and should be specified in the proposal.

Nominal Milestones and Deliverables

- **Program Kickoff**
  Deliverable: Slide deck summarizing approach to meet overall goals, risks, and risk mitigations, as well as schedule and budget review.
- **Quarterly Reviews**
  Deliverables: Comprehensive quarterly technical reports due within 15 days of the end of the given quarter, describing progress made on the specific milestones as required in the statement of work.
- **Preliminary Design Review**
  Deliverable: A written report summarizing the preliminary design of the detector.
- **Critical Design Review**
  Deliverable: A written report summarizing the critical design of the detector.
- **Performance Demonstration**
  Deliverable: Slide deck of results supporting progress towards the demonstration of QuSeN metrics (Table 1). Participation in the program review for a potential program expansion.
- **Final report**
  Deliverable: A written report summarizing the entire 30-month effort. Materials from prior deliverables may be used.

QuSeN performers will be expected to participate in monthly telecons, presenting a succinct slide deck discussing technical accomplishments, potential issues, overall progress, key next steps, and budget status. In addition, coordination meetings with the Government Team are anticipated.

Other negotiated milestones and deliverables are specific to the objectives of the individual efforts. These may include registered reports; experimental protocols; publications; data management plans; intermediate and final versions of software, including documentation and

user manuals; and/or a comprehensive assemblage of design documents, models, modeling data and results, and model validation data.

Section II: Evaluation Criteria

- Proposals will be evaluated using the following criteria listed in ***descending order of importance***: Overall Scientific and Technical Merit; Potential Contribution and Relevance to the DARPA Mission; and Cost and Schedule Realism.

    - **Overall Scientific and Technical Merit**: The proposed technical approach is innovative, feasible, achievable, and complete. Detailed technical rationale is provided delineating why the proposed approach can achieve the program goals and metrics. The proposed technical team has the expertise and experience to accomplish the proposed tasks. Task descriptions and associated technical elements provided are complete and logically sequenced with all proposed deliverables clearly defined so the final outcome of the award's work achieves the goal. The proposal identifies major technical risks, and planned mitigation efforts are clearly defined and feasible.
    - **Potential Contribution and Relevance to the DARPA Mission**: The potential contributions of the proposed effort bolster the national security technology base and support DARPA's mission to make pivotal early technology investments that create or prevent technological surprise. The proposed intellectual property restrictions (if any) will not significantly impact the Government's ability to transition the technology.
    - **Cost and Schedule Realism**: The proposed costs and schedule are realistic for the technical and management approach and accurately reflect the technical goals and objectives of the solicitation. All proposed labor, material, and travel costs are necessary to achieve the program metrics, consistent with the proposer's statement of work, and reflect a sufficient understanding of the costs and level of effort needed to successfully accomplish the proposed technical approach. The costs for the prime proposer and proposed sub-awardees are substantiated by the details provided in the proposal (e.g., the type and number of labor hours proposed per task, the types and quantities of materials, equipment and fabrication costs, travel, and any other applicable costs and the basis for the estimates). The proposed schedule aggressively pursues performance metrics in an efficient time frame that accurately accounts for the anticipated workload. The proposed schedule identifies and mitigates any potential schedule risk. It is expected the effort will leverage all available, relevant, prior research to obtain the maximum benefit from the available funding. For proposals containing cost share, the proposer has provided sufficient rationale regarding the appropriateness of the cost share arrangement, relative to the objectives of the proposed solution (e.g., high likelihood of commercial application, etc.).

- Unless otherwise specified in this announcement, for additional information on how DARPA reviews and evaluates proposals through the Scientific Review Process, please visit: Proposer Instructions: General Terms and Conditions

Section III: Submission Information

This announcement allows for multiple award instrument types to be awarded to include Procurement Contracts, Cooperative Agreements, and Other Transaction Agreements for Research. Other Transaction Agreements for Prototype are not permitted as an award instrument. Some award instrument types have specific cost-sharing requirements. The following websites are incorporated by reference and contain additional information regarding overall proposer instructions, general terms and conditions, and each specific award instrument type.

Proposers must review the following links:

- **Proposer Instructions and General Terms and Conditions**: Proposer Instructions: General Terms and Conditions
- **Procurement Contracts**: Proposer Instructions: Procurement Contracts
- **Cooperative Agreements**: Proposer Instructions: Grants/Cooperative Agreements
- **Other Transaction Agreements**: Proposer Instructions: Other Transactions

- This announcement contains an abstract phase. Abstracts are strongly encouraged but not required. Abstracts are due November 25, 2024, at 4:00 p.m. as stated in the Overview section. DARPA will respond to abstracts with a statement as to whether DARPA recommends the proposer submit a full proposal or does not recommend the proposer submit a full proposal with a rationale for this decision and may provide specific feedback on recommended changes for the full proposal phase. Additional instructions for abstract submission are contained within **Attachments A and Attachment B Amendment 1**. (Regardless of instrument type desired, all abstracts must be submitted through the Broad Agency Announcement Tool (BAAT)). For detailed information on how to submit to BAAT, visit the "Unclassified Submission Instructions" section at Proposer Instructions: General Terms and Conditions.

  Proposers that required resources that are primarily accessible at National Laboratories (including FFRDCs and UARCS), may include requests for program support resources from these organizations to be procured separately by DARPA. Abstracts should provide sufficient detail of the need and justification for the requested support. For example: [Company/Institution Name] requests [FFRDC/UARC/National Lab name] support to [technical rational].

- Full proposals are due February 3, 2025, at 4:00 p.m. as stated in the Overview section.

- **Attachments C, D, E, and F** contain specific instructions and templates and constitute a full proposal submission for proposers requesting a Procurement Contract or Other Transaction Agreement for Research.

- **Attachments C, D, and F** contain specific instructions and templates and constitute a full proposal submission for proposers requesting a Cooperative Agreement.
- Please visit Proposer Instructions: General Terms and Conditions for General Terms and Conditions for all requested contract types. Visit Proposer Instructions: Procurement Contracts for submission instructions for proposers requesting Procurement Contracts. Visit Proposer Instructions: Grants/Cooperative Agreements for submission instructions for proposers requesting Cooperative Agreements. Visit Proposer Instructions: Other Transactions for submission instructions for proposers requesting Other Transaction Agreements for Research. (Proposers requesting Procurement Contracts or Other Transaction Agreement for Research must submit proposals through the Broad Agency Announcement Tool. For proposers requesting a Cooperative Agreement, proposals must be submitted through grants.gov.)
- **BAA Attachments**:
  - **(required) Attachment A**: Abstract Summary Slide Template
  - **(required) Attachment B**: Abstract Instructions and Template Amendment 1
  - **(required) Attachment C**: Proposal Summary Slide Template
  - **(required) Attachment D**: Proposal Instructions and Volume I Template (Technical and Management)
  - **(required for proposers requesting Procurement Contracts or Other Transaction Agreements for Research) Attachment E**: Proposal Instructions and Volume II Template (Cost)
  - **(required) Attachment F**: MS Excel™ DARPA Standard Cost Proposal Spreadsheet

Section IV: Special Considerations

- This announcement, stated attachments, and websites incorporated by reference constitute the entire solicitation. In the event of a discrepancy between the announcement, attachments, or websites, the announcement takes precedence.

- All responsible sources capable of satisfying the Government's needs, including both U.S. and non-U.S. sources, may submit a proposal DARPA will consider. Historically Black Colleges and Universities, small businesses, small, disadvantaged businesses, and minority institutions are encouraged to submit proposals and join others in submitting proposals; however, no portion of this announcement will be set aside for these organizations' participation due to the impracticality of reserving discrete or severable areas of this research for exclusive competition among these entities. Non-U.S. organizations and/or individuals may participate to the extent that such participants comply with any necessary nondisclosure agreements, security regulations, export control laws, and other governing statutes applicable under the circumstances.

- As of the time of publication of this solicitation, all proposal submissions are anticipated to be unclassified.

- **Federally Funded Research and Development Centers (FFRDCs), University Affiliated Research Centers, and Government entities interested in participating in the QuSeN program or proposing to this BAA in any manner should first contact the agency point**

of contact listed in the Overview section prior to the Abstract due date to discuss eligibility. Complete information regarding eligibility can be found at Proposer Instructions: General Terms and Conditions.

- As of the date of publication of this solicitation, the Government expects that program goals as described herein may be met by proposers intending to perform fundamental research and does not anticipate applying publication restrictions of any kind to individual awards for fundamental research that may result from this solicitation. Notwithstanding this statement of expectation, the Government is not prohibited from considering and selecting research proposals that, while perhaps not qualifying as fundamental research under the foregoing definition, still meet the solicitation criteria for submissions. If proposals are selected for award that offer other than a fundamental research solution, the Government will either work with the proposer to modify the proposed statement of work to bring the research back into line with fundamental research or else the proposer will agree to restrictions in order to receive an award. For additional information on fundamental research, please visit Proposer Instructions and General Terms and Conditions.

- Proposers should indicate in their proposal whether they believe the scope of the research included in their proposal is fundamental or not. While proposers should clearly explain the intended results of their research, the Government shall have sole discretion to determine whether the proposed research shall be considered fundamental and to select the award instrument type. Appropriate language will be included in resultant awards for non-fundamental research to prescribe publication requirements and other restrictions, as appropriate. This language can be found at Proposer Instructions: General Terms and Conditions.

- For certain research projects, it may be possible that although the research to be performed by a potential awardee is non-fundamental research, their proposed sub-awardee's effort may be fundamental research. It is also possible the research performed by a potential awardee is fundamental research while their proposed sub-awardee's effort may be non-fundamental research. In all cases, it is the potential awardee's responsibility to explain in their proposal which proposed efforts are fundamental research and why the proposed efforts should be considered fundamental research.

- DARPA's Fundamental Research Risk-Based Security Review Process (formerly CFIP, now FRR-BS a.k.a. "FERBS") is an adaptive risk management security program designed to help protect the critical technology and performer intellectual property associated with DARPA's research projects by identifying the possible vectors of undue foreign influence. DARPA will create risk assessments of all proposed senior/key personnel selected for negotiation of a fundamental research grant or cooperative agreement award. The DARPA risk assessment process will be conducted separately from the DARPA scientific review process and adjudicated prior to final award. For additional information on this process, please visit Proposer Instructions: Grants/Cooperative Agreements.

- The APEX Accelerators program, formerly known as the Procurement Technical Assistance Program (PTAP), focuses on building a strong, sustainable, and resilient U.S. supply chains

by assisting a wide range of businesses that pursue and perform under contracts with the DoD, other federal agencies, state and local governments and with government prime contractors. See https://www.apexaccelerators.us/ for more information.

APEX Accelerators helps businesses:

- Complete registration with a wide range of databases necessary for them to participate in the government marketplace (e.g., SAM).
- Identify which agencies and offices may need their products or services and how connect with buying agencies and offices.
- Determine whether they are ready for government opportunities and how to position themselves to succeed.
- Navigate solicitations and potential funding opportunities.
- Receive notifications of government contract opportunities on a regular basis.
- Network with buying officers, prime contractors, and other businesses.
- Resolve performance issues and prepare for audit, only if the service is needed, after receiving an award.

- Project Spectrum is a nonprofit effort funded by the DoD Office of Small Business Programs to help educate the Defense Industrial Base (DIB) on compliance. Project Spectrum is vendor-neutral and available to assist businesses with their cybersecurity and compliance needs. Their mission is to improve cybersecurity readiness, resilience, and compliance for small/medium-sized businesses and the federal manufacturing supply chain. Project Spectrum events and programs will enhance awareness of cybersecurity threats within the manufacturing, research and development, as well as knowledge-based services sectors of the industrial base. Project Spectrum will leverage strategic partnerships within and outside of the DoD to accelerate the overall cybersecurity compliance of the DIB.

  www.Projectspectrum.io is a web portal that will provide resources such as individualized dashboards, a marketplace, and Pilot Program to help accelerate cybersecurity compliance.

- DARPAConnect offers free resources to potential performers to help them navigate DARPA, including "Understanding DARPA Award Vehicles and Solicitations," "Making the Most of Proposers Days," and "Tips for DARPA Proposal Success." Join DARPAConnect at www.DARPAConnect.us to leverage on-demand learning and networking resources.

- DARPA has streamlined our Broad Agency Announcements and is interested in your feedback on this new format. Please send any comments to DARPAsolicitations@darpa.mil.