A. Appendices

Appendix A: NASA Mission Directorates and Center Alignment
NASA's Mission to drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth, draws support from four Mission Directorates, nine NASA Centers, and JPL, each with a specific responsibility and research requirements.

A.1 Aeronautics Research Mission Directorate (ARMD)
Aeronautics Research Mission Directorate (ARMD) conducts high-quality, cutting-edge research and flight tests that generate innovative concepts, tools, and technologies to enable revolutionary advances in our Nation's future aircraft, as well as in the airspace in which they will fly.

NASA Aeronautics is partnering with industry and academia to accomplish the aviation community's aggressive carbon reduction goals. Through collective work in three areas -- advanced vehicle technologies, efficient airline operations and sustainable aviation fuels **–** NASA is committed to supporting the U.S. climate goal of achieving net-zero greenhouse gas emissions from the aviation sector by 2050.

ARMD's current major missions include:

- Sustainable Aviation
- High Speed Commercial Flight
- Advanced Air Mobility
- Future Airspace
- Transformative Tools

Additional information on the Aeronautics Research Mission Directorate (ARMD) can be found at: https://www.nasa.gov/aeroresearch and in ARMD's Strategic Implementation plan that can be found at: https://www.nasa.gov/aeroresearch/strategy.

Areas of Interest - POC: Dave Berger, dave.e.berger@nasa.gov

Proposers are directed to the following:

- ARMD Programs: https://www.nasa.gov/aeroresearch/programs
- The ARMD current year version of the NASA Research Announcement (NRA) entitled, "Research Opportunities in Aeronautics (ROA)" is posted on the NSPIRES web site at http://nspires.nasaprs.com (*Key word:* Aeronautics). This solicitation provides a complete range of ARMD research interests.

A.2 Space Operations Mission Directorate (SOMD)

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

POC: Marc Timm, marc.g.timm@nasa.gov

Warren Ruemmele, warren.p.ruemmele@nasa.gov

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 goal 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. Such advances might also have eventual benefits to commercial operations on Moon or even Mars.

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)

https://www.nasa.gov/directorates/exploration-systems-development

POC: Matt Simon, matthew.a.simon@nasa.gov

The Exploration Systems Development Mission Directorate (ESDMD) provides the Agency with leadership and management of NASA space operations related to human exploration in and beyond low-Earth orbit. Through the 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. NASA is collaborating with 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 (ESDMD) defines and manages systems development for programs critical to the NASA's Artemis program and planning for NASA's Moon to Mars exploration approach in an integrated manner. ESDMD manages the human exploration system development for lunar orbital, lunar surface, and Mars exploration. ESDMD leads the human aspects of the Artemis activities as well as the integration of science into the human system elements. ESDMD is responsible for development of the lunar and Mars architectures. 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/directorates/exploration-systems-development.

Engineering Research

- Spacecraft: Guidance, navigation, and control; thermal; electrical; structures; software; avionics; displays; high speed re-entry; modeling; power systems; interoperability/ commonality; advanced spacecraft materials; crew/vehicle health monitoring; life support.
- Propulsion: Propulsion methods that will utilize materials found on the moon or Mars, "green" propellants, on-orbit propellant storage, motors, testing, fuels, manufacturing, soft landing, throttle-able propellants, high performance, and descent.
- Robotic Systems for Lunar Precursor Missions: Precision landing and hazard avoidance hardware and software; high-bandwidth communication; in-situ resource utilization (ISRU) and prospecting; navigation systems; robotics (specifically environmental scouting prior to human arrival, and to assist astronaut with surface exploration); environmental analysis, radiation protection; small payloads to accomplish science and research objectives, as well as for risk reduction for human-rated systems.
- Data and Visualization Systems for Exploration: Area focus on turning precursor mission data into meaningful engineering knowledge for system design and mission planning of lunar and Mars surfaces; visualization and data display; interactive data manipulation and sharing; modeling of lighting and thermal environments; simulation of environmental interactions for pressurized and unpressurized vehicles.
- Research and technology development areas in ESDMD support exploration systems development including in-space vehicles, space communications, commercial space, and the International Space Station. Examples of research and technology development areas (and the associated lead NASA Center) with great potential include:

- Research and technology development areas in ESDMD support exploration systems development including in-space vehicles, space communications, commercial space, and the International Space Station. Examples of research and technology development areas (and the associated lead NASA Center) with great potential include:
    - Processing *and Operations*

    - Crew Health and Safety Including Medical Operations, Johnson Space Center (JSC)
    - Non-invasive diagnostic aides that work in a communication delay setting (JSC)
    - In-helmet Speech Audio Systems and Technologies (JSC)
    - Vehicle Integration and Ground Processing, Kennedy Space Center (KSC)
    - Mission Operations (JSC)
    - Portable Life Support Systems (JSC)
    - Pressure Garments and Gloves (JSC)
    - Air Revitalization Technologies (ARC)
    - In-Space Waste Processing Technologies (JSC)
    - Cryogenic Fluids Management Systems (MSFC)
  - *Space Communications and Navigation*
    - Coding, Modulation, and Compression, Goddard Spaceflight Center (GSFC)
    - Precision Spacecraft & Lunar/Planetary Surface Navigation and Tracking (GSFC)
    - Communication for Space-Based Range (GSFC)
    - Antenna Technology, Glenn Research Center (GRC)
    - Reconfigurable/Reprogrammable Communication Systems (GRC)
    - Miniaturized Digital EVA Radio (JSC)
    - Transformational Communications Technology (GRC)
    - Long Range Optical Telecommunications, Jet Propulsion Laboratory (JPL)
    - Long Range Space RF Telecommunications (JPL)
    - Surface Networks and Orbit Access Links (GRC)
    - Software for Space Communications Infrastructure Operations (JPL)
    - TDRS transponders for launch vehicle applications that support space communication and launch services (GRC)
  - *Space Transportation*
    - Optical Tracking and Image Analysis (KSC and GSFC)
    - Space Transportation Propulsion System and Test Facility Requirements and Instrumentation (Stennis Space Center (SSC)
    - Automated Collection and Transfer of Launch Range Surveillance/Intrusion Data (KSC)
    - Technology tools to assess secondary payload capability with launch vehicles (KSC)
    - Spacecraft Charging/Plasma Interactions (Environment definition & arcing mitigation), Marshall Space Flight Center (MSFC)
  - *Commercial Space Capabilities*
    - The goal of this area is to support research, development, and commercial adoption of technologies of interest to the U.S. spaceflight industry to further their space-related capabilities. (KSC)
    - These include capabilities for Moon, Mars, and Earth orbit. Such efforts are in pursuit of the goals of the National Space Policy and NASA’s strategic plans,

to foster developments that will lead to education and job growth in science and engineering, and spur economic growth as capabilities for new space markets are created. (KSC)

- U.S. commercial spaceflight industry interests naturally vary by company. Proposers are encouraged to determine what those interests are by engagement with such companies in various ways, and such interests may also be reflected in the efforts of various NASA partnerships. (KSC)
- Proposals should discuss how the effort aligns with U.S. commercial spaceflight company interest(s) and identify potential alignments with NASA interests. (KSC)

A.4 Human Research Program

Space Operations Mission Directorate (SOMD)

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

The Human Research Program (HRP) is focused on investigating and mitigating the highest risks to human health and performance to enable safe, reliable, and productive human space exploration. The HRP budget enables NASA to resolve health risks for humans to safely live and work on missions in the inner solar system. HRP conducts research, develops countermeasures, and undertakes technology development to address human health risks in space and ensure compliance with NASA's health, medical, human performance, and environmental standards.

A.4.1 Office of Chief Health and Medical Officer (OCHMO)

POC: Dr. Victor Schneider, vschneider@nasa.gov P: (202) 258-3645
Dr. James D. Polk, james.d.polk@nasa.gov P: (202) 358-1959

Areas of Research Interest:

- Development and elaboration of Functional aids and testing paradigms to measure activity for use by parastronauts during spaceflight. This may include egressing and exiting space capsules and donning and doffing spacesuits and other aids for parastronauts. The European Space Agency is establishing a parastronaut feasibility project. Since NASA offers its international partners access to NASA supported spacecraft and the International Space Station, NASA wants to establish appropriate functional testing measures to determine the time it takes fit astronaut-like subjects compared to fit parastronaut subjects to egress and exit simulated space capsules and simulated donning and doffing spacesuit. Research proposals are sought to establish appropriate functional testing.

- Evaluation space capsule and spacesuit activity in stable and fit lower or upper extremity amputees and compare their responses to non-amputee fit individuals. The

European Space Agency is establishing a parastronaut feasibility project. Since NASA offers its international partners access to NASA supported spacecraft and the International Space Station, NASA wants to obtain research data measuring the time it takes fit astronaut-like subjects compared to fit parastronaut subject to egress and exit simulated space capsules and simulated donning and doffing spacesuit. Research proposals are sought to obtain data measuring the functional testing indicated

A.4.2 Human Research Program/Space Radiation Element

POC: Dr. Robin Elgart, shona.elgart@nasa.gov, P: (281) 244-0596

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 define the mechanisms underlying sexual dimorphism following exposure to space radiation. Research should focus on translational biomarkers relevant to changes in cognitive and/or behavioral performance, cardiovascular function, and the development of carcinogenesis **in non-sex-specific organs**. Due to limited time and budget, researchers are encouraged to utilize radiation sources located at home institutions at space relevant doses (0-5 Gy of photons or proton irradiation). A successful proposal will not necessitate the use of the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory at this phase. Collaborations between investigators and institutions for the sharing of data and tissue samples are highly encouraged. Samples available for use by SRE, can be found at https://lsda.jsc.nasa.gov/Biospecimen by searching “NASA Space Radiation Laboratory (NSRL)” in the payloads field (SRE approval required). Instructions for accessing the tissue sharing information are posted at: https://spaceradiation.jsc.nasa.gov/tissue-sharing/. Other topics include:
   - Individual sensitivity
   - Early disease detection (Cancer, CVD, neurological/behavioral conditions)
   - Biomarker identification
   - High-throughput countermeasure screening
   - Sex-specific risk assessment
   - Radiation quality and/or dose-rate effects

3. Research proposals are sought to establish 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.

4. Research proposals are sought to evaluate the role of the inflammasome in the pathogenesis of radiation-associated cardiovascular disease (CVD), carcinogenesis, and/or central nervous system changes that impact behavioral and cognitive function. Although innate inflammatory immune responses are necessary for survival from infections and injury, dysregulated and persistent inflammation is thought to contribute to the pathogenesis of various acute and chronic conditions in humans, including CVD. A main contributor to the development of inflammatory diseases involves activation of inflammasomes. Recently, inflammasome activation has been increasingly linked to an increased risk and greater severity of CVD. Characterization of the role of inflammasome-mediated pathogenesis of disease after space-like chronic radiation exposure can provide evidence to better quantify space radiation risks as well as identify high value for countermeasure development.

A.4.3 Human Research Program/ Exploration Medical Capability(ExMC) Element

POC: Moriah Thompson: moriah.s.thompson@nasa.gov P: (713) 437-2500

Title: Non-Invasive Behavioral Health Diagnostic Capabilities for Mars
Description: Missions to Mars will involve increased stressors such as isolation, confinement, interpersonal issues, etc. The risk of behavioral health issues increases with such missions. Current behavioral health diagnostic and treatment techniques rely on real-time communication. Non-invasive diagnostic aides that work in a communication delay setting are needed to improve behavioral health support for exploration missions to Mars.

A.5 Science Mission Directorate (SMD)

SMD POC: Lin Chambers lin.h.chambers@nasa.gov

Science Mission Directorate (SMD) leads the Agency in five areas of research: Biological and Physical Sciences (BPS), Heliophysics, Earth Science, Planetary Science, and Astrophysics. 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. SMD's high-level strategic objectives are presented in the 2022 NASA Strategic Plan. Detailed plans by science area corresponding to the science divisions of SMD: Heliophysics, Earth Science, Planetary Science, Biological and Physical Science, and Astrophysics appear in *SCIENCE 2020-2024: A Vision for Scientific Excellence Updated*", which is available at http://science.nasa.gov/about-us/science-strategy/. The best expression of specific research topics of interest to each Division within SMD are represented in by the topics listed in SMD's "ROSES" research solicitation, see ROSES 2023 and the text in the Division research overviews of ROSES. By perusing the tables of contents from this year at https://solicitation.nasaprs.com/ROSES2023table3 and last year at https://solicitation.nasaprs.com/ROSES2022table3, proposers can view all of the topics that are of interest, even if a given topic is not solicited in any given year.

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

A.5.1 Biological and Physical Sciences (BPS)

POC: Douglas Gruendel, Douglas.J.Gruendel@nasa.gov
Dr. Francis Chiaramonte francis.p.chiaramonte@nasa.gov

The mission of BPS is two-pronged:

- Pioneer scientific discovery in and beyond low Earth orbit to drive advances in science, technology, and enhance knowledge, education, innovation, and economic vitality

- Enable human spaceflight exploration to expand the frontiers of knowledge, capability, and opportunity in space

Execution of this mission requires both scientific research and technology development.

BPS administers NASA's:
- Space Biology Program, which solicits and conducts research to use the space environment to advance our knowledge of how gravity affects the design and function of living organisms, and to understand how biological systems accommodate to spaceflight environments
- Physical Sciences Program, which solicits and conducts research using the space environment as a tool to provide transformational insights in physics and engineering science, and to understand how physical systems respond to spaceflight environments, particularly weightlessness and the partial gravity of planetary bodies
- Commercially Enabled Rapid Space Science project (CERISS), which will develop transformative research capabilities with commercial space industry to dramatically increase the pace of research

BPS partners with the research community and a wide range of organizations to accomplish its mission. Grants to academic, commercial and government laboratories are the core of BPS's research and technology development efforts.

Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

Space Biology Program

The Space Biology Program within NASA's Biological and Physical Sciences Division focuses on pioneering scientific discovery and enabling human spaceflight exploration. Research in space biology has the following goals:
- To understand how radiation, altered gravity, and the other characteristics of the space environment alter fundamental biological processes;
- To develop the scientific and technological foundations for a safe, productive human presence in space for extended periods and in preparation for exploration; and
- To apply this knowledge and technology to improve our nation's competitiveness, education, and the quality of life on Earth.

Research proposals for this opportunity are being solicited on the following topic:
- Mammalian Biology – biological and physiological responses of rodents to ionizing radiation and other spaceflight-relevant stressors such as altered gravity (*i.e.,* through hindlimb unloading or partial weightbearing, etc.).
  - Proposals must be for ground-based studies.
  - All proposals for rodent studies must address the five points outlined in the Vertebrate Animal and Higher Order Cephalopod Section (VACS) instructional

document which can be found here. This response should be included as part of the research plan and should be limited to two pages. A sample VACS is provided in the VACS instructional document posted on NSPIRES alongside this document

- Ionizing radiation and altered gravity regimes (partial gravity and microgravity) are a hallmark of the deep space environment. These stressors may cause direct physiological changes in the organisms or result in indirect effects such as loss of sleep in some organisms. Studies shall effectively delineate the biological effects of these factors, separately and/or in combination where possible.
- The proposed use of other spaceflight stressors, including altered atmospheric pressures, altered levels of CO2, altered light spectra/durations, etc., in lieu of altered gravity is acceptable, however, all proposed studies must include the use of ionizing radiation as the primary stressor.
- While all rodent studies involving radiation in combination with another spaceflight stressors will be considered responsive to this topic, Space Biology is particularly interested in studies that utilize rats as the model system to be investigated.
- Proposed investigators should focus on understanding the mechanistic bases of the changes induced by these stressor, preferably from a systems biology perspective, and could include genetic, cellular, or molecular biological effects. Further information for the Space Biology program are available at https://science.nasa.gov/biological-physical/programs/space-biology, and at https://science.nasa.gov/biological-physical/documents.
- Investigators are encouraged to propose experiments that use the radiation facilities at the NASA Space Radiation Laboratory (NSRL) located at the Brookhaven National Lab, however Space Biology cannot not directly pay the cost of their use. Proposers planning to use these facilities must contact NSRL (https://www.bnl.gov/nsrl/) for cost estimates and necessary logistical information and must appropriately account for the cost of beam-time and facility use in their budget

If a Space Biology research topic is proposed, other than Mammalian Biology research noted above, please reach out to the Space Biology POC listed above at spacebiology@nasaprs.com to discuss proposed research for consideration.

Investigators receiving awards from this opportunity for a proposal submitted to a Space Biology Focus Area will be required to upload all relevant data produced by their funded project in the GeneLab Data Systems (https://genelab.nasa.gov). They must also make the source code of any computational simulations developed via awards under this proposal available in an open source repository. Furthermore, articles published in peer-reviewed scholarly journals and papers published in peer-reviewed conference proceedings, should be made publicly accessible via NASA's PubSpace website (Submit to PubSpace - Scientific and Technical

Information Program (nasa.gov)). Proposers submitting application that are responsive to this focus are will therefore be expected to address these requirements in their proposal's data management plan.

Further information for the Space Biology program are available at:
https://science.nasa.gov/biological-physical/programs/space-biology
https://science.nasa.gov/biological-physical/documents

Physical Science Program

The Physical Science Research Program conducts fundamental and applied research to advance scientific knowledge, to improve space systems, and to advance technologies that may produce new products offering benefits on Earth. Space offers unique advantages for experimental research in the physical sciences. NASA supports research that uses the space environment to make significant scientific advances. Many of NASA's experiments in the physical sciences reveal how physical systems respond to the near absence of gravity. Forces that on Earth are small compared to gravity can dominate system behavior in space. Understanding the consequences is a critical aspect of space system design. Research in physical sciences includes both basic and applied research in the areas of combustion science, fluid physics, materials science, soft matter physics and fundamental physics.

Combustion Science

The goal of the microgravity combustion science research program is to advance understanding of combustion processes, leading to added benefits to human health, comfort, and safety on both Earth and during crewed exploration missions. 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 micro 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.

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

Fluid Physics

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.

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

Materials Science

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.

The research area of materials science includes the following themes:
Glasses and ceramics
Granular materials
Metals
Polymers and organics
Semiconductors

Soft Matter Physics

Granular material is one of the key focus areas of research areas in the field of soft matter. The fundamental understanding of physics of granular materials under different gravity condition is of key importance for deep space exploration and long-term habitation to sample collection from asteroids to improving the understanding of granular material handling on earth. Also, fundamental understanding of granular materials can help us understand motions in large bodies on earth (e.g.- landslides) that can help us save lives in case of natural emergencies. This research topic focuses on developing fundamental knowledge base in the field of-

- Rheology of granular materials (both wet and dry)
    - Impact of anisotropy and structure
    - Impact of electrostatic charging
- In depth understanding of stress distribution in granular materials
- Dynamics of interparticle interaction and short range forces in granular materials

Both experimental and theoretical/numerical work will be in scope.

Fundamental Physics

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.

Proposals are sought for ground-based theory and experimental research that may help to develop concepts for future flight experiments. Research in field effects in quantum superposition and entanglement are of particular interest.

For any Physical Sciences proposal selected for award, all data must be deposited in the Physical Sciences Informatics Database starting one year after award completion. They must also make the source code of any computational simulations developed via awards under this proposal available in an open-source repository.

The two NASA GRC drop towers described below are also available to augment research investigations. These facilities are typically used to conduct combustion or fluid physics experiments. Please go to link for further information. The Points of Contact for each research area are:
Fluid Physics: John McQuillen, john.b.mcquillen@nasa.gov
Combustion Science: Dan Dietrich, daniel.l.dietrich@nasa.gov

Since there is a cost involved to use these drop towers, please contact the appropriate POC for cost estimates for your proposal.

2.2 s tower : https://www1.grc.nasa.gov/facilities/drop/

The 2.2 Second Drop Tower has been used for nearly 50 years by researchers from around the world to study the effects of microgravity on physical phenomena such as combustion and fluid dynamics and to develop technology for future space missions. It provides rapid turnaround testing (up to 12 drops/day) of 2.2 seconds in duration.

5.2 s tower : https://www1.grc.nasa.gov/facilities/zero-g/

The Zero Gravity Research Facility is NASA's premier facility for ground based microgravity research, and the largest facility of its kind in the world. It provides researchers with a near weightless environment for a duration of 5.18 seconds. It has been primarily used for combustion and fluid physics investigations.

Implementing Centers: NASA's Physical Sciences Research Program is carried out at the Glenn Research Center (GRC), Jet Propulsion Laboratory (JPL) and Marshall Space Flight Center (MSFC). Further information on physical sciences research is available at:
https://science.nasa.gov/biological-physical/programs/physical-sciences

Commercially Enabled Rapid Space Science Project (CERISS)

The Commercially Enabled Rapid Space Science initiative (CERISS) will develop transformative research capabilities with commercial space industry to dramatically increase the pace of research. Long-range goals include conducting scientist astronaut missions on the International Space Station and commercial low-earth orbit (LEO) destinations and develop automated hardware for experiments beyond low Earth orbit, such as to the lunar surface.

The benefits will include a 10-to-100-fold faster pace of research for a wide range of research sponsored by Biological and Physical Sciences Division, the NASA Human Research Program, other government agencies, and industry. Another benefit will be the increased demand for research and development in low earth orbit, facilitating growth of the commercial space industry.

Area of particular interest include:

Sample preparation Characterization of materials (e.g. differential scanning calorimetry, x-ray diffraction, Fourier transform infrared spectroscopy, etc.) Analysis of samples (e.g. fluorescent activated cell sorting, protein and -omics, imaging, etc.)

Further information on CERISS is available at: https://science.nasa.gov/biological-physical/commercial

A.5.2 Heliophysics Division

POC: Patrick Koehn, Ph.D. NASA HQ patrick.koehn@nasa.gov
Madhulika Guhathakurta, Ph.D. NASA HQ madhulika.guhathakurta@nasa.gov

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-23 Heliophysics Research Program Overview for further

information about the Heliophysics Research Program.

A.5.3 Earth Science Division

Yaitza Luna-Cruz, yaitza.luna-cruz@nasa.gov NASA Headquarters (HQ)
Laura Lorenzoni, laura.lorenzoni@nasa.gov NASA HQ
Nancy Searby, nancy.d.searby@nasa.gov NASA HQ

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

In applied sciences, the ESD encourages the use of data from NASA's Earth-observing satellites and airborne missions to tackle tough challenges and develop solutions that improve our daily lives. Specific areas of interest include efforts that help institutions and individuals make better decisions about our environment, food, water, health, and safety (see http://appliedsciences.nasa.gov). In technological research, the ESD 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 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.5.4 Planetary Science Division

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Manager, Planetary Exploration Science Technology Office (PESTO)
Planetary Science Division

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Planetary Science Division

The Planetary Science Research Program, managed by the Planetary Science Division, sponsors research 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 2022 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 objective spl, the Planetary Research Program invites a wide range of planetary science and astrobiology investigations. Example topics include, but are not limited to:

- Investigations aimed at 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;
- Investigations aimed at understanding materials present, and processes occurring, in the early stages of Solar System history, including the protoplanetary disk;
- Investigations aimed at understanding planetary differentiation processes;
- Investigations of extraterrestrial materials, including meteorites, cosmic dust, presolar grains, and samples returned by the Apollo, Stardust, Genesis, and Hayabusa missions;
- Investigations of the properties of planets, satellites (including the Moon), satellite and ring systems, and smaller Solar System bodies such as asteroids and comets;
- Investigations 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;
- Investigations into the origins, evolution, and properties of the atmospheres of planetary bodies (including satellites, small bodies, and exoplanets);
- Investigations that use 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;
- Investigations into the origin and early evolution of life, the potential of life to adapt to different environments, and the implications for life elsewhere;
- Investigations that provide the fundamental research and analysis necessary to characterize exoplanetary systems;
- Investigations related to understanding the chemistry, astrobiology, dynamics, and energetics of exoplanetary systems;
- Astronomical observations of our Solar System that contribute to the understanding of the nature and evolution of the Solar System and its individual constituents;

- Investigations to inventory and characterize the population of Near Earth Objects (NEOs) or mitigate the risk of NEOs impacting the Earth;
- Investigations into the potential for both forward and backward contamination during planetary exploration, methods to minimize such contamination, and standards in these areas for spacecraft preparation and operating procedures;
- Investigations which enhance 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 technology 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.

Additional information on technologies needed to support NASA Planetary Science Division missions may be found on the Planetary Exploration Science Technology Office website.

Proposers may also review the information in the ROSES-2023 Planetary Science Research Program Overview for further information about the Planetary Science Research Program. 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.5.5 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, the Astrophysics Roadmap (available at https://science.nasa.gov/astrophysics/documents/astrophysics-roadmap), 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.6 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: http://www.nasa.gov/directorates/spacetech/about_us/index.html.

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
- Encourage technology driven economic growth with an emphasis on the expanding space economy
- Inspire and develop a diverse and powerful US aerospace technology community

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

- ***Land***: *Expanded Access to Diverse Surface Destinations*
  - Enable Lunar/Mars global access with ~20t payloads to support human missions.
  - Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies.
  - Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.

- ***Live***: *Sustainable Living and Working Farther from Earth*
  - Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities.
    - Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations.
    - Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface.
    - Technologies that enable surviving the extreme lunar and Mars environments.
    - Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources.
  - Enable long duration human exploration missions with Advanced Habitation System technologies. [Low TRL STMD: Mid-High TRL SOMD/ESDMD]

- ***Explore***: *Transformative Missions and Discoveries*
  - Develop next generation high performance computing, communications, and navigation.

- Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions.
- Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies.
- Develop vehicle platform technologies supporting new discoveries.
- Develop technologies for science instrumentation supporting new discoveries. [Low TRL STMD/Mid-High TRL SMD. SMD funds mission specific instrumentation (TRL 1-9)]
- Develop transformative technologies that enable future NASA or commercial missions and 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.

POC	Technology Area	NASA Email
Andrew Abercromby	ECLSS	andrew.f.abercromby@nasa.gov
Danette Allen	Autonomous Systems	danette.allen@nasa.gov
Jim Broyan	ECLSS Lead	james.l.broyan@nasa.gov
John Carson	EDL Precision Landing	john.m.carson@nasa.gov
John Dankanich	In Space Transportation	john.dankanich@nasa.gov
Bernie Edwards	Communications & Navigation	bernard.l.edwards@nasa.gov
Mark Hilburger	Structures/Materials; Excavation, Construction and Outfitting	mark.w.hilburger@nasa.gov
Kristen John	Dust Mitigation	kristen.k.john@nasa.gov
Julie Kleinhenz	In Situ Resource Utilization	julie.e.kleinhenz@nasa.gov
Angela Krenn	Thermal and Surface Systems	angela.g.krenn@nasa.gov
Ron Litchford	Propulsion Systems	ron.litchford@nasa.gov
Josh Mehling	Robotics	joshua.s.mehling@nasa.gov
Jason Mitchell	Communications & Navigation	jason.w.mitchell@nasa.gov
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/Quantum	denise.a.podolski@nasa.gov
Wes Powell	Avionics	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
Arthur Werkheiser	Cryo Fluid Management	arthur.werkheiser@nasa.gov
Mike Wright	Entry, Descent and Landing (EDL)	michael.j.wright@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: John Scott (john.h.scott@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 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.7 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.7.1 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.7.2 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.7.3 Glenn Research Center (GRC)

POC: Kurt Sacksteder, kurt.sacksteder@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.7.4 Goddard Space Flight Center (GSFC)

A.7.4.1 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

<u>ETD Research Areas:</u>

- 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.7.4.2 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.

  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, 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 Samburna (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, 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 include: advanced software environments and data-mining strategies to collect, collate and analyze data relevant to the Sun and its effects on the solar system and the Earth ("space weather"); 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.7.5 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>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

• <u>Space Power and Energy Storage</u> Power generation Energy storage Power management & distribution Cross-cutting technologies 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	systems (near room temperature); Thermal protection systems • <u>Other Research Areas</u> Small Satellite 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.7.6 Johnson Space Center (JSC)

Schwing, Brian M. (JSC-AA211) brian.m.schwing@nasa.gov
Goodman, William {Doug} (JSC-XT)[Jacobs Technology, Inc.] doug.goodman@nasa.gov
Linda Ham, linda.j.ham@nasa.gov
Exploration Integration and Science Directorate

https://beta.nasa.gov/johnson/frontdoor/capabilities/

Active Thermal Control
- Condensing heat exchanger coatings with robust hydrophilic, antimicrobial properties
- Development and demonstration of wax and water-based phase change material heat exchangers
- Lightweight heat exchangers and cold plates

ECLSS
- Advancements in Carbon Dioxide Reduction
- Habitation systems that minimize consumables
- Human thermal modeling
- Low toxicity hygiene and cleaning products and methods

EVA
- Portable Life Support System
- Power, Avionics and Software
- Pressure Garment

Entry, Descent, and Landing
- Innovative, Groundbreaking, and High Impact Developments in Spacecraft GN&C Technologies
- Deployable Decelerator Technologies
- High-Fidelity Parachute Fluid/Structure Interaction
- Mechanical Reefing Release Mechanism for Parachutes
- Next Generation Parachute Systems & Modeling
- Precision Landing & Hazard Avoidance Technologies
- Regolith – Rocket Plume Interaction: In-situ Measurements to Enable Multiple Landings at the Same Site
- Optical / Vision-Based Navigation for EDL Applications
- 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 and Control
- Lightweight, radiation tolerant cables and spools for Lunar/Mars surface power
- Dust tolerant electrical connectors
- Radiation hard power convertors.

Energy Storage technologies
- Batteries, Regenerative Fuel cells
- High energy, long-life fuel cell membranes

In-Situ Resource Utilization

- Lunar/Mars regolith processing and water-ice mining (Regolith collection, delivery, regolith processing, and drying; Water separation and capture, water cleanup ~~collection~~ and processing, water electrolysis)
- Mars atmosphere processing (CO2 collection; Dust filtering; Solid Oxide CO2 electrolysis; Sabatier; Reverse water gas shift)
- Methane/Oxygen liquefaction and storage
- ISRU regolith processing simulation and modeling

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 test

- Miniature pyrovalves
- Low energy, long duration pyrotechnic devices

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 - Next generation In-space docking systems concepts addressing challenges of mass, environments, flight operations and including long duration missions, consider:

- New Rendezvous & Docking strategies ie;, greater vehicle reliance vs kinetic energy, addressing vehicle capabilities, sensors, etc…
- Simplification of soft capture system attenuation; less complex and lighter systems
- Docking independent LRU strategies vs Integrated vehicle solution
- Seals and sealing technology
- Consumables transfer technology (power, data, water, air, fluids)
- Maintenance

Surface Docking System Concepts addressing*:*

- System design and interfaces
- Environment's tolerance including long duration exposure

Human Research

- Behavioral health diagnostic and treatment techniques
- Non-invasive diagnostic aides that work in a communication delay setting

Inflatables and Attachments

- Inflatable Technology Archive/Database (Inflatables data from 30+ years being compiled/tech transfer)
- Advanced Material Development (Lunar/Martian Surface Protection)
- Inflatables Structural Design (hard structure Integration)
- Inflatable Attachment Technology Development (hatches, windows, handrails, floors, internal walls, grapple fixture, docking hatch, radiators, solar panels, etc.)
- Softgoods Structural Health Monitoring (Strain measurement, impact detection)
- Softgoods Folding and Packaging Testing (Cold temp folding)
- Softgoods Materials Testing (Creep test, Air barrier, Permeability)
- Sub-scale Structural Testing (Proof, Burst, Creep Testing)
- Full-scale Thermal Vacuum Testing (Chamber A environmental testing)

Spacecraft Glass & Windows

- Further the state of the art in light weight windows by advancing polymer materials as windowpanes.
  - Understand and mitigate the effects of UV/Radiation and other spaceflight environments on polymer windowpane materials and developing accurate testing techniques for environmental characterization
  - Produce accurate loads/stress modeling and correlation techniques of non-linear materials.
  - Conduct elevated temperature creep testing for polymer windowpane materials.
  - Develop mechanical material properties as a function of temperature, and optical material properties a function of wavelength for polymer windowpane materials.
  - Investigate methods of reducing flammability of polymer windowpane materials.
  - Understand storage effects of polymer window materials.
  - Develop inspection techniques correlated to residual polymer window materials.
  - Evolve the design of polymer windows to allow for long term spaceflight and enhanced viewability.
- Reduce the overhead of processing brittle material windowpanes by improving ground inspection and assessment techniques and developing on-orbit inspection techniques.

Computer Human Interfaces (CHI)

CHI - Human System Integration

- Human Computer Interaction design methods (Multi-modal and Intelligent Interaction) and apparatuses

- Human Systems Integration, Human Factors Engineering: state of the art in Usability, workload, and performance assessment methods and apparatus.
- Inclusion of Human Readiness Level into HSI
- Humans Systems Integration Inclusion in Systems Engineering
- Human-in-the-loop system data acquisition and performance modeling
- Trust computing methodology

CHI - Informatics
- 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
- CHI machine learning methods and algorithms
- Imaging and information processing
- Audio system architecture for Exploration Missions

CHI - Audio
- 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

CHI - Imaging and Display
- 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
- EPCglobal-type RFID ICs at frequencies above 2 G
- Radiation Hardened EPCglobal 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

A.7.7 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.7.8 Langley Research Center (LaRC)

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

POC	Technology Area - Topics	NASA Email
Alireza Mazaheri	Topic 1: Aerosciences	ali.r.mazaheri@nasa.gov

Topic 1: Aerosciences

- 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

<table>
<tr><td>Mike” Fremaux</td><td>Topic 2: Intelligent Flight Systems & Trusted Autonomy</td><td>c.m.fremaux@nasa.gov</td></tr>
<tr><td colspan="3">Topic 2: Intelligent Flight Systems & Trusted Autonomy
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, 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 experimental ground and flight test facilities and labs.</td></tr>
<tr><td>Chris Wohl</td><td>Topic 3: Advanced Materials, Manufacturing Technologies & Structural Systems</td><td>c.j.wohl@nasa.gov</td></tr>
<tr><td colspan="3">Topic 3: Advanced Materials, Manufacturing Technologies & Structural Systems
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
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</td></tr>
<tr><td>“Tony” Humphreys</td><td>Topic 4: Measurement Systems - Advanced Sensors and Optical Diagnostics</td><td>william.m.humphreys@nasa.gov</td></tr>
<tr><td colspan="3">Topic 4: Measurement Systems - Advanced Sensors and Optical Diagnostics
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</td></tr>
</table>

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: Jay Ely, jay.j.ely@nasa.gov
- Weather sensors for Advanced Air Mobility (AAM) applications
  POC: Jay Ely, jay.j.ely@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

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

Topic 5: Entry, Descent & Landing

- 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		
Allen Larar	Topic 6: Terrestrial and Planetary Atmospheric Sciences	allen.m.larar@nasa.gov
Topic 6: Terrestrial and Planetary Atmospheric Sciences • 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		
Allen Larar	Topic 7: Innovative Concepts for Earth and Space Science Measurements	allen.m.larar@nasa.gov
Topic 7: Innovative Concepts for Earth and Space Science Measurements • Advanced active and passive remote sensing and in-situ concepts & sensors for new and improved measurements, including: ○ LiDAR ○ Radiometers ○ Spectrometers ○ Interferometers		

A.7.9 Marshall Space Flight Center (MSFC)

POC: John Dankanich, john.dankanich@nasa.gov and https://www.nasa.gov/offices/oct/center-chief-technologists-2

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
Jim Broyan	ECLSS[1] Deputy	james.l.broyan@nasa.gov
John Carson	EDL Precision Landing; HPSC	john.m.carson@nasa.gov
Scott Cryan	Rendezvous & Capture	scott.p.cryan@nasa.gov
John Dankanich	In Space Transportation	john.dankanich@nasa.gov
Terry Fong	Autonomous Systems	terry.fong@nasa.gov
Robyn Gatens	ECLSS Lead	robyn.gatens@nasa.gov
Julie Grantier	In Space Transportation	julie.a.grantier@nasa.gov
Mark Hilburger	Structures/Materials	mark.w.hilburger@nasa.gov
Michael Johansen	Dust Mitigation	michael.r.johansen@nasa.gov
Julie Kleinhenz	In Situ Resource Utilization	julie.e.kleinhenz@nasa.gov
Angela Krenn	Thermal Technologies	angela.g.krenn@nasa.gov
Ron Litchford	Propulsion Systems	ron.litchford@nasa.gov
Jason Mitchell	Communications & Navigation	jason.w.mitchell@nasa.gov
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
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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)

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.7.10 Stennis Space Center (SSC)

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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.)

Appendix B: Contact/Inquiries

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

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