DARPA-EA-25-02-02
Hybridizing Biology and Robotics through Integration for Deployable Systems (HyBRIDS)

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 biohybrid robotics. This ARC Opportunity, Hybridizing Biology and Robotics through Integration for Deployable Systems (HyBRIDS), 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 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. Only minimal variation to this requirement will be accepted. 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 HyBRIDS@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 April 7, 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

Robotic platforms are deployed in various national security contexts, but many operational environments and applications remain out of reach for existing technologies. Nature provides inspiration and solutions to advance robotic technologies, but the performance of biological systems remains largely unmatched even as robotic systems become increasingly sophisticated. Recent advancements in—coupled with the convergence of—engineering and biology have propelled the development of biohybrid robots, which combine biological and synthetic components. Biohybrid systems could have distinct advantages over traditional synthetic robots in some operational contexts. While fully engineered abiotic systems prioritize controllability and precision for on-demand performance, biological systems inherently excel in their resiliency, sensitivity, adaptability, and efficiency. Biohybrid robots aim to combine the best features of both realms by leveraging the precise control of engineered parts while harnessing the unique, innate capabilities of biological elements. Successfully integrating biological components (e.g., cells, tissues, or organisms) could extend the functionality of robotic systems.

Despite their promise, today's biohybrid robots typically underperform their fully synthetic counterparts and their potential as predicted from a reductionist assessment of constituents. Many systems represent enticing proofs of concept with limited practical applicability. Most remain confined to controlled laboratory settings and lack feasibility in complex real-world environments. Developing biohybrid robots is currently a painstaking, bespoke process, and the resulting systems are routinely inadequately characterized. Complex, intertwined relationships between component, interface, and system performance are poorly understood, and methodologies to guide informed design of biohybrid systems are lacking.

The HyBRIDS ARC opportunity seeks ideas to address the question: *How can synthetic and biological components be integrated to enable biohybrid platforms that outperform traditional robotic systems?*

A. ARC Opportunity Technical Objective

The HyBRIDS ARC opportunity aims to address significant engineering and design obstacles that prevent the development of deployable biohybrid robotic systems by understanding and controlling the integration of synthetic and biological components to achieve desired emergent system properties. Key technical challenges in this area that impede the advancement of biohybrid robotics, and are potential areas for research efforts include, but are not limited to:

- *Biological component integration into robotic platforms.* Moving beyond readily available and well-characterized biological materials requires innovation. Systematically assessing possible components and developing methods to modify biological materials to enhance system integration or other properties is necessary.
- *Robust design methods for integrating biological and synthetic materials.* Improved computer-aided approaches are needed to represent, analyze, and predict the relationships between system- and component-level properties and performance.
- *Approaches to achieve and quantitatively characterize interfaces.* Methods should

systematically measure performance over time to enable resilient multidirectional interfaces that transmit information, energy, load, and material.

- *Techniques to overcome common deployment obstacles.* Focusing on robust, repeatable strategies that elicit targeted emergent properties can help address at-scale shared needs, such as maintaining the operational integrity of biological components.

Investigative approaches should be quantitative, replicable, reproducible, and generalizable across different scales and application domains. Where possible, methods and metrics applicable to multiple systems should be used to allow direct comparison or verification to the greatest extent possible. If successful, the outcomes will extend biohybrid system capabilities beyond those of traditional robotics to enable performance in regimes where they offer distinct or improved functionality.

This ARC Opportunity encourages a diverse range of ideas but explicitly discourages incremental advancements in research, emphasizing a preference for bold, daring, and innovative proposals. Efforts should quantitatively explore emerging approaches in biohybrid robotics design that will drive a paradigm shift toward practical applications in demanding, complex environments. This opportunity is not seeking proposals that merely add additional features or incrementally enhance existing functionalities of biohybrid robots. Proposals focusing exclusively on advancing an individual component or specific system are not in scope, though proposals may work with a single model or exemplar system. 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.

For the purposes of this ARC opportunity, a biohybrid robot is defined as a scaffold equipped with actuators, sensors, and control mechanisms that enable it to interact with its surroundings in an autonomous or semi-autonomous fashion, achieved by merging functional, engineered components with biological materials and components. Fully synthetic systems, including bioinspired and biomimetic robots, are not in scope.

B. ARC Abstracts

HyBRIDS ARC Abstract submitters should clearly define the scope and novelty of their idea and highlight intended practical applications for the proposed technology or designed system. The Abstract should justify how the idea or approach would overcome at least one technical obstacle and facilitate future biohybrid system operations in the envisioned application. Abstracts must articulate the uniqueness of the proposed approach—what distinguishes the approach from the current state-of-the-art—and demonstrate how quantitative research outcomes would address a technical barrier to advance the design of biohybrid robotic devices for real-world deployment.

Proposers should prepare a quantitative analytical framework for their Abstract that contextualizes their proposed idea and justifies their focus and approach. Successful frameworks will:

- Identify the obstacle(s) addressed by the idea and a potential application and deployment environment, if successful
- Identify and quantify the key performance parameters of the proposed biohybrid system, and compare its performance with current state-of-the-art systems—both biohybrid and fully synthetic—used in the relevant application domain, as well as with any applicable biological systems

- Justify through clear quantitative calculations how, and to what extent, the proposed concept could verifiably exceed the performance of existing alternatives.

In conveying this framework, proposers should explain which regimes, and along which dimensions of performance, a specified biohybrid system enabled by outcomes of the proposed research effort could demonstrably outperform fully synthetic ones. A successful Abstract will present anticipated verifiable metrics, to be reported upon completion of the proposed research period, that could support or substantiate these assertions.

Abstracts should describe a research plan for investigating the proposed idea including (1) detailed intermediate technical objectives with defined evaluation measures and (2) a schedule segmented monthly or quarterly outlining corresponding deliverables (see Sections II.B and II.C below for additional information on milestones and reports). In formulating their idea and research plan, proposers should consider the ethical, legal, and societal implications (ELSI) of their work. Selected performers will be expected to identify and adhere to some framework for incorporating ELSI into their efforts,[1] and should consider including corresponding deliverables, as appropriate.

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

The specific milestones and due dates listed below are common to all Abstracts and OPPs. Abstracts selected to submit an OPP will be required to propose milestones associated with the program plan as part of the oral proposal.

- Kick-off meeting (NLT 1 Month after award): Should define the technical approach and steps forward.
- Milestone status meetings: Briefing to include detailed progress towards all research objectives, progress to plan, and discussion of subsequent objectives.
- Final milestone: Must include:
    - Detailed analytical framework, updated from the proposal (Section II.B), to reflect changes during the performance period, including outcomes of the effort.
    - Discussion of remaining technical obstacles for deploying the proposed or designed biohybrid robot in the envisioned application; should provide a "roadmap to realization" that comprehensively identifies any technical obstacles to real-world deployment, regardless of whether they were addressed during the effort.

[1] Mestre, Rafael, et al. "Ethics and responsibility in biohybrid robotics research." *Proceedings of the National Academy of Sciences of the United States of America* 121.31 (2024): e2310458121.

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 reports. Each written report should detail progress, including failures, towards all research objectives, as well as adherence to the selected framework for incorporating ELSI. Reports should include a master summary document that refers to previous progress towards all objectives and any relevant associated materials, such as explanatory presentation slides, publications, design documents, protocols, data and records, and fully documented source code.
- Final technical report. The final report should include the final master document from the milestone technical reports and detail 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 an 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 HyBRIDS@darpa.mil. Questions regarding submission contents, format, deadlines, etc., should be emailed to HyBRIDS@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 HyBRIDS@darpa.mil to verify receipt.

No Abstracts will be accepted after the end of the overall submission period listed in Section I. 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 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 HyBRIDS@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 HyBRIDS ARC Opportunity on the DARPA website, 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.