Disruption Opportunity
DARPA-PA-23-03-15
Materials Investigation for Novel Operations in Space (MINOS)

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 low-drag material system solutions for resident space objects (RSOs) in low Earth orbit (LEO). 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 a maximum of $1,000,000. This total award value includes Government funding and performer cost share if required or proposed.

To view the latest amendment of the DARPA Program Announcement (PA) for Disruptioneering, visit SAM.gov under solicitation number DARPA-PA-23-03: https://sam.gov/opp/5f9a53644e934e6585aea6cfae12cfd5/view.

A. Introduction

In LEO (altitudes of up to 2,000 km), RSOs must regularly perform thrust maneuvers to counteract atmospheric drag and remain in the correct operational orbit. These corrective maneuvers are carefully considered to minimize both fuel consumption and impact on the RSO mission life. Low-drag materials on the RSO exterior would extend mission life by decreasing the amount of thrust needed to stay in orbit, without increasing onboard fuel storage.

Eroded and corroded spacecraft components increase drag and degrade operations. The LEO environment is extremely reactive and includes from 10^2 to 10^{11} atoms per cm^{-3} of atomic oxygen (AO), which accelerates RSO erosion and corrosion. While atomic oxygen is the largest concern, other environmental concerns such as ultraviolet radiation and temperature changes from day to night are also important.

The erosion and corrosion caused by the LEO environment greatly decrease the effectiveness of low-drag materials and significantly reduce the useful mission life of an RSO. To extend useful mission life in LEO, lower-drag material systems that reduce the total drag of the RSO and are resistant to atmospheric degradation are needed.

B. Objective/Technical Scope

MINOS seeks material system solutions with low drag characteristics and significantly increased erosion and corrosion resistance for LEO RSOs. These materials could be used on outer mold lines, solar panels, or other surfaces that are in contact with the exterior environment. The material systems developed under this program do not need to perform for all these applications, but the intended application should be noted in the proposal.

Performers must identify, select, and refine all material systems necessary for their design to meet performance and lifetime metrics. A “material system” is any combination of substrate and coating materials assembled by a manufacturing process to meet a set of bulk materials and surface requirements. MINOS effort intends to find novel combinations of substrate and coating

materials, and/or to use innovative manufacturing processes to create a material system for use on LEO RSOs. Performers are not required to develop new materials for this effort, but new materials may be acceptable if the performer can feasibly incorporate them within the scope of the MINOS DO.

Current state of the art (SOA) for low drag are materials such as polyhedral oligomeric silsesquioxane (POSS)-polymides. These materials have "drag values for the "conservative" and "best-case" coated POSS-Novastrat [of] 47 and 34%, respectively, of the fully diffuse baseline value."[1]

By the end of the effort, proposed material system solutions should have at least 10% lower drag than the SOA when compared to a fully diffuse material. Additionally, the material system solution should have a multiyear lifetime in an AO-rich environment. Such material system solutions could include, but are not limited to:

- Advanced oxides or other specular coatings that are highly robust to AO.
- Materials or manufacturing improvements with low-drag characteristics that either can be applied to or can wholly replace common spacecraft surfaces.
- Novel techniques that produce uniform and defect-free coatings on low temperature substrates.
- Other materials, processes, or technologies that can significantly lower drag on LEO spacecraft while maintaining resistance to AO.

Proposers should outline their approach to advance the current SOA. Proposers must clearly explain the technical and scientific basis of their approach to finding a material system solution that meets program objectives.

Proposals must include:

- An initial selection of a low-drag, high-AO-resistance material system with description of the material's composition and why it was selected.
- A quantitative assessment of how the proposed material solution will perform against program metrics, including supporting empirical data and relevant open literature citations. The assessment should also include a discussion of the material system's theoretical best performance in the areas of low drag characteristics and AO resistance and supporting evidence.
- A plan for refining the material system based on laboratory test results. This may include, but is not limited to, adding materials to the system, using artificial intelligence or

[1] Minton, TK., Schwartzentruber, TE, and C. Xu, "On the Utility of Coated POSS-Polyimides for Vehicles in Very Low Earth Orbit", Applied Materials and Interfaces, Vol 13, 51673−51684, https://doi.org/10.1021/acsami.1c14196

machine learning to guide the choice of future material selections, or using novel manufacturing techniques to improve performance of the chosen materials.

- A description of the proposer's capabilities for fabricating material system coupons, including the proposer's intended initial substrate material.
- A qualitative description of the material system solution approach to illustrate feasibility of the material system on realistic geometries for RSOs, including:
    - A detailed description of how material system solutions will be applied to realistic surface geometries (e.g., those with tight curves, sharp corners, steps, gaps, etc.) and substrates (e.g., aluminum, stainless steel, graphite composites, etc.)
    - A detailed description of how the material system solution will scale to large surfaces, structures, and/or multilayer insulation (MLI) typically used on RSOs.
    - A detailed description of the proposer's capabilities to support material system solution development (i.e., software, tooling, instrumentation, facilities, previous expertise, etc.).
    - If available, a description of the proposer's capability for rapid internal screening of material system samples to evaluate AO resistance in accordance with ASTM E2089-15R20, *Standard Practices for Ground Laboratory Atomic Oxygen Interaction Evaluation of Materials for Space Applications.*
- A list of key technical risks, challenges, and planned mitigations.

Material system solutions developed under this DO are specifically intended for use in space . Therefore, proposers should consider the suitability and survivability of the material solution in conditions such as vacuum, UV radiation, ionizing radiation, temperature extremes and thermal cycling, surface charging, etc. Proposed material solutions are expected to adhere to standard practices for selecting spacecraft materials found in ASTM E1997-15(2021), *Standard Practice for the Selection of Spacecraft Materials*.

C. Structure

MINOS will consist of two phases: a 12-month Phase 1 Feasibility Study (base) and a 12-month Phase 2 Proof of Concept (option).

MINOS program metrics for Phases 1 and 2 are listed below in Table 1, and test conditions are listed in Table 2.

Table 1. MINOS Program Metrics

Metric	Phase 1	Phase 2
Drag reduction relative to a fully diffuse scattering material* [%]	30	60
Sample Total Mass Loss Threshold, relative to Kapton per ASTM E2089 [%]	<0.5	<0.1

**Minimum drag reduction expected for an incident angle of <30° from parallel to the velocity vector.*

Table 2. MINOS Test Conditions

Test Conditions	Phase 1	Phase 2
AO test fluence [cm^{-2}]	1×10^{21}	3×10^{21}

Advances in computational capabilities and resources to identify potentially impactful material system solutions and refine them. An identified issue with using advanced computational capability is having enough data to validate models and calculations. During Phase 1, performers will engage in a rapid, iterative cycle of developing, fabricating, and bench testing candidate material system solutions, with a focus on identifying the key variables that most influence program metric achievement. Performers will optimize material system solutions based on those key variables. An initial set of key variables that the performer expects to explore should be discussed in the proposal along with the rational for choosing these key variables. The intent of this is to provide data to help rapidly identify the key variables as well as improve the ability to refine the material selection quickly.

At three, six-, and nine-months following contract award (FCA), performers must provide three copies of a 25-mm-diameter material coupon sample to the Government Independent Validation and Verification (IV&V) team. All coupons must be constructed from and/or coated with the performers' selected material system. Performers must be able to fabricate material coupons 25 mm in diameter on a substrate of their choice during Phase 1.

These coupons will be mounted in a vacuum chamber and subjected to a neutral beam representative of LEO atmospheric gas composition at orbital speeds. The material system test result datasets from each test will be provided to each performer for their test coupons to help them refine their selected material(s). The IV&V conducted tests will also measure the performers' material system solutions against program metrics. The mounting apparatus will be a plate upon which performers will adhere their material system sample coupon. A computer-aided design (CAD) drawing of the mounting apparatus will be provided by the Government no later than contract start.

In Phase 2, performers will demonstrate scalability and suitability by iterative testing on larger and more complex samples applied to representative spacecraft substrates. At 15, 18, and 22 months FCA, performers must provide to the IV&V team three copies of 200-mm material coupon samples with the performer-selected material system applied. Performers must adhere their material system sample coupon to a mounting plate. A CAD drawing of the mounting apparatus will be provided by the Government no later than the start of Phase 2. At 15 months FCA, the material system must be applied to fully cover a 200-mm flat aluminum alloy 6061 (AA 6061) plate. At 18 months FCA, the material system must be applied to fully cover a 200-mm AA 6061 plate that will then be formed into a government-provided geometry. At 22 months FCA, the material system must be applied to fully cover a 200-mm section of MLI material chosen by the performer.

The Government IV&V team will conduct test validation campaigns in a government-provided facility to ensure consistent conditions and results across all performers' material systems. Only IV&V-conducted tests will determine performance relative to the program metrics. Test result data will be made available to individual performers after each test campaign.

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 $400,000. The Phase 2 (option) award value is limited to $600,000. 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. This total award value includes Government funding and performer cost share, if required or if proposed.

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:
  - Attend a virtual kick-off meeting and present initial concept from the proposal and path for development.
  - Assign personnel to all supporting positions identified in the proposal and provide their names to the Government.
- Month 2:
  - Deliver a test plan describing the iterative process to evaluate material system solutions during Phase 1, including: a description of the testing facility, data acquisition and instrumentation, and proposed data analysis techniques.
- Month 3:
  - Present the test plan at a quarterly review with the Government team.
  - Deliver three (3) copies of 25-mm-diameter with first iteration of the material system coupons to the Government.
- Month 6:
  - Present results from tests performed on the first iteration material system coupons at a quarterly review with the Government team.
  - Deliver three (3) copies of 25-mm-diameter coupons with an improved material system based on the results from the first iteration to the Government.
- Month 9:
  - Present the results from the improved material system at a quarterly review with the Government team.
  - Deliver three (3) copies of 25-mm-diameter coupons with the final Phase 1 material system which incorporates lessons learned from the first two test iterations.

- Month 11:
    - Present an end-of-phase brief detailing:
        - The results and lessons learned on key performance parameters and lifetime limit mechanisms from all Phase 1 testing.
        - A detailed description of material solutions that were explored and an evaluation of manufacturing processes and/or methods investigated in Phase 1 to meet program metrics.
        - A path forward for advancements that will allow Phase 2 metrics to be realized, including any testing or references to show viability of the path.
- End of Phase 1 Period of Performance (PoP):
    - Deliver a Phase 1 final report and presentation materials which document the information covered during the end-of-phase brief.

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

- Month 13:
    - Attend a Phase 2 kickoff meeting. Presents the results from Phase 1 and a path forward for improvement in Phase 2.
- Month 15:
    - Present the improvements to the materials system status at a quarterly review with the Government team.
    - Deliver three (3) copies of flat 200-mm material system samples applied to AA 6061 flat plate to the Government.
- Month 18:
    - Present status at a quarterly review with results from the 200-mm samples on AA 6061 flat plates. .
    - Deliver three (3) copies of 200-mm material system samples applied to modified AA 6061 plate to the Government.
- Month 22:
    - Present status at a quarterly review with results from the 200-mm samples on modified AA 6061 plates..
    - Deliver three (3) copies of 200-mm material system samples applied to MLI substrate to the Government.
- Month 23:
    - Present an end-of-phase brief detailing:
        - A list of material solutions explored, including all fabrication and application methods that were investigated.
        - An evaluation of key physical insights and design processes, and engineering risks, challenges, and planned mitigations.
        - An assessment of material system solutions' performance against program metrics with supporting evidence.
        - Lessons learned from the program and considerations for technology transition.
        - A detailed analysis of potential future challenges/risks for the chosen material system, including fabrication, application, large-scale manufacturing, effective material lifespan in LEO, drag performance

reductions over time as the material system degrades, and other relevant factors that may have affects over a long duration mission in LEO.

- Month 24:
    - Deliver a program final report and presentation materials documenting the information covered during the end-of-phase brief.

For planning and budgetary purposes, proposers should assume a program start date of November 12, 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:

- Attending a half-day virtual kick off.
- Regular teleconference meetings will be scheduled with the Government team for progress reporting and problem identification/mitigation.
- Proposers should also anticipate one site visit per phase by a member of the Government team, during which they will have the opportunity to demonstrate progress towards agreed upon milestones.
- Conference travel and publication costs should not be included in the proposed costs.

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, and test articles for government testing.

II. Award Information

Selected proposals that are successfully negotiated will result in the award of an OT for Prototype project. See Section 4 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 (July 15, 2024) 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 November 12, 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. All proposers must use 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-23-03-15 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 MINOS@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 MINOS@darpa.mil. Questions regarding submission contents, format, deadlines, etc., should be emailed to MINOS@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 August 29, 2024. 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

Susan Swithenbank, Program Manager, DARPA/DSO, MINOS@darpa.mil

VIII. Frequently Asked Questions (FAQs)

All technical, contractual, and administrative questions regarding this announcement must be emailed to MINOS@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.

For those new to DARPA or national security, DARPA makes available a free, comprehensive resource via DARPAConnect on how to do business with the agency. In addition to DARPA 101 materials, relevant preparatory modules include "Making the Most of a Proposers Day" and "Understanding DARPA Broad Agency Announcements." Registration and access are free at www.darpaconnect.us.