Section A: FY25 Basic Research Topics

A.1 Human Research Program

Space Operations Mission Directorate (SOMD)

https://www.nasa.gov/directorates/space-operations-mission-directorate

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The NASA Human Research Program (HRP) drives advances in scientific and technological research to enable human space exploration. It is a human-focused Program dedicated to providing solutions and mitigation strategies beyond low-earth orbit by reducing the risks to human health & performance through focused translational, applied, and operational research. HRP's primary deliverables include:

- Human health, performance, and habitability standards
- Countermeasures and other risk mitigation solutions
- Advanced habitability and medical support technologies

Recently, HRP has developed a strategy to deliver critical components for an evolvable Crew Health and Performance System by 2032. This will be central to how HRP characterizes spaceflight risks and produces mitigation strategies that enable optimal crew health and performance during exploration missions. HRP will demonstrate and mature this system in ground analogs, in LEO, and on and around the moon to support a 2039 Mars mission. The Human Research Roadmap (https://humanresearchroadmap.nasa.gov) is a web-based version of an HRP Integrated Research Plan that allows users to search HRP risks, gaps, and tasks.

The HRP is organized into several research Elements:

- Human Health Countermeasures
- Human Factors and Behavioral Performance
- Exploration Medical Capability
- Space Radiation

Each of the HRP Elements addresses a subset of the risks. Proposals should address specific gaps listed in the Human Research Roadmap (https://humanresearchroadmap.nasa.gov/Gaps/). Researchers from proposals selected for this research opportunity should consider attending the Human Research Program Investigators' Workshop (HRP IWS) in Galveston, TX (February 2025).

A.1.1 Development or Adaptation of Analog Facilities for Human Behavioral Health and Performance Research in Long-duration Lunar and Mars Missions

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This call addresses the need for terrestrial research platforms that replicate future exploration spaceflight missions as highlighted by ongoing research in NASA HRP Human Factors Behavioral Performance Element, or HFBP. Research is needed to characterize and mitigate individual and team behavioral health and performance outcomes relative to future lunar missions and Mars missions; hence, platforms (i.e., analogs) that accurately reflect future spaceflight scenarios, are needed. Proposals are encouraged to build innovative approaches for the development, adaptation, and/or operationalization of analog environments that address the unique challenges of long-duration space missions.

Research Focus

Future missions will extend beyond current LEO capabilities, requiring crew face prolonged periods of confinement, with extreme environmental exposures in context of increased crew autonomy due to the vast distance from Earth of these anticipated missions. Depending on the target mission (e.g., lunar long, Mars) and research goals, current and/or future analogs will require enhancements or modifications to accurately simulate the range of these mission-specific conditions. The primary objective of this solicitation is to foster research that either proposes novel and relevant analog facilities, or modifications to existing ones to simulate the unique challenges of long-duration lunar and Mars missions. This encompasses environmental, operational, and psychological fidelity to real space missions, with an emphasis on addressing human behavioral health and performance risks.

Description of the Problem

To align analog facilities with the forefront of behavioral health and performance-focused space exploration research, a concerted effort is needed to ensure these environments accurately simulate the range of mission-specific characteristics outlined in NASA's Design Reference Missions (DRM). This requires an accurate understanding of the unique demands of each mission type, and a commitment to advancing the capabilities of analog facilities to mirror these requirements precisely. The goal is to augment research platforms, analogs, and facilities to accelerate the development, testing, and validation of technologies, strategies, and countermeasures.

The development of new analog research facilities can pose practical and financial constraints. It can be a more practical approach to identify and/or modify existing research platforms or facilities that share one or more characteristics with a spaceflight environment, such an isolated, confined, and extreme platform (ICE) or an isolated, confined, and controlled platform (ICC). The augmentation of certain analog characteristics can expedite research advancement, verification of mission-critical technologies, operational strategies, and human performance countermeasures for prolonged space missions. Additionally, securing adequate funding and institutional support is essential for the advancements and accessibility of spaceflight analog research, underscoring the need for a unified commitment to enhancing the fidelity, accessibility, and effectiveness of analog research platforms.

Areas of Research Interest

Target Analog Missions and Facility Designs: The proposal scope should be built around the development and/or enhancement of an analog environment that will facilitate research needed to mitigate risks related to behavioral health and performance for individuals and teams. Proposers are encouraged to consider enhancements not only related to facility improvements, but towards the implementation of research missions as a whole. Collaborations with technology developers, interdisciplinary research teams, and academic or industry partners to pool expertise and resources can be considered. Proposals should describe how the use of funds will assist the development or modification of their analog/facility and infrastructure to address one or more of HFBP's target platforms/risks outlined in the Human Research Roadmap. Approaches may also address efforts to enhancing the fidelity of their simulation or target-mission, analog infrastructure design, scenario developments, or technology integration for research or testing.

Alignment with NASA's DRM Specifications: Proposed analogs should accurately replicate the specific conditions detailed in NASA's Design Reference Missions (DRM) for lunar long missions or Mars missions, to customize their simulations, research inquiries, and additional mission-related elements to enhance the relevance and applicability of research findings. This includes accurately simulating mission length, the distance from Earth, the size and functionality of habitats, the impact of communication delays, and the nature of in-flight or surface extravehicular activities (EVAs).

Ability to Measure Behavioral Health and Performance Metrics: Proposed analogs should facilitate the implementation of sensitive, reliable, and validated measures for assessing crew behavioral health and performance risks, leveraging the systematic approach currently used in other spaceflight analogs. This includes the utilization of multi-modal data collection tools and physiological measurements to monitor crew health and performance unobtrusively. A list of standard measures currently used in several spaceflight analogs can be found here.

Repeated Simulations Across Diverse Missions: The significance of conducting research or simulations across a variety of missions cannot be overstated, as reliance on single-mission or short-duration simulations provides a limited view of certain variables, constraining applicability of findings to long-duration missions. A comprehensive approach, featuring repeated simulations of varying durations, ensures a broader understanding of mission-critical factors.

Infrastructure Adaptation for Diverse Mission Simulations: An adaptive analog infrastructure should support a range of mission simulations, from short-duration lunar stays to extended Mars missions. This includes the flexibility to modify habitat designs and test protocols to reflect the variable internal design of habitats and vehicles across different missions, addressing the challenges highlighted in the consideration of missions' variability.

Mission Characteristics

Once a target mission for an analog is identified, proposals should mirror mission-specific characteristics (e.g., mission durations, habitat, and space-analogous environmental conditions) to measure effects of isolation, confinement, crew autonomy, and performance. Proposals should consider the following characteristics in reference to their target mission:

- **Duration:** Analog facilities are often bounded by logistical constraints in their capability of simulating the extended periods astronauts will spend in space, ranging from months to potentially years. This includes creating environments that sustain resources and scientific research over long durations, enabling the tracking of performance changes over time, challenging crews with the psychological and physical aspects of time spent away from Earth.

- **Distance from Earth:** Simulations should account for the vast distances of lunar and Mars missions, which impact communication times, visible views of Earth, delay emergency support, and necessitate a higher degree of crew autonomy. Analogs should incorporate delayed communication systems to simulate the time it takes for messages to travel between Earth and the spacecraft, affecting decision-making and operational independence.

- **Habitat Volume and Capacity:** The design of analog habitats should reflect the actual dimensions of constrained living and working spaces expected on lunar or Mars missions, including considerations for storage, habitability, and the functionality required to support crew health and mission objectives. This entails designing versatile spaces that can adapt to various mission scenarios and crew sizes.

- **Communication Delays:** Analogs should implement systems that replicate the communication delays encountered in deep space missions. This includes not only the technical aspects of delayed communication but also training crews to manage the psychological and operational challenges posed by these delays, such as decision-making autonomy and the maintenance of morale and team cohesion over time.

- **In-Flight or Surface Activities:** Including realistic extravehicular activities (EVAs) in analog simulations is crucial. Facilities should offer diverse EVA scenarios, from routine maintenance tasks to emergency situation drills, that reflect the surface conditions of the Moon or Mars. This involves simulating the gravitational differences, terrain challenges, and the use of EVA suits and equipment designed for these environments. This also includes the application of virtual reality to enhance the realism of environmental simulations, the use of advanced robotics to mimic extravehicular activities.

Selection and Recruitment of Analog Participants

- The selection criteria for participants should closely mimic the astronaut selection requirements as closely as possible. Selection should extend beyond physical fitness and technical expertise to include psychological fitness through a comprehensive evaluation process, targeting the selection of astronaut-like individuals.

- Selection and pre-mission training process should focus on interpersonal skills, such as conflict resolution and effective communication, which are vital for maintaining team cohesion and performance in confined and isolated environments. The ability to cope with monotony, manage uncertainty, and maintain motivation over extended periods should also be key considerations.

- Generalizability of future research conducted in these analog platforms, to future exploration missions, is key.

Impact

The advancement of analog facilities and research methodologies in line with these objectives is vital for preparing astronauts for the unprecedented challenges of lunar and Mars missions. Improved analog fidelity and research capabilities will enable more accurate characterization of behavioral health and performance risks, and development of effective countermeasures. Proposals that address these needs have the potential to significantly impact the preparation and resilience of crews undertaking long-duration space missions, enhancing their safety, well-being, and performance.

A.1.2 Human Research Program/Space Radiation Element

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Research Overview: Space radiation exposure is one of numerous hazards astronauts encounter during spaceflight that impact human health. High priority health outcomes associated with space radiation exposure are carcinogenesis, cardiovascular disease (CVD), and central nervous sytem (CNS) changes that impact astronaut health and performance.

Areas of Research Interest:

1. Research proposals are sought to **accelerate risk characterization for high priority radiation health risks and inform mitigation strategies the NASA Human Research Program (HRP) Space Radiation Element (SRE) by sharing animal tissue samples and data.** The proposed work should focus is on translational studies that support priority risk characterization (cancer, CVD, CNS), development of relative biological effectiveness (RBE) values, identification of actionable biomarkers, and evaluation of dose thresholds for relevant radiation-associated disease endpoints. Cross-species comparative analyses of rodent data/samples with higher order species (including human archival data and tissue banks) are highly encouraged.
    - Data can include but is not limited to behavioral tasks, tumor data, physiological measurements, imaging, omics', etc. that has already been, or is in the process of being, collected.
    - Tissue samples can include, but are not limited to, samples that have already been, or are in the process of, being collected and stored as well as tissues from other external archived banks (e.g., http://janus.northwestern.edu/janus2/index.php).
    - Relevant tissue samples and data from other externally funded (e.g., non-NASA) programs and tissue repositories/archives for comparison with high linear energy transfer (LET), medical proton, neutron and other exposures can be proposed.
    - A more detailed list of samples and tissues available from SRE can be found at our tissue sharing websites:
        - https://lsda.jsc.nasa.gov/Document/doc_detail/Doc13726
        - https://lsda.jsc.nasa.gov/Document/doc_detail/Doc13766
        - https://lsda.jsc.nasa.gov/Biospecimen by searching "NASA Space Radiation Laboratory (NSRL)" in the payloads field.
        - Instructions for accessing the tissue sharing information are posted at: https://spaceradiation.jsc.nasa.gov/tissue-sharing/.

2. Research proposals are sought to establish innovative screening techniques for compound-based countermeasures to assess their efficacy in modulating biological responses to radiation exposure relevant to the high priority health risks of cancer, CVD, and/or CNS. Techniques that can be translated into high-throughput screening protocols are highly desired, however high-content protocols will also be considered responsive.

Research Topic: Use of human-based tissue engineered models for characterization of space stressor and/or hazard effects.

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3. Complex *in vitro* models that mimic component of human physiology continue to evolve and show promise for various research. These tissue-engineered models, including organoids and tissue chips, could be ideal in better understanding space flight stressors and hazards such as chronic effects of low-dose radiation exposure to the human, microgravity, etc.. ***Research proposals are sought to establish translational value of human-based tissue models for characterization of space flight hazards and/or stressor, and countermeasure studies. Such research should include models relevant to cancer, cardiovascular health, neurocognitive health, bone, immune, retinal etc. (For additional information concerning areas of interest please visit*** https://humanresearchroadmap.nasa.gov/Risks/) Selected stressor and or hazard levels should be

relevant to space exploration missions.

Respondents can propose the following types of activities:

- Conduct research on HUMAN tissue models and compare to existing human data on vascular, cancer, cardiovascular health, neurocognitive health, bone, immune, retinal etc.. Structural and functional sturdies should be included, in addition to cell/molecular biomarker readouts. Selected stressor and or hazard levels should be relevant to space exploration missions.
- Conduct research on ANIMAL tissue models and compare to existing in vivo data on vascular, cancer, cardiovascular health, neurocognitive health, bone, immune, retinal etc.. Structural and functional sturdies should be included, in addition to cell/molecular biomarker readouts. Selected stressor and or hazard levels should be relevant to space exploration missions
- Obtain relevant preliminary data from either activities 1 or 2 that can be used in a future HRP OMNIBUS or FLAGSHIP grant application

Research Topic: Aging related effects of space radiation
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Normal aging processes have been shown to include many cellular processes that are shared with the pathogenesis of late degenerative diseases. Aging involves a progressive loss of physiological integrity and impaired function and is considered a primary risk factor for cancer, diabetes, cardiovascular disorders, and neurodegenerative diseases. Recently aging processes have been organized into a unified framework called the Hallmarks of Aging (e.g. López-Otin 2013, http://dx.doi.org/10.1016/j.cell.2013.05.039). The nine identified hallmarks of aging are: genomic instability, telomere length reduction, epigenetic changes, altered protein homeostasis, deregulated nutrient sensing, mitochondrial dysfunction, cellular senescence, stem cell depletion, and altered intercellular communication. Many of these processes have been investigated in detail in the context of low LET radiation exposure and "accelerated aging" has been proposed as a conceptual framework for radiation effects. However, much less understood about the effects of high LET space-like radiation exposure, especially at low doses and dose rates. These processes underly impairments to human risk imposed by space radiation exposure and an understanding of their responses is required for astronaut risk estimation, health management and countermeasure development. ***Research proposals are sought to explore the pathogenic processes associated with aging and late degenerative diseases that are also elicited by charged particle radiation of composition and dose corresponding to spaceflight exposures. Such research should include models relevant to, but not limited to, cancer, cardiovascular and central nervous system health.***

Respondents can propose the following types of activities:

- Conduct research on adult animals (sexually and immunologically mature) exposed to space-like radiation that characterize pathogenic processes common to aging and radiation injury. Outcome measures that relate to altered protein homeostasis, mitochondrial dysfunction, cellular senescence, and inflammation are of particular interest as well as those that can be used as predictive biomarkers for translation to humans. Use of both wild type and transgenic animals of both sexes is appropriate. Selected radiation doses, dose rates and sources should be relevant to space exploration missions.
- Conduct research comparing human and animal tissue models using engineered tissue and organoid models. Structural and functional studies should be included, in addition to cell/molecular biomarker readouts. Selected radiation doses and sources should be relevant to space exploration missions.

A.1.3 Human Research Program/ Exploration Medical Capability(ExMC) Element

POC: Jay Lemery, MD,jay.lemery@nasa.gov

Topic : Artificial Intelligence Solutions to Support Exploration Spaceflight Autonomous Medical Systems
Research Focus: Earth Independent Medical Operations
Description of the problem : As long-term mission planning shifts from a paradigm of LEO to Lunar and subsequently Martian missions, there is a commensurate imperative for Earth-based medical authority to transition to space-based assets for the continued assurance of optimal astronaut health and performance. The transition to Earth Independent Medical Operations (EIMO) will be a process that enables progressively resilient systems and crews to reduce risk and enhance wellness and overall mission success for deep space exploration. Terrestrial assets will be paramount in pre-mission screening, planning, maintenance, and prevention. Yet on-board care, response to unexpected medical events, and management of communication delays and dropouts will increasingly become the purview of the crew for primary management. A key strategy for this is utilizing artificial intelligence (AI) as an integrated platform for crew health and performance that is robust, nimble, malleable, and capable to evolve over time. Crew health and performance will need to be supported across multiple habitats, vehicles, and suits, in some cases designed over many years and with differing requirements.

Areas of Research Interest (your objectives/needs): An ideal solution end state would be able to synthesize large and variable sources of data, including prior medical history, reference databases, real time monitoring using wearable sensors, environmental controls, point of care diagnostics, laboratory results, etc. that can be utilized to diagnose, treat, and perhaps even predict medical events and performance decrements. Inclusion of advanced training tools will enable the increasingly autonomous medical care that can aid a crew medical officer in the circumstance where ground support is unavailable or where availability is time-delayed to the point of being irrelevant as in an emergent medical situation.

Examples of such solutions may include use of natural language processing or large language models that can provide guidance to crew medical officers of varying levels of knowledge, skills, and abilities to aid in medical decision-making in the absence or delay of medical operations ground support. Other attributes may address medical decision-making support tools that can provide task off-loading, autonomous decision support, or just-in-time training with concomitant benefits in cognitive load reduction.

Impact: Impact of this technology will increase inflight medical capabilities and identify new capabilities that (a) maximize benefit and (b) reduce “costs” on the human system/mission/vehicle resources.

A.1.4 Office of Chief Health and Medical Officer (OCHMO)

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Areas Of Research Interest
Development and elaboration of the current state of the science for the manufacture of biologics using synthetic biology and 3-D printing of drugs. On long duration space exploration missions, potential medical problems could occur during the ~3 year Mars mission (6-8 months in microgravity to the planet, 1 year on Mars, and 6-8 months return to Earth) that would require prevention and therapy. Although the risk of illness can be approximated, which illnesses will occur and what medications are needed will be unknown. A best risk accessed pharmacy will be provided as depot storage of pills,

capsules, and liquid based medications. However, both the length of the mission and the potential of other illnesses occurring suggests the need for de novo manufactured medications. Research proposals are sought to establish the current state of potential use of the use of synthetic biology and 3-D drug printing.

A.2 Space Operations Mission Directorate (SOMD)

https://www.nasa.gov/directorates/space-operations-mission-directorate

POC: Marc Timm, marc.g.timm@nasa.gov
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Commercial Space Capabilities (CSC)

The SOMD Commercial Space Division (CSD)'s Commercial Crew and Commercial Low Earth Orbit (LEO) Development Programs encompass Crew and Cargo Transportation to and from, and in-space Destinations and operations in, LEO. The purpose of this CSC focus area is to harness the capabilities of the U.S. research community to mature theoretical concepts that are of interest to U.S. commercial spaceflight companies into initial practice. The intent is that such companies can then apply and further evolve that initial practice to improve state-of-art of current capabilities, or to create new capabilities to benefit the growth of a robust near-Earth orbit US economy. The overall goal of this area is to encourage and facilitate a robust and competitive U.S. low Earth orbit economy. Efforts that primarily benefit near-Earth commercial activities but that may might also be extensible Moon and/or Mars are also in scope.

U.S. commercial spaceflight industry interests vary by company and change over time, so Researchers are encouraged to directly engage with industry to determine relevant interests. Before submitting proposals in this area, the Proposer is encouraged to contact the NASA CSC POCs to discuss the intended proposal. Some current high level interests include:

- Low consumable environmental control and life support (ECLS), crew hygiene, and/or clothes washing. (Closed loop or nearly so. Includes waste product repurposing.)
- Small cargo return, Destination resupply systems, and related technologies
- In-Space Welding
- Materials and Processes Improvements for Chemical Propulsion State of Art
- Materials and Processes Improvements for Electric Propulsion State of Art
- Improvements to Space Solar Power State of Art (SoA)
- Other topics in this area that have demonstrable need and support from a U.S. company(ies)

A.3 Exploration Systems Development Mission Directorate (ESDMD)
POC: Matt Simon, matthew.a.simon@nasa.gov

With Artemis missions, NASA will land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface than ever before. We will collaborate with our commercial and international partners to establish the first long-term human-robotic presence on and around the Moon. Then, we will use what we learn on and at the Moon to take the next giant leap: sending the first astronauts to Mars.

The Exploration Systems Development Mission Directorate defines and manages systems development for programs critical to NASA's Artemis program and planning for NASA's Moon to Mars exploration approach. ESDMD manages the human exploration system development for lunar orbital, lunar surface, and Mars exploration. Programs in the mission directorate include Orion, Space Launch System, Exploration Ground Systems, Gateway, Human Landing System, and Extravehicular Activity (xEVA) and Human Surface Mobility. Additional information about the Exploration Systems Development Mission Directorate can be found at: https://www.nasa.gov/exploration-systems-development-mission-directorate

ESDMD is also designing a roadmap for the long-term exploration of the lunar surface, our first steps on Mars, and the journey beyond, working with our partners in industry, academia, and the international community. NASA's "Moon to Mars Objectives" document establishes an objectives-based approach to the agency's human deep space exploration efforts. This approach focuses on the big picture, the “what” and “why” of deep space exploration, before prescribing the “how.” Capabilities needed to enable these missions are decomposed from NASA’s Moon to Mars Objectives, and will require NASA to master the following areas of research interest:

- **Communications, Navigation, Positioning, and Timing Systems:** Enable transmission and reception of data, determination of location and orientation, and acquisition of precise time.
- **Habitation Systems:** Ensure the health and performance of astronauts in controlled environments.
- **Human Systems:** Execute human and robotic missions; this includes crew, ground personnel, and supporting systems.
- **Logistics Systems:** Package, handle, transport, stage, store, track, and transfer items and cargo.
- **Mobility Systems:** Move crew and cargo around the lunar and Martian surfaces.
- **Power Systems:** Generate, store, condition, and distribute electricity for architectural elements.
- **Transportation Systems:** Convey crew and cargo to and from Earth to the Moon and Mars.
- **Utilization Systems:** Enable science and technology demonstrations.
- **Data Systems and Management:** Transfer, distribute, receive, validate, secure, decode, format, compile, and process data and commands.
- **In-situ Resource Utilization (ISRU) Systems:** Extract resources in space or on the Moon or Mars to generate products.
- **Infrastructure Support:** Includes facilities, systems, operations planning and control, equipment, and services needed on Earth, in space, and on planetary surfaces.
- **Autonomous Systems and Robotics:** Employ software and hardware to assist the crew and operate during uncrewed periods.

More information on future plans for exploring the Moon and Mars and capabilities needed can be found at: https://www.nasa.gov/MoonToMarsArchitecture.

Proposers are directed to the resources linked above to guide areas of potential interest to ESDMD.

A.4 Science Mission Directorate (SMD)

Science Mission Directorate (SMD) leads the Agency in five areas of research: Heliophysics, Earth Science, Planetary Science, Astrophysics and Biological and Physical Sciences (BPS). SMD, using the vantage point of space to achieve with the science community and our partners a deep scientific understanding of our planet, other planets and solar system bodies, the interplanetary environment, the Sun and its effects on the solar system, and the universe beyond. In so doing, we lay the intellectual foundation for the robotic and human expeditions of the future while meeting today's needs for scientific information to address national concerns, such as climate change and space weather.

Additional information about the SMD may be found at: https://science.nasa.gov/

A.4.1 Heliophysics Division

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Heliophysics encompasses science that improves our understanding of fundamental physical processes throughout the solar system, and enables us to understand how the Sun, as the major driver of the energy throughout the solar system, impacts our technological society. The scope of heliophysics is vast, spanning from the Sun's interior to Earth's upper atmosphere, throughout interplanetary space, to the edges of the heliosphere, where the solar wind interacts with the local interstellar medium. Heliophysics incorporates studies of the interconnected elements in a single system that produces dynamic space weather and that evolves in response to solar, planetary, and interstellar conditions.

In this framework, the Heliophysics Research Program is guided by *Science 2020-2024: A Vision for Scientific Excellence* and any more up to date versions of the Science Plan (available at https://science.nasa.gov/about-us/science-strategy) and by the *2013 National Research Council Decadal Strategy for Solar and Space Physics report, Solar and Space Physics: A Science for a Technological Society* (www.nap.edu/catalog.php?record_id=13060).
The decadal survey articulates the scientific challenges for this field of study and recommends a slate of design reference missions to meet them, to culminate in the achievement of a predictive capability to aid human endeavors on Earth and in space. The fundamental science questions are:

- What causes the Sun to vary?
- How do the geospace, planetary space environments and the heliosphere respond?
- What are the impacts on humanity?

To answer these questions, the Heliophysics Division implements a program to achieve three overarching objectives:

- Explore and characterize the physical processes in the space environment from the Sun to the heliopause and throughout the universe
- Advance our understanding of the Sun's activity, and the connections between solar variability and Earth and planetary space environments, the outer reaches of our solar system, and the interstellar medium
- Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

The program supports theory, modeling, and data analysis utilizing remote sensing and in situ measurements from a fleet of missions; the Heliophysics System Observatory (HSO). Frequent CubeSats, suborbital rockets, balloons, and ground-based instruments add to the observational base. Investigations that develop new observables and technologies for heliophysics science are sought.

Supported research activities include projects that address understanding of the Sun and planetary space environments, including the origin, evolution, and interactions of space plasmas and electromagnetic fields throughout the heliosphere. The program seeks to characterize these phenomena on a broad range of spatial and temporal scales, to understand the fundamental processes that drive them, to understand how these processes combine to create space weather events, and to enable a capability for predicting future space weather events.

The program supports investigations of the Sun, including processes taking place throughout the solar interior and atmosphere and the evolution and cyclic activity of the Sun. It supports investigations of the origin and behavior of the solar wind, energetic particles, and magnetic fields in the heliosphere and their interaction with the Earth and other planets, as well as with the interstellar medium.
The program also supports investigations of the physics of magnetospheres, including their formation and fundamental interactions with plasmas, fields, and particles and the physics of the terrestrial mesosphere, thermosphere, ionosphere, and auroras, including the coupling of these phenomena to the lower atmosphere and magnetosphere. Proposers may also review the information in the ROSES-24 Heliophysics Research Program Overview B.01_Helio Overview.pdf (nasaprs.com) for further information about the Heliophysics Research Program.

A.4.2 Earth Science Division

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The overarching goal of NASA's Earth Science program is to develop a scientific understanding of Earth as a system. The Earth Science Division of the Science Mission Directorate (https://science.nasa.gov/earth-science) contributes to NASA's mission, in particular, Strategic Objective 1.1: Understanding The Sun, Earth, Solar System, And Universe. This strategic objective is motivated by the following key questions:

- How is the global Earth system changing?
- What causes these changes in the Earth system?
- How will the Earth system change in the future?
- How can Earth system science provide societal benefit?

These science questions translate into seven overarching science goals to guide the Earth Science Division’s selection of investigations and other programmatic decisions:

- Advance the understanding of changes in the Earth’s radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition (Atmospheric Composition)
- Improve the capability to predict weather and extreme weather events (Weather)
- Detect and predict changes in Earth’s ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle (Carbon Cycle and Ecosystems)
- Enable better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change (Water and Energy Cycle)
- Improve the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land and ice in the climate system (Climate Variability and Change)
- Characterize the dynamics of Earth’s surface and interior, improving the capability to assess and respond to natural hazards and extreme events (Earth Surface and Interior)
- Further the use of Earth system science research to inform decisions and provide benefits to society

The Earth Science Division has a new Earth Science to Action Strategy that leverages the foundational science that NASA, as a space and science agency with unique end-to-end capabilities, generates to enable society and decision-makers everywhere to address the most pressing challenges posed by the changing environment. Within this framework, the ESD also aims to foster the creation and infusion of new technologies – such as data processing, interoperability, visualization, and analysis as well as autonomy, modeling, and mission architecture design – in order to enable new scientific measurements of the Earth system or reduce the cost of current observations (see http://esto.nasa.gov). The ESD also promotes innovative development in computing and information science and engineering of direct relevance to ESD. NASA makes Earth observation data and information freely and widely available through the Earth Science Data System program, which is responsible for the stewardship, archival and distribution of open data for all users

The Earth Science Division (ESD) places particular emphasis on the investigators' ability to promote and increase the use of space-based remote sensing through the proposed research. Proposals with objectives connected to needs identified in most recent Decadal Survey (2017-2027) from the National Academies of Science, Engineering, and Medicine, *Thriving on our Changing Planet: A Decadal Strategy for Earth Observation from Space* are welcomed. (see https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth).

NASA's ability to view the Earth from a global perspective enables it to provide a broad, integrated set of uniformly high-quality data covering all parts of the planet. NASA shares this unique knowledge with the global community, including members of the science, government, industry, education, and policy-maker communities.

A.4.3 Planetary Science Division

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The Planetary Science Exploration Technology Office (PESTO), managed by the Planetary Science Division, sponsors technology development that addresses the broad strategic objective to "Ascertain the content, origin, and evolution of the Solar System and the potential for life elsewhere." To pursue this objective, the Planetary Science Division has strategic goals and objectives that guide the focus of the division's science research and technology development activities. As described in the NASA 2023 Science Strategic Plan (https://science.nasa.gov/about-us/science-strategy), these are:

Discover:

- Expand human knowledge through new scientific discoveries
  - 1.2: Understand the Sun, solar system, and universe

Explore:

- Extend human presence to the Moon and on towards Mars for sustainable long-term exploration, development, and utilization
  - 2.1: Explore the surface of the Moon and deep space

Innovate:

- Catalyze economic growth and drive innovation to address national challenges
    - 3.1: Innovate and advance transformational space technologies

The NASA Planetary Science strategic objective is to advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.

In order to address these goals and objectives, the Planetary Science Exploration Technology Office invites a wide range of planetary science and astrobiology technology development investigations. Example topics for technology developments include, but are not limited to:

- Technology developments for supporting the understanding the formation and evolution of the Solar System and (exo) planetary systems in general, and of the planetary bodies, satellites, and small bodies in these systems;
- Technology developments for supporting the understanding materials present, and processes occurring, in the early stages of Solar System history, including the protoplanetary disk;
- Technology developments the supporting the understanding planetary differentiation processes;
- Technology developments for supporting evaluation of extraterrestrial materials, including meteorites, cosmic dust, presolar grains, and samples returned by the Apollo, Stardust, Genesis, and Hayabusa missions;
- Technology developments for supporting the understanding of properties of planets, satellites (including the Moon), satellite and ring systems, and smaller Solar System bodies such as asteroids and comets;
- Technology developments for supporting the understanding of the coupling of a planetary body's intrinsic magnetic field, atmosphere, surface, and interior with each other, with other planetary bodies, and with the local plasma environment;
- Technology developments for supporting the understanding of the origins, evolution, and properties of the atmospheres of planetary bodies (including satellites, small bodies, and exoplanets);
- Technology developments for supporting the understanding of the knowledge of the history of the Earth and the life upon it as a guide for determining the processes and conditions that create and maintain habitable environments and to search for ancient and contemporary habitable environments and explore the possibility of extant life beyond the Earth;
- Technology developments for supporting the understanding of the origin and early evolution of life, the potential of life to adapt to different environments, and the implications for life elsewhere;
- Technology developments for supporting the understanding to provide the fundamental research and analysis necessary to characterize exoplanetary systems;
- Technology developments for supporting the understanding of the chemistry, astrobiology, dynamics, and energetics of exoplanetary systems;
- Technology developments for supporting astronomical observations of our Solar System that contribute to the understanding of the nature and evolution of the Solar System and its individual constituents;
- Technology developments for supporting the inventory and characterization of the population of Near Earth Objects (NEOs) or mitigate the risk of NEOs impacting the Earth;
- Technology developments for evaluating and preventing forward and backward contamination during planetary exploration, methods to minimize such contamination, and standards in these areas for spacecraft preparation and operating procedures;
- Technology developments for supporting the enhancement of the scientific return of NASA Planetary Science Division missions through the analysis of data collected by those missions;

- Advancement of laboratory- or spacecraft-based (including small satellites, e.g., CubeSats) instrument technologies that shows promise for use in scientific investigations on future planetary missions; and
- Analog studies, laboratory experiments, or fieldwork to increase our understanding of Solar System bodies or processes and/or to prepare for future missions.

The technologies needed to support NASA Planetary Science Division may be found in the Planetary Science Technology Strategy document (https://www1.grc.nasa.gov/space/pesto/tech-dev-plan/), which includes the Planetary Science Prioritized Technology Focus Areas:

- Instrumentation, with an emphasis on:
  - In Situ Search for Life/Astrobiology
- Sample Containment and Return
  - Planetary Protection and Contamination Control
  - Sample Thermal Management
  - Sample Acquisition and Handling
- Autonomy
  - Global Positioning System (GPS) deprived navigation
  - Surface (planetary) operations
  - On-board science data processing
  - Ground Operations
- Robotics, with an emphasis on Advanced Mobility for:
  - Aerial Platforms
  - Subsurface Access (including drilling)
- Higher-efficiency power conversion technology for radioisotope system

Proposers may also review the information in the ROSES Planetary Science Research Program Overview for further information about the Planetary Science Research Programs. The use of NASA Research Facilities is available to supported investigators (see section IVe Demonstration of Access to Required Facility). If their use is anticipated, this use must be discussed and justified in the submitted proposals and include a letter of support from the facility (or resource) confirming that it is available for the proposed use during the proposed period.

A.4.4 Astrophysics Division

Science Mission Directorate (SMD)

Dr. Hashima Hasan, hhasan@nasa.gov NASA Headquarters (HQ)
Dr. Mario Perez, mario.perez@nasa.gov NASA HQ

NASA's strategic objective in astrophysics is to discover how the universe works, explore how it began and evolved, and search for life on planets around other stars. Three broad scientific questions flow from this objective:

- How does the universe work?
- How did we get here?
- Are we alone?

Each of these questions is accompanied by a science goal that shapes the Astrophysics Division's efforts towards fulfilling NASA's strategic objective:

- Probe the origin and destiny of our universe, including the nature of black holes, dark energy, dark matter and gravity
- Explore the origin and evolution of the galaxies, stars and planets that make up our universe
- Discover and study planets around other stars, and explore whether they could harbor life

To address these Astrophysics goals, the Astrophysics Research Analysis and Technology Program invites a wide range of astrophysics science investigations from space that can be broadly placed in the following categories.

- The development of new technology covering all wavelengths and fundamental particles, that can be applied to future space flight missions. This includes, but is not limited to, detector development, and optical components such as primary or secondary mirrors, coatings, gratings, filters, and spectrographs.
- New technologies and techniques that may be tested by flying them on suborbital platforms such as rockets and balloons that are developed and launched by commercial suborbital flight providers or from NASA's launch range facilities, or by flying them on small and innovative orbital platforms such as cubesats.
- Studies in laboratory astrophysics. Examples of these studies could include atomic and molecular data and properties of plasmas explored under conditions approximating those of astrophysical environments.
- Theoretical studies and simulations that advance the goals of the astrophysics program
- Analysis of data that could lead to original discoveries from space astrophysics missions. This could include the compilations of catalogs, statistical studies, algorithms and pattern recognition, artificial intelligence applications, development of data pipelines, etc.

Citizen Science programs, which are a form of open collaboration in which individuals or organizations participate voluntarily in the scientific process, are also invited. The current SMD Policy (https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/SPD%2033%20Citizen%20Science.pdf) on citizen science describes standards for evaluating proposed and funded SMD citizen science projects. For more information see the https://science.nasa.gov/citizenscience webpage, that provides information about existing SMD-funded projects.

Proposals should address the goals of the Science Mission Directorate's (SMD) Astrophysics Research Program, defined in SMD's Science 2020-2024: A Vision for Scientific Excellence (available at http://science.nasa.gov/about-us/science-strategy). Proposers are encouraged to read this NASA Science Plan, and the report of National Academy of Sciences Decadal Survey on Astronomy and Astrophysics 2020, Pathways to Discovery in Astronomy and Astrophysics for the 2020s,(available at https://www.nap.edu/catalog/26141/pathways- to-discovery-in-astronomy-and-astrophysics for-the-2020s).

Investigations submitted to this program element should explicitly support past, present, or future NASA astrophysics missions. These investigations can include theory, simulation, data analysis, and technology development. Information on the Astrophysics research program and missions are available at https://science.nasa.gov/astrophysics.

A.4.5 Biological and Physical Sciences (BPS)

Dr. Francis Chiaramonte francis.p.chiaramonte@nasa.gov

A.4.5.1 Fundamental Physics

POC: Mike Robinson michael.p.robinson@nasa.gov

Research Overview: Space offers a unique environment for experimental physics in many areas. Current areas of focus for NASA's Fundamental Physics program are cold atom physics, the application of cold atom technologies to research in quantum science and general relativity.

A primary objective of NASA's solicitations in Fundamental Physics is to engage the skills of the U.S. research community to establish and maintain a world-leading program in space-based quantum science. Quantum mechanics is one of the most successful theories in physics. It describes the very small, such as atoms and their formation into the complex molecules necessary for life, to structures as large as cosmic strings. The behavior of exotic matter such as superfluids and neutron stars is explained by quantum mechanics, as are everyday phenomena such as the transmission of electricity and heat by metals. The frontline of modern quantum science involves cross-cutting fundamental and applied research. For example, world-wide efforts concentrate on harnessing quantum coherence and entanglement for applications such as the enhanced sensing of electromagnetic fields, secure communications, and the exponential speed-up of quantum computing. This area is tightly coupled to research on the foundations of quantum mechanics, which involves exotica such as many-worlds theory and the interface between classical and quantum behavior. Another frontier encompasses understanding how novel quantum matter— such as high-temperature superconductivity and topological states—emerges from the interactions between many quantum particles. Quantum science is also central to the field of precision measurement, which seeks to expand our knowledge of the underlying principles and symmetries of the universe by testing ideas such as the equivalence between gravitational and inertial mass.

Quantum physics is a cornerstone of our understanding of the universe. The importance of quantum mechanics is extraordinarily wide ranging, from explaining emergent phenomena such as superconductivity, to underpinning next-generation technologies such as quantum computers, quantum communication networks, and sensor technologies. Laser-cooled cold atoms are a versatile platform for quantum physics on Earth, and one that can greatly benefit from space-based research. The virtual elimination of gravity in the reference frame of a free-flying space vehicle enables cold atom experiments to achieve longer observation times and colder temperatures than are possible on Earth. The NASA Fundamental Physics program plans to support research in quantum physics that will lead to transformational outcomes, such as the discovery of phenomena at the intersection of quantum mechanics and general relativity that inform a unified theory, the direct detection of dark matter via atom interferometry or atomic clocks, and the creation of exotic quantum matter than cannot exist on Earth.

Focus areas for research in fundamental physics:

- Quantum coherence and entanglement
- Quantum interferometry and precision measurements
- Properties of quantum matter
- Quantum phenomena in many-body systems
- Particle Physics
- General Relativity

A.4.5.2 Soft Matter/Complex Fluids

POC: Mike Robinson michael.p.robinson@nasa.gov

Research Overview: Research goals of the soft matter program is to investigate the fundamental principles that organize the structure and functionality of materials such as active and soft mater, and to study the fundamental laws that govern the behavior of systems that are far from equilibrium.

Soft Matter comprises a large class of deformable materials, including colloids, microemulsions, foams, liquid crystals, and granular material. Studying these systems focuses on gaining insight into many diverse fields such as phase transitions, nucleation and crystal growth, coarsening, glass formation, chaos, field theory, dusty plasmas and much more. Complex fluids are a subset of soft materials that can flow and exhibit non-Newtonian rheology. Research in soft matter and complex fluids can provide foundational knowledge for NASA's exploration of planetary surfaces such as, forces on particles, particle charging and agglomeration in complex plasmas or the complex rheology during the flow of a lunar regolith derived slurry to produce construction materials. Furthermore, terrestrial applications are relevant in industries such as pharmaceutical, chemical, plastics, soap and detergent, electronic display, and petroleum. Because of the relatively large size of the basic structures, gravitational forces dominate and cause sedimentation, buoyancy-driven convective flows, hydrostatic pressure gradients, jamming, drainage, etc. Weaker forces such as surface tension and entropic forces, completely masked on Earth, can become dominant in space. In addition, particles can remain suspended without gravitational forces. In weightlessness external fields such as thermal, magnetic, electric and acoustic can be used without the impediments of gravity to create and investigate tunable soft matter (e.g. colloidal) systems.

The research area of soft matter/complex fluids includes the following themes:

- Colloids
- Emulsions
- Liquid crystals
- Foams
- Gels
- Granular flows
- Dusty or complex plasmas

A.4.5.3 Fluid Physics

POC: Brad Carpenter bcarpenter@nasa.gov

Research Overview: The goal of the microgravity fluid physics program is to understand fluid behavior of physical systems in space, providing a foundation for predicting, controlling, and improving a vast range of technological processes. Specifically, in reduced gravity, the absence of buoyancy and the stronger influence of capillary forces can have a dramatic effect on fluid behavior. For example, capillary flows in space can pump fluids to higher levels than those achieved on Earth. In the case of systems where phase-change heat transfer is required, experimental results demonstrate that bubbles will not rise under pool boiling conditions in microgravity, resulting in a change in the heat transfer rate at the heater surface. The microgravity experimental data can be used to verify computational fluid dynamics models. These improved models can then be utilized by future spacecraft designers to predict the performance of fluid conditions in space exploration systems such as air revitalization, solid waste management, water recovery, thermal control, cryogenic storage and transfer, energy conversion systems, and liquid propulsion systems. Some examples include: Nuclear fission Rankine power cycle for future space missions (Moon, Mars) and deep space missions, Vapor Compression heat pump for planetary bases (Moon, Mars), Thermal Control Systems and advanced Life Support Systems for spacecraft and Cryogenic systems, such as nuclear thermal propulsion, fuel depots, tank chill-down.

One of the most important directions of research that is partly addressed by the Zero Boiloff series of experiments is development of innovative and transformative pressure control strategies that allows efficient, reliable and lossless storage and transfer of cryogenic propellants. Understanding the phase change and transport of volatile fluids in microgravity is essential to preserve propellants on orbit and allowing refueling operation is space to carry out and sustain long-duration human planetary exploration missions to Moon, Mars and beyond. The need for scientific understanding and discoveries of liquid/vapor phase change phenomena in the absence of gravity will remain valuable in providing the foundation for development of next generation of light weight thermal management and power generation systems. Novel technologies will be based on multi-physics phenomena, such as the electro-hydrodynamically driven cooling devices. Also, there is a need to develop a fundamental understanding of two-phase flow condensation heat transfer in reduced gravity. Areas of interest include the observation of the condensate film and relevant temperature measurements. Condensation research is relevant to spacecraft thermal control, humidity control, water recovery and certain power generation systems.

NASA has a growing need for improved passive thermal management of electronics, batteries, high capability sensors, power system heat rejection, etc. for future spacecraft and planetary habitat systems. Due to the potential to extract heat at significantly higher heat flux levels, oscillating heat pipes (OHP) offer the promise of significantly higher efficiencies compared to conventional heat pipes used on today's spacecraft. However, the underlying liquid-vapor fluid dynamics (distinct liquid plugs and vapor plugs), interfacial phenomena, and two-phase heat transfer in the pulsating flows of OHPs are not well understood. It is imperative that a physical model that can predict the performance of an OHP be developed. As a first step, NASA is seeking proposals for an instrumented, ground-based OHP experiment to provide insight into the mechanisms, fundamental processes and governing equations. The resulting high-fidelity data will be used for computational fluid dynamics model validation to better predict OHP performance and limits of operation. NASA is currently funding the development of an advanced OHP computer model at JPL. The experimental data from this project will be provided to the JPL OHP numerical modeling team. Specifically, NASA is interested in fundamental experimental research to address some or all of the topics below. The list of needs is given in a somewhat prioritized order. Please note: all OHP proposals must include liquid film characterization.

The research area of fluid physics includes the following themes:

- Adiabatic two-phase flow
- Boiling and condensation
- Capillary flow
- Interfacial phenomena
- Cryogenic propellant storage and transfer

A.4.5.4 Combustion Science

POC: Brad Carpenter bcarpenter@nasa.gov

Research Overview: One of the goals of the microgravity combustion science research program is to improve combustion processes, leading to added benefits to human health, comfort, and safety. NASA's microgravity combustion science research focuses on effects that can be studied in the absence of buoyancy-driven flows caused by Earth's gravity. Research conducted without the interference of buoyant flows can lead to an improvement in combustion efficiency, producing a considerable economic and environmental impact. Combustion science is also relevant to a range of challenges for long-term human exploration of space that involve reacting systems in reduced and low gravity. These challenges include - spacecraft fire prevention; fire detection and suppression; thermal processing of regolith for oxygen and water production; thermal processing of the Martian atmosphere for fuel and oxidizer production; and processing of waste and other organic matter for stabilization and recovery of water, oxygen and carbon. Substantial progress in any of these areas will be accelerated significantly by an active reduced-gravity combustion research program.

Research is needed in the flammability of solid fuels to advance fire safety research. Specifically, testing is necessary to understand the fire performance of representative spacecraft and planetary habitat materials at all g-levels (Microgravity, Lunar, Martian, and Earth gravity). Study is needed of these materials at a research level - ignition, flame spread, size, heat output, radiation, O2 level, g level, etc. In 1-g and drop tower. Also, to organize results by type of materials. Also, to use these gravity dependent data for the improvement of computational models. The goal is to use the experimental results and numerical simulations to support NASA material flammability testing, material controls, and habitat/vehicle designs which depend on g-level. Use of the NASA Glenn Research Center (GRC) drop is a useful method to achieve 5 seconds of microgravity and, with the use of the centrifuge drop rig, any partial gravity levels as well. The POCs for the GRC 5 second drop tower facility are David Urban, david.urban@nasa.gov and Nancy Hall, nancy.r.hall@nasa.gov

Research is needed to develop carbon-free and carbon-neutral transportation fuels. Airlines have committed to reduce carbon emissions by 50% by 2050 (relative to 2005 levels). Doing this requires (1) moving to carbon-neutral feedstocks that are drop-in replacements for petroleum-based fuels (PBFs, i.e., biofuels that have a closed-carbon cycle) and (2) moving whenever possible to carbon-free fuels (e.g., ammonia) that have no carbon footprint. Given the capital cost of aircraft an airplane put into service today will still be in operation 20+ years from today. There are needs for drop-in replacements for PBFs that will enable current generation aircraft to remain in service for their entire service life. Low-gravity research proposals that will improve our understanding of the kinetics, flame structure, and product emission from carbon-free and carbon-neutral fuels will facilitate use of these fuels in the transportation sector.

The research area of combustion science includes the following themes:

- Spacecraft fire safety
- Droplets
- Gaseous – premixed and non-premixed
- High pressure – transcritical combustion and supercritical reacting fluids
- Solid fuels
- Carbon free fuels

A.4.5.5 Materials Science

POC: Brad Carpenter BCarpenter@nasa.gov

Research Overview: The goal of the microgravity materials science program is to improve the understanding of materials properties that will enable the development of higher-performing materials and processes for use both in space and on Earth. The program takes advantage of the unique features of the microgravity environment, where gravity-driven phenomena, such as sedimentation and thermosolutal convection, are nearly negligible. On Earth, natural convection leads to dendrite deformation and clustering, whereas in microgravity, in the absence of buoyant flow, the dendritic structure is nearly uniform. Major types of research that can be investigated include solidification effects and the resulting morphology, as well as accurate and precise measurement of thermophysical property data. These data can be used to develop computational models. The ability to predict microstructures accurately is a promising computational tool for advancing materials science and manufacturing.

Research is needed to demonstrate the feasibility of creating lunar construction "concrete" materials by alkali-activation of regolith simulant. Specifically, to conduct 1-g ground studies to understand the solidification, microstructure and properties of the construction material using alternative binders (regolith simulant replacing cement) and alkaline solution (replacing water) to form a geopolymer. Also, to measure the mechanical properties of the solidified material. Future applications of lunar construction materials include launch pads, habitats, and other components of lunar infrastructure. The research area of materials science includes the following themes:

- Glasses and ceramics
- Granular materials
- Composite materials
- Metals
- Polymers and organics
- Semiconductors

A.4.5.6 Growth of plants in "deep space-relevant" Earth soils or conditions

POC: Sharmila Bhattacharya SpaceBiology@nasaprs.com

Research Overview: As human exploration continues to move further out beyond Low Earth Orbit (BLEO), exploration missions will need to become increasingly self-sufficient, and will not be able to rely as heavily on resupply efforts from Earth, as they now do within Low Earth Orbit (LEO). The NASA Space Biology Program is interested in basic research that will ultimately translate into the ability to grow edible plants and crops in deep space environments. Research supported by our program has already demonstrated that 1) edible plants can be grown in the LEO environment of the International Space Station (Massa *et al*., 2017), and that 2) model (non-edible) plant organisms can germinate from seeds planted in lunar regolith obtained from the Apollo 11, 12, and 17 missions (Paul *et al.*, 2022; for a historic perspective refer to Ferl and Paul, 2010). While both these results are very promising, there is still much work that needs to be done to move exploration efforts to the point where astronauts can begin to think about practicing agriculture in harsh deep space environments such as the lunar and Martian surfaces.

While much of Space Biology's funded plant research efforts have focused on experiments conducted in spacecraft, or in the presence of simulated spaceflight/deep-space stressors, the program is interested in exploring other potential niches that exist here on Earth that may provide important insights into how both plants and the surrounding environment can be manipulated to support crop growth under harsh, inhospitable conditions. As early humans spread out across the globe, they have repeatedly encountered extreme environments that were far from being innately supportive of agriculture and settlement. Despite these challenges, humans have often found ways to live and even flourish in such environments, either by finding food sources that were robust enough to grow under such conditions, and/or by altering the terrain through irrigation and natural farming (soil modification with natural composts, crop rotation, etc.) to enable crop growth. Therefore, for this research focus area, Space Biology is soliciting proposals that will provide insights into how plants grow and continue to adapt to Earth's extreme geochemically diverse environments, as well as how these environments can be manipulated to support such growth.

Research Focus: This Space Biology Research Emphasis requests proposals for hypothesis-driven studies that will either provide a better understanding of the mechanisms by which some plants are able to grow and thrive in extreme or geochemically diverse environments on Earth or will identify plants and/or alternative methods that can be used to facilitate plant/crop growth in such extreme environments. Ideally, studies funded from this opportunity will in the future translate to improved agricultural methods and tools that can be utilized in extreme environments on Earth and eventually in harsh environments of the lunar and Martian surfaces.

Such topics of study may include, but are not limited to:

- Characterizing the molecular and/or biological mechanisms by which plants already known for their agricultural robustness are able to grow in soil types found in Earth's more extreme environments, including volcanic soils and sands (deserts), clay, etc. Particular emphasis may be given to edible plants.
- Identifying new plants that are able to grow in such soil samples and characterizing their growth and vitality.
- Genetic modification of plants to improve growth and robustness in such soils.
- Identifying or engineering microbiomes that will optimize plant growth and vitality in such soils.
- Testing or developing new composting methods or other natural methods to enrich such soils which will enable them to better support plant growth.

If logistics and costs permit, proposed studies may be conducted on location directly in the types of environments mentioned above, however, proposed studies may also use soil samples collected (or purchased) from these environments. It will be up to the proposer to identify the extreme environment/soil samples they will use for their studies, as well as provide justification in their proposal as to why these environments/soils were chosen and have relevance to space exploration.

Additional Information: While the Space Biology Program can be contacted at SpaceBiology@nasaprs.com for general questions about this RFA, the program itself is not able to foster collaborations between applicants and NASA scientists or NASA-funded scientists. If potential applicants are seeking to establish such collaborations for their project, then we recommend that they consult the NASA Task Book (at https://taskbook.nasaprs.com) to identify potential collaborators. The NASA Task Book is a database that contains information about all the projects that the NASA Space Biology Program has funded since 2004. Here applicants will also find the names of investigators that have been funded by our program as well as their contact information.

All publications that result from an awarded EPSCOR study shall acknowledge the Space Biology Program within NASA's Biological and Physical Science (BPS) Division. If the NASA GeneLab Data Systems (genelab.nasa.gov) is used, GeneLab shall be referenced in the resulting publication and included in the keyword list. All omics data obtained from this study shall be uploaded to the NASA GeneLab (https://genelab.nasa.gov).

References:

Ferl RJ, Paul AL. Lunar plant biology--a review of the Apollo era. Astrobiology. 2010 Apr;10. doi/10.1089/ast.2009.04173:261-73. doi: 10.1089/ast.2009.0417.

Massa GD, Dufour NF, Carver JA, Hummerick ME, Wheeler RM, Morrow RC, Smith TM. VEG-01: Veggie hardware validation testing on the International Space Station. Open Agriculture. 2017 Feb;2(1):33-41. doi.org/10.1515/opag-2017-0003 , Feb-2017.

Paul AL, Elardo SM, Ferl R. Plants grown in Apollo lunar regolith present stress-associated transcriptomes that inform prospects for lunar exploration. Commun Biol. 2022 May 12;5(1):382. doi: 10.1038/s42003-022-03334-8. PMID: 35552509; PMCID: PMC9098553.

A.4.5.7 The impact of space-associated stressors on energy metabolism and oxidative stress

POC: Sharmila Bhattacharya SpaceBiology@nasaprs.com

Research Overview: The spaceflight environment is known to impose cellular and physiological changes in living systems that are common across species and even across the taxonomic biological kingdoms. These changes can not only adversely impact the well-being of entire organisms, but of entire ecosystems in spacecraft and planetary habitats. In order to help enable life to thrive in space, an understanding of both the effects of these changes, and the mechanisms by which these changes occur, is critical. Recent Space Biology-funded research that employed muti-omics and system biology approaches to profile the transcriptomic, proteomic, metabolomic, and epigenetic responses to spaceflight in tissue samples collected from astronauts, as well as other organisms flown in space, showed that mitochondrial dysfunction is a common consequence of exposure to the spaceflight environment across diverse biological systems (da Silveira *et al*., 2020). These results, however, are not the only findings that indicate that space travel has an impact on biological pathways responsible for cellular and physiological energy metabolism. There are a plethora of studies demonstrating that exposure to space-associated stressors induces oxidative stress and changes within the biological pathways responsible for redox responses in plant, animal, and fungal model systems (Choi *et al.*, 2019; Hateley, *et al*., 2016; Tahimic and Globus, 2017; Nislow et al., 2015), which both regulate and are regulated by mitochondrial function. Furthermore, additional research with the plant model *Arabidopsis thaliana* has shown that exposure to microgravity downregulates the expression of genes encoding proteins associated with the chloroplast (Land *et al*., 2024), thus providing mechanistic data of how space-associated stressors can impact photosynthesis.

While these studies have provided important clues on how the stressors encountered during space exploration dysregulate energy metabolism and homeostasis, a mechanistic understanding of how these stressors, either individually or in combination, contribute to this dysregulation and the impact that such dysregulation has on the overall health of an organism is needed. Therefore, for this research focus area, Space Biology is soliciting ground-based proposals that elucidate the effects of spaceflight related stressors on energy metabolism and/or oxidative stress.

Research Focus: This Space Biology Research Emphasis requests proposals for hypothesis-driven studies that will characterize the impacts that stressors associated with space exploration have on cellular energy metabolism and/or redox responses, and how changes in these processes impact the overall health of an entire organism, or in the case of microbial studies, the health of individual microbes or of communities containing multiple microbes. Such stressors may include, but are not limited to, simulated microgravity or partial gravity, changes in atmospheric pressure or composition (*i.e.*, oxygen and carbon dioxide concentrations), hypoxia, and ionizing radiation (radiation sources that are easily accessible in a laboratory environment, such as X-ray or gamma radiation, can be used).

Such topics of study may include, but are not limited to:

- Characterizing how space-relevant stressors impact mitochondrial integrity and function in eukaryotic organisms, and how changes in these properties impact the overall fitness of the entire organism (within plant/animal/microbial models) or of an entire community (within unicellular models).
- Characterizing how space-associated stressors impact the accumulation of reactive oxygen species cellular redox responses, and how changes in these properties impact the overall fitness of the entire organism (within plant/animal models) or of an entire community

(within unicellular models).

- Characterizing how space-associated stressors impact chloroplast integrity and function in plant model systems, and how changes in these properties impact the overall fitness of the entire organism.
- Characterizing the response of prokaryotic organisms to these stressors with the goal of gaining a heuristic understanding of how such stressors impact energy-related metabolic pathways.
- The identification of cross species biosignatures in response to oxidative stress or stressors that impact energy metabolism/homeostasis.

Investigators are also welcome to propose additional types of studies, including those that focus on other cellular components or processes, as long as the overall research focus of the proposed project address the emphasis of this RFA, which is how spaceflight stressors impact energy metabolism/homeostasis and/or oxidative stress/redox responses. Applicants may propose to use any plant or microbial model system for their studies, but animal models will be limited to cell cultures or invertebrates (excluding cephalopods), and applicants will be expected to include their rationale and justification for their choice of model system, and space-relevant variables to be tested in their proposal.

Additional Information: While the Space Biology Program can be contacted at SpaceBiology@nasaprs.com for general questions about this RFA, the program itself is not able to foster collaborations between applicants and NASA scientists or NASA-funded scientists. If potential applicants are seeking to establish such collaborations for their project, then we recommend that they consult the NASA Task Book (at https://taskbook.nasaprs.com) to identify potential collaborators. The NASA Task Book is a database that contains information about all the projects that the NASA Space Biology Program has funded since 2004. Here applicants will also find the names of investigators that have been funded by our program as well as their contact information.

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References:

Choi, W-G, Barker, RJ, Kim S-H, Swanson, SJ, Gilroy, S. Variation in the transcriptome of different ecotypes of Arabidopsis thaliana reveals signatures of oxidative stress in plant responses to spaceflight. Botany. 2019. 106(1): 123-136. DOI: 10.1002/ajb2.1223

da Silveira WA,…Beheshti A. Comprehensive Multi-omics Analysis Reveals Mitochondrial Stress as a Central Biological Hub for Spaceflight Impact. Cell. 2020. 183(5): 1185-1201 DOI:10.1016/j.cell.2020.11.002

Hateley S, Hosamani R, Bhardwaj SR, Pachter L, Bhattacharya S. Transcriptomic response of Drosophila melanogaster pupae developed in hypergravity. Genomics. 2016. 108(3-4):158-167. DOI: 10.1016/j.ygeno.2016.09.002

Land ES, Sheppard J, Doherty CJ, Perera IY. Conserved plant transcriptional responses to microgravity from two consecutive spaceflight experiments. Front Plant Sci. 202. 14:130871 DOI:

10.3389/fpls.2023.1308713.

Nislow C, Lee AY, Allen PL, Giaever G, Smith A, Gebbia M, Stodieck LS, Hammond JS, Birdsall HH, Hammond TG. Genes required for survival in microgravity revealed by genome-wide yeast deletion collections cultured during spaceflight. Biomed Res Int. 2015;2015:976458. DOI: 10.1155/2015/976458.

A.4.5.8 The role of genetic diversity in enabling life to thrive in space

POC: Sharmila Bhattacharya SpaceBiology@nasaprs.com

Research Overview: While model systems provide an invaluable tool for helping researchers gain an understanding of how biological systems respond to the harsh environmental factors and stressors that may be encountered during space exploration, much of this research has been conducted using specimens with limited genetic diversity. For example, many animal and plant studies use inbred strains/lines or specific cultivars, respectively, and many microbiology studies use organisms that have the same genetic background, or groups of organisms with limited genetic variability between them. The use of such specimens for initial studies is both appropriate and necessary to reduce variability caused by genetic diversity, which can contribute to "noisy" data when trying to characterize the impacts that multiple space-associated stressors have on biological systems. However, in natural populations, organisms within a single species can be highly genetically diverse and this diversity can translate into vastly different responses to the same stressor among individuals. Therefore, for this research focus area, Space Biology is soliciting proposals that will characterize how genetic diversity impacts the ability of organisms to respond to space-associated stressors as well as how genetic diversity impacts the organism overall fitness under these conditions.

Research Focus: This Space Biology Research Focus Area requests proposals for hypothesis-driven studies that will increase our understanding of how genetic variability or different genetic background modulates an organism's ability to respond to environmental stressors encountered during space exploration. Such stressors may include, but are not limited to, simulated microgravity or partial gravity, changes in atmospheric pressure or composition (*i.e.*, oxygen and carbon dioxide concentrations), hypoxia, and ionizing radiation (radiation sources that are easily accessible in a laboratory environment, such as X-ray or gamma radiation, can be used).

Such topics of study may include, but are not limited to:

- Comparing the responses (and the resulting overall fitness) of multiple genetic backgrounds within a single species to space-associated stressors.
- Following up on previously published observations regarding an organism's response to space-associated stressors and testing how different genetic background/mutations alter that response.
- Use of forward/and or reverse genetic approaches to identify genes or family/subset of genes that modulate an organism's overall fitness in and response to the presence of space-associated stressors.
- Using synthetic biology approaches to engineer organisms that are better able to tolerate exposure to space-associated stressors.
- Population studies using microbes or plant/animal models with a quick generation time to examine how genetic diversity impacts overall survival, fitness and/or evolution in the presence of space-associated stressors.

Investigators are also welcome to propose additional types of studies as long as the overall research focus of the proposed project address the emphasis of this RFA, which is how genetic diversity enables life to thrive in space. Applicants may propose to use any plant or microbial model system for their studies, but animal models will be limited to cell cultures or invertebrates (excluding cephalopods), and applicants will be expected to include their rationale and justification for their choice of model system, and space-relevant variables to be tested in their proposal.

Additional Information: While the Space Biology Program can be contacted at SpaceBiology@nasaprs.com for general questions about this RFA, the program itself is not able to foster collaborations between applicants and NASA scientists or NASA-funded scientists. If potential applicants are seeking to establish such collaborations for their project, then we recommend that they consult the NASA Task Book (at https://taskbook.nasaprs.com/) to identify potential collaborators. The NASA Task Book is a database that contains information about all the projects that the NASA Space Biology Program has funded since 2004. Here applicants will also find the names of investigators that have been funded by our program as well as their contact information.

All publications that result from an awarded EPSCOR study shall acknowledge the Space Biology Program within NASA's Biological and Physical Science (BPS) Division. If the NASA GeneLab Data Systems (genelab.nasa.gov) is used, GeneLab shall be referenced in the resulting publication and included in the keyword list. All omics data obtained from this study shall be uploaded to the NASA GeneLab (https://genelab.nasa.gov).

A.5 Space Technology Mission Directorate (STMD)

POC: Damian Taylor, Damian.Taylor@nasa.gov

The Space Technology Mission Directorate (STMD) is where technology drives exploration and the space economy; and aims to transform future missions while ensuring American leadership in aerospace.

STMD rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise. STMD employs a merit-based competition model with a portfolio approach, spanning a range of discipline areas and technology readiness levels. By investing in bold, broadly applicable, disruptive technology that industry cannot tackle today, STMD seeks to mature the technology required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost for other government agencies and commercial space activities.

Research and technology development takes place within NASA Centers, at JPL, in academia and industry, and leverages partnerships with other government agencies and international partners. STMD engages and inspires thousands of technologists and innovators creating a community of our best and brightest working on the nation's toughest challenges. By pushing the boundaries of technology and innovation, STMD allows NASA and our nation to remain at the cutting edge. Additional information on STMD can be found at: https://www.nasa.gov/directorates/

STMD looks to engage new and diverse partners to garner different perspectives and approaches to our biggest technology challenges. An overarching principle guiding STMD's work is our commitment to inspiring and developing a diverse and powerful US aerospace technology community. As part of our strategic approach, STMD is committed to empowering innovators by expanding our work with and support for underrepresented communities. Furthermore, we are focused on demonstrating engaging practices for underserved and underrepresented communities through the R&D process that strengthens and supports economic growth for a diverse technology community. This is paramount to our ***Lead*** strategic thrust through which ***Go***, ***Land***, ***Live*** and ***Explore*** thrusts are realized.

STMD plans future investments to support our strategic thrusts as follows:

Lead: *Ensuring American global leadership in Space Technology*

- Advance US space technology innovation and competitiveness in a global context: Address national aerospace challenges; Enable rapid and efficient technology development; Take risks; capture and disseminate knowledge.
- Encourage technology driven economic growth with an emphasis on the expanding space economy: Foster the creation and growth of aerospace businesses; Increase the commercialization of NASA-supported technologies; Partner in innovative ways for research and development to expand the aerospace sector; Collaborate with stakeholders in geographic communities across the country.
- Inspire and develop a diverse and powerful US aerospace technology community: Make it easier for all U.S. individuals and organizations to contribute to NASA technology development; Increase representation of diverse and non-traditional groups across STMD's portfolio to leverage creativity and innovation from across America; Cultivate a pipeline of technologists and innovators.

- ***Go***: *Rapid, Safe, & Efficient Space Transportation*
  - Space Nuclear Propulsion: Develop nuclear technologies enabling fast in-space transits.
  - Cryogenic Fluid Management: Develop cryogenic storage, transport, and fluid management technologies for surface and in-space applications.
  - Advance Propulsion: Produce advanced propulsion technologies that enable future science/exploration missions.

- ***Land***: *Expanded Access to Diverse Surface Destinations*
  - Precision Landing and Hazard Avoidance: Develop capabilities to enable lighting-independent precise landing on any terrain.
  - Entry, Descent, and Landing to Enable Science Missions: Develop capabilities enabling small to large missions to efficiently enter any atmospheres and/or land on surfaces within our solar system.
  - 20t and Lunar/Mars Global Access: Develop capabilities to support global access to the moon and Mars including accurate prediction of plume surface interaction.

- ***Live***: *Sustainable Living and Working Farther from Earth*
  - Advanced Habitation Systems (AHS): Keep astronauts healthy and productive while living in space and planetary vehicles.
  - In-Situ Resource Utilization: Develop scalable ISRU production/utilization capabilities including sustainable commodities on the lunar and Mars surface.
  - Power and Energy Storage Systems: Develop sustainable power sources and other surface utilities to enable continuous in-space and lunar and Mars surface operations.
  - Thermal Management Systems: Develop thermal management technologies that enable surviving the extreme in-space and lunar and Mars surface environments.
  - Excavation, Construction, and Outfitting (ECO): Develop methodologies for moving regolith for in-situ purposes such as commodities extraction and constructing infrastructure like roads, foundations and structures using in-situ resources.
  - Surface Systems: Develop surface support systems to enable long duration surface stays.
- ***Explore***: *Transformative Missions and Discoveries*

- Advanced Avionics: Develop advanced avionics to meet agency objectives, including radiation-hardened spaceflight computing technologies.
- Advanced Manufacturing: Develop both terrestrial and in-space manufacturing technologies to make commercial and exploration missions more capable and affordable.
- Autonomous Systems and Robotics: Develop autonomy and robotics technologies that enable and enhance the full range of science and exploration missions (both with and without crew).
- Communications and Navigation: Develop communication, navigation, and timing approaches to support diverse asset (human or robotic) needs including establishing asset location in-space.
- In-space Servicing, Assembly, and Manufacturing (ISAM) and Rendezvous, Proximity Operations, and Capture (RPOC): Develop technologies for in-space creation, maintenance, and evolution of space assets leveraging expanding in-space infrastructure.
- Small Spacecraft Technologies: Develop technologies for small spacecraft and responsive launch to rapidly expand space capabilities at dramatically lower costs.
- Sensors, Instruments, and Observatories: Develop technologies for science instrumentation supporting new discoveries.

Furthermore, the above strategic thrusts describe the STMD investment priority strategy and are further detailed in the Strategic Technology Architecture Roundtable (STAR) Process: https://techport.nasa.gov/framework.

STMD's Principal Technologists and System Capability Leads are available for consultation with proposers regarding the state-of-the-art, on-going activities and investments, and strategic needs in their respective areas of expertise. Proposers are encouraged to consult with the appropriate PT or SCLT early in the proposal process.

STMD POC	Technology Area	NASA Email
John Vickers	Advanced Manufacturing	john.h.vickers@nasa.gov
Danette Allen	Autonomous Systems	danette.allen@nasa.gov
Wes Powell	Avionics	wesley.a.powell@nasa.gov
Bernie Edwards	Communications & Navigation	bernard.l.edwards@nasa.gov
Jason Mitchell	Communications & Navigation	jason.w.mitchell@nasa.gov
Arthur Werkheiser	Cryo Fluid Management	arthur.werkheiser@nasa.gov
Kristen John	Dust Mitigation	kristen.k.john@nasa.gov
Michelle Munk	Entry, Descent and Landing (EDL)	michelle.m.munk@nasa.gov
Mike Wright	Entry, Descent and Landing (EDL)	michael.j.wright@nasa.gov
John Carson	EDL Precision Landing	john.m.carson@nasa.gov
Jim Broyan	Environmental Control and Life Support System (ECLSS) Lead	james.l.broyan@nasa.gov
Mark Hilburger	Excavation, Construction and Outfitting (ECO)	mark.w.hilburger@nasa.gov
Julie Kleinhenz	In Situ Resource Utilization	julie.e.kleinhenz@nasa.gov
Jerry Sanders	In Situ Resource Utilization	gerald.b.sanders@nasa.gov
John Dankanich	In Space Transportation	john.dankanich@nasa.gov
Jeremiah McNatt	Power	jmcnatt@nasa.gov
Ron Litchford	Propulsion Systems	ron.litchford@nasa.gov
Bo Naasz	Rendezvous & Capture	bo.j.naasz@nasa.gov

Josh Mehling	Robotics	joshua.s.mehling@nasa.gov
Denise Podolski	Sensors/Radiation/Quantum	denise.a.podolski@nasa.gov
Mark Hilburger	Structures/Materials;	mark.w.hilburger@nasa.gov
Angela Krenn	Surface Systems	angela.g.krenn@nasa.gov
Angela Krenn	Thermal	angela.g.krenn@nasa.gov

In recognition of NASA's leadership in developing advanced technologies for the benefit of all, research topics related to advancing national capabilities in the following climate-related and addressing orbital debris technology areas are of interest:

- Clean Energy and Emissions Technologies: Clean energy and emissions mitigation technology projects focusing on the research and development, demonstration, or deployment of systems, processes, best practices, and sources that reduce the amount of greenhouse gas emitted to, or concentrated in, the atmosphere.

- U.S. Climate Change Research Program: Earth-observing capabilities to support breakthrough science and National efforts to address climate change.
  - Specific topic areas could include:
    - Reductions in greenhouse gas emissions (including CO2, CH4, N2O, HFCs)
      - Fuel Cells
      - Batteries and Energy Storage
      - Carbon Capture, Utilization, and Storage
      - Processes that enhance industrial efficiency and reduce emissions
      - Production of clean energy including solar, hydrogen, nuclear, or other clean energy sources
    - Enabling platforms and early-stage instruments for climate-relevant science observations

- Addressing Orbital Debris: Control the long-term growth of debris population.

- POCs for additional information:
  - Clean energy: Jeremiah Mcnatt (jmcnatt@nasa.gov)
  - Nuclear systems: Anthony Calomino (anthony.m.calomino@nasa.gov)
  - Hydrogen: Jerry Sanders (gerald.b.sanders@nasa.gov)
  - Earth-observing capabilities: Chris Baker (christopher.e.baker@nasa.gov), Justin Treptow (justin.treptow@nasa.gov)
  - Carbon capture and utilization: James Broyan (james.l.broyan@nasa.gov)
  - Harnessing data for improved visualization: Lawrence Friedl (SMD) (lfriedl@nasa.gov)
  - Addressing Orbital Debris: Bo Naasz (Bo.j.naasz@nasa.gov)

Applicants are strongly encouraged to familiarize themselves with the 2020 NASA Technology Taxonomy (replaced the 2015 NASA Technology Roadmaps) and the NASA Strategic Technology Framework that most closely aligns with their space technology interests. The 2020 NASA Technology Taxonomy may be downloaded at the following link: https://www.nasa.gov/offices/oct/taxonomy/index.html. The NASA Strategic Technology Framework, including presentations describing the Envisioned Future and strategy for addressing each of the STMD capability areas and outcomes, can be found at: https://techport.nasa.gov/framework.

The National Aeronautics and Space Administration (NASA) Space Technology Mission Directorate (STMD) current year version of the NASA Research Announcement (NRA) entitled, "Space Technology Research, Development, Demonstration, and Infusion" has been posted on the NSPIRES web site at: http://nspires.nasaprs.com (select "Solicitations" and then "Open Solicitations"). The NRA provides detailed information on specific proposals being sought across STMD programs. Specifically, STMD supports research from universities through a number of other solicitations from early stage programs such as NASA's Innovation Corps Pilot, NASA Innovative Advanced Concepts, Space Technology Research Grants, Small Business Technology Transfer, and Lunar Surface Innovation Consortium. Additionally, here's a link to other STMD program opportunities that potentially could benefit from university research ideas.

A.6 NASA Centers Areas of Interest

"Engagement with Center Chief Technologists and the Agency Capability Leadership Teams is critical to value of the research and selection of proposals." Examples of Center research interest areas include these specific areas from the following Centers. If no POC is listed in the Center write-up and contact information is needed, please contact the POC listed in Appendix D for that Center and request contacts for the research area of interest.

A.6.1 Ames Research Center (ARC)

POC: Harry Partridge, harry.partridge@nasa.gov

- Entry systems: Safely delivering spacecraft to Earth & other celestial bodies
- Advanced Computing & IT Systems: Enabling NASA's advanced modeling and simulation
  - Supercomputing
  - Quantum computing, quantum sensors and quantum algorithms
  - Applied physics and Computational materials
- **Aero sciences**:
  - Wind Tunnels: Testing on the ground before you take to the sky
- **Air Traffic Management**:
  - NextGen air transportation: Transforming the way we fly
  - Airborne science: Examining our own world & beyond from the sky
  - Airspace Systems, Unmanned aerial Systems
- **Astrobiology and Life Science**: Understanding life on Earth - and in space
  - Biology & Astrobiology
  - Space radiation health risks
  - Biotechnology, Synthetic biology
  - Instruments
- Cost-Effective Space Missions: Enabling high value science to low Earth orbit & the moon
  - Small Satellites, Cube satellites
- **Intelligent/Adaptive Systems**: Complementing humans in space
  - Autonomy & Robotics: Enabling complex air and space missions, and complementing humans in space
  - Human Systems Integration: Advancing human-technology interaction for NASA missions
  - Nanotechnology-electronics and sensors, flexible electronics
- **Space and Earth Science:** *Understanding our planet, our solar system and everything beyond*

- **Exoplanets**: Finding worlds beyond our own
- **Airborne Science**: Examining our own world & beyond from the sky
- Lunar Sciences: Rediscovering our moon, searching for water

A.6.2 Armstrong Flight Research Center (AFRC)

POC: Timothy Risch, timothy.k.risch@nasa.gov

POC	**Technology Area**	**Email**
Sean Clarke	Hybrid Electric Propulsion	sean.clarke@nasa.gov
Ed Hearing	Supersonic Research (Boom mitigation and measurement)	edward.a.haering@nasa.gov
Dan Banks	Supersonic Research (Laminar Flow)	daniel.w.banks@nasa.gov
Larry Hudson	Hypersonic Structures & Sensors	larry.d.hudson@nasa.gov
Matt Boucher Jeff Ouellette	Control of Flexible Structures, Modeling, System Identification, Advanced Sensors	matthew.j.boucher@nasa.gov jeffrey.a.ouellette@nasa.gov
Nelson Brown	Autonomy (Collision Avoidance, Perception, and Runtime Assurance)	nelson.brown@nasa.gov
Curt Hanson	Urban Air Mobility (UAM) Vehicle Handling and Ride Qualities	curtis.e.hanson@nasa.gov
Shawn McWherter	Urban Air Mobility (UAM) Envelope Protection	shaun.c.mcwherter@nasa.gov
Peter Suh Kurt Kloesel	Aircraft Electrical Powertrain Modeling	peter.m.suh@nasa.gov kurt.j.kloesel@nasa.gov
Bruce Cogan	Un-crewed Aerial Platforms for Earth and Planetary Science Missions	bruce.r.cogan@nasa.gov

A.6.3 Glenn Research Center (GRC)

POC: Briggs, Maxwell H. (GRC-T000) maxwell.h.briggs@nasa.gov

- **Power and Energy Storage Systems for Aviation and Space Applications:** sustainable, reduced- and zero-carbon emission approaches, substantial mass and efficiency improvements, and operability in challenging environments
- **Power System Architectures, Networks, and Systems Management and Integration Approaches:** including microgrids and power conversion and management electronics
- **Breakthrough Concepts in Photovoltaics, Electrochemistry, Photocatalysis, Photo/Thermal Energy Conversion:** including enabling manufacturing approaches and integration
- **Electronics for Extreme Temperature Environments:** devices, components, and subsystems
- **Microwave, Optical, and Cognitive Communications Devices, Components, and Systems:** expanded bandwidth and reductions in size and power consumption
- **Quantum Sensors, Communications, and Networks:** devices and simulations
- **Communication Architectures, Networks, and Systems:** integration and simulation
- **Intelligent and Autonomous Systems:** smart sensors, extreme environment instruments
- **Advanced Concepts in Systems Engineering for Aeronautical and Space Systems:** physics-based models, machine learning, and artificial intelligence applications
- **Electrified Aircraft:** architectures, components, systems, and system-level simulations
- **Space-Based Electric Propulsion:** advanced materials, components, and systems
- **Cryogenic Fluid Systems:** components, systems, and cryofluid management simulations
- **Thermal Management Systems:** propulsion and/or power systems for aviation and space
- **Acoustic Emission Mitigation:** aviation and space propulsion applications
- **Aircraft Icing:** prevention, mitigation, and simulation
- **Aviation Safety:** simulation, system concepts, architectures
- **Advanced Computational Fluid Dynamics and Systems Engineering** related to aviation propulsion systems including internal and external aerodynamics, aero-thermochemistry
- **Multi-Functional Materials:** concepts, components, and simulations engaging mechanical, structural, electrical, thermal, energy, communications, or propulsion features, especially including applications enabled by advanced manufacturing processes
- **Shape Memory Alloy Utilization:** actuation, harsh environments, high-strain applications
- **Advanced Metallic Alloy, Ceramic, Macromolecular, and Composite Materials and Coatings:** for extreme environments, especially where enabled by advanced manufacturing processes
- **Nanotechnology Applications:** enhanced mechanical, thermal, electrical, chemical, electrochemical, or catalytic properties
- **Fundamentals of Fluid Physics, Combustion Phenomena, Complex Fluids, and Bioengineering** in reduced- or near-zero gravitational environments
- **Transformational Technologies** such as In-Situ Resource Utilization ((ISRU), in-Space Assembly and Manufacturing (ISAM), and Thermal Management, that are optimized for reduced-gravity environments

A.6.4 Goddard Space Flight Center (GSFC)

A.6.4.1 Engineering Technology Directorate (ETD)

POC: Denise Cervantes, Ph.D. denise.cervantes@nasa.gov

NASA Goddard Space Flight Center is home to the nation's largest organization of scientists, engineers, and technologists who conceive, design and build new technology to study the solar system and universe.

The Engineering and Technology Directorate (ETD) is the engine that powers Goddard. ETD is the largest organization at Goddard and is home to approximately 1,300 engineers who provide multidisciplinary engineering expertise to NASA's many missions. Goddard has six distinctive facilities & installations. ETD has employees at the Greenbelt main campus in Maryland, Wallops Flight Facility in Virginia, and White Sands Test Facility Ground Stations in New Mexico.

ETD provides multi-disciplinary engineering expertise for the development of cutting-edge science and exploration systems and technologies in the following areas: Earth Science, Astrophysics, Solar System, Heliophysics and Exploration. In addition, ETD acquires and distributes science data worldwide. Goddard encompasses major laboratories and facilities for developing and operating unmanned scientific spacecraft.

GSFC ETD POCS:

- Code 500/GSFC ETD Workforce Development & OSTEM/Higher Education Manager, Dr. Denise Cervantes, denise.cervantes@nasa.gov
- Code 500/GSFC ETD Chief Technologist, Michael Johnson, michael.a.johnson@nasa.gov
    - Code 500/ETD Wallops Flight Facility Engineering Division
        - Associate Chief Technologist, Sarah Wright, sarah.wright@nasa.gov
    - Code 540/ETD Mechanical Systems Division
        - Associate Chief Technologist, Dr. Vivek Dwivedi, vivek.h.dwivedi@nasa.gov
    - Code 550/ETD Instrument Systems and Technology Division
        - Associate Chief Technologist, Renee Reynolds, renee.m.reynolds@nasa.gov
    - Code 560/ETD Electrical Engineering Division
        - Associate Chief Technologist, Chris Green, christopher.m.green-1@nasa.gov
    - Code 580/ETD Software Engineering Division
        - Associate Chief Technologist, Karin Blank, karin.b.blank@nasa.gov
    - Code 590/ETD Mission Engineering and Systems Analysis Division
        - Associate Chief Technologist, Cheryl Gramling, cheryl.j.gramling@nasa.gov
- Code 500/GSFC ETD New Business Leads
    - Code 500/ETD Wallops Flight Facility Engineering Division
        - WFF New Business Lead, Benjamin Cervantes, benjamin.w.cervantes@nasa.gov
    - Code 540/ETD Mechanical Systems Division
        - New Business Lead, Sharon Cooper, sharon.cooper@nasa.gov
    - Code 550/ETD Instrument Systems and Technology Division
        - New Business Lead, Dr. Aprille Ericsson, aprille.j.ericsson@nasa.gov
    - Code 560/ETD Electrical Engineering Division
        - New Business Lead, Marcellus Proctor, marcellus.proctor@nasa.gov
    - Code 580/ETD Software Engineering Division
        - New Business Lead, Steve Tompkins, steven.d.tompkins@nasa.gov
    - Code 590/ETD Mission Engineering and Systems Analysis Division
        - New Business Lead, Peter Knudtson, peter.a.knudtson@nasa.gov

ETD Research Areas:

- Advanced Manufacturing - facilitates the development, evaluation, and deployment of efficient and flexible additive manufacturing technologies. (ref: NAMII.org)
- Advanced Multi-functional Systems and Structures - novel approaches to increase spacecraft systems resource utilization
- Micro - and Nanotechnology - Based Detector Systems - research and application of these technologies to increase the efficiency of detector and optical systems
- Ultra-Miniature Spaceflight Systems and Instruments - miniaturization approaches from multiple disciplines - materials, mechanical, electrical, software, and optical - to achieve substantial resource reductions
- Systems Robust to Extreme Environments - materials and design approaches that will preserve designed system properties and operational parameters (e.g. mechanical, electrical, thermal), and enable reliable systems operations in hostile space environments.
- Spacecraft Navigation Technologies
    - Surface Localization algorithm for autonomous navigation based on sensor observation fusion
    - Spacecraft GNSS receivers, ranging crosslink transceivers, and relative navigation sensors
    - Optical navigation and satellite laser ranging
    - Deep-space autonomous navigation techniques
    - Software tools for spacecraft navigation ground operations and navigation analysis
    - Formation Flying
- Automated Rendezvous and Docking (AR&D) techniques
    - Algorithm development
    - Pose estimation for satellite servicing missions
    - Sensors (e.g., LiDARs, natural feature recognition)
    - Actuation (e.g., micro propulsion, electromagnetic formation flying)
- Mission and Trajectory Design Technologies
    - Mission design tools that will enable new mission classes (e.g., low thrust planetary missions, precision formation flying missions)
    - Mission design tools that reduce the costs and risks of current mission design methodologies
    - Trajectory design techniques that enable integrated optimal designs across multiple orbital dynamic regimes (i.e. earth orbiting, earth-moon libration point, sun-earth libration point, interplanetary)
- Spacecraft Attitude Determination and Control Technologies
    - Modeling, simulation, and advanced estimation algorithms
    - Advanced spacecraft attitude sensor technologies (e.g., MEMS IMU's, precision optical trackers)
    - Advanced spacecraft actuator technologies (e.g. modular and scalable momentum control devices, 'green' propulsion, micropropulsion, low power electric propulsion)
- CubeSats - Participating institutions will develop CubeSat/Smallsat components, technologies and systems to support NASA technology demonstration and risk reduction efforts. Student teams will develop miniature CubeSat/Smallsat systems for: power generation and distribution, navigation, communication, on-board computing, structures (fixed and deployable), orbital stabilization, pointing, and de-orbiting. These components, technologies and systems shall be made available for use by NASA for integration into NASA Cubesat/Smallsats. They may be integrated into complete off-the-shelf "CubeSat/Smallsat bus" systems, with a goal of minimizing "bus" weight/power/volume/cost and maximizing available "payload" weight/power/volume. NASA technologists will then use these components/systems to develop payloads that demonstrate key technologies to prove concepts and/or reduce risks for future Earth Science, Space Science and Exploration/Robotic Servicing missions.

- On-Orbit Multicore Computing - High performance multicore processing for advanced automation and science data processing on spacecraft. There are multiple multicore processing platforms in development that are being targeted for the next generation of science and exploration missions, but there is little work in the area of software frameworks and architectures to utilize these platforms. It is proposed that research in the areas of efficient inter-core communications, software partitioning, fault detection, isolation & recovery, memory management, core power management, scheduling algorithms, and software frameworks be done to enable a transition to these newer platforms. Participating institutions can select areas to research and work with NASA technologists to develop and prototype the resulting concepts.
- Integrated Photonic Components and Systems - Integrated photonic components and systems for Sensors, Spectrometers, Chemical/biological sensors, Microwave, Sub-millimeter and Long-Wave Infra-Red photonics, Telecom- inter and intra satellite communications.
- Quantum Sensors and Quantum Networking
- Artificial Intelligence and Machine Learning
    - Generative Design- leveraging an artificial intelligence-based iterative design process to optimize the design of systems.
- Radiation Effects and Analysis
    - Flight validation of advanced event rate prediction techniques
    - New approaches for testing and evaluating 3-D integrated microcircuits and other advanced microelectronic devices
    - End-to-end system (e.g., integrated component level or higher) modeling of radiation effects
    - Statistical approaches to tackle radiation hardness assurance (i.e., total dose, displacement damage, and/or single-event effects) for high-risk, low-cost missions.
- Model Based System Engineering (MBSE)

A.6.4.2 Sciences and Exploration Directorate

POC: Blanche Meeson, Blanche.W.Meeson@nasa.gov

Dr. Blanche Meeson (she/her/hers)
Chief for Higher Education and GSFC NASA Postdoctoral Program

The Sciences and Exploration Directorate at NASA Goddard Space Flight Center (http://science.gsfc.nasa.gov) is the largest Earth and space science research organization in the world. Its scientists advance understanding of the Earth and its life-sustaining environment, the Sun, the solar system, and the wider universe beyond. All are engaged in the full life cycle of satellite missions and instruments from concept development to implementation, analysis and application of the scientific information, and community access and services.

- The **Earth Sciences Division** plans, organizes, evaluates, and implements a broad program of research on our planet's natural systems and processes. Major focus areas include climate change, severe weather, the atmosphere, the oceans, sea ice and glaciers, and the land surface. To study the planet from the unique perspective of space, the Earth Science Division develops and operates remote-sensing satellites and instruments. We analyze observational data from these spacecraft and make it available to the world's scientists and policy makers. The Division conducts extensive field campaigns to gather data from the surface and airborne platforms. The Division also develops, uses, and assimilates observations into models that simulate planetary processes involving the water, energy, and carbon cycles at multiple scales up to global. Please refer to https://science.gsfc.nasa.gov/earth/ for more information on the Earth Sciences Division at GSFC and the Laboratories that support it, as well as recent research highlights.

POC: Eric Brown de Colstoun (eric.c.browndecolsto@nasa.gov)

- The **Astrophysics Science Division** conducts a broad program of research in astronomy, astrophysics, and fundamental physics. Individual investigations address issues such as the nature of dark matter and dark energy, star formation and evolution, which planets outside our solar system may harbor life, and the nature of space, time, and matter at the edges of black holes. Observing photons, particles, and gravitational waves enables researchers to probe astrophysical objects and processes. Researchers develop theoretical models, design experiments and hardware to test theories, and interpret and evaluate observational data.

  POC: Rita Sam**bru**na (Rita.m.Sambruna@nasa.gov).

- The **Heliophysics Science Division** conducts research on the Sun, its extended solar-system environment (the heliosphere), and interactions of Earth, other planets, small bodies, and interstellar gas with the heliosphere. Division research also encompasses geospace, comprising Earth's magnetosphere and its outer atmosphere, and space weather—the important effects that heliospheric disturbances have on spacecraft and terrestrial systems. Division scientists develop spacecraft missions and instruments, systems to manage and disseminate heliophysical data, and theoretical and computational models to interpret the data. Possible heliophysics-related research topics include: advanced software environments and data-mining strategies (including artificial intelligence and machine learning) to collect, collate and analyze data relevant to the Sun and its effects on the solar system and the Earth; and advanced computational techniques, including but not limited to parallel architectures and the effective use of graphics processing units, for the simulation of magnetized and highly dynamic plasmas and neutral gases in the heliosphere.

  POC: Doug Rabin (*Douglas.Rabin@nasa.gov*).

- The **Solar System Exploration Division** builds science instruments and conducts theoretical and experimental research to explore the solar system and understand the formation and evolution of planetary systems. Laboratories within the division investigate areas as diverse as astrochemistry, planetary atmospheres, extrasolar planetary systems, earth science, planetary geodynamics, space geodesy, and comparative planetary studies. To study how planetary systems form and evolve, division scientists develop theoretical models and experimental research programs, as well as mission investigations and space instruments to test them. The researchers participate in planetary and Earth science missions, and collect, interpret, and evaluate measurements.

  POC: Terry Hurford (Terry.a.Hurford@nasa.gov)

- **Artificial Intelligence, Machine Learning, Big Data Analytics:** The Data Science Group (DSG) supports science through the implementation and applications of artificial intelligence, machine learning, and big data analytics. The DSG supports all science divisions across a wide variety of applications using standard software engineering practices. The DSG is focused on accelerating science and enabling new discoveries through such activities as creation of AI/ML ready data sets, Foundation Models, uncertainty quantification, explainable AI/ML, reproducibility, and open science.

  POC: Dr. Mark Carroll *(mark.carroll@nasa.gov)*

Scientists in all four divisions and our computational and information science organization publish research results in the peer-reviewed literature, participate in the archiving and public dissemination of scientific data, and provide expert user support.

A.6.5 Jet Propulsion Laboratory (JPL)
POC: Dr. Tom Cwik, thomas.a.cwik@jpl.nasa.gov

• <u>Solar System Science</u> Planetary Atmospheres and Geology Solar System characteristics and origin of life Primitive (1) solar systems bodies Lunar (9) science Preparing for returned sample investigations • <u>Earth Science</u> Atmospheric composition and dynamics (Atmospheric Dynamics Land and solid earth processes (Solid Earth Processes Water and carbon cycles, Carbon Cycles, Water Cycles Ocean and ice Earth analogs to planets, Earth Analog Climate Science • <u>Astronomy and Fundamental Physics</u> Origin, evolution, and structure of the universe, Origin Universe, Evolution Universe, Structure Universe Gravitational astrophysics and fundamental physics Extra-solar planets: Exoplanets; Star formation; Planetary formation Solar and Space Physics Formation and evolution of galaxies; Formation Galaxies; Evolution Galaxies • <u>In-Space Propulsion Technologies</u> Chemical propulsion Non-chemical propulsion Advanced propulsion technologies Supporting technologies Thermal Electric Propulsion Electric Propulsion • <u>Space Power and Energy Storage</u> Power generation Energy storage Power management & distribution Cross-cutting technologies	• <u>Human Exploration Destination Systems</u> In situ resource utilization and Cross-cutting systems • <u>Science Instruments, Observatories and Sensor Systems</u> Science Mission Directorate Technology Needs Remote Sensing instruments/Remote Sensing Sensors Observatory technologies In-situ instruments, Sensor technologies Sensors In situ technologies Instrument technologies Precision frequency Precision timing • <u>Entry, Descent and Landing Systems</u> Aerobraking, Aerocapture and entry system; Descent; Engineered materials; Energy generation and storage; Propulsion; Electronics, devices, and sensors Nanotechnology Microtechnology Microelectronics Microdevice Orbital Mechanics Spectroscopy • <u>Modeling, Simulation, Information Technology and Processing</u> Flight and ground computing; Modeling; Simulation; Information processing • <u>Materials, Structures, Mechanical Systems and Manufacturing</u> Materials; Structures; Mechanical systems; Cross cutting • <u>Thermal Management Systems</u> Cryogenic systems; Thermal control systems (near room temperature); Thermal protection systems • <u>Other Research Areas</u> Small Satellite

Solar power, Photovoltaic Tethers Radioisotope Thermoelectric • <u>Robotics, Tele-Robotics, and Autonomous Systems</u> Sensing (Robotic Sensing) Mobility Manipulation technology Human-systems interfaces Autonomy Autonomous rendezvous & docking Systems engineering Vision Virtual reality Telepresence Computer Aided • <u>Communication and Navigation</u> Optical communications & navigation technology Radio frequency communications, Radio Technologies Internetworking Position navigation and timing Integrated technologies Revolutionary concepts Communication technology Antennas Radar Remote Sensing Optoelectronics	Small Satellite Technologies Balloons Radio Science MEMS Advanced High Temperature Spectroscopy Magnetosphere Plasma Physics Ionospheres Ground Data Systems Laser Drills High Energy Astrophysics Solar physics Interstellar Astrophysics Interstellar Medium Astrobiology Astro bio geochemistry Life Detection Cosmo chemistry Adaptive Optics Artificial Intelligence

A.6.6 Johnson Space Center (JSC) / White Sands Test Facility (WSTF)

POCSs
Brian Schwing | brian.m.schwing@nasa.gov
Doug Goodman | doug.goodman@nasa.gov

An overview of JSC/WSTF capabilities and domains of interest can be found at:
https://www.nasa.gov/johnson/frontdoor/capabilities/

JSC/WSTF research areas of interest for this solicitation period include:

- **Active Thermal Control |** Condensing heat exchanger coatings with robust hydrophilic, antimicrobial properties, Wax and water-based phase change material heat exchangers, Lightweight heat exchangers and cold plates
- **Environment Control and Life Support Systems |** Advancements in Carbon Dioxide Reduction, Habitation systems that minimize consumables, Human thermal modeling, Low toxicity hygiene and cleaning products and methods, Odor and Offgas Testing, Oxygen Flammability Testing
- **Extravehicular Activity (EVA) |** Portable Life Support System, Power, Avionics and Software, Pressure Garments
- **Entry, Descent, and Landing |** Spacecraft GN&C Technologies, Deployable Decelerator Technologies, High-Fidelity Parachute Fluid/Structure Interaction, Mechanical Reefing Release Mechanism for Parachutes, Parachute Systems & Modeling, Precision Landing & Hazard Avoidance Technologies, Regolith – Rocket Plume Interaction and Measurement, Embedded Sensors) including those embedded in thermal protection systems and proximity operations and landing), Additive Manufacturing for Thermal Protection Systems, Advanced Materials and Instrumentation for Thermal Protection Systems, Predictive Material Modeling
- **Power Distribution, Control, and Storage |** Lightweight radiation tolerant cables and spools for Lunar/Mars surface power, Dust tolerant electrical connectors, Radiation hard power convertors, Batteries, Regenerative Fuel cells, High energy long-life fuel cell membranes
- **In-Situ Resource Utilization |** Lunar/Mars regolith processing and water-ice mining, Mars atmosphere processing, Methane/Oxygen liquefaction and storage, ISRU regolith processing simulation and modeling
- **Autonomy and Robotics |** Biomechanics, Crew Exercise, Human Robotic interface, Autonomous Vehicle Systems/Management, Data Mining and Fusion, Robotics and TeleRobotics, Simulation and modeling
- **Autonomous Rendezvous and Docking |** Low complexity low mass soft capture systems, Seals and sealing technology, Consumables transfer interfaces (power, data, water, air, fluids), Surface System Docking Interfaces and Environmental Tolerance
- **Human Research |** Behavioral health diagnostic and treatment techniques, Non-invasive diagnostic aides to support communication delay operations
- **Inflatable Structures |** Materials, attachment methods, monitoring, packaging, testing and analysis
- **Spacecraft Glass & Windows |** Light weight and polymer materials windows and pane attachment, Polymer window environmental tolerance and creep testing, Produce accurate loads/stress modeling and correlation techniques of non-linear materials.
- **Computer Human Interfaces (CHI) and Informatics |** Human System Integration, Human Computer Interaction design methods (Multi-modal and Intelligent Interaction), Human-in-the-loop system data acquisition and performance modeling, Trust computing methodology, Crew decision support systems, Advanced Situation Awareness Technologies, Intelligent Displays for Time-Critical Maneuvering of Multi-Axis Vehicles, Intelligent Response and Interaction System, Exploration Space Suit (xEMU) Informatics, Graphic Displays to Facilitate Rapid Discovery, Diagnosis and

Treatment of Medical Emergencies, Machine learning methods and algorithms, Imaging and information processing

- **Spacecraft Voice and Audio Systems |** Array Microphone Systems and processing, Machine-learning front end audio processing, Audio Compression algorithms implementable in FPGAs, COMSOL Acoustic modeling, Front end audio noise cancellation algorithms implementable in FPGAs-example Independent Component Analysis, Large bandwidth (audio to ultra-sonic) MEMs Microphones, Sonification Algorithms implementable in DSPs/FPGAs, Far-Field Speech Recognition in Noisy Environments
- **Imaging and Display Systems |** Lightweight/low power/radiation tolerant displays, OLED Technology Evaluation for Space Applications, Radiation tolerant Graphics Processing Units (GPUs), Scalable complex electronics & software-implementable graphics processing unit, Radiation-Tolerant Imagers, Immersive Imagery capture and display, H265 Video Compression, Ultra High Video Compressions, A Head Mounted Display Without Focus/Fixation Disparity, EVA Heads-Up Display (HUD) Optics
- **Wearable Technology |** Tattooed Electronic Sensors, Wearable Audio Communicator, Wearable sensing and hands-free control, Wearable Sensors and Controls, Wearable digital twin/transformation sensor systems
- **Wireless and Communications Systems |** Computational Electromagnetics (CEM) Fast and Multi-Scale Methods/Algorithms, RFID ICs at frequencies above 2 G, Radiation Hardened Radio Frequency Identification (RFID) Readers, Radiation robust 3GPP network technologies, Robust Dynamic Ad hoc Wireless Mesh Communication Networks, Wireless Energy Harvesting Sensor Technologies, Flight and Ground communication systems
- **Radiation and EEE Parts |** Mitigation and Biological countermeasures, Monitoring, Protection systems, Risk assessment modeling, Space weather prediction
- **In-space Propulsion Technologies |** Human rated in-space propulsion systems (storable and cryogenic), EVA-IVA compatible miniature propulsion systems (including CubeSat), Propellant transfer and refueling, Propellant gauging
- **Pyrotechnic Device Development and Testing |** Miniature pyro valves, Low energy long duration pyrotechnic devices
- **Composite Overwrapped Pressure Vessels (COPV) |** COPV testing and evaluation, COPV life extension protocol development, COPV damage detection course
- **Propulsion System Testing |** Ambient testing at 5000 feet up to 60,000 lb thrust, Altitude testing >100,000 feet up to 25,000 lb thrust, Propellants include cryogenic and storable liquids
- **Oxygen Systems Analysis and Testing** | Oxygen Compatibility Assessment, Material and Component Compatibility, Systems Safety Analysis and Failure Investigation, High flow, high pressure particle impact ignition testing, (subsonic and supersonic velocities), Flowing Oxygen Promoted Combustion testing, Friction Ignition testing, Ultra-High Pressure Promoted Combustion Testing, Arc/Spark ignition test systems, Liquid Oxygen (LOX) for pumps, turbopumps, immersion tests, and various other LOX applications
- **Propellants and Aerospace Fluids Testing and Analysis |** Storable propellant analysis, Material testing in propellants, Propellant hazards testing and analysis
- **Hydrogen Testing and Hazard Analysis |** Gaseous and liquid hydrogen testing
- **Micrometeoroid and Orbital Debris (MMOD) Testing |** testing protocols, instrumentation and analysis

A.6.7 Kennedy Space Center (KSC)

POC: Tim Griffin (timothy.p.griffin@nasa.gov)

- Storage, Distribution, and Conservation of Cryogenic Fluids and Commodities
- Tools and Techniques for Control, Operation, Inspection, Analysis and Repair
- Environmental and Green Technologies
- Safety Systems for Operations
- Communication and Tracking Technologies
- Robotic, Automated, and Autonomous Systems and Operations
- Operations Support and Advanced Studies Leveraging Primary Center Role Expertise
- Payload Processing and Integration Technologies
- Logistics
- Water/Nutrient Recovery and Management
- Food Production and Waste Management
- Plant Habitats and Flight Systems
- Robotic, Automated and Autonomous Food Production
- ISRU Development Planning/Strategy to Fit Into Architecture
- Resource Acquisition - Regolith/Trash & Gases Liquids
- Consumable Production - Extract/Produce Fuel
- In Situ Construction such as, Landing Pads, Roads, and Berms
- Distribution and Storage of In Situ Resources
- Scientific Instruments
- Resource Assessment/Prospecting

A.6.8 Langley Research Center (LaRC)

POC: Neyda Abreu, neyda.m.abreu@nasa.gov

Topics:
(See detailed Description of Topic descriptions below)
Topic 1: Aerosciences: (POC: Alireza Mazaheri - ali.r.mazaheri@nasa.gov)
Topic 2: Intelligent Flight Systems & Trusted Autonomy: (POC: "Mike" Fremaux - c.m.fremaux@nasa.gov)
Topic 3: Advanced Materials, Manufacturing Technologies & Structural Systems: (POC: Chris Wohl - c.j.wohl@nasa.gov)
Topic 4: Measurement Systems - Advanced Sensors and Optical Diagnostics (POC: "Tony" Humphreys - william.m.humphreys@nasa.gov)
Topic 5: Entry, Descent & Landing (POC: Ron Merski – n.r.merski@nasa.gov)
Topic 6: Terrestrial and Planetary Atmospheric Sciences: (POC: Allen Larar - allen.m.larar@nasa.gov)
Topic 7: Innovative Concepts for Earth and Space Science Measurements: (POC: Allen Larar - allen.m.larar@nasa.gov)

Description of Topics – Langley Research Center (LaRC)
Langley Research Center (LaRC), POC: Neyda Abreu, neyda.m.abreu@nasa.gov

Topic 1: Aerosciences: (POC: Alireza Mazaheri - ali.r.mazaheri@nasa.gov)

- Uncertainty quantification for high-fidelity multidisciplinary (e.g., aeroelastic, aeroacoustic) analysis for aircraft flight (POC: Beth Lee-Rauch, e.lee-rausch@nasa.gov)
- Multi-physics high-fidelity approaches for advanced or emerging computer architectures (POC: Beth Lee-Rauch, e.lee-rausch@nasa.gov)
- Machine learning for turbulent or transitional flow modeling (POC: Beth Lee-Rauch, e.lee-rausch@nasa.gov)
- HYBRID turbulent simulation methods and models to simulate highly separated turbulent flows (POC: Luther Jenkins, luther.n.jenkins@nasa.gov)
- Efficient synthetic turbulence generation methods (POC: Luther Jenkins, luther.n.jenkins@nasa.gov)
- Wall models for compressible flows (POC: Luther Jenkins, luther.n.jenkins@nasa.gov)
- High-order unstructured schemes for high-speed flows and aerothermodynamics (POC: Alireza Mazaheri, ali.r.mazaheri@nasa.gov)
- Modular GPU-based chemically reacting solver with stiff integrator (POC: Andrew Norris andrew.t.norris@nasa.gov)
- Uncertainty quantification for stochastic probability density function (PDF) methods (POC: Andrew Norris andrew.t.norris@nasa.gov)
- Gas lattice methods for continuum (high density) flows (POC: Andrew Norris andrew.t.norris@nasa.gov)
- Broadband noise prediction of advanced air mobility aircraft (POC: Mike Doty, michael.j.doty@nasa.gov)
- Novel material concepts to extend the frequency range of acoustic liners (POC: Ran Cabell, randolph.h.cabell@nasa.gov)
- Novel noise reduction concepts for urban air mobility (UAM) propulsors (POC: Ran Cabell, randolph.h.cabell@nasa.gov)

Topic 2: Intelligent Flight Systems & Trusted Autonomy: (POC: "Mike" Fremaux - c.m.fremaux@nasa.gov)

Research in areas of advanced air mobility, increasingly automated and autonomous systems, robotics, and "smart cities" to enable current and future NASA missions and maintain U.S. aerospace preeminence. Development and validation of new architectures, technologies, and operations for increasingly complex and increasingly autonomous aerospace systems is accomplished by:

- Enabling robust control, vehicle performance, and mission management under nominal conditions, and contingency management under off-nominal conditions.
- Ensuring robust and flexible human-machine integration and teaming.
- Advancing technologies for vehicle and system-autonomy, robotics, and flight vehicle environment awareness.
- Developing new methods and tools for the verification, validation, and safety assurance of complex and autonomous systems.
- Developing, maintaining, and utilizing advanced experimental ground and flight test facilities and labs that enable intelligent flight systems and trusted autonomy.

Topic 3: Advanced Materials, Manufacturing Technologies & Structural Systems: (POC: Chris Wohl - c.j.wohl@nasa.gov)

- Rapid, scalable additive manufacturing
- Materials for extreme environments
- Materials manufacturing and characterization in extreme environments
- Computational modeling of the manufacturing process influence on metallic microscale and bulk properties
- Characterization and evaluation of additive manufactured, multifunctional, and sustainable materials
- Computational modeling of polymer synthesis, processing, and additive manufacturing
- Multifunctional materials supporting electric aircraft
- Composite materials supporting green aviation
- Process monitoring during composites fabrication
- Materials systems supporting Human Landing System (HLS) and Environmental Control and Life Support System (ECLSS) objectives

Topic 4: Measurement Systems - Advanced Sensors and Optical Diagnostics (POC: "Tony" Humphreys - william.m.humphreys@nasa.gov)

- Detectors and focal planes for Low Earth Orbit observing platforms (POC: Alan Little, a.little@nasa.gov)
- Electronics for both flight platforms and ground test facilities (POC: Arthur Bradley, arthur.t.bradley@nasa.gov)
- Optical components including adaptive optics based on phase change materials (POC: Hyun Jung Kim, hyunjung.kim@nasa.gov)
- Microwave, millimeter, and sub-millimeter wave detection systems (POC: Steve Harrah, steve.harrah-1@nasa.gov)
- Weather sensors for Advanced Air Mobility (AAM) applications (POC: Grady Koch, grady.j.koch@nasa.gov)
- Custom laser designs (wavelengths, pulse durations, etc.) for remote sensing and ground facility test applications (POC: Paul Danehy, paul.m.danehy@nasa.gov)
- Flow visualization methods for high-speed ground test facilities (supersonic to hypersonic) (POC: Brett Bathel, brett.f.bathel@nasa.gov)

- High spatial and temporal resolution velocimetry measurements, both seeded and seedless (POC: Paul Danehy, paul.m.danehy@nasa.gov)
- Global surface pressure and temperature measurements (POC: Neal Watkins, anthony.n.watkins@nasa.gov)
- Cryogenic and thermal sensors for ground test facilities (POC: Lisa Le Vie, lisa.r.levie@nasa.gov)
- Non-destructive evaluation (NDE) methods for crewed vehicle structural health (POC: Patti Howell, patricia.a.howell@nasa.gov)
- Automated non-destructive evaluation (NDE) methods and systems utilizing machine learning (POC: Patti Howell, patricia.a.howell@nasa.gov)

Topic 5: Entry, Descent & Landing (POC: Ron Merski – n.r.merski@nasa.gov)

- Advanced EDL architecture approaches
- Advanced EDL vehicle concepts – small spacecraft
- EDL systems analysis (empirical performance assessment tools, packaging)
- Aero-assist technologies -- Aerocapture concepts
- Aero maneuvering technologies – trim tabs, morphing, RCS, magneto-hydrodynamics (MHD)
- Decelerator technologies – ballutes, parachutes, supersonic retro-propulsion, hypersonic inflatable aerodecelerators (HIADs)
- High end computing for EDL modeling -- GPUs
- Flight mechanics and GNC methods
- Atmospheric model development
- Computational fluid dynamics methods and modeling
- Rarefied flow computations -- DSMC
- Complex fluid dynamics characterization -- plume surface interaction, supersonic retro-propulsion, RCS
- Unsteady aerodynamics measurement approaches
- Wind tunnel (subsonic, transonic, supersonic, hypersonic) aero and aeroheating instrumentation, flow characterization methods (MDOE), and testing approaches
- Entry systems structures, composites manufacturing and testing methods
- Landing system concepts
- Ultra-precise velocity and ranging methods -- lidar
- Flight test instrumentation and low-cost data acquisition
- Flight data reconstruction
- Uncertainty quantification

Topic 6: Terrestrial and Planetary Atmospheric Sciences: (POC: Allen Larar - allen.m.larar@nasa.gov)

- Atmospheric science focus areas cover a broad range of measurements and applications, including:
    - Measurements of water vapor, carbon dioxide, ozone, methane, nitrogen oxides, and other important greenhouse gases
    - Aerosol and cloud properties
    - Atmospheric winds
    - Radiation budget
    - Atmospheric chemistry and air quality
    - Climate change

Topic 7: Innovative Concepts for Earth and Space Science Measurements: (POC: Allen Larar - allen.m.larar@nasa.gov)

- Advanced active and passive remote sensing and in-situ concepts & sensors for new and improved measurements, including:
    - LiDAR
    - Radiometers
    - Spectrometers
    - Interferometers

A.6.9 Marshall Space Flight Center (MSFC)

POC: John Dankanich, john.dankanich@nasa.gov and https://www.nasa.gov/offices/oct/center-chief-technologists

These Principal Technologists and System Capability Leads are available for consultation with proposers regarding the state-of-the-art, on-going activities and investments, and strategic needs in their respective areas of expertise. Proposers are encouraged to consult with the appropriate PT or SCLT early in the proposal process.

POC	Technology Area	NASA Email
Danette Allen	Autonomous Systems	danette.allen@nasa.gov
Shaun Azimi	Robotics	shaun.m.azimi@nasa.gov
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John Dankanich	In Space Transportation	john.dankanich@nasa.gov
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Julie Grantier	In Space Transportation	julie.a.grantier@nasa.gov
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Michelle Munk	Entry, Descent and Landing (EDL)	michelle.m.munk@nasa.gov
Bo Naasz	Rendezvous & Capture	bo.j.naasz@nasa.gov
Denise Podolski	Sensors/Radiation/Comm.	denise.a.podolski@nasa.gov
Wes Powell	Avionics/Communications	wesley.a.powell@nasa.gov
Jerry Sanders	In Situ Resource Utilization	gerald.b.sanders@nasa.gov
John Scott	Space Power & Energy Storage	john.h.scott@nasa.gov

John Vickers	Advanced Manufacturing	john.h.vickers@nasa.gov
Sharada Vitalpur	Communications & Navigation	sharada.v.vitalpur@nasa.gov
Arthur Werkheiser	Cryofluid Management	arthur.wekheiser@nasa.gov
Mike Wright	Entry, Descent and Landing	michael.j.wright@nasa.gov

Propulsion Systems

- Launch Propulsion Systems, Solid & Liquid
- In Space Propulsion (Cryogenics, Green Propellants, Nuclear, Fuel Elements, Solar-Thermal, Solar Sails, Tethers)
- Propulsion Testbeds and Demonstrators (Pressure Systems)
- Combustion Physics
- Cryogenic Fluid Management
- Turbomachinery
- Rotordynamics
- Solid Propellant Chemistry
- Solid Ballistics
- Rapid Affordable Manufacturing of Propulsion Components
- Materials Research (Nano Crystalline Metallics, Diamond Film Coatings)
- Materials Compatibility
- Computational Fluid Dynamics
- Unsteady Flow Environments
- Acoustics and Stability
- Low Leakage Valves

Space Systems

- Surface Habitation
- Surface Construction and Manufacturing
- In Space Habitation (Life Support Systems and Nodes, 3D Printing)
- Mechanical Design & Fabrication
- Small Payloads (For International Space Station, Space Launch System)
- In-Space Asset Management (Automated Rendezvous & Capture, De-Orbit, Orbital Debris Mitigation, Proximity Operations)
- Radiation Shielding
- Thermal Protection
- Electromagnetic Interference
- Advanced Communications
- Small Satellite Systems (CubeSats)
- Structural Modeling and Analysis
- Spacecraft Design (CAD)
- Large Space Structures

- In-Space Manufacturing

Space Transportation

- Mission and Architecture Analysis
- Advanced Manufacturing
- Space Environmental Effects and Space Weather
- Lander Systems and Technologies
- Small Spacecraft and Enabling Technologies (Nanolaunch Systems)
- 3D Printing/Additive Manufacturing/Rapid Prototyping
- Meteoroid Environment
- Friction Stir and Ultrasonic Welding
- Advanced Closed-Loop Life Support Systems
- Composites and Composites Manufacturing
- Wireless Data & Comm. Systems
- Ionic Liquids
- Guidance, Navigation and Control (Autonomous, Small Launch Vehicle)
- Systems Health Management
- Martian Navigation Architecture/Systems
- Planetary Environment Modeling
- Autonomous Systems (reconfiguration, Mission Planning)
- Digital Thread / Product Lifecycle Management (for AM and/or Composites)
- Material Failure Diagnostics

Science

- Replicated Optics
- Large Optics (IR, visible, UV, X-Ray)
- High Energy Astrophysics (X-Ray, Gamma Ray, Cosmic Ray)
- Radiation Mitigation/Shielding
- Regolith (simulants, ISRU applications, extraction)
- Gravitational Waves and their Electromagnetic Counterparts
- Solar, Magnetospheric and Ionospheric Physics
- Planetary Geology and Seismology
- Planetary Dust, Space Physics and Remote Sensing
- Surface, Atmospheres and Interior of Planetary Bodies
- Earth Science Applications
- Convective and Severe Storms Research
- Lightning Research
- Data Informatics
- Disaster Monitoring
- Energy and Water Cycle Research

- Remote Sensing of Precipitation

A.6.10 Stennis Space Center (SSC)

POC: Anne Peek anne.h.peek@nasa.gov

Intelligent Integrated System Health Management (ISHM) for Ground and Space Applications

Integrated system health management (ISHM) is a unified approach to assess the current and future state of a system. ISHM incorporates interdependencies with other systems, available resources, concepts of operations, and operational demands. Multiple sources of data are used to analyze the behavior of a system, identify trends, and estimate the remaining useful life of a system. SSC is interested in methodologies to assess the "health" of ground and space systems that enable sustainable lunar exploration and a commercial lunar economy. SSC creates and applies intelligent models of components that constitute systems. EPSCoR research could: (1) develop monitoring and diagnostic capabilities that use, or can be incorporated by, intelligent models to monitor and document the operation of the system; or (2) develop prognostics capabilities to accurately estimate the remaining useful life of a component or a system.

Autonomous Operations for Ground and Space Applications

Unprecedented levels of autonomy will be required by government and industry to enable sustainable space exploration of the Moon and Mars. Trust in these autonomous systems must be established. SSC is interested in creating robust, predictable, intelligent, hierarchical, distributed, autonomous systems to operate ground (Earth) systems, surface (Moon or Mars) systems, and space vehicles. EPSCoR research could: (1) create architectures and/or procedures to design predictable, safe autonomous systems (no black box approaches dependent on sparse training data); or (2) design and demonstrate edge-enabled autonomous operations (no connection to a cloud or off-premises/vehicle server) translatable to radiation-tolerant hardware suitable for Moon or Mars missions.

Advanced Propulsion Test Technology Development

Launch systems continue to undergo a design and manufacturing revolution. Rigorous testing mitigates design and manufacturing issues with these systems. However, as the launch industry grows dramatically, rocket propulsion testing must significantly lower the costs of testing and increase test throughput.

EPSCoR research could: (1) investigate the use of design-of-experiments techniques to optimize test operations to reduce the total number of tests required to accurately estimate the performance of a rocket engine or its components; (2) investigate options to transform the 2 design and manufacture of high-pressure (up to 15,000 psi), LOX-compatible, cryogenic tanks; (3) investigate the use of artificial intelligence and/or quantum computing to rapidly (and costeffectively) evaluate test site locations and optimize test stand configurations to meet customer needs, and generate the essential design information (preliminary design review level) for the best candidates; (4) improve capabilities and methods to accurately predict and model the transient fluid structure interaction between cryogenic fluids and immersed components to predict the dynamic loads and frequency response of facilities; and (5) improve capabilities to predict the behavior of components (valves, check valves, chokes, etc.) during the facility design process are needed. These capabilities are required for modeling components in high pressure (to 12,000 psi), with flow rates up to several thousand lb/sec, in cryogenic environments and must address two-phase flows. Challenges include accurate, efficient, thermodynamic state models; cavitation models for propellant tanks, valve flows, and run lines; reduction in solution time; improved stability; acoustic interactions; and fluid-structure interactions in internal flows

Advanced Rocket Propulsion Test Instrumentation

Rocket propulsion system development is enabled by rigorous ground testing to mitigate the propulsion system risks inherent in spaceflight. Test articles and facilities are highly instrumented to enable a comprehensive analysis of propulsion system performance. Advanced instrumentation has the potential for substantial reduction in time and cost of propulsion systems development, with substantially reduced operational costs and improvements in ground, launch, and flight system operational robustness.

EPSCoR research could design and demonstrate a wireless, highly flexible instrumentation solution capable of multiple types of measurements (e.g., heat flux, temperature, pressure, strain, and/or near-field acoustics). These advanced instruments should function as a modular node in a sensor network, capable of performing some processing, gathering data, and communicating with other nodes in the network. The sensor network must be capable of integration with data from conventional data acquisition systems adhering to strict calibration and timing standards (e.g., Synchronization with Inter-Range Instrumentation Group— Time Code Format B (IRIG-B) and National Institute of Standards and Technology (NIST) traceability is critical to propulsion test data analysis.)

Section B: Contact/Inquiries
For inquiries regarding technical and scientific aspects of NASA's Research Focus Areas in this NOFO, please contact the designated POC.

Section B.1 Mission Directorates : Inquiries/Contacts

Mission Directorates	**POC**
Aeronautics Research Mission Directorate (ARMD)	Dave Berger, dave.e.berger@nasa.gov
Space Operations Mission Directorate (SOMD), Human Research Program • Analog Facilities • Space Radiation • Human-based tissue • Exploration Medical Capability	Kristin Fabre kristin.m.fabre@nasa.gov Alexandra Whitmire: alexandra.m.whitmire@nasa.gov Katherine Rahill: katherine.m.rahill@nasa.gov Janice Zawaski janice.zawaski@nasa.gov Janapriya Saha janapriya.saha@nasa.gov Gregory Nelson gregory.a.nelson@nasa.gov Jay Lemery, MD jay.lemery@nasa.gov
Space Operations Mission Directorate (SOMD) Office of Chief Health and Medical Officer (OCHMO)	Victor Schneider, vschneider@nasa.gov James D. Polk, james.d.polk@nasa.gov
Space Operations Mission Directorate (SOMD) Commercial *Space Capabilities*	Marc Timm, marc.g.timm@nasa.gov Warren Ruemmele, warren.p.ruemmele@nasa.gov
Exploration Systems Development Mission Directorate (ESDMD)	Matt Simon, matthew.a.simon@nasa.gov
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Science Mission Directorate (SMD) Earth Science Division	Yaitza Luna-Cruz, yaitza.luna-cruz@nasa.gov Laura Lorenzoni laura.lorenzoni@nasa.gov
Science Mission Directorate (SMD) Planetary Science Division	Erica Montbach (she/her) erica.n.montbach@nasa.gov Michael Lienhard (*he/him*) michael.a.lienhard@nasa.gov
Science Mission Directorate (SMD) Astrophysics Division	Hashima Hasan, hhasan@nasa.gov Mario Perez, mario.perez@nasa.gov
Science Mission Directorate (SMD) Biological and Physical Sciences (BPS)	Francis Chiaramonte francis.p.chiaramonte@nasa.gov
Biological and Physical Sciences (BPS) • Fundamental Physics • Soft Matter/Complex Fluids	Mike Robinson michael.p.robinson@nasa.gov
Biological and Physical Sciences (BPS) • Fluid Physics • Combustion Science • Materials Science	Brad Carpenter bcarpenter@nasa.gov
Biological and Physical Sciences (BPS) • Growth of plants in “deep space-relevant” Earth soils or conditions • The impact of space-associated stressors on energy metabolism and oxidative stress • The role of genetic diversity in enabling life to thrive in space	Sharmila Bhattacharya SpaceBiology@nasaprs.com
Space Technology Mission Directorate (STMD)	Damian Taylor, Damian.Taylor@nasa.gov

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STMD, Nuclear systems	Anthony Calomino, anthony.m.calomino@nasa.gov
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Code 590/ETD Mission Engineering and Systems Analysis Division
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Doug Goodman | doug.goodman@nasa.gov</td></tr>
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<tr><td>Langley Research Center (LaRC)
Aerosciences</td><td>Alireza Mazaheri, ali.r.mazaheri@nasa.gov</td></tr>
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Uncertainty quantification for high-fidelity multidisciplinary (e.g., aeroelastic, aeroacoustic) analysis for aircraft flight (POC: Beth Lee-Rauch, e.lee-rausch@nasa.gov)
Multi-physics high-fidelity approaches for advanced or emerging computer architectures (POC: Beth Lee-Rauch, e.lee-rausch@nasa.gov)
Machine learning for turbulent or transitional flow modeling (POC: Beth Lee-Rauch, e.lee-rausch@nasa.gov)
HYBRID turbulent simulation methods and models to simulate highly separated turbulent flows (POC: Luther Jenkins, luther.n.jenkins@nasa.gov)
Efficient synthetic turbulence generation methods (POC: Luther Jenkins, luther.n.jenkins@nasa.gov)
Wall models for compressible flows (POC: Luther Jenkins, luther.n.jenkins@nasa.gov)
High-order unstructured schemes for high-speed flows and aerothermodynamics (POC: Alireza Mazaheri, ali.r.mazaheri@nasa.gov)
Modular GPU-based chemically reacting solver with stiff integrator (POC: Andrew Norris andrew.t.norris@nasa.gov)
Uncertainty quantification for stochastic probability density function (PDF) methods (POC: Andrew Norris andrew.t.norris@nasa.gov)
Gas lattice methods for continuum (high density) flows (POC: Andrew Norris andrew.t.norris@nasa.gov)
Broadband noise prediction of advanced air mobility aircraft (POC: Mike Doty, michael.j.doty@nasa.gov)
Novel material concepts to extend the frequency range of acoustic liners (POC: Ran Cabell, randolph.h.cabell@nasa.gov)
Novel noise reduction concepts for urban air mobility (UAM) propulsors (POC: Ran Cabell, randolph.h.cabell@nasa.gov)

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<tr><td>Langley Research Center (LaRC)
Measurement Systems - Advanced Sensors and Optical Diagnostics</td><td>“Tony” Humphreys,
william.m.humphreys@nasa.gov</td></tr>
</table>

- Detectors and focal planes for Low Earth Orbit observing platforms (POC: Alan Little, a.little@nasa.gov)
- Electronics for both flight platforms and ground test facilities (POC: Arthur Bradley, arthur.t.bradley@nasa.gov)
- Optical components including adaptive optics based on phase change materials (POC: Hyun Jung Kim, hyunjung.kim@nasa.gov)
- Microwave, millimeter, and sub-millimeter wave detection systems (POC: Steve Harrah, steve.harrah-1@nasa.gov)
- Weather sensors for Advanced Air Mobility (AAM) applications (POC: Grady Koch, grady.j.koch@nasa.gov)
- Custom laser designs (wavelengths, pulse durations, etc.) for remote sensing and ground facility test applications (POC: Paul Danehy, paul.m.danehy@nasa.gov)
- Flow visualization methods for high-speed ground test facilities (supersonic to hypersonic) (POC: Brett Bathel, brett.f.bathel@nasa.gov)
- High spatial and temporal resolution velocimetry measurements, both seeded and seedless (POC: Paul Danehy, paul.m.danehy@nasa.gov)
- Global surface pressure and temperature measurements (POC: Neal Watkins, anthony.n.watkins@nasa.gov)
- Cryogenic and thermal sensors for ground test facilities (POC: Lisa Le Vie, lisa.r.levie@nasa.gov)
- Non-destructive evaluation (NDE) methods for crewed vehicle structural health (POC: Patti Howell, patricia.a.howell@nasa.gov)
- Automated non-destructive evaluation (NDE) methods and systems utilizing machine learning (POC: Patti Howell, patricia.a.howell@nasa.gov)

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Section C: Definitions

- NASA Centers – NASA Centers, located throughout the United States, provide leadership for and execution of NASA's work. There are nine NASA Centers, plus NASA's only Federally Funded Research and Development Center, the Jet Propulsion Laboratory (JPL). JPL is eligible for collaboration within NASA EPSCoR on par with NASA Centers. The nine NASA Centers are:
    - Ames Research Center (ARC)
    - Armstrong Flight Research Center (AFRC)
    - Glenn Research Center (GRC)
    - Goddard Space Flight Center (GSFC)
    - Johnson Space Center (JSC)
    - Kennedy Space Center (KSC)
    - Langley Research Center (LaRC)
    - Marshall Space Flight Center (MSFC)
    - Stennis Space Center (SSC)

- Cooperative Agreement – An award of federal assistance similar to a grant with the exception that NASA will be substantially involved in the recipient's performance of the project. Cooperative agreements are managed pursuant to the policies set forth in 2 CFR § 200, 2 CFR § 1800, and the *NASA Grant and Cooperative Agreement Manual* (GCAM).
- Jurisdiction – A State or Commonwealth that is eligible to submit a proposal in response to this announcement.
- NASA Research Contact – The primary NASA point of contact during the proposal writing stage for the proposed research area. If the proposer has contacted and received permission from a NASA scientific or technical person, that individual may be listed in the proposal as the NASA Research Contact. Otherwise, the NASA Research Contact is the University Affairs Officer at the NASA Center, or the NASA Mission Directorate contact at NASA Headquarters.
- Principal Investigator (PI) – A jurisdiction's EPSCoR Director is considered the Principal Investigator (PI). The PI is responsible for proper conduct of the research, including appropriate use of funds and administrative requirements such as the submission of the scientific progress reports to the Agency. The PI is the administrator of the proposal.
- Science-Investigator (Sc-I) – The Sc-I will serve as the point of contact (POC) with the International Space Station (ISS) Program. The formally stated PI will remain responsible for the overall direction of the effort and the use of funds.
- Research Focus Area (RFA) – An area of research focus aligned with the objectives of NASA.
- Research Assistant – A student (undergraduate, graduate, or postdoctoral) who receives a research appointment in direct support of the NASA EPSCoR research in a research proposal.
- Mission Directorates
    - Aeronautics Research Mission Directorate (ARMD)
    - Exploration Systems Development Mission Directorate (ESDMD)
    - Human Exploration and Operations (HEO) Mission Directorate
    - Science Mission Directorate (SMD)
    - Space Operations Mission Directorate (SOMD)
    - Space Technology Mission Directorate (STMD)

Section D: Certifications

Certification of Compliance, Assurances, and Representations

Awards from this funding announcement that are issued under 2 CFR 1800 are subject to the Federal Research Terms and Conditions (RTC) located at http://www.nsf.gov/awards/managing/rtc.jsp. In addition to the RTC and NASA-specific guidance, three companion resources can also be found on the website: Appendix A— Prior Approval Matrix, Appendix B—Subaward Requirements Matrix, and Appendix C—National Policy Requirements Matrix.

By submitting the proposal identified in the Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorized Organizational Representative (AOR) of the proposing organization (or the individual Proposer if there is no proposing organization) as identified below—

(a) Certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;

(b) Agrees to accept the obligation to comply with NASA award terms and conditions if an award is made as a result of this proposal; and

(c) Confirms compliance with all applicable terms and conditions, rules, and stipulations set forth in the Certifications, Assurances, and Representations contained in this NRA or CAN. Willful inclusion of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

The AOR's signature on the Proposal Cover Page automatically certifies that the proposing organization has read and is in compliance with all certifications, assurances, and representations as detailed in the NASA GCAM Appendix A, Standard Format for a NASA Notice of Funding Opportunity (NOFO).

Note: On February 2, 2019, the System for Award Management (SAM) implemented a new process that allows financial assistance registrants to submit common Federal Government-wide certifications and representations. The new process will be required effective January 1, 2020. Guidance on the new process and system change can be found at: https://interact.gsa.gov/blog/certifications-and-representation-improvements-sam

Section E: Useful Web Sites

NASA http://www.nasa.gov

NASA Office of STEM Engagement http://stem.nasa.gov

NASA EPSCoR https://www.nasa.gov/stem/epscor/home/index.html

Vision for Space Exploration
https://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf

NASA Centers & Facilities https://www.nasa.gov/about/sites/index.html

Guidebook for Proposers Responding to a NASA Research Announcement
https://www.nasa.gov/wp-content/uploads/2023/09/2023-nasa-proposers-guide-final.pdf

NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES)
http://nspires.nasaprs.com

NASA Grant and Cooperative Agreement Manual (GCAM)

https://www.nasa.gov/offices/procurement/gpc/regulations_and_guidance

NPR 5810.1A, Standard Format for NASA Research Announcement and Other Announcements for Grants and Cooperative Agreements

https://nodis3.gsfc.nasa.gov/displayCA.cfm?Internal_ID=N_PR_5810_001A_&page_name=main

Electronic Code of Federal Regulations (2 CFR 200, 2 CFR 1800)
https://ecfr.federalregister.gov/current/title-2

NASA EPSCoR Director's Contact Information

https://www.nasa.gov/learning-resources/established-program-to-stimulate-competitive-research/epscor-directors/