

**Disruption Opportunity
DARPA-PA-23-03-06**

Structural Evaluation through Non-contact Sensor Embedding (SENSE)

I. Opportunity Description

The Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office (DSO) is issuing a Disruption Opportunity (DO), inviting submissions of innovative basic or applied research concepts in the technical domain of embedded structural health monitoring. This DO is issued under the Program Announcement for Disruptioneering, DARPA-PA-23-03. All awards will be made in the form of an Other Transaction (OT) for Prototype project. The total award value for the combined Phase 1 base (Feasibility Study) and Phase 2 option (Proof of Concept) is limited to \$1,000,000. This total award value includes Government funding and performer cost share if required or proposed.

To view the original DARPA Program Announcement (PA) for Disruptioneering, visit SAM.gov under solicitation number DARPA-PA-23-03:

<https://sam.gov/opp/718d2f6417d848549394f6248f4fadb9/view>.

A. Introduction

A longstanding goal of structural health monitoring (SHM) has been to quantify the condition of load-bearing or stressed components over time to detect damage and forecast potential failure events. Commonly associated with civil infrastructure (e.g., bridges, buildings, railways), SHM has been applied more recently to other engineered systems including ships, aircraft, and turbomachinery. Benefits include prevention of catastrophic failures, the ability to execute need-based (instead of schedule-based) maintenance, and the collection of performance data to inform future designs. In spite of these advantages, widespread adoption of SHM has been limited due to the fragility of existing methods, sensor placement constraints, and the risk of sensor failure in service. Nearly all SHM solutions today rely on surface-mounted, wired sensors that are prone to damage, require complex installation procedures, and cannot be used in extreme environments where they may provide the most value. Novel approaches are needed to overcome these limitations and fully realize the benefits of SHM in practice.

B. Objective/Technical Scope

The goal of the Structural Evaluation through Non-contact Sensor Embedding (SENSE) DO is to explore new approaches to embed sensors within metallic structural components during production. Recent advances in additive manufacturing (AM) for structural metals and electronics may enable hybrid approaches where sensing capability is integrated into components at the point of manufacture without sacrificing structural performance. The benefits of embedding sensors include inherent protection from the external environment and the ability to position sensors strategically within a part to acquire data at or near potential failure points. If successful, this paradigm shift will overcome existing limitations and enable the collection of part-level performance data in service.

Two major challenges will need to be addressed on SENSE: (1) designing sensors and their placement such that they do not introduce a significant parasitic effect on load-bearing capacity and (2) developing a manufacturing approach to embed or directly print sensing elements within an electrically conductive structural metallic part. SENSE will focus on measuring two key state variables for structural performance: internal temperature and strain. During the program, performers must quantify damage accumulation (e.g., cracking, void formation, etc.) either

directly from the measured state variables or, desirably, from an independent signal (e.g., conductivity, ultrasonic attenuation, etc.). Commercial devices or custom manufactured sensing elements may be proposed and can be either active (e.g., strain gauges, thermocouples) or passive (e.g., microwire methods, magnetomicrometry). DARPA is most interested in approaches that include wireless communication (and/or power, if required) embedded with the sensors, but wired options are also acceptable. Proposers must address how they will handle the interface between the sensing elements and surrounding structural material to ensure adequate coupling for accurate measurements, while also mitigating negative interactions that may lead to degradation in sensor capability or structural performance over time.

Performers must experimentally demonstrate novel embedded sensing technologies to measure full three-dimensional temperature and strain fields concurrently within a standard bend test specimen geometry (cantilever, 3-point, or 4-point configurations are acceptable). Controlled strain and temperature gradients must be applied to the test beam geometry with known solutions based on calculated or simulated results for direct comparison to state variable fields measured by the proposed sensor network. It is anticipated that multiple sensors will need to be embedded in the test specimens to accurately measure the full temperature and strain fields. Manufacturing and testing of identical specimens *without* embedded sensors must also be completed as benchmarks to assess property debits in static and dynamic loading scenarios. Sensor lifetime must be demonstrated through repeated measurements over time, following transients in applied temperature and strain. Proposers must specify a specific alloy, notional use case, and realistic ranges for temperature and strain that could be expected in service. Aggressive operating conditions are encouraged. Successful approaches will achieve the metrics outlined below:

	Metric	Units	Threshold	Target
Phase I	Temperature accuracy ^a	°C	±20°C	±2°C ^b
	Strain accuracy ^a	ε (m/m)	±5x10 ⁻⁴	±5x10 ⁻⁵ ^c
	Static property debit ^d	GPa/MPa/%	<10%	0 (no debit)
Phase II	Sensor durability ^e	hrs	100	1000
	Dynamic property debit ^f	Cycles to failure	<20%	0 (no debit)

^a Three-dimensional embedded sensor measurements and interpolated values between sensors must fall within the threshold/target bounds based on calculated or simulated fields. Temperature must be measured under zero and maximum strain, and strain must be measured at room temperature and at the proposed temperature extreme(s).

^b Based on a standard Type K thermocouple; ±5% threshold/±1% target is acceptable for temperatures >500°C.

^c Typical error for a standard ¼ bridge strain gauge configuration.

^d Flexural modulus (GPa), yield strength (MPa), and strain to failure (%) measured at room temperature. Threshold and target values are relative to tests conducted on benchmark specimens without embedded sensors.

^e Demonstrated through repeatable temperature and strain field measurements taken every hour following maximum strain and temperature transient exposure.

^f Low cycle fatigue in bending conducted at room temperature; test conditions chosen such that average life in baseline specimens is approximately 24hr.

C. Structure

In Phase 1 (12-months), performers must demonstrate feasibility for their proposed sensor functionality and manufacturing process. All proposed sensor types/modalities must be demonstrated including the ability to embed during manufacturing and extract state variables per the accuracy thresholds outlined in the metrics table. Any additional proposed damage

accumulation signal(s) must also be demonstrated. Static bend testing must be conducted on specimens with and without the proposed sensors, showing no significant property debit as defined in the metrics table.

Performers that continue into Phase 2 (12-months) must demonstrate proof-of-concept through sensor lifetime testing and dynamic property measurements. Sensor lifetime must be assessed through hourly measurement of fixed strain and temperature fields taken after transient strain and temperature exposures to the maximum proposed levels. Strain and temperature measurements must remain within the accuracy tolerances detailed in the metrics table for at least 100 hours of continuous operation. Dynamic properties must be assessed by fatigue testing at least ten (10) specimens to failure, demonstrating continuous tracking of temperature, strain, and any other proposed damage accumulation variable(s). A minimum of ten (10) additional specimens must also be built and tested without the proposed sensors to establish a baseline. Average cycles to failure for the sensor-embedded specimen must be no less than 80% of the baseline result.

Proposals submitted in response to this DO must be unclassified and must address two independent and sequential project phases: a Phase 1 Feasibility Study (base) and a Phase 2 Proof of Concept (option). The periods of performance for these phases are 12 months for the Phase 1 base effort and 12 months for the Phase 2 option effort. Combined Phase 1 base and Phase 2 option efforts for this DO should not exceed 24 months. The Phase 1 (base) award value is limited to \$600,000. The Phase 2 (option) award value is limited to \$400,000. Both Phase 1 and Phase 2 award value limits include performer cost share, if required or if proposed. The total award value for the combined Phase 1 and Phase 2 is limited to \$1,000,000.

D. Schedule/Milestones

Proposers must address the following fixed payable milestones in their proposals. Proposers must complete the “Schedule of Milestones and Payments” Excel Attachment provided with this DO to submit a complete proposal and fulfill the requirements under Volume 2, Price Volume. If selected for award negotiation, the fixed payable milestones provided will be directly incorporated into Attachment 3 of the OT agreement (“Schedule of Milestones and Payments”). Proposers must use the Task Description Document template provided with the Program Announcement DARPA-PA-23-03, which will be Attachment 1 of the OT agreement.

Phase 1 fixed milestones for this program must include, at a minimum, the following:

- Month 1: Conduct project kickoff meeting to review detailed development plan and timeline; identify all key personnel working on the project and proposed level of effort.
- Month 3: Independently demonstrate additive manufacturing methods required to build the structural metal alloy and perform preliminary testing of the sensing devices. Additionally, all key personnel must be working at the proposed levels of effort.
- Month 6: Demonstrate feasibility for at least one (1) embedded sensor type measuring temperature or strain.
- Month 8: Demonstrate both temperature and strain field measurement. Complete initial accuracy estimates and a plan to improve accuracy, as necessary.
- Month 10: Complete static property testing, establishing debits on modulus, strength, and ductility relative to baseline tests. Demonstrate optional proposed damage accumulation signal and improved temperature and strain field measurements, as needed.
- Month 12: Deliver integrated build plan to construct fatigue test specimens, incorporating all sensor types into test specimen geometry. Deliver Phase 1 final report detailing

developed capabilities.

Phase 2 fixed milestones for this program must include, at a minimum, the following:

- Month 13: Conduct phase 2 project kickoff meeting to review detailed plan and timeline for lifetime and dynamic property demonstrations.
- Month 16: Complete preliminary fatigue testing, demonstrating continuous temperature and strain measurement to failure. Investigate failure mode and propose plan to modify sensor location(s), as needed.
- Month 18: Complete sensor durability assessment. Complete at least five (5) baseline fatigue tests on specimens without embedded sensors.
- Month 20: Complete at least five (5) fatigue tests on sensor-embedded specimens and five (5) additional fatigue tests on baseline specimens.
- Month 22: Complete at least five (5) additional fatigue tests complete on sensor-embedded specimens. Quantify fatigue debit.
- Month 24: Deliver final report detailing the developed capabilities and directions for future research and development.

For planning and budgetary purposes, proposers should assume a program start date of January 22, 2024. Schedules will be synchronized across performers, as required, and monitored/revised as necessary throughout the program's period of performance.

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

- A one-day project kickoff meeting to be held in Arlington, VA.
- A one-day Phase 2 kickoff meeting to be held in Arlington, VA.
- Monthly teleconference meetings will be scheduled with the Government team for progress reporting and problem identification and mitigation.

E. Deliverables

Performers will be expected to provide, at a minimum, the following deliverables:

- Negotiated deliverables specific to the objectives of the individual efforts. These may include registered reports, experimental protocols, publications, intermediate and final versions of software libraries, code, and APIs, including documentation and user manuals, and/or a comprehensive assemblage of design documents, models, modeling data and results, and model validation data.

II. Award Information

Selected proposals that are successfully negotiated will result in the award of an OT for Prototype project. See Section 3 of DARPA-PA-23-03 for information on awards that may result from proposals submitted in response to this announcement.

Proposers must review the model OT for Prototype agreement provided as an attachment to DARPA-PA-23-03 prior to submitting a proposal. DARPA has provided the model OT to expedite the negotiation and award process and ensure DARPA achieves the goal of Disruptioneering, which is to enable DARPA to initiate a new investment in less than 120 calendar days from idea inception. The model OT is representative of the terms and conditions that DARPA intends to include in all DO awards. The task description document, schedule of milestones and payments, and data rights assertions requested under Volumes 1, 2, and 3 will be included as attachments to the OT agreement upon negotiation and award.

Proposers may suggest edits to the model OT for consideration by DARPA and provide a copy of the model OT with track changes as part of their proposal package. DARPA may not accept suggested edits. The Government reserves the right to remove a proposal from award consideration should the parties fail to reach an agreement on OT award terms and conditions. If edits to the model OT are not provided as part of the proposal package, DARPA assumes that the proposer has reviewed and accepted the award terms and conditions to which they may have to adhere and the model OT agreement provided as an attachment, indicating agreement (in principle) with the listed terms and conditions applicable to the specific award instrument.

To ensure that DARPA achieves the Disruptioneering goal of an award within 120 calendar days from the posting date (September 29, 2023) of this announcement, DARPA reserves the right to cease negotiations when an award is not executed by both parties (DARPA and the selected organization) on or before January 22, 2024.

III. Eligibility

See Section 7 of DARPA-PA-23-03 for information on who may be eligible to respond to this announcement.

IV. Disruption Opportunity Responses

A. Proposal Content and Format

All proposals submitted in response to this announcement must comply with the content and format instructions in Section 5 of DARPA-PA-23-03. All proposals must use the templates provided as Attachments to DARPA-PA-23-03 and the “Schedule of Milestones and Payments” Excel Attachment provided with this DO and follow the instructions therein.

Information not explicitly requested in DARPA-PA-23-03, its Attachments, or this announcement may not be evaluated.

B. Proposal Submission Instructions

Responses to DARPA-PA-23-03-06 shall be submitted electronically to DARPA’s Broad Agency Announcement (BAA) Portal (<https://baa.darpa.mil>).

DARPA will acknowledge receipt of complete submissions via email and assign identifying numbers that should be used in all further correspondence regarding those submissions. If no confirmation is received within two (2) business days, please contact SENSE@darpa.mil to verify receipt.

When planning a response to this DO, proposers should take into account the submission time zone and that some parts of the submission process may take from one (1) business day to one month to complete (e.g., registering for a SAM Unique Entity ID (UEI) number or Tax Identification Number (TIN)).

Electronic Upload

First-time users of the DARPA BAA Portal must complete a two-step account creation process. The first step consists of registering for an extranet account by going to the URL above and selecting the “Account Request” link. Upon completion of the online form, proposers will receive two separate emails; one will contain a username, and the second will provide a temporary password. Once both emails have been received, the second step requires proposers to go back to the submission website and log in using that username and password. After accessing

the extranet, proposers may then create a user account for the DARPA Submission website by selecting the “Register your Organization” link at the top of the page. Once the user account is created, proposers will be able to see a list of solicitations open for submissions, view submission instructions, and upload/finalize their proposal.

Proposers who already have an account on the DARPA BAA Portal may log in at <https://baa.darpa.mil>, select this solicitation from the list of open DARPA solicitations and proceed with their proposal submission. Note: proposers who have created a DARPA Submission website account to submit to another DARPA Technical Office’s solicitations do not need to create a new account to submit to this solicitation.

All full proposals submitted electronically through the DARPA Submission website must meet the following requirements: (1) uploaded as a zip file (.zip or .zipx extension); (2) only contain the document(s) requested herein; (3) only contain unclassified information; and (4) must not exceed 100 MB in size. Only one zip file will be accepted per full proposal. DARPA will reject full proposals not uploaded as zip files. Technical support for the DARPA Submission website is available during regular business hours, Monday – Friday, 9:00 a.m. – 5:00 p.m. Requests for technical support must be emailed to BAAT_Support@darpa.mil with a copy to SENSE@darpa.mil. Questions regarding submission contents, format, deadlines, etc., should be emailed to SENSE@darpa.mil. Questions/requests for support sent to any other email address may result in delayed/no response.

Since proposers may encounter heavy traffic on the web server, DARPA discourages waiting until the day proposals are due to request an account and/or upload the submission. Note: Proposers submitting a proposal via the DARPA Submission site MUST (1) click the “Finalize” button for the submission to upload AND (2) do so with sufficient time for the upload to complete prior to the deadline. Failure to do so will result in a late submission.

C. Proposal Due Date and Time

Proposals in response to this announcement are due no later than 4:00 p.m. on November 21, 2023. As described in Section 5 of DARPA-PA-23-03, full proposal packages must be submitted per the instructions outlined in this DO *and received by DARPA* no later than the above time and date. Proposals received after this time and date may not be reviewed.

Proposers are warned that the proposal deadline outlined herein is in Eastern Time and will be strictly enforced. When planning a response to this announcement, proposers should consider that some parts of the submission process may take from one (1) business day to one (1) month to complete.

V. Proposal Evaluation and Selection

Proposals will be evaluated and selected in accordance with Section 6 of DARPA-PA-23-03. Proposers will be notified of the results of this process as described in Section 8.1 of DARPA-PA-23-03

VI. Administrative and National Policy Requirements

Section 8.2 of DARPA-PA-23-03 provides information on Administrative and National Policy Requirements that may be applicable for proposal submission and performance under an award.

VII. Point of Contact Information

Andrew Detor, Program Manager, DARPA/DSO, SENSE@darpa.mil

VIII. Frequently Asked Questions (FAQs)

All technical, contractual, and administrative questions regarding this announcement must be emailed to SENSE@darpa.mil. Emails sent directly to the Program Manager or any other address may result in delayed or no response.

All questions must be in English and must include the name, email address, and telephone number of a point of contact. DARPA will attempt to answer questions publicly in a timely manner; however, questions submitted within seven (7) calendar days of the proposal due date listed herein may not be answered.

DARPA will post an FAQ list under the DO on the DARPA/DSO Opportunities page at (<http://www.darpa.mil/work-with-us/opportunities>). The list will be updated on an ongoing basis until one (1) week before the proposal due date.