Request for Information (RFI) – Large bio-mechanical space structures

DARPA-SN-25-51

Building Space Elevators, Space Nets, and other Large Bio-Mechanical Space Structures

Responses Deadline: March 27, 2025, 4:00 PM ET

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URL: https://www.darpa.mil/research#research-opportunities

Given recent advances in metabolic engineering for rapid growth, extremophiles with novel properties, biological self-assembly properties of tunable materials, and emergent mechanical design principles of biological systems, DARPA is interested in exploring the feasibility of "growing" biological structures of unprecedented size in microgravity. Rapid, controlled, directional growth to create very large (500+ meter length) useful space structures would disrupt the current state-of-the-art and position biology as a complimentary component of the in-space assembly infrastructure. Some examples of structures that could be biologically manufactured and assembled, but that may be infeasible to produce traditionally, include tethers for a space elevator, grid-nets for orbital debris remediation, kilometer-scale interferometers for radio science, new self-assembled wings of a commercial space station for hosting additional payloads, or on-demand production of patch materials to adhere and repair micrometeorite damage.

To address major barriers to the safe creation of 500-meter-long bio-mechanical structures in space, the Defense Advanced Research Projects Agency (DARPA) Biological Technologies Office (BTO) is requesting information related to methods and new technical insights by which to create and functionalize large, self-assembled, mechanically stable biological growths in space that have structural rigidity (stiffness/strength). A hybrid workshop is planned in the San Francisco Bay Area to discuss credible responses and assess if there are dramatically new technical insights that may be worth investment by DARPA.

BACKGROUND AND VALUE PROPOSITION

The specific advantage of large biological structures in microgravity is that they can be grown in space, i.e., the value proposition lies in the potential for drastic reduction in the amount of upmass or volume launched from Earth. There are numerous examples of exploiting the self-assembly and rapid growth properties inherent to engineered biology. However, purely biological growth mechanisms are unlikely to be successful on their own. Creating useful structures capable of structural rigidity (stiffness/strength/load bearing), while growing in microgravity conditions, requires a close partnership between mechanical, structural, and biological engineering.

A relevant analogy is that of a tent. Given the structural material of the tent poles, biological growth mechanisms are envisioned to be the "cover" of the tent. The tent can be shaped a particular way by the underlying poles, and when embedded with appropriate electronics, perform a given function. The key value proposition for spaceflight would be a *favorable ratio between the mass and/or volume* of traditional (non-biological) materials versus in-situ grown biological materials. Maximizing this value proposition requires co-engineering between the structural/mechanical and the biological to arrive at useful structures.

A key unknown in creating such bio-mechanical structures in space is *how the structure would be assembled*. Feedstock must be provided (and relocated if necessary) to the growing edge, or to the area from which biological materials are being extruded. If aerobic organisms or mechanisms are required (grown in space and then desiccated by exposure to vacuum when growth is complete), the methods and support equipment required to preserve key aerobic variables (e.g., atmosphere, pressure, temperature) must be part of the *biomechanical assembly system design*. Anaerobic organisms or mechanisms may allow for less support hardware but may require other controls to support continued growth in the space environment (e.g. pressure, temperature, humidity).

Finally, the envisioned large-scale biomechanical structures must be *directional* in their growth. Depending on the use case envisioned, they may require the ability to embed or integrate electronics or structural materials between/around grown biological "filler".

REQUESTED INFORMATION

This RFI seeks responses that address development pathways for very large (defined as 500 meters or greater in primary dimension) bio-mechanical space structures. Responses should directly address the following five items:

1. *Use case.* Elucidate the "use case" for the envisioned large bio-mechanical space structures. Some examples are: space elevator tether from geostationary to low-Earth orbit, grid-nets for orbital debris remediation, self-assembled space stations for payload hosting.
2. *Co-engineering.* Insights from both the structural/mechanical point of view, and the biological engineering point of view, to arrive at the envisioned useful structure. This should include information on the specific biological material(s)[1] envisioned for 500-meter scale growth, and the method by which to control its directionality.
3. *Feedstock.* How feedstock will be provided (and relocated if necessary) to the continuously growing edge. Clearly identify if the leading edge is the growth edge, or if the leading edge is extruded away from the growth region, and explain rationale.
4. *Value proposition.* Order of magnitude estimation of the mass ratio between traditional (non-biological) materials and biological materials, with a strong preference for as little traditional material as feasible.
    a. The ratio of "launched from Earth" biological growth materials, with respect to the biological mass of the completed structure, is of particular interest.
    b. The ratio of "launched from Earth" system volume, with respect to the volume of the completed structure, is of particular interest.
    c. Unless specifically biological in nature (e.g. bio-concrete, living bricks), any assembly system would count against traditional materials when calculating ratios.
5. *Scope of Proof-of-concept experiment.* Ground-based proofs of concept that address factors specific to the space environment and go from inception to notional finished structure. If executed, this experiment would prove the concept for an in-space use case.

[1] Examples of biological materials or building blocks may include, but are not limited to, thread-like hyphae such as fungal mycelia, graphene aerogels or other biocompatible materials, filamentous protein-based fibers like those found in hagfish slime, etc.

If the concept can only be proven in microgravity[2], please explain rationale.

Responses that include any of the following information are particularly helpful to scope a potential future DARPA investment:

- Timescale for growth as a function of dimension,
- Proof of feasibility, such as existing modeling, simulation, or empirical data,
- New insights into the emergent mechanics of large-scale biological structures to predict and engineer spatial/temporal patterns of dynamic bio-structures,
- Space-specific issues such as survivability, radiation tolerance or durability,
- Design details for mass and volume estimates used to calculate the value proposition.

WORKSHOP

A DARPA-sponsored workshop is being planned for April 2025, for the purpose of reviewing and discussing current and future research relevant to this RFI and assessing new methods to prove the potential of future very large bio-mechanical structures in space. Information discussed at this workshop may assist in the formulation of possible future areas of DARPA research.

DARPA wishes to encourage maximum participation and the presentation of as many innovative solutions as possible. To enable this goal, the workshop will be hybrid with both the option for in-person attendance (San Francisco Bay Area, CA) and hybrid attendance available.

The workshop will occur over two days: Day 1 for group interactions and Day 2 for individual interactions with DARPA. Space for both days is limited, and attendance will be by invitation only. Invitations will be based on white papers submitted, per the instructions below, no later than the date specified on Page 1 of this RFI. On day 1, each participant will be asked to make a formal non-proprietary presentation summarizing their method and anticipated primary technical challenge. The workshop format will be a combination of group discussion and presentations and may continue into Day 2. Day 2 may include proprietary discussions with DARPA and other government partners. Invitations for booth days will be sent via email and will provide further details on the workshop (times, location, etc.). All attendees will be encouraged to participate in general discussions and to make recommendations for future research in the area.

For attendance on either day, U.S. Permanent Resident and Foreign National participants must submit a DARPA eForm60 no later than 72 hours in advance of attending the workshop in-person and/or virtually.

SUBMISSION FORMAT

Respondents to this RFI are encouraged to be as succinct as possible, while also providing actionable insight. Page limits for each section are indicated below. Format specifications for responses include 12-point font, single-spaced, single-sided, 8.5 by 11-inch paper, with 1-inch margins in MS Word or Adobe PDF format.

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[2] The microgravity or partial gravity spaceflight environment may provide critically advantageous physical properties for the testing and demonstration of certain materials or construction paradigms. Therefore, spaceflight testing is not an expectation, but should be highlighted when it is required to test, confirm or iterate on a concept.

To the maximum extent possible, respondents are encouraged to send non-proprietary information; if proprietary information is included, respondents are responsible for clearly identifying such information. Responses containing proprietary information must have each page containing such information clearly marked with a label such as "Proprietary" or "Company Proprietary." Do not use "CONFIDENTIAL" as this term indicates classified national security information. DO NOT INCLUDE ANY CLASSIFIED INFORMATION IN THE RFI RESPONSE.

A. Cover Sheet (1 page): Provide the following information.
    a. Response Title,
    b. Bio-focused technical point of contact name, organization, telephone number, and email address,
    c. Structural/Mechanical-focused technical point of contact name, organization, telephone number, and email address,
    d. If all five requested information items (use case, co-engineering, feedstock, value proposition, proof of concept experiment) are included in the response.
    e. If expecting to attend DARPA Workshop in person.
B. Technical Description: At least 1 page, 3-5 pages preferred, 10 page maximum.
C. Bibliography (not to exceed 2 pages): All references must be cited in the Technical Description.
D. References (no page limit): Respondents should include copies in PDF format of *all* cited papers or reports, in sequential order as listed in the Bibliography, combined into one file. Respondents are encouraged, though not required, to highlight sections, figures or statements directly relevant to their technical proposition.

SUBMISSION INSTRUCTIONS AND CONTACT INFORMATION
All responses to this RFI must be emailed to DARPA-SN-25-51@darpa.mil. Responses will be accepted any time from the publication of this RFI until the date specified on Page 1. Early responses are highly encouraged. All technical and administrative correspondence and questions regarding this RFI should also be sent to DARPA-SN-25-51@darpa.mil. Emails sent directly to the Program Manager may result in delayed/no response. If the file size is anticipated to be larger than 10 MB, please email DARPA-SN-25-51@darpa.mil at least 48 hours prior to the submission deadline to request a secure link by which to submit large files. A maximum of two files will be accepted: one file for the RFI response, and one file for the References.

ELIGIBILITY
DARPA invites participation from all those engaged in related research activities and appreciates responses from all capable and qualified sources including, but not limited to, universities, university-affiliated research centers (UARCs), Federally Funded Research and Development Centers (FFRDCs), private or public companies and Government research laboratories.

DISCLAIMERS AND IMPORTANT NOTES
- Responses that rely on material generated by AI tools will not be reviewed.
- This is an RFI issued solely for information and new program planning purposes; it does not constitute a formal solicitation for proposals. In accordance with FAR 15.201(e), responses to this RFI are not offers and cannot be accepted by the Government as such.
- Responses do not bind DARPA to any further actions related to this topic including

requesting follow-on proposals from respondents to this RFI.

- Submission is voluntary and is not required to propose to a subsequent Broad Agency Announcement (BAA) (if any) or other research solicitation (if any) on this topic.
- DARPA will not provide reimbursement for costs incurred in responding to this RFI, or travel to the workshop (no-cost hybrid options are available).
- DARPA is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI.
- DARPA will disclose submission contents only for the purpose of review. Submissions may be reviewed by, and both days of the workshop may be attended by, the Government (DARPA and partners) and Scientific, Engineering and Technical Assistance (SETA) support contractors.