AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT

1. CONTRACT ID CODE	PAGE OF PAGES
	1 of 1

2. AMENDMENT/MODIFICATION NUMBER	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQUISITION NUMBER	5. PROJECT NUMBER *(If applicable)*
P0001	See Block 16C		

6. ISSUED BY CODE NSSC	7. ADMINISTERED BY *(If other than Item 6)* CODE NSSC
NASA/Shared Services Center (NSSC) Building 1111, Jerry Hlass Road Stennis Space Center MS 39529-0001	NASA/Shared Services Center (NSSC) Building 1111, Jerry Hlass Road Stennis Space Center MS 39529-0001

8. NAME AND ADDRESS OF CONTRACTOR *(Number, street, county, State and ZIP Code)*

CODE | FACILITY CODE

(X)	
X	9A. AMENDMENT OF SOLICITATION NUMBER 80NSSC26R005 9B. DATED *(SEE ITEM 11)*
☐	10A. MODIFICATION OF CONTRACT/ORDER NUMBER 10B. DATED *(SEE ITEM 13)*

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

☐ The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☐ is extended. ☒ is not extended.

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods:
(a) By completing items 8 and 15, and returning ____________ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or electronic communication which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by letter or electronic communication, provided each letter or electronic communication makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*
See Schedule

13. THIS ITEM APPLIES ONLY TO MODIFICATIONS OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NUMBER AS DESCRIBED IN ITEM 14.

CHECK ONE	
☐	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NUMBER IN ITEM 10A.
☒	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES *(such as changes in paying office, appropriation data, etc.)* SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
☐	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
☐	D. OTHER *(Specify type of modification and authority)*

E. IMPORTANT: Contractor ☒ is not ☐ is required to sign this document and return __________ copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION (*Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*

NASA SBIR Appendix 26A is amended to add FAR 52.222-90 Addressing DEI Discrimination by Federal Contractors (APR 2026) (DEVIATION APR 2026) is incorporated by reference as required by Executive Order (E.O.) 14398, “Addressing DEI Discrimination by Federal Contractors.”

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*		16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)*	
15B. CONTRACTOR/OFFEROR *(Signature of person authorized to sign)*	15C. DATE SIGNED	16B. UNITED STATES OF AMERICA KENNETH ALBRIGHT Digitally signed by KENNETH ALBRIGHT Date: 2026.04.29 09:57:07 -05'00' *(Signature of Contracting Officer)*	16C. DATE SIGNED

Previous edition unusable

STANDARD FORM 30 (REV. 11/2016)
Prescribed by GSA FAR (48 CFR) 53.243

National Aeronautics and Space Administration

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs

FY26-27 Broad Agency Announcement (BAA)

Broad Agency Announcement 80NSSC26R0003

Appendix 26A:

Small Business Innovation Research (SBIR) Phase I

Funding Opportunity

Originally Issued: April 21, 2026

Proposals Due: May 21, 2026 by 5:00 PM ET

FY26-27 BAA- Appendix 26A: Small Business Innovation Research (SBIR)

Phase I

Change Log

Version	Description of Changes	Date
Original Release	-----	April 21, 2026
Amendment 1	Added clause FAR 52.222-90	April 28, 2026

Contents

Executive Summary

This is the first appendix to NASA SBIR/STTR Program FY2026-2027 Broad Agency Announcement (BAA) and solicits proposals for the Small Business Innovation Research (SBIR) Phase I funding opportunity.

Chapter 6 of this appendix contains the proposal submission instructions and Chapter 9 contains the technical research topics. Instructions for how to prepare your proposal can be found in the BAA (https://sam.gov/workspace/contract/opp/bf991b7587b1438ca7930a9b840635dc/view). The chapter numbers align to the chapters in the BAA and can be used to locate additional information within the BAA. In any instance where specific requirements in this appendix conflict with requirements in the BAA, the specific requirements in this appendix take precedence for this opportunity.

Important Dates

Proposals Due: May 21, 2026, by 5:00 PM ET

Note that the submission open period is shorter than prior years.

Deadline for guaranteed response from the Help Desk: May 20, 2026, by 5:00 PM ET

Multiple Submissions

NASA will not accept more than two (2) proposal packages from any one offeror for this funding opportunity. See sections 3.2 in this appendix and section 4 in the BAA.

1. Program Description

1.13.1 Questions About This Solicitation and Means of Contacting NASA SBIR/STTR Program

The Help Desk will not guarantee a timely answer to questions about this appendix after May 20, 2026, at 5:00pm ET.

2. Registrations, Certifications and Other Information

No additional content, requirements, or exceptions beyond information in BAA.

3. Proposal Preparation Instructions and Requirements

3.2 Multiple Proposal Submissions

Each proposal must be based on a unique innovation, limited in scope to just one subtopic, and submitted only under that one subtopic. **You may not submit more than two (2) proposals to the funding opportunity in this appendix.** You may submit more than one unique proposal to the same subtopic; however, you must not submit the same (or substantially equivalent) proposal to more than one subtopic. If you submit substantially equivalent proposals to several subtopics, NASA may decline all such proposals.

4. Method of Selection and Evaluation Criteria

The rubric containing all evaluation criteria is available in attachment 26A.1 SBIR.

5. Considerations for Contracting and Additional Information

No additional content, requirements, or exceptions beyond information in BAA.

6. Submission of Proposals

6.1 How to Submit your Proposal Package

NASA uses electronically supported business processes for the SBIR/STTR program. You must have internet access and an email address. NASA will not accept paper submissions. NASA's electronic systems for submission and contract management are not document repositories. NASA follows federal regulations for records management and disposal (NPR 1441.1E).

6.1.1 Electronic Submission of Proposals

NASA will be using ProSAMS for the submission of these proposal packages. ProSAMS requires firm registration and login. To access ProSAMS, go to https://prosams.nasa.gov/. To submit proposals to this appendix, select "SBIR 2026A-I" from the solicitation type dropdown as you start a new proposal.

NASA recommends that an authorized small business representative be the person to register the firm and complete the required firm level forms. They will be the only person allowed to edit the firm level forms.

For successful submission of a complete proposal package, you must complete all required and applicable forms and upload the required documents per the submission requirements indicated in ProSAMS.

6.1.2 Deadline for Proposal Package Submission

NASA must receive your proposal package for SBIR Phase I no later than 5:00 p.m. ET on Thursday, May 21, 2026, via ProSAMS.

You are responsible for ensuring that all files constituting the proposal package are uploaded and endorsed prior to the deadline. **If a proposal package is not received by the 5:00 p.m. ET deadline, NASA will determine the proposal package to be incomplete and will not evaluate it.** Start the submission process early to allow sufficient time to upload the complete proposal package.

If you wait to submit a proposal package near the deadline, you are at risk of not completing the required uploads and endorsements by the required deadline, and NASA may decline the proposal package.

6.1.3 Proposal Package Submission

Upload all components of a proposal package using the Proposal Submissions module in ProSAMS. The designated business representative and principal investigator must endorse the proposal package. All transactions via ProSAMS are encrypted for security purposes.

If your proposal contains ITAR/EAR information, it may be submitted via ProSAMS.

Do not submit security/password-protected PDF files, as reviewers may not be able to open and read these files. NASA will decline proposal packages containing security/password-protected PDF files and they will not be evaluated.

You are responsible for virus checking all files prior to submission. NASA may decline any proposal package that contains a file with a detected virus.

You may upload a proposal package multiple times, with each new upload replacing the previous version, but only the final uploaded and electronically endorsed version will be considered for review. Embedded animation or video, as well as reference technical papers for "further reading," will not be considered for evaluation. **NASA may decline a proposal package that is missing the final endorsements.**

6.1.4 Acknowledgement of a Proposal Package Receipt

NASA will acknowledge receipt of an electronically submitted proposal package by sending an email to the designated Business Official's email address as provided on the proposal package cover sheet. **If you do not receive a proposal package acknowledgment after submission, immediately contact the NASA SBIR/STTR Help Desk at agency-sbir@mail.nasa.gov.**

6.1.5 Withdrawal of Proposal Packages

Prior to the close of submissions, you may withdraw proposal packages. To withdraw a proposal package after the deadline, the designated small business representative must send written notification via email to agency-sbir@mail.nasa.gov.

6.1.6 Service of Protests

Protests, as defined in section FAR 33.101 of the Federal Acquisition Regulation, that are filed directly with an agency, and copies of any protests that are filed with the Government Accountability Office (GAO), must be served on the Contracting Officer (addressed as follows) by obtaining written and dated acknowledgment of receipt from:

Kenneth Albright
NASA Shared Services Center

Building 1111, Jerry Hlass Road
Stennis Space Center, MS 39529
Agency-SBIR-STTRSolicitation@mail.nasa.gov

The copy of any protest must be received in the office designated above within one day of filing a protest with the GAO.

6.2 Phase II Information

If you are awarded a Phase I contract, you will be eligible to submit a proposal for an SBIR/STTR Phase II follow-on contract. NASA will send instructions directly to you with information on how to submit your Phase II proposal(s). You will receive details on the due date, content, and submission requirements for Phase II proposals. The Phase II proposal submission will open approximately 60 days prior to the proposal due date stated in your contract.

If you submit your Phase II proposal outside of the timeframe specified by NASA, your proposal will be declined without evaluation. Additional guidance can be found in your Phase I contract (Request for Proposal for Phase II Follow-on Contract).

7. Proposal, Scientific and Technical Information Sources

No additional content, requirements, or exceptions beyond information in BAA.

8. Submissions Checklist

For assistance in completing your Phase I proposal package, use the following checklist:

- ☐ The technical proposal and innovation are submitted for one subtopic only.
- ☐ The entire proposal package is submitted consistent with the requirements outlined in BAA chapter 3.
    - ☐ Proposal Contact Information
    - ☐ Proposal Certifications
    - ☐ Proposal Summary
    - ☐ Proposal Budget
        - ☐ Including letters of commitment for government resources and subcontractors/ consultants (if applicable)
        - ☐ Foreign Vendor form (if applicable)
    - ☐ Technical Proposal including all 9 parts in order as stated in BAA section 3.1.5.5.
    - ☐ Briefing Chart
    - ☐ NASA Evaluation License Application, only if TAV is being proposed
    - ☐ I-Corps Interest Form
    - ☐ Technical and Business Assistance (TABA) Request, if applicable
    - ☐ SBC-Level Forms completed once for all proposal packages submitted to a single solicitation
        - ☐ SBC Certifications
        - ☐ Audit Information
        - ☐ Prior Awards Addendum
        - ☐ Commercialization Metrics Report (CMR)
        - ☐ Disclosure of Foreign Affiliations
- ☐ The technical proposal does not exceed a total of 15 standard 8.5- by 11-inch pages with one-inch margins and follows the format requirements (BAA section 3.1.4).
- ☐ All required letters/documentation are included.
    - ☐ A letter of commitment from the appropriate government official if the research effort requires use of government resources (BAA sections 3.1.5.4 and 5.13).
    - ☐ A letter from the Small Business Official explaining why the SBIR research project requires the use of government resources, if the effort requires government resources (BAA sections 3.1.5.4 and 5.13)
    - ☐ Letters of commitment from subcontractors/consultants.
    - ☐ If the SBC is an eligible joint venture or a limited partnership, a copy or comprehensive summary of the joint venture agreement or partnership agreement is included.
    - ☐ NASA Evaluation License Application if proposing the use of NASA technology (TAV).
    - ☐ Supporting documentation of budgeted costs.
- ☐ Total proposed funding for the effort does not exceed $225,000 (BAA section 1.3), and if requesting TABA, the cost for TABA does not exceed $6,500 (BAA sections 1.8 and 3.1.5.9).
- ☐ Proposed project duration does not exceed six (6) months (BAA section 1.3).
- ☐ Confirm you received an acknowledgement of submission email before 5:00 p.m. ET on May 21, 2026 (Appendix 26A section 6.1.4).

9. Research Topics

The 12 SBIR subtopics are organized by topic based on technical theme. There are 10 topics and 12 total subtopics in this appendix. This appendix only contains SBIR subtopics.

You should be thoughtful in selecting a subtopic to ensure the proposal is responsive to the NASA need as defined by the subtopic. The NASA SBIR/STTR program will NOT move a completed proposal package between SBIR subtopics.

Guidance for Locating Subtopic Reference Materials

Each subtopic contains references that are intended to provide additional information about the technology need. Some of those references include technical articles that may be available through NASA's Technical Reports Server (NTRS) or through other technical journals or sources.

NTRS (https://ntrs.nasa.gov/) provides access to publicly available scientific and technical documents, images and videos created or funded by NASA.

While we work to only reference publicly available documents, if you find that referenced technical articles are behind a paywall, please contact your local library to request assistance in obtaining access.

NASA has changed the subtopic numbering convention for the SBIR/STTR program this year:

Subtopics are organized and numbered according to their topic alignment and appendix. Prior subtopics numbers are listed in the subtopic title as appropriate to help you locate returning subtopics.

Research Subtopics

Critical At-Risk Industrial Technologies (CARITL)

CARITL.1.S26A: Development of Hydrazine-Compatible Elastomeric Materials for Long-Duration Spaceflight (SBIR)

Lead Center: KSC

Participating Center(s): JSC

Subtopic Problem Statement/Description:

Heritage AF-E-411 rubber was originally developed in the 1970s to provide extended-duration hydrazine compatibility for propulsion systems. However, the original formulation is no longer viable because several key precursors are no longer commercially available, leading to increased variability and reduced chemical compatibility. This creates a critical gap for NASA missions that require long-duration exposure to hydrazine in space environments. A replacement elastomer, formulated from currently available precursors and capable of meeting or exceeding the performance of AF-E-411, is urgently needed to ensure reliable propulsion system operation for ongoing and future missions.

Scope and Objectives:

- The objective of this subtopic is to develop and validate a new elastomeric material that:
    - Maintains chemical compatibility with hydrazine for extended durations (multi-year exposure).
    - Exhibits mechanical properties comparable to or better than AF-E-411 (e.g., tensile strength, elongation, compression set).
    - Is manufacturable using commercially available precursors and scalable processes.
    - Performs reliably under spaceflight conditions, including vacuum, thermal cycling, and radiation exposure.
- The effort should include:
    - Identification and screening of candidate formulations.
    - Compatibility testing with hydrazine under relevant environmental conditions per NASA-6001 Test 15.
    - Evaluation of aging and degradation mechanisms over extended durations.

Expected TRL or TRL Range at completion of the Project: 2 – 4

Primary Technology Taxonomy:

- Level 1: TX12 Materials, Structures, Mechanical Systems, and Manufacturing
- Level 2: TX12.1 Materials

Desired Deliverables of Phase I:

Phase I Goals:

- Conduct trade studies to identify candidate elastomer formulations using currently available precursors.
- Demonstrate preliminary hydrazine compatibility through short-duration exposure tests. Gross compatibility evaluation (beaker level test per NASA-STD-6001B Test 15)

- Provide initial mechanical property characterization and feasibility assessment. Identify candidate materials for compatibility and with pre-exposure mechanical properties to down select for materials to be further optimized and evaluated (full Test 15 evaluation) for Phase 2.

Desired Deliverables of Phase II:

Phase II Goals:

- Optimize formulation for long-duration hydrazine exposure.
- Perform extended aging tests under simulated spaceflight conditions.
- Develop manufacturing processes and produce prototype components for NASA propulsion systems.
- Deliver a validated material specification and test data package.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results

State of the Art:

- Potential NASA Applications:
    - Propulsion system seals, gaskets, and diaphragms for spacecraft and planetary landers.
    - Long-duration storage of hydrazine-based propellants for deep-space missions.
    - Replacement parts for legacy systems requiring hydrazine compatibility.

Critical Gaps:

A new formulation is required that shows compatibility with hydrazine, not purely mechanical response. The compatibility needs to be shown over a range of exposure times and/temperatures. The post-exposure mechanical behavior needs to be quantified.

Shortfalls And Decadal Surveys:

1221: Mars Ascent Vehicle Propulsion, Loss of Robust Domestic Supply

Need Horizon: Near-Term (Less than 5 years)

References:

1. NASA Technical Memorandum (1973): Long-Time Dynamic Compatibility of Elastomeric Materials With Hydrazine https://ntrs.nasa.gov/api/citations/19730021806/downloads/19730021806.pdf
2. DTIC Report (1969): Hydrazine Compatibility with Ethylene-Propylene Elastomers https://apps.dtic.mil/sti/tr/pdf/AD0688486.pdf

EXPAND - In-Space Infrastructure and Discovery (EXPAND)

EXPAND.1.S26A: Flight Demonstrations of Commercial In-Space Logistics, Robotic Manipulation, and Automation Systems for Future Space Operations (SBIR)

Lead Center: GSFC

Participating Center(s): ARC, JSC, LaRC

Subtopic Problem Statement/Description:

This subtopic seeks innovative concepts for flight demonstration of commercial in-space logistics, robotic manipulation, and automation systems that will enable advanced exploration, science operations, and in-space production capabilities enabling a commercial ecosystem. All proposals must include a plan to develop a flight demonstration with launch within the next five years, with strong recommendation to utilize NASA's Space Technology Mission Directorate (STMD) Flight Opportunities program or other low-cost flight demonstration options that enable space flight validation. Proposals must advance space logistics and/or robotic manipulation capabilities and must be applicable to one or more of the target applications defined below. Proposals may include planetary surface (Moon and Mars) demonstration but will only be considered if relevance of an orbital flight technology demonstration mission can be demonstrated or surface demos are achievable at NASA funding levels similar to low Earth orbit (LEO) demonstrations. Innovative partnerships are highly encouraged but must include evidence of partner funding viability.

In-space logistics systems encompass three primary functions: 1) Delivery systems for transportation of materiel to pre-existing space assets; 2) Aggregation systems for collection, sorting, and temporary storage of materials and components, enabling cost-effective orbital aggregation for robotic operations; 3) Earth-return systems for packaging and returning products, samples, or equipment to Earth, providing independent and more frequent return capability to support commercial market commitments (Note that this subtopic does not solicit reentry system technology, only in-space systems to support reentry via delivery, staging, loading, or other manipulation of return materiel and capsules.)

Robotic Manipulation and Autonomous System Architectures: Cost-effective, modular, and versatile robotics solutions may include: 1) Mobile robotic systems: walking/inchworm/climbing robots, rover-based systems, or free-flyers capable of locomotion to enable low-cost manipulation in a workspace much larger than the robots themselves; 2) Multi-degree-of-freedom manipulators, end effectors, and tools: Serial and parallel link robotic systems optimized for space and planetary surface environments; 3) Pick-and-place automation systems: Specialized for material handling and assembly operations; 4) Hybrid and novel configurations: Specialized electromechanical systems designed for specific space applications; 5) Multi-agent systems: Proliferated robotics for cost-effective collaborative operations; 6) Surface-mobile platforms: Robotic systems capable of traversing planetary terrain while manipulating equipment and supplies (Note that this subtopic does not solicit rover technology, but rover-mounted manipulation and logistics systems are in scope.)

Target Applications include five key operational areas:

1. In-Space Servicing Operations
    - Delivery and installation of Orbital Replacement Units (ORUs)
    - Propellant transfer and refueling operations
    - Maintenance and upgrade activities on operational spacecraft
    - Removal of derelict spacecraft and rocket bodies

- Surface mobility asset maintenance and upgrade

2. In-Space Assembly and Construction Operations
   - Delivery, integration, and outfitting of structural components and subsystems
   - Robotic assembly of large platforms, structures, and apertures in space and on planetary surfaces
   - Construction and maintenance of surface infrastructure including landing pads, communication arrays, and power systems
3. Automated Science Operations
   - Glovebox-equivalent robotic manipulation for biological and physical science experiments
   - Robotic support of novel automated experiments
   - Sample handling, processing, and preparation of geological samples and scientific specimens for Earth return
   - Support for commercial LEO scientific operations
4. In-Space Production Support
   - Delivery and management of production consumables
   - Robotic manipulation for manufacturing processes
   - Handling of in-situ analytical tools
   - Automated restocking and material handling
   - Product packaging for Earth return via capsule systems
5. Commercial Platform and Human Spaceflight Support Operations
   - Free-flying robotic systems for routine inspection, inventory management, and workspace setup in orbital and surface environments
   - Intravehicular robotic handling, assembly, and inspection tasks
   - Cooperative human-robot and robot-robot operations
   - Pre-positioning and set up of habitat modules, scientific equipment, and exploration assets prior to crew arrival
   - Cargo handling and inventory management for human exploration missions including unpacking, sorting, and staging of crew supplies
   - Emergency response capabilities for crew support including equipment replacement, repair operations, and evacuation support

Expected TRL or TRL Range at completion of the Project: 3 – 6

Primary Technology Taxonomy:

- Level 1: TX04 Robotics Systems

Desired Deliverables of Phase I:

- Integrated system concept with preliminary design emphasizing cost-effectiveness and modularity.
- Comprehensive feasibility analysis including technical and economic risk assessment.
- Mission scenario definition with detailed concept of operations (CONOPS) addressing specific logistics gaps and crew support requirements.

- Cost-effectiveness analysis comparing to existing solutions and market alternatives.
- Technology maturation roadmap with TRL advancement plan and risk mitigation strategies.
- Detailed flight demonstration mission plan with identified flight opportunity, timeline, and budget within five-year launch window.
- For planetary surface applications, justification of orbital demonstration relevance and technology validation approach.
- Phase II development plan with key milestones, success criteria, and commercialization pathway.

Desired Deliverables of Phase II:

- Mature Phase I technology and concepts and to conduct a ground demonstration of in-space logistics, robotic manipulation, or automation systems for future space operations.
- Mission analysis of Phase I concept for in-space logistics, robotic manipulation, or automation systems for future space operations.
- Commercialization plans for proposed technology and concepts, including potential mission partners.
- Subsystems in the state are ready for integration into a suborbital flight or other method of testing in a relevant space environment.
- Detailed flight demonstration mission plan with identified flight opportunity, timeline, and budget within five-year launch window.
- Detailed risk assessment and mitigation plan for potential flight demonstration.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype

State of the Art:

The current state of the art for in-space logistics includes launch capabilities to LEO, in-space transfer vehicles, International Space Station (ISS) and multiple hosted payload options, concepts for commercial space stations, Mission Extension Vehicles (MEV) in geostationary orbit (GEO).

The current state of the art for robotic manipulation includes robot arm systems such as Canadarm2, Japanese Module Remote Manipulator System, OSAM-1, Robotic Servicing of Geosynchronous Satellites (RSGS) robot arms. Most systems have been used in LEO. Future servicing and assembly applications require expanded capabilities in multiple orbital domains, including LEO, GEO, Lagrange points, and beyond.

Robotic assembly of structures in space is an active area of research for NASA and will help push towards a paradigm of sustainable and scalable space exploration. This technology is essential for establishing critical long-term orbital infrastructure. Recent efforts within NASA’s Robotic Assembly Community (e.g., Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS), NASA’s Precision Assembled Space Structure (PASS), Tall Lunar Tower (TLT)) have developed modular structural elements and multi-agent robot systems for building complex lightweight structures, telescope array backbones, and tall towers in space. The teams have demonstrated the potential of these construction methods by building various structures with assembly agents ranging in complexity from astronaut assembly to teleoperated robotic arms to fully autonomous multi-agent systems. Previous work at NASA Jet Propulsion Laboratory (JPL) have also developed truss modules for observatories.

Commercial developers have also developed various assembly systems demonstrating structural beam assembly, tower assembly, and telescope element assembly.

Critical Gaps:

Gaps in technology development include development of flight rated components and integration of robotic systems to enable assembly capabilities. There are also gaps in affordability to enable future missions and proliferated commercial implementation.

Shortfalls And Decadal Surveys:

Civil Space Shortfall Rankings https://www.nasa.gov/spacetechpriorities

- 376: Modular design for in-space installation
- 379: Upgrade or install instruments on large space observatories
- 498: Broad and dependable supply chain for space qualified robotic hardware, electronics, and associated software
- 512: Cooperative interfaces, aids, and standards
- 513: Robotic Assembly and Construction of Modular Systems for Sustained In-Space Infrastructure
- 680: Robust Robotic Intelligence for High-Tempo Autonomous Operations in Dynamic Mission Conditions
- 1480: On-surface Outfitting of Lunar Structures
- 1486: In-Space and On-Surface NDE and Qualification of Components for Manufacturing, Assembly, and Construction
- 1487: In-Space and On-Surface Welding Technologies for Manufacturing, Assembly, and Construction
- 1490: Additive Manufacturing for New and High-Performance Materials
- 1532: Autonomous Planning, Scheduling, and Decision Support to Enable Sustained Earth-Independent Operations
- 1535: Autonomous Vehicle, System, Habitat, and Infrastructure Health Monitoring and Management
- 1537: Free-Flying Systems for Robotic Inspection, Data Collection, and Servicing of In-Space Assets
- 1538: General-Purpose Robotic Manipulation to Perform Human-Scale Logistics, Maintenance, Outfitting, and Utilization
- 1540: Intelligent Robots for the Servicing, Assembly, and Outfitting of In Space Assets and Industrial Scale Surface Infrastructure
- 1542: Metrics and Processes for Establishing Trust and Certifying the Trustworthiness of Autonomous Systems
- 1543: Multi Agent Robotic Coordination and Interoperability for Cooperative Task Planning and Performance
- 1545: Robotic Actuation, Subsystem Components, and System Architectures for Long Duration and Extreme Environment Operation
- 1546: Robotic Mobile Manipulation for Autonomous Large-Scale Logistics, Payload Handling, and Surface Transport
- 1548: Sensing for Autonomous Robotic Operations in Challenging Environmental Conditions

Need Horizon: Near-Term (Less than 5 years)

References:

1. On-Orbit Satellite Servicing Study Project Report. October 2010 https://www.nasa.gov/wp-content/uploads/2023/10/nasa-satellite-servicing-project-report-0511.pdf
2. Cooper, John R.; Martin, Jacob R.; Stohlman, Olive R.; Cresta, Collin J.; Avila, Thea V.; Rajaram, Radhika; McQuarry, Andrew K. *Test Results for Autonomous Assembly of Modular Space Structures.* NASA Langley Research Center/ Analytical Mechanics Associates, 2023. https://ntrs.nasa.gov/api/citations/20230013537/downloads/main.pdf
3. Gregg, Christine E.; Catanoso, Damiana; Formoso, Olivia Irene B.; ostitsyna, Irina; Ochalek, Megan E.; Olatunde, Taiwo J.; Park, In Won; Sebastianelli, Frank M.; Taylor, Elizabeth M.; Trinh, Greenfield T.; Cheung, Kenneth C. *Ultra-Light, Strong, and Self-Reprogrammable Mechanical Metamaterials* (AAM submitted manuscript for publication in *Science Robotics*). NASA Ames Research Center / KBR (under contract), 2023.https://ntrs.nasa.gov/api/citations/20230005194/downloads/SciRobotics-ARMADAS_System_Paper_Distribution.pdf
4. Ochalek, Megan; Jenett, Benjamin; Formoso, Olivia; Trinh, Greenfield; Cheung, Kenneth; Gregg, Christine. *Geometry Systems for Lattice-Based Reconfigurable Space Structures.* NASA Ames Research Center, 2019. (ARC-E-DAA-TN62635; presented at IEEE Aerospace Conference, Big Sky, MT, March 2–9, 2019) https://ntrs.nasa.gov/api/citations/20190004967/downloads/20190004967.pdf
5. Tall Lunar Tower: https://ntrs.nasa.gov/citations/20230007930
6. Robot Operating System (ROS): https://www.ros.org/
7. Astrobee: https://www.nasa.gov/astrobee
8. Space Robot Operating System: Space ROS https://space.ros.org/; and TechPort Space Robot Operating System (SpaceROS-ACO) https://techport.nasa.gov/view/116403
9. NASA Outlines Lunar Surface Sustainability Concept: https://www.nasa.gov/feature/nasa-outlines-lunar-surface-sustainability-concept
10. Comstock, Douglas A.; Gatens, Robyn; Cox, Christie; Keaton, Jacob L.; Edeen, Marybeth; Read, Mike. “NASA's Plan for Commercial LEO Development.” *2020 IEEE Aerospace Conference*, March 7, 2020. https://ieeexplore.ieee.org/document/9172512
11. JSC iMETRO (Integrated Mobile Evaluation Testbed for Robotics Operations) Facility: https://ntrs.nasa.gov/citations/20230015485
12. NASA STMD National Space Technology Priority Shortfall List: https://www.spacetechpriorities.org/
13. Cold Operable Lunar Deployable Arm (COLDArm): https://www.nasa.gov/cold-operable-lunar-deployable-arm-coldarm/
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15. Doggett et al., "Persistent Assets in Zero-G and on Planetary Surfaces: Enabled by Modular Technology and Robotic Operations," AIAA SPACE Forum, 2018. https://arc.aiaa.org/doi/pdf/10.2514/6.2018-5305
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21. Towers: Critical Initial Infrastructure for the Moon, Such as a Power Module Support: https://ntrs.nasa.gov/citations/20220017244
22. Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS): https://www.nasa.gov/general/robot-team-builds-high-performance-digital-structure-for-nasa/
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Extravehicular Activity (EVA)

EVA.1.S26A: Advanced Spacesuit Architectures, Technologies, and Designs for Mars Exploration (SBIR) (previously H4.11)

Lead Center: JSC

Participating Center(s): Not Defined

Subtopic Problem Statement/Description:

This subtopic solicits technologies and concepts for advanced Extravehicular Activity (EVA) suit architectures optimized for the Martian surface environment. Areas of interest include mass reduction strategies for the Mars gravity environment, enhanced durability and performance capabilities for Mars conditions, thermal control solutions for the Mars thermal environment, and design approaches that balance mass reduction with maintainability requirements. Examples of high-value targets include lightweight upper torso architectures, advanced bearing and disconnect interfaces, materials and components providing necessary thermal control across the suit system, and technologies that offer enhanced durability and/or performance as documented in the EVA Development Roadmap (see References).

Expected TRL or TRL Range at completion of the Project: 1 – 4

Primary Technology Taxonomy:

- Level 1: TX06 Human Health, Life Support, and Habitation Systems
- Level 2: TX06.2 Extravehicular Activity Systems

Desired Deliverables of Phase I:

1. Analysis and testing of candidate architectures, technologies, materials, and designs against requirements as discussed with NASA during the period of performance to determine feasibility and/or feasible optimizations related to composition, design, processing, and/or manufacturing.

2. If relevant, prototype material coupons, sub-scale or full-scale Pressure Garment Subsystem (PGS) components in sufficient quantity for vendors testing against requirements and for delivery of appropriate quantity to NASA.

3. Final report.

Desired Deliverables of Phase II:

1. Analysis of Phase I results and opportunities for material or design optimization.

2. Optimization of material properties or design with respect to requirements.

3. Manufacturing and Non-Destructive Evaluation (NDE) plan for the material/component.

4. If applicable, sub-scale or full-scale PGS component prototype in sufficient quantity for NDE and destructive testing by vendor, and for delivery to NASA.

5. Testing results and analysis.

6. Final report.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype
- Digital Models

State of the Art:

The current state of the art materials exists in the (waist entry) Extravehicular Mobility Unit (EMU) that is in operation on the International Space Station. This includes MXB7701/7781 epoxy/fiberglass prepreg for the EMU Hard Upper Torso (HUT) and stainless- steel bearings. At a lower Technology Readiness Level (TRL), current state of the art is also available for reference in the (rear entry) Exploration Extravehicular Mobility Unit (xEMU) government reference design advanced suit prototype. This suit has two options for hard structural materials (HUT, brief) - Aluminum 6061-T6, and a lightweight fiberglass composite (HexForce 6781HT/Patz PMT-F4A). Additionally, bearings and disconnects are constructed out of Titanium 6AL4V.

While these materials offer reduced mass for the Moon, they are still insufficient to enable EVAs on Mars due to the combination of mass and impact resistance of structures. Interfaces between soft or hard structural segments and bearings/disconnects provide resizing and maintainability, but at the expense of increased mass. Aggressive reduction of mass is required to meet requirements in the Mars suit application.

State of the art for heat rejection is seen in all current and previous flight suits, using only multi-layer insulation (MLI) in which no heat is rejected, and minimal heat is added. Heat is rejected from the suit via sublimation/evaporation to close the energy balance.

Critical Gaps:

Suit mass must be reduced considerably for the Mars gravity environment to ensure requirements are met. Initial estimates for mass of the xEMU need to be reduced by approximately 1/3. It is believed that this mass reduction will take the form of (1) material selection (2) maturation of new advanced architectural concepts that reduce system mass compared to the xEMU which uses a rear-entry design, and (3) lightweighting of interfaces between bearings and structure, possibly at the expense of maintainability and cycle life.

Additionally, thermal control of the full-suit system in the Mars environment is a critical gap that must be closed and may be accomplished by selection of new materials and/or technologies.

This proposal seeks (1) development of a platform to evaluate the solution space for a lightweight Mars suit architecture, (2) bearing/disconnect lightweighting through simplified design, (3) new technologies or materials that enable NASA to close critical gaps documented on the EVA Development Roadmap, and/or (4) suit system thermal control materials and/or technologies.

Possible proposal scopes include but are not limited to: Low (1 to 2 psid) pressure, additively manufactured suit platform for rapid architectural evaluations; flexible/adaptable architecture suit concepts; bonded, roved, or otherwise simplified hard/soft interface designs; advanced lightweight bearing designs/technologies; integrated structural/thermal materials for a partial atmosphere; variable emissivity radiators and any other form of heat rejection/isolation from a partial atmosphere; technologies that improve suit durability with minimal/no mass increase; in-situ printable suit components; EVA-borne planetary protection technologies; active dust mitigation; enhanced in-helmet communication architectures; dust-tolerant or maintainable bearings.

Shortfalls And Decadal Surveys:

1529: EVA and IVA Suit System Capabilities for Mars Missions

Need Horizon: Near-Term (Less than 5 years)

References:

1. EVA Roadmap ICES paper
   https://ntrs.nasa.gov/api/citations/20250004024/downloads/ICES-2025-61.pdf
2. EVA Roadmap ICES Presentation
   https://ntrs.nasa.gov/api/citations/20250006297/downloads/ICES-2025-61%20Roadmaps%20Presentation.pdf
3. NASA Advanced Space Suit Pressure Garment System Status and Development Priorities 2022, and referenced component papers
   https://ttu-ir.tdl.org/items/76a63da4-236e-4b1f-8f1b-9dfe79c59cc5
4. NASA Advanced Space Suit Pressure Garment System Status and Development Priorities 2023
   https://ttu-ir.tdl.org/items/f9e01334-8a4d-4f71-a060-575cf4718e3e
5. NASA Advanced Space Suit Pressure Garment System Status and Development Priorities 2024
   https://ttu-ir.tdl.org/items/2004e3db-84f8-49df-a5d7-fb1c7b3c18b5
6. NASA Advanced Space Suit Pressure Garment System Status and Development Priorities 2025
   https://ttu-ir.tdl.org/items/ec48e3c7-a4f4-48d0-b7a8-614cdd2abae6

GO – Space Transportation (GO)

GO.1.S26A: ASCENT Thruster Pre-heat Optimization (SBIR)

Lead Center: MSFC

Participating Center(s): GRC, JPL, GSFC

Subtopic Problem Statement/Description:

Traditional Advanced Spacecraft Energetic Non-Toxic (ASCENT) based propulsion systems require catalyst bed pre-heat temperatures ≥ 400 °C prior to the introduction of propellant. For small spacecraft (CubeSats) this is performed with close coupled resistive heaters mounted to the thruster. The power requirements for such thrusters are manageable with duty-cycled warmup modes / peak-power-limited power architectures [1]. Now that the feasibility of ASCENT has been demonstrated successfully, the industry is moving towards larger and longer life thrusters [2, 3]. The larger thrusters require more power than the current SOA (100 mN class thrust) which leads to additional complications for thermal management and pre-heat times/power needs. NASA is seeking heater technologies that enable reliable catalyst-bed to preheat for ASCENT-based thrusters up to approximately 25 N while reducing peak electrical power demand, total preheat energy, and warmup time and maintaining adequate thermal uniformity. ASCENT thrusters require catalyst-bed preheat temperatures of ≥ 400 °C before propellant injection; current 100 mN-class systems achieve this with closely coupled resistive heaters that small spacecraft can generally support using duty-cycled warmup modes and peak-power-limited power architectures. As ASCENT technology scales to larger thrusters (nominally in the 5 N and 22–25 N class), heater power demand, thermal management, and preheat duration become significant constraints on spacecraft power systems and mission design. This subtopic therefore invites solutions such as optimized resistive heater designs (including packaging, mounting, insulation/thermal breaks, and control strategies) as well as alternative heater concepts that can provide the required ≥ 400 °C preheat for larger ASCENT thrusters and can be adapted to other thrust levels.

Expected TRL or TRL Range at completion of the Project: 3 - 5

Primary Technology Taxonomy:

- Level 1: TX01 Propulsion Systems
- Level 2: TX01.1 Chemical Space Propulsion
- Level 3: TX01.1.1 Integrated Systems and Ancillary Technologies

Desired Deliverables of Phase I:

The desired Phase I deliverable is a hardware-based test article that simulates a thruster with representative mass/geometries, or an engineering unit that matches thermal capacitance and conduction paths. The goal is to match thermal analyses with the hardware in a vacuum environment that will lead to a potential phase II project. The hardware is not expected to be a flight-like thruster but should match the thermal properties as similar as possible to a flight design. A simplified thermal model with tunable parameters is also requested within the Phase I scope of work. A suitable interface definition (mounting approach, sensor/TC placement, power interface assumptions, and insulation/heat rejection) is also required.

Desired Deliverables of Phase II:

The desired Phase II deliverable is a prototype heater for a thruster. The thruster geometry can either be a vendor designed thruster or a provided NASA design that requires a heater for functionality. The vendor can perform hot-fire tests at their facility as appropriate for commercialization, but hardware must be delivered for NASA testing regardless. If multiple prototypes are feasible for different thrust classes, the vendor is encouraged to submit hardware and/or designs for them.

Phase II should result in a prototype unit fabrication and testing to demonstrate performance and validate thermal modeling activities.

The commercialization path and infusion are critical to this SBIR subtopic. While not required, a partnership with an infusion partner, e.g. thruster supplier may be appropriate.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype

State of the Art:

ASCENT catalyst bed heaters are flight proven on the 100 mN thrust class. Industry has potential solutions working towards 1 N and larger thrusters but limited/no flight heritage at ≥1 N class exists.

Critical Gaps:

A critical gap between the SOA and what is needed is an investigation into alternative approaches to catalyst bed heaters. This could be anything from optimized resistive heaters up to completely different sources of heat generation. We are actively working towards higher thrust class thrusters, and providing spacecraft designers with the needed heat and power profiles is a critical need for the larger systems. The gap is not only on the heater design but is also applicable to the system-level thermal efficiency, heat retention/rejection, and packaging.

Shortfalls And Decadal Surveys:

- This investment is relevant to the 2026 Civil Space Shortfalls:
  - Perform missions with small spacecraft beyond low Earth orbit.
- Provide reliable transportation for small spacecraft to destinations beyond cislunar space.
  - Transport and maneuver uncrewed spacecraft for missions in cislunar and deep space.
- Develop novel power and propulsion technologies for rapid and efficient in-space transportation across the solar system.
  - Develop an affordable and resilient supply chain for space exploration.
- Ensure a sufficient number of domestic suppliers can provide space qualified systems within required lead times.

Need Horizon: Near-Term (Less than 5 years)

References:

1. The Journey of the Lunar Flashlight Propulsion System from Launch through End of Mission, SSC23-VI-03, https://digitalcommons.usu.edu/smallsat/2023/all2023/93/

2. NASA 5N Thruster Requirements: https://sam.gov/opp/4c2e27d690714f829d028b280dca345b/view

3. NASA 22N Thruster Requirements: https://sam.gov/opp/539409eac9b94fd681690a5ad1b0d05e/view

Lightweight Structures (LWS)

LWS.1.S26A: Mars Solar Array Technology (MSAT) Innovations (SBIR) (previously H5.01)

Lead Center: LaRC

Participating Center(s): GRC

Subtopic Problem Statement/Description:

This subtopic seeks innovations for lightweight deployable solar arrays for Mars surface power ranging from 3 to 20 kW at beginning-of-life. Proposals are requested in at least one of these two areas:

1) Structural Design and Analysis: Conceive and validate novel minimum-mass and -launch volume mechanical designs and their deployment and/or assembly methods through design and analysis in Phase I, and test scaled prototype hardware in Phase II. Solar arrays can be envisioned to remain on landers for early missions or be offloaded and moved on later missions.

2) Survivability, Especially from Dust: Develop design solutions for surviving the Mars environment, including performance- and mission-threatening accumulation of dust particles on solar cells, mechanisms, and radiators; dust storms and dust devils with winds to 25 m/s requiring adequate strength and anchoring; persistent sub-0° C temperatures with seasonal changes (darker, colder winters); and slow, one-way communication (3-22 min) if required from Earth.

While nuclear fission is the primary option for initial crewed missions [Reference 1], a diverse suite of power generation options will provide mission flexibility and power for a variety of other missions of various power scales [References 2-3].

These MSAT arrays might be built on technologies to be used on the lunar surface by multiple companies that originated out of NASA's Vertical Solar Array Technology (VSAT) project [Reference 4] and related SBIR contracts, in the multi-Center Mars Surface Solar Arrays with Storage (SAWS) study [Reference 5], or on other successful space missions such as the International Space Station (ISS).

Solar arrays are lightweight, reliable, and generally long-lasting, and they have been selected for most space missions. Their consistent durability has often led to mission extensions for numerous space missions throughout the Space Age, allowing for prolonged exploration and data collection. For example, the Mars Exploration Opportunity rover successfully operated over 14 years—much longer than its planned lifetime of 90 Mars days (sols)--but eventually succumbed to a major dust storm that disabled the solar panels, which did not have active dust-control technology [Reference 6].

NASA estimates solar arrays for Mars with state-of-the-art space solar cells will require about 150 m2 per 10 kW of deployed area (4x lunar) with clear skies and solar cells, and the mass of solar cell blankets will be about 1 kg/m2. And, of course, power generation (W/m2) decreases with higher atmosphere haziness (optical depth) and dust coverage. Achieving the overall total power using modules of about 50-150 m2 is permitted and is, in fact, likely constructive. Firms are encouraged to propose adaptable designs for the entire 3 to 20 kW power range (approx. 45

to 300 m2 area) assuming landing sites in the northern lowlands at 30° to 60° N latitude like Arcadia Planitia, or at other latitudes if missions and solar array requirements are discussed [Reference 7].

Better environment-resistant solar arrays have the potential to be a lower cost, flexible alternative to mission operations that do not require extensive lifetime capabilities or rapid deployments. Furthermore, mobility and operability innovations can allow maximum flexibility in site selection, dust storm survival, and repurposing. Much preliminary design and analysis of potential Mars solar power systems have been accomplished for decades [e.g., Reference 8].

Proposals should address one or both areas mentioned at the beginning of the solicitation and should primarily include structural and mechanical innovations, not photovoltaics, electrical, or energy storage innovations, although a complete solar array systems analysis is encouraged. If solar concentrators are proposed, strong arguments must be developed to justify why they are better than planar solar arrays. These arguments should include analysis with a dusty atmosphere. Of special interest are novel modular concepts, improved deployment/assembly and anchoring methods, and innovations for keeping solar cells and radiators at least 90% free of dust most of the time. Using futuristic construction assistants such as intelligent robots will be considered [e.g., Reference 9]. Requirements for lander payload mass and volume capacity and other infrastructure should be well defined.

Solar array concepts should be compatible with state-of-the-art solar cell products with documented environmental degradation properties. Design, build, and test of scaled flight hardware or functioning lab models to validate proposed innovations is of high interest. Improved dust-resistant coatings are also of interest.

Expected TRL or TRL Range at completion of the Project: 2 – 4

Primary Technology Taxonomy:

- Level 1: TX12 Materials, Structures, Mechanical Systems, and Manufacturing
- Level 2: TX12.2 Structures

Desired Deliverables of Phase I:

In Phase I, contractors should prove the feasibility of proposed innovations using suitable analyses and tests.

Desired Deliverables of Phase II:

In Phase II, significant hardware or software capabilities that can be tested at NASA should be developed to advance their Technology Readiness Level (TRL). At the end of Phase II, TRL 3-4 or higher is desired.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype
- Digital Models

State of the Art:

Existing solar arrays on Mars have small sizes up to ~3 m^2 for several successful Mars landers and rovers.

Critical Gaps:

Much larger sizes are needed, up to 300 m^2 (100x increase) for envisioned future Mars exploration.

Shortfalls And Decadal Surveys:

Civil Space Shortfall ID 1596: High Power Energy Generation on Moon and Mars Surfaces

Need Horizon: Mid-Term (5-10 years)

References:

1. Moon-to-Mars 2024 White Paper, "Mars Surface Power Technology Decision." https://www.nasa.gov/wp-content/uploads/2024/12/acr24-mars-surface-power-decision.pdf?emrc=90a15b
2. Lee Mason and Michelle Rucker, "Common Power and Energy Storage Solutions to Support Lunar and Mars Surface Exploration Missions." October 2019. https://ntrs.nasa.gov/citations/20190032521
3. Moon-to-Mars 2023 White Paper, "Mars Surface Power Generation Challenges and Considerations." https://www.nasa.gov/wp-content/uploads/2024/01/mars-surface-power-generation-challenges-and-considerations.pdf?emrc=76f56b
4. NASA Edge video, "Powering the Moon Using Vertical Solar Array Technology (VSAT)." July 2025. https://www.youtube.com/watch?v=TbVIMSVuEFU
5. Fred Elliott et al., "Mars Surface Solar Arrays with Storage (SAWS) Seedling Study." June 2023. https://ntrs.nasa.gov/citations/20200004325
6. Innovation in Action video, "NASA Extends Recovery Efforts for Opportunity as the Mars Rover Remains Silent After Dust Storm." November 2018. https://www.youtube.com/watch?v=jhkYhmRfsTU
7. Human Landing Sites Study HLS2 (Exploraton Zones) video, "Surface Power Considerations and How They Affect Latitude Choices." June 2017. https://www.youtube.com/watch?v=SGPum1TG-Jg
8. Geoff Landis, Tom Kerslake, Phillip Jenkins, and David Scheiman, "Mars Solar Power." November 2004. https://ntrs.nasa.gov/citations/20040191326
9. Robotbids, "Tesla Optimus is Going to Mars." June 2025. https://www.youtube.com/watch?v=4k2XLJnqXPk

LIVE - Surface Power (LIVEP)

LIVEP.1.S26A: Energy Storage for Long-Duration Missions (SBIR)

Lead Center: GRC

Subtopic Problem Statement/Description:

NASA faces a critical challenge in enabling sustained lunar and planetary surface operations: existing energy storage technologies cannot reliably survive or perform under the extreme thermal, environmental, and longevity demands of these missions. Lunar nights last up to 14 Earth days, with temperatures plunging to -200 °C, far beyond the operating limits of state-of-the-art lithium-ion batteries, which suffer severe capacity loss below room temperature and fail below -40 °C. To power mobile and stationary platforms (i.e. landers, rovers, habitats, and scientific payloads), NASA requires lightweight, modular, and long-lived energy storage systems capable of delivering >200 Wh/kg at room temperature while maintaining functionality across repeated lunar day/night cycles. Beyond batteries, regenerative fuel cell systems must operate maintenance-free for ≥3 years, yet current components degrade rapidly due to prolonged exposure to ultra-high-purity deionized water, leading to corrosion and shunt currents. Innovations in pumps, biocide-free contamination control, and long-life electrolysis hardware are essential to overcome these reliability gaps. Looking ahead to Mars, energy storage solutions must also leverage in-situ resources, such as $CO/CO_2/O_2$ reactant triads, to reduce launch mass and enable scalable, efficient power generation. Without breakthroughs in both advanced battery architectures and durable fuel cell technologies, future exploration missions' risk being constrained by energy limitations rather than scientific or operational potential.

The specific components of research and development sought include:

- Further development of advanced secondary/rechargeable battery technologies is required to enable and extend lunar surface operations for mobility, scientific exploration, habitats, and ISRU operations. State-of-the-art lithium-ion batteries (LIB) suffer significant capacity loss below room temperature (20 °C) and generally do not operate below -40 °C. New technologies must enable battery modules that can safely provide >200 Wh/kg (at 20 °C) while also operating in ambient conditions as low as -200 °C. These batteries must be capable of surviving exposure to multiple lunar day/night cycles without degradation, and at best be capable of operation during lunar night. Modular battery concepts with common building blocks that allow for mission interoperability and commonality are of high interest and will be given priority compared to application-specific solutions. Combinations of cell-level improvements and/or battery pack-level improvements for enhanced temperature capabilities or safety will be considered, but a path must be shown toward a battery module design. Solutions focused solely on an individual cell component (e.g., anode, cathode, etc.) development and demonstration will not be considered.
- Long-life, High Pressure Deionized (DI) Water Pump. Currently available pumps, both high-lift and recirculating pumps, require unacceptably high power and fail well before the 3-year requirement when pumping the ultra-high purity deionized water specified by this application. Regenerative Fuel Cell (RFC) process water ranges from 4 °C to 90 °C with system pressures ranging from 15 psia (0.24 MPa) to 2,500 psia (17.2 MPa) and must remain above > 9 MΩ·cm as measured at 25 °C. NASA seeks innovations of materials, coatings, bearings, dynamics seals, etc. that enable devices to move and pressurize the deionized water without introducing contaminants for the mission duration. Preference will be given to solutions resulting in pumps with the longest mean time between failures (MTBF), lowest power and mass.
- Non-chemical Biocides for Long-life, High-Pressure DI Water Electrolysis Systems. NASA seeks technologies that can prevent and/or remove biological contamination from closed-loop DI water electrolysis systems containing carbon-based materials. Chemical biological mitigation options are not acceptable because these solutions limit the operational life of the water electrolysis stacks and the pressurized ultra-high-purity water (>14 MΩ·cm at 25 °C) remains in closed loops for very long periods of time.
- Regenerative Fuel Cells utilizing $CO/CO_2/O_2$ reactant for Mars Energy Storage. NASA seeks electrochemical hardware that can draw resources from the Mars atmosphere by both electrolyzing CO_2 to produce O_2 and CO and generate direct current electrical power by reacting CO and O_2. These electrochemical reactions need to be demonstrated in hardware at a minimally viable active areas (>80 cm^2 by Phase 2) with stack cell counts (>15 cells by Phase 2) for extensible durations (>100 hours per mode) to be a feasible option for system integration. Critical performance metrics are round-trip efficiency (electricity in / electricity out), specific energy (Wh/kg) at the system level, and power -efficient CO/CO_2 separation technology with a performance metric of kg $_{CO2\ separated}$ / (kW * kg$_{Feedstock}$) at 400kPa (60 psia).

Expected TRL or TRL Range at completion of the Project: 3 – 4

Primary Technology Taxonomy:

- Level 1: TX03 Aerospace Power and Energy Storage
- Level 2: TX03.2 Energy Storage

Desired Deliverables of Phase I:

Research should be conducted to demonstrate technical feasibility in a final report for Phase I and show a path toward Phase II, and when possible, deliver a demonstration unit for NASA testing at the completion of the Phase II contract. Phase I deliverables should include thermal data demonstrating feasibility of the design over the intended operational ranges.

Models, test reports and technology development plans.

Desired Deliverables of Phase II:

Phase II emphasis should be placed on developing and demonstrating the technology under as many relevant test conditions as feasible within Phase II resources. Additionally, a path should be outlined that shows how the technology could be commercialized or further developed into science-worthy systems.

Prototype hardware (cells/modules) with test reports and an updated technology development plan.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype

State of the Art:

State-of-the-art rechargeable cells are limited in both capacity and temperature range. Typical rechargeable Li-ion cells operate within a narrow temperature range of -20 to 40 °C and suffer from extreme capacity loss at lower temperatures. The lower limit of temperature range of rechargeable cells can be extended through the use of low temperature electrolytes but with limited rate capability and concerns about lithium plating during charge. Modular battery concepts that offer common building blocks allow interoperability and repairability across missions, reducing risk and increasing reliability. This scope is aimed at the development of batteries that can maintain performance across the lunar temperature extremes, along with advanced thermal management and packaging techniques to allow functionality and survivability of the battery system at these temperature extremes.

Critical Gaps:

Long-life, High Pressure Deionized Water Pump. Currently available pumps, both high-lift and recirculating pumps, require unacceptably high power and fail well before the 3-year requirement when pumping the ultra-high-purity deionized water specified by this application.

Non-chemical biocides for Long-life, High Pressure Deionized Water Electrolysis Systems that can prevent and/or remove biological contamination from closed-loop DI water electrolysis systems containing carbon-based materials. Chemical biological mitigation options are not acceptable because these solutions limit the operational life of the water electrolysis stacks and the pressurized ultra-high purity water (>14 MΩ·cm at 25 °C) remains in closed loops for very long periods of time.

Reliable, high capacity, high specific energy storage technologies for Mars applications that do not require refilling with H2 for large scale energy storage applications for use in close proximity to inhabited volumes. Utilizing the Mars atmosphere as a source for reactants minimizes ramifications when leaks occur and provides a mechanism to minimize system mass during transit from the initial launch on Earth to landing on Mars.

Shortfalls And Decadal Surveys:

These batteries are applicable over a broad range of exploration and science missions. Low-temperature batteries are needed to enable science and exploration missions aligned with Artemis, including supporting science missions such as Commercial Lunar Payload Services and Lunar Quest. These batteries may also serve for potential NASA decadal missions to ocean worlds (Europa, Enceladus, Titan) and the icy giants (Neptune, Uranus). Sodium-ion batteries would allow for pulse power applications such as directed energy laser systems for ISRU construction operations or beaming surface technologies. Low-temperature batteries developed under this subtopic would enhance these missions and could be enabling, particularly for missions that are highly mass- or volume- limited.
Civil Space Shortfall Ranking https://www.nasa.gov/spacetechpriorities/
1618 - Survive and Operate Through the Lunar Night
1592 - High-Power, Long-Distance Energy Transmission Across Distributed Surface Assets
1595 - Energy Storage to Enable Robust and Long Duration Operations on Moon and Mars Surface

Need Horizon: Near-Term (Less than 5 years)

References:

1. P. Smith et al.,"Lunar Equator Regenerative Fuel Cell System Efficiency Analysis." NASA TM 2021001462. https://ntrs.nasa.gov/citations/20210014627
2. P. Smith et al., "Aerospace Regenerative Fuel Cell Fluidic Component Design Challenges." NASA TM 20210024659. https://ntrs.nasa.gov/citations/20210024659
3. M. Guzik et al., "Regenerative Fuel Cell Power Systems for Lunar and Martian Surface Exploration." NASA TM 20170009088. https://ntrs.nasa.gov/citations/20170009088
4. F. Eliott et al., "Mars Surface Solar Arrays With Storage (SAWS) Seedling Study." NASA TM 20200004325. https://ntrs.nasa.gov/citations/20200004325
5. M. Guzik et al., "Energy Storage for Lunar Surface Exploration." NASA TM 20190000472. https://ntrs.nasa.gov/citations/20190000472
6. K. Takada, "Advanced Oxygen Generation Assembly for Exploration Missions." NASA TM 20190030425. https://ntrs.nasa.gov/citations/20190030425
7. L. Carter et al., "Status of ISS Water Management and Recovery." NASA TM 20180006341. https://ntrs.nasa.gov/citations/20180006341
8. E. Brown et al., "Investigation of the Makeup, Source, and Removal Strategies for Total Organic Carbon in the Oxygen Generation System Recirculation Loop." NASA TM 20150016495. https://ntrs.nasa.gov/citations/20150016495

LIVEP.2.S26A: Mars and Lunar Power Transfer Technology Development (SBIR)

Lead Center: GRC

Participating Center(s): KSC

Subtopic Problem Statement/Description:

NASA seeks innovative solutions to enable reliable and efficient power transfer systems for sustained lunar and Mars missions. The unique environmental and operational challenges demand the development of advanced technologies that minimize mass, maximize efficiency, and ensure durability under extreme conditions. The challenge is to create scalable, lightweight, and resilient power transmission systems that can operate reliably while supporting mission-critical infrastructure. Addressing these requirements will advance the capability to establish long-duration human and robotic presence on the Moon and Mars. Multiple technology approaches can address this problem, and the examples below represent possible — but not the only — paths forward. The scope of this problem includes:

Low-mass, highly conductive transmission cables capable of operating across the extreme temperature ranges of the lunar south pole (-230 °C to -100 °C). These cables must support small-gauge, long-distance transmission in the 1 to 10 kW range, incorporate insulation materials with high dielectric breakdown strength to enable up to 1,500 Vdc or 3,000 Vac 3-phase operation at 1,000 Hz, and integrate low-loss, lightweight EMI shielding.

Robust electrical connectors engineered to withstand lunar dust exposure, extreme thermal cycling, and mechanical handling by both astronauts in protective gloves and robotic systems. These connectors must reliably support primary transmission lines carrying up to 50 kW at either 1,000 Vdc or 3.0 kVac 3-phase (line-to-line) at 1,000 Hz.

Optical power beaming systems achieving end-to-end efficiencies greater than 40% over distances exceeding 1 km, delivering greater than 500 W. High-efficiency transmitters, receivers, and converters, with potential integration of communications and navigation functions into power beaming architectures are of high interest.

Millimeter-wave (mmWave) power beaming technologies for high-power wireless transmission, meeting performance targets of >95% beam efficiency, >65% source efficiency, and >70% rectifier efficiency.

Expected TRL or TRL Range at completion of the Project: 3 – 5

Primary Technology Taxonomy:

- Level 1: TX03 Aerospace Power and Energy Storage
- Level 2: TX03.3 Power Management and Distribution

Desired Deliverables of Phase I:

Phase I Deliverables are geared toward a technology concept with associated analysis and design. Scale benchtop prototype hardware that may aid in validating analytical models make for excellent deliverables.

A final report on the high-fidelity design and analysis is a minimum requirement for Phase I, but selected component development and test results are preferred.

Desired Deliverables of Phase II:

Deliverables for Phase II should include hardware prototypes that prove performance and feasibility of the design for potential infusion into NASA missions, technology testbeds and commercial landers.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results

- Hardware
- Prototype
- Digital Models

State of the Art:

While high-power terrestrial distribution systems exist, there is no equivalent to a lunar or planetary base. There are no demonstrated lunar or Mars power wired or wireless power transmission systems to date.

Critical Gaps:

Unique challenges must be overcome in order to enable a realistic power architecture for these future applications, especially when dealing with the environmental extremes that will be encountered. Operability in environments subject to temperature swings will be a critical requirement for any technology developed, especially for cabling or power-beaming concepts. In addition, proposals will have to consider lunar regolith and Mars dust storms. To enable a new Mars transportation capability for human exploration, new technology development must be started soon to address the unique needs of a mixed alternating current/direct current (AC/DC) space-rated power system to prove feasibility and provide realistic performance metrics for detailed vehicle design concepts and mission trade studies.

Shortfalls And Decadal Surveys:

Civil Space Shortfall Ranking https://www.nasa.gov/spacetechpriorities/
1618 - Survive and Operate Through the Lunar Night
1592 - High-Power, Long-Distance Energy Transmission Across Distributed Surface Assets
1595 - Energy Storage to Enable Robust and Long Duration Operations on Moon and Mars Surface

Need Horizon: Near-Term (Less than 5 years)

References:

1. The Global Exploration Roadmap, January 2018: https://www.nasa.gov/sites/default/files/atoms/files/ger_2018_small_mobile.pdf

2. Space Policy Directive-1, Reinvigorating America's Human Space Exploration Program, December 11, 2017: https://www.federalregister.gov/documents/2017/12/14/2017-27160/reinvigorating-americas-human-space-exploration-program

Science Instruments and Computing to Study Planetary Bodies (INSTALG)

INSTALG.1.S26A: In Situ Instruments and Instrument Components for Lunar and Planetary Science (SBIR) (previously S13.05)

Lead Center: JPL

Participating Center(s): ARC, GSFC, MSFC, GRC

Subtopic Problem Statement/Description:

This subtopic solicits development of instruments and instrument components suitable for deployment on in situ planetary and lunar missions. To narrow the critical gaps between the current state of art and the technology needed for the ever-increasing science and exploration requirements, in situ technologies are being sought to increase instrument resolution and sensitivity and/or reduce mass, power, and volume as well as increase data rates without loss of scientific capability. Of particular interest are technologies to support future missions described in the National Research Council Planetary Decadal Survey report "Origin, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032" (hereafter referred to as the Planetary Decadal Survey) and/or in the "Artemis III Science Definition Team (SDT) Report." Novel instrument concepts are encouraged, particularly if they enable a new class of scientific discovery. Technology developments relevant to multiple environments and platforms are also desired.

Specifically, the subtopic is seeking instruments/components that provide significant advances to address the following critical gaps:

- (Higher priority) Technologies that enable or improve measurement capabilities for lunar and Mars science missions (such as New Frontiers, Commercial Lunar Payload Services (CLPS), Commercial Mars Payload Services (CMPS), and Artemis). Examples include technologies relevant to geotechnical/physical characterization, environmental monitoring, volatile monitoring, site assessment and sample containment and return, as well as handheld instruments/components.
- (Higher priority) Technologies relevant to detection and/or identification of organic molecules (including biomolecules), salts, and/or minerals on Mars, ocean worlds, and other bodies, whether present as soluble/extractable molecules or insoluble particles/organic matter. Examples include high-resolution gas for liquid chromatographs, miniaturized mass spectrometers and their drive electronics (e.g., radio frequency (RF) tanks) and front-end/back-end advancements (e.g., electrospray ionization sources, lasers, ion mobility sources/separators, RF guides/funnels, pumps), isotope analyzers, dust detectors, organic analysis instruments with chiral discrimination, microscopes that characterize micro/nano-scale particle structure, morphology and/or spatial distributions of chemical functionalities, x-ray spectrometers, laser-induced breakdown spectroscopy, electrochemical methods, nanopore technologies, etc.). These developments should be geared towards analyzing and handling very small sample sizes (microgram to milligram) with concentrations appropriate for the relevant planetary bodies, and/or low column densities/abundances.
- Instruments capable of monitoring the bulk chemical composition and physical characteristics of gas samples and ice particles such as the plume (density, velocity, variation with time, etc.).
- (High priority) Seismometers, mass analyzers, heat flow probes, and trace-gas detectors with improved robustness and high-g-force survivability that are applicable to impactor deployment to the surface of Mars to the surface of Mars.
- Technologies for quantifying lunar water and measuring the D/H ratio in lunar water and other solar system destinations.

The proposed technologies must directly address lunar and/or planetary science instrumentation needs and must be capable of withstanding operation in space and planetary environments, including the expected pressures, radiation levels, launch and impact stresses, and range of survival and operational temperatures. Novel instrument concepts are encouraged, particularly if they enable a new class of scientific discovery. Technology developments relevant to multiple environments and platforms are also desired.

Expected TRL or TRL Range at completion of the Project: 1 – 5

Primary Technology Taxonomy:

- Level 1: TX08 Sensors and Instruments
- Level 2: TX08.3 In Situ Instruments and Sensors

Desired Deliverables of Phase I:

Feasibility assessment, proof-of-concept demonstration (TRL 2 to 3), concept of operations, simulations and/or measurements, and a plan for further development to be performed in Phase II. Documentation of the proposed innovation, its status at the end of the Phase I effort, and the evaluation of its strengths and weaknesses compared to the SOA. For low-cost innovations, the proposal must specify and outline a plan to meet the cost target of the delivered instrument at the end of Phase II.

Desired Deliverables of Phase II:

Component and/or breadboard development with the delivery of specific hardware for NASA (TRL 4 to 5). The working prototype of the proposed hardware should be standalone with any needed interface specifications, along with documentation of development, capabilities, and performance. Phase II deliverables should also include/delineate any further work that would be required to bring the technologies to full operational and/or commercial use.

Desired Deliverable Types of Phase II:

- Analysis,
- Hardware
- Prototype
- Test Results
- Digital Models

State of the Art:

In situ instruments and technologies are essential bases to achieve Science Mission Directorate's (SMD's) planetary science goals summarized in the Planetary Decadal Survey. There are currently various in situ instruments for diverse planetary bodies, and the state-of-the-art instruments are discussed in references provided in the "References" section.

Critical Gaps:

In situ technologies are being sought to continually advance instrument resolution and sensitivity; reduce mass, power, and volume; and/or increase data rates without loss of scientific capability. There are ever-increasing science and exploration requirements and challenges. For example, there is a growing demand for in situ technologies amenable to small spacecrafts for exploring the Moon and Mars. The Artemis III SDT (Science Definition Team) Report captures the highest priority science for Artemis III and provides information on instruments/components that would provide the greatest feed-forward to follow-on missions and lead up to the Artemis Base Camp.

Shortfalls And Decadal Surveys:

"Origins, Worlds, and Life: Planetary Science and Astrobiology in the Next Decade," National Academics: https://nap.nationalacademies.org/catalog/26522/origins-worlds-and-life-a-decadal-strategy-for-planetary-science

This subtopic addresses the following shortfall(s) identified in the 2026 Civil Space Shortfall list:

- Perform advanced remote sensing and science measurements with improved sensing capabilities and autonomy

Need Horizon: Near-Term (Less than 5 years)

References:

1. National Academies Planetary Decadal Survey report, "Origin, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032": https://nap.nationalacademies.org/catalog/26522/origins-worlds-and-life-a-decadal-strategy-for-planetary-science
2. "Roadmap to Ocean Worlds (ROW)," Lunar and Planetary Institute: http://www.lpi.usra.edu/opag/ROW
3. "Ocean Worlds," National Aeronautics and Space Administration: https://www.nasa.gov/specials/ocean-worlds/
4. “Artemis III Science Definition Team Report," National Aeronautics and Space Administration: https://www.nasa.gov/wp-content/uploads/2015/01/artemis-iii-science-definition-report-12042020c.pdf
5. "The Scientific Context for Exploration of the Moon," National Academies:https://nap.nationalacademies.org/catalog/11954/the-scientific-context-for-exploration-of-the-moon
6. "The Global Exploration Roadmap," National Aeronautics and Space Administration: https://www.nasa.gov/wp-content/uploads/2015/01/ger_2018_small_mobile.pdf?emrc=4abb2f
7. "The Mars Future Plan," National Aeronautics and Space Administration: https://science.nasa.gov/planetary-science/programs/mars-exploration/future-of-mars-plan/
8. National Academies of Sciences, Engineering, and Medicine report, "A Science Strategy for the Human Exploration of Mars": https://www.nationalacademies.org/publications/28594
   - Identifies the highest priority science objectives and technical gaps for the first human mission to Mars.
9. "Moon to Mars Objectives," National Aeronautics and Space Administration: https://www.nasa.gov/wp-content/uploads/2022/09/m2m-objectives-exec-summary.pdf?emrc=119caf#:~:text=Operations%20Goal%3A%20Conduct%20human%20missions,the%20completion%20of%20the%20missions.
10. "NASA's Moon to Mars Architecture," National Aeronautics and Space Administration: https://www.nasa.gov/wp-content/uploads/2024/12/esdmd-001-add-rev-b.pdf?emrc=5ffbf4
11. "Civil Space Shortfalls," National Aeronautics and Space Administration: https://www.nasa.gov/spacetechpriorities/

INSTALG.2.S26A: Suborbital Instruments and Sensor Systems (SBIR) (previously S11.05)

Lead Center: LaRC

Participating Center(s): ARC, GSFC, JPL

Subtopic Problem Statement/Description:

NASA seeks suborbital in situ measurement capabilities that support Earth and planetary sciences with cross-cutting applications to spacecraft environments. These measurements support current and next generation satellite and model validation efforts, numerous airborne and ship-based field campaigns, and process studies that advance our scientific understanding of the Earth and planetary systems. In situ sensor systems (airborne, land, and water-based) can comprise stand-alone instrument and data packages; instrument systems configured for integration on in-water or ship-based platforms, NASA's Airborne Science Program aircraft fleet or commercial providers, uncrewed aerial systems (UAS), balloons, ground networks; or end-to-end solutions providing needed data products from mated sensor and airborne/surface/subsurface platforms. An important goal is enabling measurement capabilities to support NASA's cross-cutting Earth and planetary science objectives, with infusion of new technologies and systems into current/future NASA research programs.

Complete instrument systems are generally desired, including features such as remote/unattended operation and data acquisition, and minimum size, weight, and power consumption. All proposals must summarize the current state-of-the-art and demonstrate how the proposed sensor or sensor system represents a significant improvement.

Expected TRL or TRL Range at completion of the Project: 3 – 7

Primary Technology Taxonomy:

- Level 1: TX08 Sensors and Instruments
- Level 2: TX08.3 In Situ Instruments and Sensors

Desired Deliverables of Phase I:

Demonstrate a clear idea of the problem to be solved, potential solutions, and an appreciation for potential risks or stumbling blocks that might jeopardize the success of the Phase I and II projects. The ideal Phase I effort would also address, and hopefully overcome, any major challenges to (1) demonstrate feasibility of the proposed solution and (2) clear the way for the Phase II effort. These accomplishments would be detailed in the Phase I final report and serve as the foundation for a Phase II proposal.

Desired Deliverables of Phase II:

Phase II effort would build, characterize, and deliver a prototype instrument to NASA including necessary hardware and operating software. The prototype would be fully functional, but the packaging may be more utilitarian (i.e., less polished) than a commercial model. Field demonstrations are highly encouraged. Phase II deliverables should also include/delineate any further work that would be required to bring the technologies to full operational and/or commercial use.

Desired Deliverable Types of Phase II:

- Hardware
- Prototype

State of the Art:

The subtopic is, and remains, highly relevant to NASA Science Mission Directorate (SMD) and Earth Science research programs; in particular, the Earth Science Atmospheric Composition, Climate Variability and Change, and Carbon Cycle and Ecosystems focus areas. Suborbital in situ and remote sensors inform NASA ground, ship, and airborne science campaigns led by these programs, and provide important validation of the current and next generation of satellite-based sensors (e.g., PACE, OCO-2, OCO-3, MAIA, TEMPO, GLIMR, SBG, AOS; see links in References). The solicited measurements will be highly relevant to current and future NASA campaigns with objectives and observing strategies similar to past campaigns (e.g., ACTIVATE, NAAMES, EXPORTS, CAMP2EX, FIREX-AQ, KORUS-AQ, and DISCOVER-AQ).

Critical Gaps:

Technology advancements are sought to address critical gaps in the following Earth and planetary science research areas (listed in no particular order):

Aerosols and Clouds, including sub-45-micron-diameter Lunar, Earth, and Martian dust

- Compact low power multi-angle polarimeters suitable for uncrewed aerial vehicles or high-altitude balloon platforms to complement Multi-Angle Imager for Aerosols (MAIA) and Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite calibration/validation and retrieval refinement.
- Cloud and aerosol probes for measuring super-micron particle size distributions and number concentrations relevant to ice- and mixed-phase cloud processes, dust, and coarse aerosols at ambient temperature, pressure, and humidity; versatile probes for wing-mounted canisters, fuselage mounting, and small drone applications are particularly encouraged.
- Aerosol scattering, absorption, and extinction coefficient covering the 400-800 nm spectral range for deployment on aircraft from the surface to 43,000 feet altitude; nonfilter-based techniques (e.g., photoacoustic spectroscopy) are preferred over filter-based instruments, but the instrument must be robust to temperature and pressure changes encountered during airborne operation.

Trace Gases

- Miniaturized, autonomous laser absorption or cavity-ringdown instruments for CH_4, CO, and N_2O suitable for satellite retrieval validation for Tropospheric Emissions: Monitoring of Pollution (TEMPO), OCO-2/3, and GOSAT-GW. Isotopic abundances (particularly in CH_4) are also desired for planetary (e.g., Mars) applications.
- Multi-species gas sensors with low size, weight, and power targeting vertical profile measurements (i.e., 1-10 Hz time resolution) on small aircraft or uncrewed aerial vehicles and measuring at least one of the following:
    - NO, NO_2, NOx at < 50 ppt uncertainty.
    - O_3 at < 1 ppb uncertainty.
    - SO_2 at < 100 pptv uncertainty.
    - HCl at < 40 pptv uncertainty (targeting the stratosphere).
- Small, turn-key remote sensors capable of detecting NO_2, CH_2O, and O_3, at < 5% uncertainty. These sensors must be capable of long-term measurements to support NASA ground networks. Improved performance sun and sky viewing spectrometer subsystems that increase measurement accuracy and stability and simplify instrument calibration of sun photometers may be considered.

Ocean Color

- Portable hyperspectral UV-Vis-NIR (spectral range covering at least 340-900 nm) radiometric calibration system with a stabilized optical light source for verification of field radiometer stability by traceable National Institute of Standards and Technology (NIST) standards with variable flux levels (dark ocean to bright cloud radiance). The system must include thermal stabilization for the instrument to be independent of ambient temperature for evaluation of radiometric stability as a function of time.
- Sensor capable of measuring in-water polarized hyperspectral UV-Vis volume scattering function (VSF) instrument (spectral range of 360-750 nm; spectral resolution of ~10 nm full-width half max or better) covering the angular range close to 0° and, more importantly, as far as 180° (with 5° or less angular resolution). The instrument should have the ability to measure (at least) horizontal and vertical aspects of linear polarization. The sensor should be ocean submersible to a depth of 300 m and versatile for use on ships unmonitored in flow-through mode. Degree of resolution in angles and wavelength can be decreased for instrument portability and robustness (such as for autonomous unmanned vehicle (AUV) deployments).
- A hyperspectral radiometry system with linear polarization capability covering the UV-Vis-NIR wavelength range (340-900 nm) with a spectral resolution of 5 nm full-width half max and preferably 3-nm or better across the visible spectrum) with ocean color sensitivity to use for PACE, Landsat and Geostationary Littoral Imaging and Monitoring Radiometer (GLIMR) validation. The instrument shall measure hyperspectral above water upwelling radiance, sky radiance, downwelling irradiance, and the polarization state of the atmosphere and ocean. It must be capable of autonomously positioning itself with respect to the sun for optimized measurement geometry.
- A well-calibrated airborne autonomous hyperspectral imager with spectral sensitivity in the UV-Vis-NIR (spectral range spanning at least 360 to 900 nm; preferably 340 to 1,080 nm) with spectral sampling of at least 2.5 nm, spectral resolution 5 nm or lower full-width half max, >1000 spatial pixels (preferably >3000 in spatial dimensions). It should have a wide dynamic range and non-saturating sensitivity spanning from dark ocean radiances (3% albedo) to land/ice surfaces with 70% albedo for use in comparison to PACE Ocean Color Instrument, GLIMR, and other sensors, for detection and tracking Harmful Algal Blooms. The sensor must be compact and lightweight for deployment on small AUVs, such as Group I drones.

Shortfalls And Decadal Surveys:

"Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space," National Academies: https://www.nationalacademies.org/our-work/decadal-survey-for-earth-science-and-applications-from-space

- Aerosols: Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality.
- Clouds, Convection, and Precipitation: Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback.
- Greenhouse Gases: CO_2 and methane fluxes and trends, global and regional with quantification of point sources and identification of sources and sinks.
- Ozone and Trace Gases: Vertical profiles of ozone and trace gases (including water vapor, CO, NO_2, methane, and N_2O) globally and with high spatial resolution.
- Planetary Boundary Layer: Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and air quality through high vertical and temporal profiling of PBL temperature, moisture, and heights.

"Origins, Worlds, and Life: Planetary Science and Astrobiology in the Next Decade," National Academies: https://nap.nationalacademies.org/catalog/27209/origins-worlds-and-life-planetary-science-and-astrobiology-in-the

- Priority Science Question 6.6a What Processes Are Important in Controlling the Trace Gas Composition of the Martian Atmosphere?
- Priority Science Question 6.6f What Processes Control the Formation and Composition of Clouds in the Atmospheres of Venus, Mars, Titan, Triton, and Pluto?
- Priority Science Question 7.3d What Chemical and Physical Processes Influence the Gas and Aerosol Absorbers That Produce the Diverse Colors and Spectral Properties of the Giant Planets?

This subtopic addresses the following shortfall(s) identified in the 2026 Civil Space Shortfall list:

- Perform advanced remote sensing and science measurements with improved sensing capabilities and autonomy

Need Horizon: Mid-Term (5-10 years)

References:

1. "Aircraft List," National Aeronautics and Space Administration: https://airbornescience.nasa.gov/aircraft
2. "OCO-2 Orbiting Carbon Observatory-2," National Aeronautics and Space Administration: https://science.nasa.gov/mission/oco-2
3. "OCO-3 Orbiting Carbon Observatory-3," National Aeronautics and Space Administration: https://science.nasa.gov/mission/oco-3
4. "Multi-Angle Imager for Aerosols MAIA," Jet Propulsion Laboratory: https://www.jpl.nasa.gov/missions/multi-angle-imager-for-aerosols-maia
5. "Mission Overview," Tropospheric Emissions: Monitoring of Pollution TEMPO: http://tempo.si.edu/overview.html
6. "PACE Plankton, Aerosol, Cloud, ocean Ecosystem," National Aeronautics and Space Administration: https://pace.gsfc.nasa.gov
7. "Welcome to Surface Biology and Geology study," Jet Propulsion Laboratory: https://sbg.jpl.nasa.gov
8. "GLIMR," Institute for the Study of Earth, Oceans, and Space: https://eos.unh.edu/glimr
9. "ARCSIX," National Aeronautics and Space Administration: https://espo.nasa.gov/arcsix/content/ARCSIX
10. "ASIA-AQ," National Aeronautics and Space Administration: https://espo.nasa.gov/asia-aq
11. "Field Campaigns and Projects," National Aeronautics and Space Administration: https://cce.nasa.gov/ocean_biology_biogeochemistry/field_campaigns.html
12. "FORTE," National Aeronautics and Space Administration: https://espo.nasa.gov/forte/content/FORTE_0
13. "CAMP2Ex," National Aeronautics and Space Administration: https://espo.nasa.gov/camp2ex
14. "FIREX-AQ," National Aeronautics and Space Administration: https://csl.noaa.gov/projects/firex-aq
15. "ATom," National Aeronautics and Space Administration: https://espo.nasa.gov/atom/content/ATom
16. "KORUS-AQ," National Aeronautics and Space Administration: https://espo.nasa.gov/korus-aq/content/KORUS-AQ
17. "DISCOVER-AQ," National Aeronautics and Space Administration: https://science.nasa.gov/mission/discover-aq

18. "NAAMES North Atlantic Aerosols and Marine Ecosystems Study," National Aeronautics and Space Administration: https://science.nasa.gov/mission/naames

19. "EXPORTS EXport Processes in the Ocean from RemoTe Sensing," National Aeronautics and Space Administration: https://oceanexports.org

Space Precision Components: Galaxies to Atoms (COSMO)

COSMO.1.S26A: High Performance Detector Technologies (SBIR) (previously S12.06)

Lead Center: JPL

Participating Center(s): MSFC, GSFC

Subtopic Problem Statement/Description:

Technologies that support ultraviolet (UV), X-ray, and gamma ray detector and instruments are needed to support missions and programs aligned with the National Academies' Astro2020 Decadal Survey (Pathways to Discovery in Astronomy and Astrophysics for the 2020s) [Ref. 1] and the NASA's Astrophysics Division priorities [Refs. 2-4]. Advancements in UV detector capabilities have potential to impact the detector system decisions currently being assessed for the Habitable Worlds Observatory (HWO), and X-ray astrophysics has potential short-term needs in instruments for a Probe Class mission that could launch within a decade.

This subtopic covers detector requirements for a broad range of wavelengths from UV through gamma ray for applications in Astrophysics, Earth Science, Heliophysics, and Planetary Science [Refs. 5-7]. Requirements across the board are for greater numbers of readout pixels, lower power, faster readout rates, greater quantum efficiency, low noise (e.g. enabling photon counting), and enhanced energy resolution. The subtopic broadly seeks advancements in both semiconductor and superconductor-based detector technologies, as well as supporting components such as next-generation readouts, magnetic shielding, and additive manufacturing of electronics (AME) for high-density interconnects in focal planes.

Superconducting detector technologies, especially single-photon devices, are also being investigated for NASA astrophysical applications in future space missions. Distant sources in astrophysics are naturally in the “photon-starved” regime, which makes them suitable for quantum applications. This necessitates the exploitation of quantum effects to obtain the highest sensitivity observations allowed by nature.

Proposed efforts must be directly linked to a requirement for a NASA mission and should reference current NASA missions and mission concepts where relevant. These include, but are not limited to: Explorers, Discovery, Cosmic Origins, Physics of the Cosmos, Solar-Terrestrial Probes, Vision Missions, and Earth Science Decadal Survey missions [Refs. 8-13]. Proposals are expected to be linked a particular critical gap from the the current state of the art as described in the subtopic's priority items.

Note: Detector technologies aimed at infrared (IR) applications should be directed to the INSTALG.2.S26A subtopic.

Expected TRL or TRL Range at completion of the Project: 3 – 5

Primary Technology Taxonomy:

- Level 1: TX08 Sensors and Instruments

- Level 2: TX08.1 Remote Sensing Instruments and Sensors

Desired Deliverables of Phase I:

Results of feasibility tests and analysis of designs demonstrating advancement over state-of-the-art (SOA). Proof-of-concept demonstration of detector architecture with performance metrics that show improvement over SOA. Critical parameters should be measured (e.g., quantum efficiency, noise characteristics, spectral response) with analysis showing scalability to flight requirements.

All deliverables should include comprehensive documentation of the design approach, testing methodology, and performance results. Phase I proposals should delineate the scope and benefit of proposed products that could be realized in Phase II and what further development would be necessary beyond Phase II.

Desired Deliverables of Phase II:

Prototype hardware or hardware for further testing and evaluation is desired. Prototype detector array or sensor system demonstrating key performance requirements in a relevant environment. Delivery should include performance characterization across operational parameters (temperature, radiation, etc.) and readout electronics as appropriate.

All Phase II deliverables should include detailed analysis showing how the technology meets specific mission requirements, including mechanical and thermal stability analyses where applicable. Phase II deliverables should also include/delineate any further work that would be required to bring the technologies to full operational and/or commercial use.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype

State of the Art:

The current state-of-the-art for detector arrays presents several critical limitations for future NASA missions. In the UV regime, current large-format detector arrays exhibit limited quantum efficiency (QE), especially in the far-UV (FUV; 100-200 nm), where QE typically falls below the desired 30% to 40% range.

For X-ray detection, microcalorimeter arrays are currently limited to thousands of pixels, whereas future missions require orders of magnitude more, up to 10^5 to 10^6 pixels, to achieve the necessary field of view. General X-ray and gamma-ray imaging arrays struggle to simultaneously achieve the required spatial resolution, energy resolution, and high-count rate capabilities needed for future flagship and probe-class missions.

While superconducting detector technologies show great promise for single-photon counting, further development is required to demonstrate devices that simultaneously achieve high quantum efficiency, high count rates, low power operation, and higher operational temperatures in a scalable array format. Most NASA astrophysics investments to date have focused on quantum technologies related to single-photon detectors or ultrasensitive bolometers, which can achieve high sensitivity and optimal performance by using quantum effects such as superconductivity, quantum interference, quantum capacitance, quantum tunneling, and quasiparticle trapping. Some of these include superconducting nanowire single-photon counting detectors (SNSPDs), kinetic inductance detectors (KIDs), transition edge sensors (TESs), superconducting quantum interference devices (SQUIDs), and various types of superconducting bolometers. Many of these technologies are critical for future X-ray and UV missions.

Critical Gaps:

This subtopic seeks technologies that address the following critical gaps:

- (Highest priority) Large format, high-resolution near-UV (NUV; 200-400 nm) and UV-Visible detectors suitable for mosaicking into very large (e.g., gigapixel) focal plane arrays, focusing on improving array/pixel size, read noise, dark counts, and quantum efficiency.
- (Highest priority) Large format, high-resolution far-UV (FUV; 100-200 nm) photon counting detectors with in-band quantum efficiency (QE) of 30% to 40%.
- (Highest priority) Solar-blind (visible-blind) FUV detectors with 1 x 10^{-5} out-of-band rejection for wavelengths greater than 300 nm, including stand-alone or device-integrated filter technologies.
- (Highest priority) X-ray microcalorimeter arrays with a much larger field of view, 10^5 to 10^6 pixels, to enable the X-ray Surveyor mission. This includes developing modular, superconducting magnetic shielding and improved long-wavelength blocking filters. For example, filters with supporting grids to enhance electromagnetic interference (EMI) shielding (1 to 10 GHz) and thermal uniformity for decontamination heating; filters with X-ray transmission of greater than 80% at 600 eV, IR transmission of less than 0.01%, and UV transmission of less than 5% per filter.
- (Highest priority) Fast, low-noise, megapixel X-ray imaging arrays with moderate spectral resolution, covering wide fields of view (greater than or equal to 60 x 60 mm) with excellent spatial resolution (i.e. less than 16 um pixels) and fast frame rates (i.e. greater than 20 to 100 frame/s).
- (High priority) Faster-readout detectors to support high count rates and large incident flux from the EUV and X-rays for heliophysics applications, especially solar-flare measurements.
- (High Priority) Development and maturation of innovative architectures, subsystems, and processes that would enable future improvements to superconductor devices (TESs, KIDs, SNSPDs, etc.) including novel and/or innovative readouts, shielding, superconducting material components, nanofabrication techniques, etc. Target applications should be in the X-ray and UV wavelength ranges; technologies targeting infrared applications should be submitted to subtopic 11.06.
- (High priority) Significant improvement in wide-bandgap semiconductor materials (such as AlGaN, ZnMgO, and SiC), including SiC avalanche photodiodes (APDs) that demonstrate Extreme-UV (EUV) photon counting with a linear mode gain greater than 1 x 10^6. Solar-blind EUV sensor technology with high pixel resolution, large format, high sensitivity and high dynamic range, and low voltage and power requirements.
- (High priority) Solid-state detectors with polarization sensitivity relevant to astrophysics, planetary, and Earth science applications (e.g., spectropolarimetry, air quality monitoring).
- Solar X-ray detectors with small independent pixels (10,000 count/sec/pixel) over an energy range from less than 5 to 300 keV.

Shortfalls And Decadal Surveys:

"Pathways to Discovery in Astronomy and Astrophysics for the 2020s," (Astro2020), National Academies: https://nap.nationalacademies.org/catalog/26141/pathways-to-discovery-in-astronomy-and-astrophysics-for-the-2020s

“Solar and Space Physics: A Science for a Technological Society," National Academies: http://nap.edu/13060

"Planetary Science and Astrobiology Decadal Survey 2023-2032,"
National Academies: https://www.nationalacademies.org/our-work/planetary-science-and-astrobiology-decadal-survey-2023-2032

"Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space," National Academies:https://www.nationalacademies.org/our-work/decadal-survey-for-earth-science-and-applications-from-space

This subtopic addresses the following shortfall(s) identified in the 2026 Civil Space Shortfall list:

- Perform advanced remote sensing and science measurements with improved sensing capabilities and autonomy

Need Horizon: Mid-Term (5-10 years)

References:

1. "Enduring Quests Daring Visions: NASA Astrophysics in the Next Three Decades," National Aeronautics and Space Administration: https://smd-cms.nasa.gov/wp-content/uploads/2023/09/secure-astrophysics-roadmap-2013.pdf
2. "NASA Astrophysics," National Aeronautics and Space Administration: https://science.nasa.gov/astrophysics
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5. "Explorers and Heliophysics Projects Division (EHPD)," National Aeronautics and Space Administration: https://ehpd.gsfc.nasa.gov/
6. "Heliophysics Strategic Mission Programs," National Aeronautics and Space Administration: https://science.nasa.gov/heliophysics/2024_decadal_survey/heliophysics-strategic-mission-programs
7. "Planetary Missions Program Office," National Aeronautics and Space Administration: https://www.nasa.gov/planetarymissions/
8. "The Explorers Program," National Aeronautics and Space Administration: https://explorers.gsfc.nasa.gov/
9. "Exoplanet Exploration Program," National Aeronautics and Space Administration: https://science.nasa.gov/astrophysics/programs/exep/
10. "LUVOIR: Large Ultraviolet Optical Infrared Surveyor," National Aeronautics and Space Administration: https://asd.gsfc.nasa.gov/luvoir/
11. "Habitable Exoplanet Observatory (HabEx)," National Aeronautics and Space Administration: https://www.jpl.nasa.gov/habex
12. "The Lynx Mission Concept," National Aeronautics and Space Administration: https://wwwastro.msfc.nasa.gov/lynx/
13. "Cosmic Origins," National Aeronautics and Space Administration: https://science.nasa.gov/astrophysics/programs/cosmic-origins/

Space Weather (SPWX)

SPWX.1.S26A: Advanced Data-Driven Applications for Space Weather Research-to-Operations-to-Research (R2O2R) (SBIR) (previously S14.01)

Lead Center: MSFC

Participating Center(s): GSFC, JSC, ARC, LaRC

Subtopic Problem Statement/Description:

This subtopic seeks to advance space weather operational applications and new enabling technologies that enhance our ability to predict, monitor, and mitigate the effects of space weather on critical infrastructure and human and robotic spaceflight missions. This effort aligns directly with national objectives outlined in the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act and the National Space Weather Strategy and Action Plan (NSWSAP) and seeks development and transition of emerging modeling and data analysis capabilities that will enable and enhance NASA spaceflight missions and protect astronauts and spacecraft in transit toward and landed on the Moon, Mars, and beyond.

Innovative technologies and techniques are solicited that leverage existing or upcoming space weather data and mature models to create actionable intelligence for end users. The goal is to develop innovative tools and techniques that facilitate the transition of scientific knowledge into operational products. This includes the creation of value-added space weather products tailored to specific user groups, such as spacecraft operators, power grid managers, and communications companies. Efforts are sought to explore new markets for space weather data and services and to expand existing operational space weather products, as well as integrating NASA data into the decision-making processes of a diverse community of users with whom NASA may not frequently engage to help them mitigate risks. Particularly desired are efforts to bridge the gap between the heliophysics space weather program and diverse industries in geophysics, agriculture, autonomous transport, tourism and society at large by applying NASA data to the decision-making process of an end-user to mitigate the effects of space weather events.

To ensure greater success for the Nation, evaluation of proposals will include increased focus on clearly identified needs in the marketplace and specific plans for commercializing the proposed technology. Proposals should clearly demonstrate a feasible path to transition from proof-of-concept toward commercialization and operational space weather capability, including engagement with subject matter experts and end users from the beginning of the technology development. Coordination with prospective end users, especially in non-traditional industries, is appropriate and encouraged. Engaging the resources of existing NASA capabilities, such as the Space Radiation Analysis Group (SRAG) at JSC, the Community Coordinated Modeling Center (CCMC) and Moon to Mars Space Weather Analysis Office (M2M SWAO) at GSFC, and the Short-term Prediction Research and Transition (SPoRT) Center at MSFC, is also encouraged.

Expected TRL or TRL Range at completion of the Project: 3 – 5

Primary Technology Taxonomy:

- Level 1: TX11 Software, Modeling, Simulation, and Information Processing
- Level 2: TX11.X Other Software, Modeling, Simulation, and Information Processing

Desired Deliverables of Phase I:

Proof-of-concept with model development plans that have sufficient fidelity to assess technical, management, cost, and schedule risk. Deliverables should also delineate the scope and benefit of the proposed products that could be realized as a result of Phase II and what further scope and benefit necessarily requires further development after Phase II.

Desired Deliverables of Phase II:

Functioning prototype versions of the proposed technologies with a demonstrated concept tested in a realistic environment or within a standard space-weather-community development and validation framework, such as the CCMC. The extent of the prototype development and testing will vary with the technology and will be evaluated as part of the Phase II proposal. Phase II deliverables should also include/delineate any further work that would be required to bring the technologies to full operational and commercial use.

Desired Deliverable Types of Phase II:

- Software
- Prototype
- Analysis

State of the Art:

The current state of the art models at CCMC include MagPy, HESPERIA REleASE, University of Malaga Solar Energetic Particle Model (UMASEP), SEPMOD, and Ovation Prime. CCMC and the Moon to Mars Space Weather Analysis Office (M2M SWAO) also carry out prototyping activities to enable R2O2R efforts including transition of models such as Open Solar Physics Rapid Ensemble Information (OSPREI) for improved modeling and prediction of ICME propagation and the Nowcast of Aerospace Ionization RAdiation System (NAIRAS) model for radiation effects on aircraft. Data sources such as THEMIS-ARTEMIS are being used for cis-lunar and lunar environment assessments, and data sources including Mars Science Laboratory (Curiosity), Mars 2020 (Perseverance), and Mars Odyssey are in the transition pipeline for Mars environment assessments.

Critical Gaps:

The PROSWIFT Act established a Space Weather Advisory Group (SWAG). PROSWIFT tasked SWAG, among other things, to "conduct a comprehensive survey of the needs of users of space weather products to identify the space weather research, observations, forecasting, prediction, and modeling advances required to improve space weather products." Overarching national space weather priorities are identified in the 46 findings and 113 recommendations of that survey summarized in "Findings and Recommendations to Successfully Implement PROSWIFT and Transform the National Space Weather Enterprise."

Proposals must demonstrate a clear understanding of the current state of the art, and proposed innovations are sought that address critical gaps with a feasible plan for technology development to transition into a specific operational activity. Technology needed include specific domains of interest:

- Advancing forecasting horizons for solar events (SEPs, Flares, CMEs) based on existing models and data.
- Nowcasting and forecasting tools for energetic particles and plasma conditions that directly aid in spacecraft anomaly resolution.
- Prediction of atmospheric drag effects on satellites in low-Earth orbit (LEO) to improve orbital certainty.
- Techniques to characterize and predict ionospheric variability, which can disrupt global navigation and communication systems.
- Nowcasting and forecasting tools for SpWx effects specifically affecting human explorations on the Lunar and Martian surface, and in transit to the Lunar and Martian environment.

Shortfalls And Decadal Surveys:

"Decadal Survey for Solar and Space Physics (Heliophysics) 2024-2033," National Academies of Sciences, Engineering, and Medicine (2025), https://www.nationalacademies.org/our-work/decadal-survey-for-solar-and-space-physics-heliophysics-2024-2033

This subtopic addresses the following shortfall(s) identified in the 2026 Civil Space Shortfall list:

- Provide Earth-independent safety and crew health and performance countermeasures during long duration missions
- Perform advanced remote sensing and science measurements with improved sensing capabilities and autonomy

Need Horizon: Near-Term (Less than 5 years)

References:

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5. "National Space Weather Strategy," National Science and Technology Council, 2015: https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/final_nationalspaceweatherstrategy_20151028.pdf
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9. Executive Order 138653, C.F.R. 12041 (2019), "Coordinating National Resilience to Electromagnetic Pulses (EMPs)." https://www.govinfo.gov/content/pkg/FR-2019-03-29/pdf/2019-06325.pdf
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11. "Community Coordinated Modeling Center," NASA: https://ccmc.gsfc.nasa.gov
12. "Exploration Systems Development Mission Directorate," NASA: https://www.nasa.gov/exploration-systems-development-mission-directorate
13. "Space Operations Mission Directorate," NASA: https://www.nasa.gov/directorates/space-operations

14. "NASA Strategic Plan 2022," NASA: https://www.nasa.gov/wp-content/uploads/2023/09/fy-22-strategic-plan-1.pdf

15. "Findings and Recommendations to Successfully Implement PROSWIFT and Transform the National Space Weather Enterprise," Space Weather Advisory Group (SWAG): https://www.weather.gov/media/nws/REPORT-Findings-and-Recommendations-04202023.pdf

Unlocking the Orbital Economy (ORBECON)

ORBECON.1.S26A: Catalyzing High-Throughput In-Space Production of Semiconductors and Quantum Materials (CHIPS-QM) (SBIR) (previously H8.01)

Lead Center: JSC

Participating Center(s): ARC, LaRC

Subtopic Problem Statement/Description:

NASA's In-Space Production Applications (InSPA) portfolio invests in U.S. entities to demonstrate in-space production of high-value materials that target important terrestrial applications and lead to the creation of new industries in space. InSPA portfolio goals are to: (1) Serve U.S. national interests by advancing materials and technologies that strengthen industry leadership and improve national security; (2) provide benefits to humanity by developing materials that significantly improve the quality of life on Earth; and (3) accelerate development of the space economy in low-Earth orbit (LEO) by stimulating non-NASA demand for scalable and sustainable use of Commercial LEO Destinations.
In this subtopic, NASA requests the submission of commercial application-focused proposals for high-throughput in-space production of microgravity enhanced semiconductors and quantum materials for high-value technologies through novel manufacturing processes in the unique environment of space. CHIPS-QM concepts must meet the following criteria: (1) require utilization of the International Space Station (ISS) to demonstrate proof-of-concept for in-space production of advanced semiconductor and quantum materials that are superior to what can be achieved terrestrially, (2) require return of the material (or knowledge product) to Earth to support existing and emerging markets, (3) increase U.S. industrial competitiveness and national security [1], [2], [3], [4] This subtopic is soliciting technologies to support high throughput in-space production of advanced materials and enabling technologies in two areas:
•Quantum Materials (QM): Novel materials with unique quantum mechanical properties for quantum devices for sensing, communications, and computing.[3],[5],[6] Consistent with other space enhanced materials [7], microgravity may help to achieve homogeneity, stability, and reproducibility in addition to addressing interface issues and compatibility with existing technology for integrating QMs into functional devices, bridging the gap between research and commercialization. Applications include QMs for advanced qubits in quantum computers and ultra-sensitive sensors and imaging devices, communications, mineral exploration, energy generation and storage systems, including advanced photovoltaics, thermoelectric generators, and supercapacitors, as well as for applications in electronics with ultra-fast, low-energy-consumption devices and high-transition-temperature superconductors. Examples also include photonic materials qubits, superconductors, quantum magnets, topological insulators and superconductors, and quantum-spin liquids, nitrogen-vacancy centers (e.g., diamond), quantum semimetals, and the development of hybrid systems combining QMs with other established technologies.
•Semiconductor Materials: Groundbreaking semiconductors materials and microelectronics systems produced in space including but not limited to leading-edge semiconductor materials (e.g., diamond-based semiconductors, wide bandgap semiconductors, 2-D materials), next generation electronic materials beyond complementary metal-oxide-semiconductor (CMOS) technology that addresses current scaling limitations, heterogeneous materials & process

integration, and manufacturing methods overcoming the limits of 2D manufacturing through complex 3D assemblies. Additional applications are advanced materials for natural and hostile radiation environments, RF and optical components, high-power devices, and other critical applications. [8]

Proposals should clearly describe where and how gravity impedes material quality on Earth and what unique properties and performance are expected from in-space production. Objectives may include expanded scientific scope, in-situ characterization, more advanced manufacturing techniques, and use of artificial intelligence and/or computational models (i.e. digital twins). NASA encourages proposers to pursue multi-agency initiatives [9][10] for developing, manufacturing, and commercializing advanced materials, and to seek strategic alliances to enable the sharing of cost and risk.

Expected TRL or TRL Range at completion of the Project: 3 – 5

Primary Technology Taxonomy:

- Level 1: TX12 Materials, Structures, Mechanical Systems, and Manufacturing
- Level 2: TX12.1 Materials

Desired Deliverables of Phase I:

1. Development and test of a bench-top prototype.
2. An interim and final report detailing the following:
   a. Relevant prior microgravity research and development.
   b. Test results for the prototype technology in the laboratory.
   c. Preliminary plan for a proof-of-concept demonstration at the International Space Station.
   d. Preliminary assessment of the technology business case and economic impact.

Desired Deliverables of Phase II:

1. Development and test of an Engineering Development Unit (EDU) and digital models in a relevant environment (ground, parabolic, suborbital, or orbital).
2. A report detailing the following:
   a. Preliminary Science Requirements Document (SRD).
   b. Preliminary Design Review (PDR) including Concept of operations for a demonstration on the ISS.
   c. Test results for EDU.
   d. Updated assessment of business case and economic impact.

Concepts that can achieve flight demonstration on a suborbital flight or on the ISS during Phase II are especially valuable. Applicants may seek to submit a Phase IIE application that includes a parabolic, suborbital, or orbital flight demonstration. In such cases, the applicant should request matching funding from the NASA Flight Opportunities Program.

Desired Deliverable Types of Phase II:

- Analysis
- Test Results
- Hardware
- Prototype
- Digital Models

State of the Art:

The current State of the Art (SOA) for terrestrial semiconductors varies by material and application. Past microgravity crystal growth research has been shown to improve the quality and performance of semiconductor crystals over terrestrial crystal growth for more than 80% of 160 materials tested in space going back to 1973 [11][12][13]. One recent InSPA semiconductor demonstration showed an increase in yield of greater than 10x and an increase in performance of approximately 2x for a semimetal semiconductor composite material on the first flight.
The current SOA for quantum materials is difficult to quantify because the science and engineering field of quantum technologies is still in its infancy.

Critical Gaps:

The Department of Energy has defined a national need for applied research and deployment of quantum technologies - spanning quantum sensing, communications and computing. Quantum sensors can enable precise positioning in areas with limited or no GPS, crucial for autonomous vehicles and other technologies important to national security. The ability to control defects in diamond semiconductor materials at the atomic level to a greater degree in microgravity than under unit gravity is expected to significantly improve the performance of wide bandgap semiconductors for quantum applications. Additionally, the ability to significantly reduce crystallization in exotic glass optical fibers during the microgravity annealing process is expected to enable quantum sensing for space navigation systems.

Shortfalls And Decadal Surveys:

1490 - Additive Manufacturing for New and High-Performance Materials
1559 - Quantum Sensors that use Atoms, Ions, and Spins
1598 - Quantum Sensors that use Photons
1557 - PNT for In-Orbit and Surface Applications
1552 - Extreme Environment Avionics
1531 - Autonomous Guidance and Navigation for Deep Space Missions
1559 - Deep Space Autonomous Navigation
1526 - Radiation Monitoring and Modeling (Crew and Habitat)
1558 - High-Rate Communications Across the Lunar Surface
1592 - High Power, Long Distance Energy Transmission Across Distributed Surface Assets
1595 - Energy Storage to Enable Robust and Long Duration Operations on Moon and Mars

Need Horizon: Near-Term (Less than 5 years)

References:

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2. Department of Defense - DoD Critical Technology Areas. https://www.cto.mil/osc/critical-technologies/

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5. Department of Energy Office of Technology Transitions - "U.S. Department of Energy Announces First of Its Kind Collaboration for Quantum Technology Demonstrations in Space". https://www.energy.gov/technologytransitions/articles/us-department-energy-announces-first-its-kind-collaboration-quantum

6. The White House- Fiscal Year (FY) 2027 Administration Research and Development Budget Priorities and Cross-Cutting Actions https://www.whitehouse.gov/wp-content/uploads/2025/09/M-25-34-NSTM-2-Fiscal-Year-FY-2027-Administration-Research-and-Development-Budget-Priorities-and-Cross-Cutting-Actions.pdf

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8. Center for Open Science - "Semiconductor Manufacturing in Low Earth Orbit for Terrestrial Use": Frick, J., Rodrigue, G., Senesky, D., Hill, C. https://doi.org/10.31219/osf.io/d6ar4

9. Department of Energy - Advanced Materials and Manufacturing Technologies Office https://www.energy.gov/eere/ammto/advanced-materials-and-manufacturing-technologies-office; https://www.energy.gov/eere/ammto/ammto-funding-opportunities

10. National Science Foundation - U.S. National Science Foundation's Directorate for Technology, Innovation and Partnerships. https://www.nsf.gov/tip/about-tip; https://www.nsf.gov/funding/opportunities. Manufacturing USA- https://www.manufacturingusa.com/opportunities

11. "A meta-analysis of semiconductor materials fabricated in microgravity." Wilkinson, A.R., Brewer, F., Wright, H. et al. npj Microgravity 10, 73 (2024). https://doi.org/10.1038/s41526-024-00410-7 and https://www.nature.com/articles/s41526-024-00410-7

12. "Microgravity Crystal Formation" Jackson, Keegan; Brewer, Frances; Wilkinson, Ashley; Williams, Amari; Whiteside, Ben; Wright, Hannah; Harper, Lynn; Wilson, Anne M. Crystals, 2024, 14, 12. https://mdpi-res.com › crystals › crystals-14-00012

13. "An Analysis of Publicly Available Microgravity Crystallization Data; Emergent Themes Across Crystal Types" Wright, Hannah; Williams, Amari; Wilkinson, Ashley; Harper, Lynn; Savin, Ken; Wilson, Anne, Crystal Growth and Design, 2022, 22 (12), 6849-6851, (published online 10-31-22, https://pubs.acs.org/doi/full/10.1021/acs.cgd.2c01056

SBIR and the Technology Taxonomy

NASA's technology development activities expand the frontiers of knowledge and capabilities in aeronautics, science, and space, creating opportunities, markets, and products for U.S. industry and academia. Technologies that support NASA's missions may also support science and exploration missions conducted by the commercial space industry and other Government agencies. In addition, NASA technology development results in applications for the general population, including devices that improve health, medicine, transportation, public safety, and consumer goods.

The 2024 NASA Technology Taxonomy is an evolution of the technology roadmaps developed in 2015 and 2020. The 2024 NASA Technology Taxonomy provides a structure for articulating the technology development disciplines needed to enable future space missions and support commercial air travel. The 2024 revision is composed of 17 distinct technical-discipline-based taxonomies (TX) that provide a breakdown structure for each technology area. The taxonomy uses a three-level hierarchy for grouping and organizing technology types. Level 1 represents the technology area that is the title of that area. Level 2 is a list of the subareas the taxonomy is a foundational element of NASA's technology management process. NASA references the taxonomy to solicit proposals and to inform decisions on NASA's technology policy, prioritization, and strategic investments.

The 2024 NASA Technology Taxonomy can be found at: https://techport.nasa.gov/view/taxonomy

2024 TX Mapping Level 1	2024 TX Mapping Level 2	SBIR/STTR Subtopic Number	Subtopic Title
TX01 - Propulsion Systems	TX01.1 – Chemical Space Propulsion	GO.1.S26A	ASCENT Thruster Pre-heat Optimization
TX03 - Aerospace Power and Energy Storage	TX03.1 - Power Generation and Energy Conservation	LIVEP.1.S26A	Energy Storage for Long-Duration Missions
	TX03.3 - Power Management and Distribution	LIVEP.2.S26A	Mars and Lunar Power Transfer Technology Development
TX04 - Robotics Systems		EXPAND.1.S26A	Flight Demonstrations of Commercial In-Space Logistics, Robotic Manipulation, and Automation Systems for Future Space Operations
TX06 - Human Health, Life Support, and Habitation Systems	TX06.2 - Extravehicular Activity Systems	EVA.1.S26A	Advanced Spacesuit Architectures, Technologies, and Designs for Mars Exploration
TX08 - Sensors and Instruments	TX08.1 - Remote Sensing Instruments/Sensors	COSMO.1.S26A	High Performance Detector Technologies
	TX08.3 - In-Situ Instruments/Sensor	INSTALG.1.S26A	In Situ Instruments and Instrument Components for Lunar and Planetary Science
		INSTALG.2.S26A	Suborbital Instruments and Sensor Systems

TX11 - Software, Modeling, Simulation, and Information Processing	TX11.X - Other Software, Modeling, Simulation, and Information Processing	SPWX.1.S26A	Advanced Data-Driven Applications for Space Weather Research-to-Operations-to-Research (R2O2R)
TX12 - Materials, Structures, Mechanical Systems, and Manufacturing	TX12.1 - Materials	CARITL.1.S26A	Development of Hydrazine-Compatible Elastomeric Materials for Long-Duration Spaceflight
		ORBECON.1.S26A	Catalyzing High-Throughput In-Space Production of Semiconductors and Quantum Materials (CHIPS-QM)
	TX12.2 - Structures	LWS.1.S26A	Mars Solar Array Technology (MSAT) Innovations

Attachment 26A.1 SBIR Phase I Evaluation Rubric

Subject matter experts will determine the most promising technical and scientific approaches, based on the following criteria:

Factor 1: Scientific/Technical Merit and Feasibility
NASA will evaluate the proposed effort on:

- The technical approach and the anticipated agency and commercial benefits that may be derived from the research.
- The adequacy of the proposed effort and its relationship to the fulfillment of requirements of the research subtopic.
- The soundness and technical merit of the proposed approach and its incremental progress toward subtopic solution.
- Specific objectives, approaches, and plans for developing and verifying the innovation must demonstrate a clear understanding of the problem and the current state of the art. The degree of understanding and significance of the risks involved in the proposed innovation must be presented.

Factor 2: Experience, Qualifications, and Facilities
The qualifications of the proposed principal investigator/project manager, supporting staff and consultants and subcontractors, if any, will be evaluated for consistency with the research effort and their degree of commitment and availability.

The proposed necessary equipment or facilities required to accomplish the proposed technical approach will be evaluated to determine if they are adequate. In addition, any proposed reliance on external sources, such as government-furnished equipment or facilities (section 3.1.3.4 and part 8 of the technical proposal), will be evaluated for reasonableness.

Factor 3: Effectiveness of the Proposed Work Plan
The work plan will be evaluated for comprehensiveness, its proposed effective use of available resources, and approach to labor distribution. In addition, the work plan's proposed schedule for meeting the Phase I objectives will be evaluated to make sure they are reasonable and consistent with the proposed technical approach.

Factor 4: Commercial Potential
This evaluation factor will consider whether the offeror's proposal has demonstrated a knowledge of the potential economic benefits of the innovation, potential customers including NASA mission programs, other government agency programs, and/or non-government markets and strategies to reach them, as well as risks associated with this approach. If known, offerors may indicate if there are any existing and projected commitments for funding of the innovation beyond Phase I and II (this can include investment, sales, licensing, and other indicators of commercial potential).

Attachment 26A.2 SBIR List of Clauses, Regulations and Certifications

Introduction
Offerors who submit a proposal package to this solicitation will be required to meet specific rules and regulations as part of the submission and if awarded a contract. Offerors should ensure that they understand these rules and requirements before submitting a proposal package.

Below are provisions, clauses, regulations, and certifications that apply to Phase I submissions and contracts as if they were given in full text. The full text for Federal Acquisition Regulation (FAR) and the NASA FAR Supplement (NSF) provisions and clauses can be accessed electronically here:

FAR: www.acquisition.gov
NASA FAR Supplement: www.hq.nasa.gov/office/procurement/regs/NFS.pdf

"RFO Deviation" indicates Revolutionary FAR Overhaul
Note that additional contract clauses may apply at time of award.

https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.saferfederalworkforce.gov%2Fcontractors%2F&data=04|01|scott.d.dockum%40nasa.gov|a8ff826a53314564f36808d9be6ccfbf|7005d45845be48ae8140d43da96dd17b|0|0|637750196809935729|Unknown|TWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D|3000&sdata=Rl0B4cGaiLITbkmu%2FZsXpUdoOwbVWZ550n4DT1sp7%2BQ%3D&reserved=0**Federal Acquisition Regulations (FAR) Provisions and Clauses**
52.202-1 DEFINITIONS. (Jun 2020)
52.203-3 GRATUITIES. (Apr 1984)
52.203-5 COVENANT AGAINST CONTINGENT FEES. (May 2014)
52.203-6 RESTRICTIONS ON SUBCONTRACTOR SALES TO THE GOVERNMENT. (Jun 2020)
52.203-7 ANTI-KICKBACK PROCEDURES. (Jun 2020)
52.203-8 CANCELLATION, RESCISSION, AND RECOVERY OF FUNDS FOR ILLEGAL OR IMPROPER ACTIVITY (May 2014)
52.203-10 PRICE OR FEE ADJUSTMENT FOR ILLEGAL OR IMPROPER ACTIVITY (May 2014)
52.203-11 CERTIFICATION AND DISCLOSURE REGARDING PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS. (Sep 2024)
52.203-12 LIMITATION ON PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS. (Jun 2020)
52.203-18 PROHIBITION ON CONTRACTING WITH ENTITIES THAT REQUIRE CERTAIN INTERNAL CONFIDENTIALITY AGREEMENTS OR STATEMENTS-REPRESENTATION (Jan 2017)
52.203-19 PROHIBITION ON REQUIRING CERTAIN INTERNAL CONFIDENTIALITY AGREEMENTS OR STATEMENTS.(JAN 2017)
52.204-7 SYSTEM FOR AWARD MANAGEMENT. (RFO DEVIATION SEP 2025)
52.204-10 REPORTING EXECUTIVE COMPENSATION AND FIRST-TIER SUBCONTRACT AWARDS. (RFO DEVIATION Sep 2025)
52.204-13 SYSTEM FOR AWARD MANAGEMENT MAINTENANCE. (RFO DEVIATION SEP 2025)
52.204-19 INCORPORATION BY REFERENCE OF REPRESENTATIONS AND CERTIFICATIONS. (Dec 2014)
52.209-6 PROTECTING THE GOVERNMENT'S INTEREST WHEN SUBCONTRACTING WITH CONTRACTORS DEBARRED, SUSPENDED, OR PROPOSED FOR DEBARMENT. (RFO DEVIATION Dec 2025)
52.213-4 TERMS AND CONDITIONS – SIMPLIFIED ACQUISITIONS (OTHER THAN COMMERCIAL PRODUCTS AND COMMERCIAL SERVICES (RFO DEVIATION Dec 2025)
52.215-1 INSTRUCTIONS TO OFFERORS—COMPETITIVE ACQUISITION. (RFO DEVIATION Dec 2025)
52.215-2 AUDIT AND RECORDS-NEGOTIATIONS (RFO DEVIATION Dec 2025)
52.215-8 ORDER OF PRECEDENCE—UNIFORM CONTRACT FORMAT. (RFO DEVIATION Dec 2025)

52.217-9 OPTION TO EXTEND THE TERM OF THE CONTRCT (MAR 2000)
52.219-6 NOTICE OF TOTAL SMALL BUSINESS SET-ASIDE (RFO DEVIATION Dec 2025)
52.219-8 UTILIZATION OF SMALL BUSINESS CONCERNS. (RFO DEVIATION Dec 2025)
52.219-28 POST-AWARD SMALL BUSINESS PROGRAM REREPRESENTATION. ((RFO DEVIATION Dec 2025)
52.222-3 CONVICT LABOR. (RFO DEVIATION Dec 2025)
52.222-35 EQUAL OPPORTUNITY FOR VETERANS. (RFO DEVIATION Dec 2025)
52.222-36 EQUAL OPPORTUNITY FOR WORKERS WITH DISABILITIES. (RFO DEVIATION Dec 2025)
52.222-50 COMBATING TRAFFICKING IN PERSONS. (RFO DEVIATION Dec 2025)
52.222-54 EMPLOYMENT ELIGIBILITY VERIFICATION. (RFO DEVIATION Dec 2025)
52.225-1 BUY AMERICAN-SUPPLIES (RFO DEVIATION Dec 2025)
52.226-7 DRUG FREE WORKPLACE (May 2024)
52.226-8 ENCOURAGING CONTRACTOR POLICIES TO BAN TEXT MESSAGING WHILE DRIVING. (MAY 2024)
52.227-1 AUTHORIZATION AND CONSENT. (Jun 2020)
52.227-2 NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT (Jun 2020)
52.227-11 PATENT RIGHTS—OWNERSHIP BY THE CONTRACTOR (May 2014) as Modified by NFS 1852.227-11.
52.227-20 RIGHTS IN DATA—SBIR PROGRAM. (May 2014)
52.229-3 FEDERAL, STATE, AND LOCAL TAXES. (RFO DEVIATION Aug 2025)
52.232-2 PAYMENTS UNDER FIXED-PRICE RESEARCH AND DEVELOPMENT CONTRACTS. (Apr 1984)
52.232-9 LIMITATION ON WITHHOLDING OF PAYMENTS. (Apr 1984)
52.232-12 ADVANCE PAYMENTS. (RFO DEVIATION Dec 2025) AS MODIFIED BY NFS 1852.232-70 ALTERNATE IV (APR 1984) ALTERNATE V (MAY 2001)
52.232-23 ASSIGNMENT OF CLAIMS. (May 2014)
52.232-25 PROMPT PAYMENT. (Jan 2017)
52.232-33 PAYMENT BY ELECTRONIC FUNDS TRANSFER—SYSTEM FOR AWARD MANAGEMENT. (Oct 2018)
52.232-39 UNENFORCEABILITY OF UNAUTHORIZED OBLIGATIONS. (Jun 2013)
52.232-40 PROVIDING ACCELERATED PAYMENTS TO SMALL BUSINESS SUBCONTRACTORS. (Mar 2023)
52.233-1 DISPUTES. (RFO DEVIATION Sep 2025)
52.233-3 PROTEST AFTER AWARD. (RFO DEVIATION Sep 2025)
52.233-4 APPLICABLE LAW FOR BREACH OF CONTRACT CLAIM. (RFO DEVIATION Sep 2025)
52.240-90 SECURITY PROHIBITIONS AND EXCLUSIONS REPRESENTATIONS AND CERTIFICATIONS (RFO DEVIATION Sep 2025)
52.240-91 SECURITY PROHIBITIONS AND EXCLUSIONS (RFO DEVIATION Sep 2025)
52.240-93 BASIC SAFEGUARDING OF COVERED CONTRACTOR INFORMATION SYSTEMS (RFO DEVIATION Sep 2025)
52.242-13 BANKRUPTCY (July 1995)
52.242-15 STOP-WORK ORDER. (Aug 1989)
52.243-1 CHANGES—FIXED PRICE. (RFO DEVIATION Jul 2025)
52.244-6 SUBCONTRACTS FOR COMMERCIAL PRODUCTS AND COMMERCIAL SERVICES (RFO DEVIATION Dec 2025)
52.246-7 INSPECTION OF RESEARCH AND DEVELOPMENT—FIXED PRICE. (Aug 1996)
52.246-16 RESPONSIBILITY FOR SUPPLIES. (Apr 1984)
52.247-34 F.O.B. DESTINATION (Jan 1991)
52.249-1 TERMINATION FOR CONVENIENCE OF THE GOVERNMENT (FIXED-PRICE) (SHORT FORM). (APR 1984)
52.252-1 SOLICITATION PROVISIONS INCORPORATED BY REFERENCE. (Feb 1998)
52.253-1 COMPUTER GENERATED FORMS. (RFO DEVIATION Nov 2025)
52.252-2 CLAUSES INCORPORATED BY REFERENCE. (Feb 1998)

NASA Provisions and Clauses

1852.203-71 REQUIREMENT TO INFORM EMPLOYEES OF WHISTLEBLOWER RIGHTS (Sep 2025) DEVIATION)
1852.211-70 PACKAGING, HANDLING, AND TRANSPORTATION CERTIFICATIONS—OTHER THAN COMMERCIAL ITEMS (Sep 2005)
1852.215.84 OMBUDSMAN (Nov 2023)
1852.216-78 FIRM FIXED PRICE. (Dec 2025) (DEVIATION)
1852.219-80 LIMITATION ON SUBCONTRACTING – SBIR PHASE I PROGRAM. (Oct 2011)
1852.219-81 LIMITATION ON SUBCONTRACTING – SBIR PHASE II PROGRAM (Oct 2006)
1852.219-82 LIMITATION ON SUBCONTRACTING – STTR PROGRAM (Oct 2006)
1852.219-83 LIMITATION OF THE PRINCIPAL INVESTIGATOR – SBIR PROGRAM. (Oct 2006)
1852.219-85 CONDITIONS FOR FINAL PAYMENT – SBIR AND STTR CONTRACTS(Oct 2006)
1852.225-70 EXPORT LICENSES (Feb 2000)
1852.225-71 RESTRICTION ON FUNDING ACTIVITY WITH CHINA (Dec 2025) (DEVIATION)
1852.225-72 RESTRICTION ON FUNDING ACTIVITY WITH CHINA – REPRESENTATION. (Jan 2025) (DEVIATION)
1852.215-81 PROPOSAL PAGE LIMITATIONS. (Apr 2015)
1852.226-73 MAJOR BREACH OF SAFETY OR SECURITY (Feb 2026)
1852.227-11 PATENT RIGHTS – OWNERSHIP BY THE CONTRACTOR. (Apr 2015)
an 2025)(DEVIATION)
1852.232-80 SUBMISSION OF VOUCHERS FOR PAYMENT.(Apr 2018) (Apr 2018)
1852.233-70 PROTESTS TO NASA. (Sep 2025)(DEVIATION)
1852.235-70 NASA STI COMPLIANCE AND DISTRIBUTION SERVICES (Aug 2025)(DEVIATION)
1852.235-71 ESSENTIAL PERSONNEL AND FACILITIES (Aug 2025)(DEVIATION)
1852.235-73 FINAL SCIENTIFIC AND TECHNICAL REPORTS. ALTERNATE III (Aug 2025)(DEVIATION)
1852.235-74 ADDITIONAL REPORTS OF WORK - RESEARCH AND DEVELOPMENT. (Aug 2025) (DEVIATION)
1852.237-72 ACCESS TO SENSITIVE INFORMATION. (Dec 2025)(DEVIATION)
1852.237-73 RELEASE OF SENSITIVE INFORMATION. (Dec 2025) (DEVIATION)
1852.239-73 REVIEW OF THE OFFEROR'S INFROMATION TECHNOLOGY SYSTEMS SUPPLY CHAIN (DEVIATION 15-03D) (Jan 2020)
1852.239-74 INFORMATION TECHNOLOGY SYSTEM SUPPLY CHAIN RISK ASSESSMENT. (DEVIATION 15-03D) (Jan 2020)
1852.240-76 (SECURITY REQUIREMENTS FOR UNCLASSIFIED INFORMATION TECHNOLOGY RESOURCES(Dec 2025)(DEVIATION)1852.244-70 GEOGRAPHIC PARTICIPATION IN THE AEROSPACE PROGRAM (Apr 1985)
1852.246-72 MATERIAL INSPECTION AND RECEIVING REPORT (Sep 2025)(DEVIATION)
PCD 21-02 FEDERAL ACQUISITION REGULATION (FAR) CLASS DEVIATION – PROTECTION OF DATA UNDER THE SMALL BUSINESS INNOVATIVE RESEARCH/SMALL TECHNOLOGY TRANSFER RESEARCH (SBIR/STTR) PROGRAM
PCD 21-04A CLASS DEVIATION FROM THE FEDERAL ACQUISITION REGULATION (FAR) AND NASA FAR SUPPLEMENT (NFS) REGARDING REQUIREMENTS FOR NONAVAILABILITY DETERMINATIONS UNDER THE BUY AMERICAN STATUTE

Additional Regulations

SBA Certifications required for Phase I