DARPA-EA-25-02-03
Critical Orientation of Mathematics to Produce Advancements in Science and Security (COMPASS)

Amendment 1

I. ARC Opportunity

The Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office (DSO) is issuing an Advanced Research Concepts (ARC) Opportunity, inviting submissions of Abstracts for innovative exploratory research concepts in the technical domain of advanced mathematics. This ARC Opportunity, Critical Orientation of Mathematics to Produce Advancements in Science and Security (COMPASS), is issued under the master ARC Exploration Announcement (EA), DARPA-EA-25-02.

ARC Opportunities are designed to allow an individual researcher the opportunity and time to focus on nascent, paradigm-shifting ideas for national security applications. While multiple researchers from the same organization may be proposed, the aggregate level of effort for a proposed research concept is expected to be equivalent to one full-time equivalent (FTE) and 12 months as ARC topics are designed for ideas that nominally would take a full year effort (1 FTE over 1 year) to properly validate. DARPA expects that the individual(s) working on the proposed idea to primarily focus on the effort for the entire period of performance to the maximum extent practical. The maximum period of performance is 12 months. Each ARC award's total cost should range from $100,000 to $300,000, including direct and indirect costs and graduate student tuition, if applicable. Proposed costs for materials, equipment, and Other Direct Costs (ODC) are limited as outlined in the master ARC EA, DARPA-EA-25-02. Under no circumstances will profit be authorized. While resource sharing is not expected, it may be offered in the proposal. DARPA understands not all ideas and organizations may fit in this parameter range and will work with a proposer to ensure truly innovative ideas can be explored with the required resources. Travel and publication costs may not be proposed. No subawardees are permitted.

To view the original DARPA Exploration Announcement and the latest amendment issued against Advanced Research Concepts, visit SAM.gov under solicitation number DARPA-EA-25-02: https://sam.gov/opp/95c31b3f3e094627a9a1e053766e46e1/view. It is incumbent upon the proposer to review DARPA-EA-25-02, any resulting amendments to DARPA-EA-25-02, and Frequently Asked Questions (FAQs) before preparing and submitting an Abstract and/or an Oral Proposal Package (OPP) (if invited). All Abstract submissions to this announcement must adhere to the instructions contained in DARPA EA-25-02.

All technical, contractual, and administrative questions regarding this notice must be emailed to COMPASS@darpa.mil. This ARC Opportunity is soliciting Abstracts only. DARPA will evaluate Abstracts submitted in response to this ARC Opportunity, as detailed in Section 4 of the latest amendment issued against DARPA-EA-25-02. If the Government selects an Abstract for an Oral Presentation, the Government will issue an invitation to submit an OPP. The invitation will include the submission instructions and deadline.

All awards made as a result of the ARC Opportunity will be Research Other Transactions (OTs) awarded under the authority of 10 U.S.C. § 4021.

Abstracts submitted to this ARC Opportunity will be evaluated on a rolling basis in accordance with the latest amendment issued against DARPA-EA-25-02. The end of the submission period will be 4:00 p.m. Eastern Time on May 12, 2025. No Abstracts will be accepted after the end of

the submission period. Proposers are encouraged to submit Abstracts as early as possible. Funding for this ARC Opportunity is limited. Should funding be exhausted, the Government may elect to shorten the overall submission period with an amendment to this ARC Opportunity.

II. ARC Opportunity Description

Mathematics is a pillar of national security. A decision-maker's ability to synchronize military activities across five domains (i.e., air, land, maritime, space, and cyberspace), and adapt to rapidly changing threat landscapes hinges on robust mathematical frameworks and effective problem formulations that fully encapsulate the complexities of real-world operational environments. Unfortunately, mathematical approaches in Defense often rely on "good-enough" approximations, resulting in fragile solutions that severely limit our nation's ability to address these evolving challenges in future conflicts. In contrast, establishing robust mathematical frameworks and properly formulating problems can yield profound and wide-reaching results.

For instance, the Wiener filter[1] was developed during World War II to help the U.S. military discern threats in the air domain from noisy radar observations. However, the technology's effectiveness was limited due to its strong assumption of signal stationarity, a condition rarely satisfied in operational settings. By leveraging a dynamical systems approach, in 1960 Rudolf Kalman reformulated the filtering problem in a more robust state-space framework that inherently addressed non-stationarity.[2] Sixty years later, the Kalman filter remains a pillar of modern control theory, supporting military decisions in autonomous navigation, flight control systems, sensor fusion, wireless communications and much more. The combination of a robust mathematical framework with the right problem formulation enables transformative Defense capabilities. Achieving this, however, requires deep mathematical insight to properly formulate the problem within the context of the specific Defense challenge at hand.

To excel in increasingly complex, dynamic, and uncertain operational environments, military decision-makers need richer mathematical frameworks that fully capture the intricacies of these challenges. Emerging fields in mathematics offer the potential to provide these frameworks, but realizing their full potential requires innovative problem formulations.

This ARC opportunity is soliciting ideas to explore the question: *How can new mathematical frameworks enable paradigm shifting problem formulations that better characterize complex systems, stochastic processes, and random geometric structures?*

A. ARC Opportunity Technical Objective

The COMPASS ARC will pioneer new frontiers in advanced mathematics for Defense, exploring nascent mathematical frameworks and innovative problem formulations that will drastically improve our understanding of modern Defense challenges. COMPASS performers should:

- Investigate a **completely novel** connection between a mathematical framework and a Defense science or technology application area
- Formulate a Defense related problem within this mathematical framework and justify that this new approach addresses significant gaps in current state of the art methods or enables

[1] *Wiener, N. (1949). Extrapolation, Interpolation, and Smoothing of Stationary Time Series. The MIT Press.*
[2] *Kalman, R. E. (1960). A New Approach to Linear Filtering and Prediction Problems. Journal of Basic Engineering, 82(1), 25-45.*

entirely new capabilities

- Chart-out a roadmap clearly identifying the mathematical problems that must be solved to realize a tractable solution and application in the future.

For the purposes of this ARC opportunity a **mathematical framework** is defined as a coherent system of assumptions, definitions, methods, and rules that provides a structured foundation for the formulation, rigorous analysis, and solution of problems. **Problem formulation** here is defined as the process of formalizing a real-world problem into a mathematical framework, which includes defining assumptions, constraints, parameters, relationships, and variables. This abstraction of a real-world problem into a mathematical structure enables the rigorous application of analytical, computational, and logical techniques necessary for the analysis and/or solution of the problem.

COMPASS aims to explore a wide range of new mathematical frameworks that have the potential to revolutionize Defense applications. Of particular interest are problem formulations that exploit recent mathematical advancements in complex systems and modern probability (e.g., graph signal processing, random geometric graphs, graphons, mean field theory, McKean-Vlasov processes, random matrices/tensors, rough path theory, stochastic partial and ordinary differential equations on manifolds, stochastic geometry, etc.) to address one or more of the following problem classes:

- Heterogeneous and multiscale behavior in large systems or networks
- Stochastic processes in dynamic, random, or information-limited environments
- Random geometric structures in high dimensions.

Some examples of relevant Department of Defense (DoD) application areas include, but are not limited to: supply chains, infrastructure or human systems, distributed networks, resource allocation, contested communications or sensor networks, intelligence analysis, multi-domain operations (i.e., air, land, maritime, space, and cyberspace), mission planning, information domain awareness, target tracking, or swarming and cooperative control.

Mathematical frameworks and problem formulations applicable to other defense science and technology challenges are also in scope, given thorough motivation of the application area is provided. Approaches that build incrementally upon existing frameworks or seek to solve existing problem formulations are explicitly out of scope.

B. ARC Abstracts

COMPASS ARC abstract submissions must provide a substantial technical argument that their proposed mathematical framework and problem formulation has the potential to significantly advance current state of the art approaches or enable entirely new capabilities. This includes a comprehensive literature review of the existing mathematical frameworks and problem formulations pertinent to the intended Defense application identifying gaps, limitations, or opportunities for advancement. Along with the review, a detailed criterion for evaluation of the proposed approach against existing methods should be presented. Abstract submitters should also indicate the primary and/or secondary American Mathematical Society Mathematical Subject Classifications relevant to their proposed work.

This ARC Opportunity is intended to be as inclusive as possible; however, proposed ideas should address the appropriate scope, have a clear deliverable at the end of the effort, and include specific practical applications of the research. Abstracts should describe a research plan including:

- Detailed intermediate technical objectives outlining necessary steps in the mathematical framework development and problem formulation process.

- Planned evaluation measure(s) to justify the utility of the proposed problem formulation in terms of tractability, practical applicability, and potential to address significant gaps in current state of the art methods or enable entirely new capabilities.
- A schedule, segmented monthly or quarterly, outlining corresponding deliverables described in Section II.C and Section II.D.

To ensure alignment with the intended application, abstract submitters are encouraged to communicate with technical subject matter experts (SMEs) relevant to the proposed application area. Submitters should include existing and/or planned connection points to SMEs. This includes, but is not limited to, performers on the team with subject matter knowledge, external relationships with SMEs (previous co-authorship, joint research initiatives, industry collaborations, etc.), or plans to consult SMEs at various points throughout the performance period.

Submitters with or without prior DoD-related research experience are highly encouraged to apply for this opportunity.

DARPA will evaluate Abstracts submitted in response to this ARC Opportunity, as detailed in Section 4 of the latest amendment issued against DARPA-EA-25-02. If the Government selects an Abstract for an Oral Presentation, the Government will issue an invitation to submit an OPP. The invitation will include the submission instructions and deadline.

C. Schedule of Milestones

Abstracts selected to submit an OPP will be required to propose milestones associated with the program plan as part of the oral proposal. Milestones must outline a progression towards all objectives to include linking the mathematical framework to the proposed application area, formulating the proposed problem, justifying the effectiveness of this problem formulation with respect to current state of the art, and constructing a roadmap towards tractable problem solving and application. Proposers are encouraged to organize these objectives in the way that best aligns with their proposed approach.

In addition to technical deliverables, the specific milestones and due dates listed below are common to all Abstracts and OPPs.

- Kick-off meeting: The first milestone should consist of a kick-off meeting to define the technical approach and steps forward.
- Milestone status meetings: Each subsequent milestone should include briefings to communicate detailed progress towards all research objectives, progress to plan, and discussion of next milestone objectives.
- Final Milestone meeting and report: The final milestone should include a written document describing the roadmap (Section II.A) that outlines remaining technical obstacles to a tractable solution and implementation of the proposed problem formulation.

D. Reporting Requirements

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

- Monthly update reports. These technical and financial reports should include progress to plan.

- Milestone technical report. Each report should detail progress towards all research objectives, including failures, and should include a master summary document that refers to previous progress towards all objectives and any relevant associated explanatory presentation slides, mathematical results (e.g., definitions, derivations, theorems/lemmas/corollaries, proofs, etc.), and algorithms, models, publications, or software source code with full documentation, if relevant.
- Final technical report. The final report should include the final roadmap document (Section II.C), the final master summary document from the milestone technical reports and detailed results of all milestones associated with the program plan for the entire period of performance.
- Final Opportunity outbrief. The final briefing should summarize all work completed on the project.

III. ARC Opportunity Submission Format, Instructions and Selection

A. Abstract Content and Format

All Abstracts submitted in response to this notice must comply with the content and format instructions in Section 3.1 of the latest amendment issued against DARPA-EA-25-02. The submission must use the template provided as attachment to DARPA-EA-25-02. Abstracts submitted in response to this ARC Opportunity must be unclassified.

B. Abstract and OPP Submission Instructions

Abstracts submitted in response to this ARC Opportunity and OPPs submitted in response to an invitation shall be submitted electronically via the DARPA Submission website at https://baa.darpa.mil. See Section 3.3 of the latest amendment issued against DARPA-EA-25-02 for Abstract and OPP submission instructions.

Technical support for the DARPA Submission website is available during regular business hours, Monday – Friday, 9:00 a.m. – 5:00 p.m. Eastern Time. Requests for technical support must be emailed to BAAT_Support@darpa.mil with a copy to COMPASS@darpa.mil. Questions regarding submission contents, format, deadlines, etc. should be emailed to COMPASS@darpa.mil. Questions/requests for support sent to any other email address may result in delayed/no response.

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 COMPASS@darpa.mil to verify receipt.

No Abstracts will be accepted after the end of the overall submission period listed in Section I above. Abstracts must be submitted per the instructions outlined in this ARC Opportunity *and received by DARPA* no later than this time and date. Proposers are advised that the Abstract submission deadline outlined herein is in Eastern Time.

Abstracts will be evaluated and selected in accordance with Section 4 of the latest amendment issued against DARPA-EA-25-02.

IV. Award Information

Selected OPPs will result in a potential award of a Research OT agreement subject to the proposer's acceptance of the terms and conditions. Proposers must review the model Research OT agreement provided as Attachment E to DARPA-EA-25-02.

The completed Task Description Document, Schedule of Milestones and Payments (templates included in Attachment E), and data rights will be included in the Research OT agreement upon award.

Given the limited funding available for each ARC Opportunity, not all proposals considered selectable may be selected for a potential award.

V. Eligibility

See Section 6 of the latest amendment issued against DARPA-EA-25-02 for information on who may be eligible to respond to this notice.

VI. Human Subject Research

Abstracts to this ARC Opportunity proposing human subjects research will be considered out of scope and may be disregarded.

VII. Administrative Requirements

Section 7.2 of the latest amendment issued against DARPA-EA-25-02 provides information on administrative requirements that may be applicable for proposal submission as well as performance under an award.

VIII. Frequently Asked Questions (FAQs)

All technical, contractual, and administrative questions regarding this notice must be emailed to COMPASS@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 abstract due date listed herein may not be answered.

DARPA may post a FAQ list under the COMPASS ARC Opportunity on the DARPA website, http://www.darpa.mil/. The list will be updated on an ongoing basis until one (1) week prior to the abstract due date. DARPA will also maintain https://www.darpa.mil/ARC as a resource page with links to all relevant ARC Opportunities and FAQs.