7.0 Research Focus Areas

7.1 Aeronautic Research Mission Directorate / Advanced Air Vehicles Program / Revolutionary Vertical Lift Technology Project

Aeronautic Research Mission Directorate
NASA Glenn Research Center

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Research Focus Area: Safe and Efficient Electro-mechanical Powertrains for Electrified Vertical Takeoff and Landing (eVTOL) Vehicles
Research Identifier: **A-001**

Research Focus Area: Electric motor technologies appropriate for eVTOL with high torque density and, concurrently, such motors being free of partial discharge and having a continuous power rating in the range 50 – 400 kW.
Research Identifier: **A-002**

Research Focus Area: High reliability, robustness, and fault-tolerance for inverter-motor systems as needed for safety-critical eVTOL propulsion.
Research Identifier: **A-003**

Research Focus Area: Lubrication and cooling technologies specifically optimized for long life and highly efficient eVTOL motors, including interest in single-fluid approaches for inverters, motors, and gearboxes.
Research Identifier: **A-004**

Research Overview: With their unique ability to take off and land from any spot, as well as hover in place, vertical lift vehicles are increasingly being contemplated for use in new ways that go far beyond those considered when thinking of traditional helicopters. NASA's Revolutionary Vertical Lift Technology (RVLT) project is working with partners in government, industry, and academia to develop critical technologies that enable revolutionary new air travel options, especially those associated with Advanced Air Mobility (AAM) such as large cargo-carrying vehicles and passenger-carrying air taxis.

These new markets are forecast to rapidly grow during the next ten years, and the vertical lift industry's ability to safely develop and certify innovative new technologies, lower operating costs, and meet acceptable community noise standards will be critical in opening these new markets.

NASA is conducting research and investigations in Advanced Air Mobility (AAM) aircraft and operations. AAM missions are characterized by ranges below 300 nm, including rural and urban operations, passenger carrying as well as cargo delivery. Such vehicles will require innovative propulsion systems, likely electric or hybrid-electric, that may need advanced electro-mechanical powertrain technology.

Research Focus: Analytical and/or experimental fundamental research is sought for electro-mechanical powertrains for electrified vertical takeoff and landing (eVTOL) vehicles. The focus is safety and efficiency, and overall goals are to obtain high power-to-weight with long life and higher reliability than the current state of the art. The scope includes electric motors and associated power electronics, possibly combined with mechanical or magnetically-geared transmissions. Research topics of particular interest are those that focus on:

1) reliable, efficient, high power density electro-mechanical powertrain technology for eVTOL
2) electric motor technologies appropriate for eVTOL with high torque density and, concurrently, such motors being free of partial discharge (refs. 7,8) and having a continuous power rating in the range 50 – 400 kW
3) high reliability, robustness, and fault-tolerance for inverter-motor systems as needed for safety-critical eVTOL propulsion
4) lubrication and cooling technologies specifically optimized for long life and highly efficient eVTOL motors, including interest in single-fluid approaches for inverters, motors, and gearboxes

The target application is eVTOL vehicles sized to carrying four to six passengers with missions as described in References 1-6. Challenges related to insulation of motor windings and the phenomena of partial discharge are discussed in the literature (examples: references 7,8).

This research opportunity is relevant to aerospace propulsion and is of mutual interest to NASA, FAA, DoD, and the US vertical lift vehicle industry.

References:

1) Silva, C.; Johnson, W.; and Solis, E. "Multidisciplinary Conceptual Design for Reduced-Emission Rotorcraft." American Helicopter Society Technical Conference on Aeromechanics Design for Transformative Vertical Flight, San Francisco, CA, January 2018.
2) Johnson, W.; Silva, C.; and Solis, E. "Concept Vehicles for VTOL Air Taxi Operations." American Helicopter Society Technical Conference on Aeromechanics Design for Transformative Vertical Flight, San Francisco, CA, January 2018.
3) Patterson, M.D.; Antcliff, K.R.; and Kohlman, L.W. "A Proposed Approach to Studying Urban Air Mobility Missions Including an Initial Exploration of Mission Requirements." American Helicopter Society 74th Annual Forum, Phoenix, AZ, May 2018.
4) Silva, C.; Johnson, W.; Antcliff, K.R.; and Patterson, M.D. "VTOL Urban Air Mobility Concept Vehicles for Technology Development." AIAA Paper No. 2018-3847, June 2018.
5) Antcliff, K. Whiteside, S., Silva, C. and Kohlman, L. "Baseline Assumptions and Future Research Areas for Urban Air Mobility Vehicles," AIAA Paper No. 2019-0528, January 2019.
6) Silva, C., and Johnson, W. "Practical Conceptual Design of Quieter Urban VTOL Aircraft." Vertical Flight Society 77th Annual Forum, May 2021.
7) Tallerico, T., Salem, J., Krantz, T. and Valco, M., "Urban Air Mobility Electric Motor Winding Insulation Reliability: Challenges in the Design and Qualification of High Reliability Electric Motors and NASA's Research Plan." NASA TM-20220004926, 2022.
8) Petri, T., Keller, M. and Parspour, N. "The Insulation Resilience of inverter-fed Low Voltage Traction Machines: Review, Challenges, Opportunities." IEEE Access (2022).

Intellectual Property Rights: All data and analysis methods will be publicly available and no intellectual property rights will be assigned to any of the parties involved in this research.

Research Focus Area: Development of Characterization Techniques to Determine Rate and

Temperature Dependent Composite Material Properties for the LS-DYNA MAT213 Model

Research Identifier: **A-005**

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Research Overview: Overview of MAT213 - MAT213 is an orthotropic macroscopic three-dimensional material model designed to simulate the impact response of composites which has been implemented in the commercial transient dynamic finite element code LS-DYNA [1-5]. The material model is a combined plasticity, damage and failure model suitable for use with both solid and shell elements. The deformation/plasticity portion of the model utilizes an orthotropic yield function and flow rule. A key feature of the material model is that the evolution of the deformation response is computed based on input tabulated stress-strain curves in the various coordinate directions.

The damage model employs a semi-coupled formulation in which applied plastic strains in one coordinate direction are assumed to lead to stiffness reductions in multiple coordinate directions. The evolution of the damage is also based on tabulated input from a series of load-unload tests. A tabulated failure model has also been implemented in which a failure surface is represented by tabulated single valued functions. While not explicitly part of MAT213, when using the model, interlaminar failure is modeled using either tie-break contacts or cohesive elements.

The MAT213 model has the ability to incorporate both rate dependency and temperature dependency in the material response, which, potentially, could be important aspects of the dynamic and impact response of composites. To date, very little has been done to assess the effectiveness of the rate- and temperature-dependence modeling approaches, or to assess the importance of incorporating these effects in dynamic crush and impact problems. In dynamic crush problems, such as drop weight tests on composite structures, differences in response at different loading rates have been observed [6,7]. In ballistic impact tests of composite panels significant temperature rises have been documented [8]. But a fundamental understanding of the effect of strain rate and temperature is needed.

For this task we are focused on developing techniques and recommended approaches to characterize the rate dependent material parameters required for input into MAT 213 using tests at the coupon scale or similar fundamental types of tests at higher structural scales. In addition, we would like to characterize the effects of temperature changes under dynamic loading to assess the need for incorporating temperature dependence in dynamic models. To carry out this task, we are interested in having NASA-supplied composite materials and structures tested at high loading rates and/or potentially varying temperatures representative of what would exist in crash and impact events. It is expected that the tests will be conducted at the proposer’s facility. NASA will attempt to provide a material for which quasi-static room temperature data are available.

A particular additional area of interest is in characterizing the post-peak material response, which can be important in simulating the response of actual structures. Currently, in many cases post peak material parameters are correlated based on the results of structural level tests. A need exists to develop capabilities and methods to characterize material parameters based on lower scale tests that are applicable for the analysis of full structures.

Research Requirements

Coupon Level Testing. Specific tests at a range of strain rates and/or temperatures that are of interest could include the following:

- Tension in the 1-direction
- Compression in the 1-direction
- Tension in the 2-direction
- Compression in the 2-direction
- Shear in the 12-direction
- Shear in the 21-direction
- 45 degrees off axis tension

Note that other tests may be conceived and conducted to develop methods to fully characterize the material of interest and to meet the goals of the project. Within the constraints of time and budget it may be necessary to prioritize tests where rate effects are expected to be more important.

Test Requirements

i. Test coupons will be machined by the grant recipient from flat panels supplied by NASA.
ii. For all tests the full set of test data must be recorded and supplied in electronic tabular format. For the tension, compression and shear tests that are conducted, the tabulated stress-strain curve, all the way to failure, must be provided. Raw data such as loads must also be supplied.
iii. All specimens must be measured and weighed prior to testing
iv. Testing is to be conducted at appropriate and relevant rate and temperature conditions.
v. The test environmental conditions must be recorded and documented
vi. A minimum of three repeats for each loading condition must be conducted
vii. Full Field Digital Image Correlation (DIC) must be used to measure deformations and strains

Deliverables

a. Full tabulated data supplied in electronic tabular format
b. All DIC images and associated calibration files
c. A final report detailing the procedures and results.

References:

1. Khaled, B., Shyamsunder, L., Schmidt, N. Hoffarth, C. and Rajan, S., “Development of a Tabulated Material Model for Composite Material Failure, MAT213. Part 2: Experimental Tests to Characterize the Behavior and Properties of T800-F3900 Toray Composite”, DOT/FAA/TC-19/51, Nov. 2018
2. T. Achstetter, “Development of a composite material shell-element model for impact applications”, *PhD Dissertation,* George Mason University, 2019
3. Goldberg, R.K.; Carney, K.S.; DuBois, P.; Hoffarth, C.; Harrington, J; Rajan, S.; and Blankenhorn, G.: “Development of an Orthotropic Elasto-Plastic Generalized Composite Material Model Suitable for Impact Problems”, *Journal of Aerospace Engineering*, Vol. 29, no. 4, 04015083, 2016.
4. Goldberg, R.K.; Carney, K.S.; DuBois, P.; Hoffarth, C.; Khaled, B.; Rajan, S.; and Blankenhorn, G.: “Analysis and Characterization of Damage Utilizing a Generalized Composite Material Model Suitable for Impact Problems”, *Journal of Aerospace Engineering*, Volume 31, Issue 4, 10.1061/(ASCE)AS.1943-5525.0000854, 04018025, 2018.

5. Goldberg, R.K.; Carney, K.S.; DuBois, P.; Hoffarth, C.; Khaled, B.; Shyamsunder, L.; Rajan, S.; and Blankenhorn, G.: "Implementation of a tabulated failure model into a generalized composite material model", *Journal of Composite Materials*, Vol. 52, Issue 25, pp. 3445-3460.
6. Chambe, J.-E., Bouvet, C., Dorival, O., Rivallant, S. and Ferrero, J.-F. "Effects of dynamics and trigger on energy absorption of composite tubes during axial crushing", Int. J. Crashworthiness, 26(5), 2021.
7. Haluza, R., "Measurement and explicit finite element modeling of dynamic crush behavior of carbon fiber reinforced polymer composites", Ph.D. Dissertation, Pennsylvania State University, 2022
8. Johnston, J. P., Pereira, J. M., Ruggeri, C. R., & Roberts, G. D. (2018). High-speed infrared thermal imaging during ballistic impact of triaxially braided composites. *Journal of Composite Materials*, *52*(25), 3549-3562.

Intellectual Property Rights: All data and analysis methods will be publicly available and no intellectual property rights will be assigned to any of the parties involved in this research.

7.2 Astrophysics

Research Focus Area: Astrophysics Technology Development
Research Identifier**:** **A-006**

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NASA Astrophysics undertakes space missions to explore the nature of the Universe at its largest scales, its earliest moments, and its most extreme conditions; missions that study how galaxies and stars formed and evolved to shape the Universe we see today; and missions that seek out and characterize planets and planetary systems orbiting other stars. These ambitious missions require advancements in science and technologies beyond the state-of-the-art to enable precise measurements that should retire current and future science and technology gaps.

TECHNOLOGY:

- Astrophysics Technology Development: https://apd440.gsfc.nasa.gov/technology.html
- Technology Highlights: https://science.nasa.gov/technology/technology-highlights?topic=11
- Astrophysics Technology Database: http://www.astrostrategictech.us/

ASTROPHYSICS DATA CENTERS:

- https://science.nasa.gov/astrophysics/astrophysics-data-centers

DOCUMENTS:

- Astrophysics Documents: https://science.nasa.gov/astrophysics/documents

DECADAL SURVEY 2020:

- Decadal Survey on Astronomy and Astrophysics 2020 (Astro 2020): https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020

CITIZEN SCIENCE PROJECTS:

- Current projects: https://science.nasa.gov/citizenscience

RESEARCH SOLICITATIONS:

- Omnibus NASA Research Announcement (NRA): https://science.nasa.gov/researchers/sara/grant-solicitations/roses-2021/schedule-research-opportunities-space-and-earth-sciences-roses-2021

7.3 NASA Biological and Physical Sciences (BPS)

NASA Headquarters Biological and Physical Sciences Division

Research Focus Area: Fundamental Physics
Research Identifier**:** **B-001**

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

Research Overview: 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.

Research Focus: 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.

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS). Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

Research Focus Area: Soft Matter Physics
Research Identifier**:** **B-002**

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

Research Overview: Granular material is one of the key focus areas of research 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.

Research Focus: 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.

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS). Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

Research Focus Area: Fluid Physics
Research Identifier**:** **B-003**

POC: Brad Carpenter bcarpenter@nasa.gov (202) 358-0826

Research Overview: The goal of the microgravity fluid physics program is to understand fluid behavior of physical systems in space, providing a foundation for predicting, controlling, and improving a vast range of technological processes. Specifically, in reduced gravity, the absence of buoyancy and the stronger influence of capillary forces can have a dramatic effect on fluid behavior. For example, capillary flows in space can pump fluids to higher levels than those achieved on Earth. In the case of systems where phase-change heat transfer is required, experimental results demonstrate that bubbles will not rise under pool boiling conditions in microgravity, resulting in a change in the heat transfer rate at the heater surface. The microgravity experimental data can be used to verify computational fluid dynamics models. These improved models can then be utilized by future spacecraft designers to predict the performance of fluid conditions in space exploration systems such as air revitalization, solid waste management, water recovery, thermal control, cryogenic storage and transfer, energy conversion systems, and liquid propulsion systems.

Research Focus: 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

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS). Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

Research Focus Area: Combustion Science
Research Identifier**:** **B-004**

POC: Brad Carpenter bcarpenter@nasa.gov (202) 358-0826

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

Research Focus: The research area of combustion science includes the following themes:

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

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS). Additional information on BPS can be found at:

https://science.nasa.gov/biological-physical

NASA Biological and Physical Sciences (BPS)
NASA Marshall Space Flight Center (MSFC) / EM41

Research Focus Area: Materials Science
Research Identifier: **B-005**

POC: Brad Carpenter bcarpenter@nasa.gov (202) 358-0826

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

Research Focus: The research area of materials science includes the following themes:

Glasses and ceramics
Granular materials
Metals
Polymers and organics
Semiconductors

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS). Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

Research Focus Area: Growth of plants in inhospitable “deep space-relevant” Earth soils or conditions
Research Identifier: **B-006**

POC: Sharmila Bhattacharya SpaceBiology@nasaprs.com

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

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

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

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

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

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

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge

NASA Space Biology Program. If the NASA GeneLab Data Systems (genelab.nasa.gov) is used, GeneLab shall be referenced in the resulting publication and included in the keyword list. All omics data obtained from this study shall be uploaded to the NASA GeneLab (https://genelab.nasa.gov).

References:

Ferl RJ, Paul AL. Lunar plant biology--a review of the Apollo era. Astrobiology. 2010 Apr;10. doi/10.1089/ast.2009.04173:261-74. doi: 10.1089/ast.2009.0417.

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

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

Research Focus Area: Commercially Enabled Rapid Space Science Project (CERISS)
Research Identifier**:** **B-007**

POC: Dr. Lisa Carnell; lisa.a.scottcarnell@nasa.gov

Research Overview: 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.

Research Focus: Advancement of capabilities in the following areas are of particular interest:

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

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS). Further information on CERISS is available at: https://science.nasa.gov/biological-physical/commercial.

7.4 Center for Design and Space Architecture

Center for Design and Space Architecture

NASA Johnson Space Center

Missions beyond LEO are challenging for traditional survivability paradigms such as redundancy management, reliability, sparing, orbital replacement, and mission aborts. Distances, transit durations, crew time limitations, onboard expertise, vehicle capabilities, and other factors significantly limit the ability of human spaceflight crews to respond to in-flight anomalies. There is a need for a Repair, Manufacturing, and Fabrication (RMAF) facility to increase the capability of the crew to recover from spacecraft component failures by combing aspects of machine shop, soft goods lab, and repair shop into an IVA capability for both microgravity and surface spacecraft. An RMAF is responsible for restoring damaged components to working order (repair), keeping components in service or properly functioning (maintenance), and creating new components from raw or scavenged materials (fabrication). This responsibility extends not only to the habitat, but to all other elements sharing the same destination environment (e.g., landers, rovers, robots, power systems, science instruments, etc.). The RMAF serves both the physical operability needs of the architectural systems and contributes in two ways to the psychological well-being of the crew: one the peace of mind from understanding the capacity to respond to failures, and two, the capacity to fabricate items that serve recreational or relaxation purposes. The RMAF has potential applicability to a wide variety of in-space habitation needs.

NASA is exploring space architectures that can serve as next steps to build upon the current Artemis program. The Common Habitat Architecture Study is based on a suite of common spacecraft elements that can be used for long-duration human spaceflight in multiple destinations, including the Moon, Mars, and deep space. NASA is seeking engineering and architectural research to aid in the development of an RMAF facility capable of packaging within mid deck of the Common Habitat, a Skylab-like habitat that uses the Space Launch System (SLS) core stage liquid oxygen tank as the primary structure, with a horizontal orientation. Because most habitats intended for use beyond LEO do not return to Earth, yet may operate for decades, it can be assumed that even low probability failures will eventually occur and there must be a way to recover from them and continue the mission. Thus, the Common Habitat must include the RMAF capability. The RMAF speaks to an overarching gap of inability to mitigate spacecraft component failures. Limited in-space experiments have been conducted with 3D printing, welding, soldering, and other RMAF tools, but they have yet to be integrated into an operable spacecraft facility. The RMAF goes beyond the replacement of failed components with spares and focuses on the capabilities to restore failed components to working order, making them effectively the new spare.

Research Focus Area:	Repair, Manufacturing, And Fabrication (RMAF) Facility for the Common Habitat Architecture
Research Identifier**:**	**C-001**
POC:	Robert Howard robert.l.howard@nasa.gov

Research Focus: Proposed studies will assess the needs of an RMAF system for long-duration, deep space habitation and create one design solution to increase crew and vehicle survivability. Prior research has identified a list of 53 component-level critical failures that could render a subsystem or element inoperable. Fourteen repair, maintenance, and fabrication functions have been identified as collectively being able to recover a system from any of these failures. This establishes the target capability of the RMAF. Proposers will design a workspace within the volume limitations of the Common Habitat, while still accommodating these fourteen functions and will determine the associated mass impacts.

Critical Failures Requiring RMAF Capability

1. Actuator FOD
2. Actuator overpressure
3. Actuator underpressure
4. Adhesive failure
5. Bad wireless connection
6. Belt break
7. Broken cables
8. Broken electrical connection
9. Broken physical structure
10. Bulb burnout
11. Bulb shatter
12. C&W software failure
13. Connector overtorque
14. Connector pin/connection failure
15. Connector under torque
16. Consumable depletion
17. Cracked housing
18. Cracked screen
19. Debris clog
20. Debris impact damage
21. Debris in motor
22. Diaphragm damage (digital)
23. Electrical lead failure
24. Electrical short
25. Fabric erosion
26. Fabric tear
27. Failed electrical connection
28. Fin breakage / bending/ding
29. Fluid line rupture
30. Fuse blown
31. Kinked line
32. Material abrasion / erosion
33. Material corrosion
34. Material delamination
35. Material stretching
36. Motor failure
37. Physical obstruction
38. Potting failure
39. Power surge
40. Pressure bladder puncture, tear, or rip
41. Spring too weak or too stiff
42. Structural bending
43. Structural buckling
44. Structural burst
45. Structural crack/fracture
46. Structural deformation
47. Structural gouge
48. Structural membrane disjoin
49. Structural rupture / puncture
50. Structural seal failure
51. Structural shear
52. Surface chemical contamination
53. Wire detach, split, tear, rip, or break

Generic RMAF Functions to Repair Critical Failures

1. Soldering
2. Drilling
3. Metal cutting and bending
4. Metallurgical analysis
5. Bonding metal, composite, and other surfaces
6. Electronics analysis and repair
7. Computer/Avionics inspection/testing and repair
8. CAD Modeling / Software Coding / Computer Analysis
9. Material Handling (inclusive of the range from large ORUs and small fasteners)
10. Precision Maintenance (manipulation, inspection, repair of small/delicate components)
11. 3D Printing (metal, plastic, and printed circuit board)

12. Soft goods (including thermoplastics, sewing, cutting, and patching)
13. Dust/Particle/Fume Mitigation
14. Welding

A design solution should include a mass equipment list (MEL), CAD model, and Concept of Operations document. CAD models must be in a format capable of being opened by Rhino 7 and must also be suitable for incorporation in Virtual Reality using the Unreal Engine 5. Physical prototyping and iterative human-in-the-loop (HITL) testing are encouraged but are not required.

References:

[1] Howard, Robert, "Opportunities and Challenges of a Common Habitat for Transit and Surface Operations," in 2019 IEEE Aerospace, Big Sky, MT, 2019.

[2] Howard, Robert, "Stowage Assessment of the Common Habitat Baseline Variants," in 2020 AIAA ASCEND, Virtual Conference, 2020.

[3] Howard, Robert, "Design Variants of a Common Habitat for Moon and Mars Exploration," 2020 AIAA ASCEND, AIAA, Virtual Conference, 2020.

[4] Howard, Robert, "A Multi-Gravity Docking and Utilities Transfer System for a Common Habitat Architecture," in 2021 AIAA ASCEND, Las Vegas, NV + Virtual, 2021.

[5] Howard, Robert, "A Two-Chamber Multi-Functional Airlock for a Common Habitat Architecture," in 2021 AIAA ASCEND, Las Vegas, NV + Virtual, 2021.

[6] Howard, Robert, "A Common Habitat Base camp for Moon and Mars Surface Operations," in 2021 AIAA ASCEND, Las Vegas, NV + Virtual, 2021.

[7] Howard, Robert, "A Common Habitat Deep Space Exploration Vehicle for Transit and Orbital Operations," in 2021 AIAA ASCEND, Las Vegas, NV + Virtual, 2021.

[8] Howard, Robert. "A Safe Haven Concept for the Common Habitat in Moon, Mars, and Transit Environments." 2021 AIAA ASCEND. Las Vegas, NV + Virtual. November 8-17, 2021.

[9] Howard, Robert, "Down-Selection of Four Common Habitat Variants," in 2022 IEEE Aerospace, Big Sky, MT, 2022.

[10] Howard, Robert, "Internal Architecture of the Common Habitat," in 2022 IEEE Aerospace Conference, Big Sky, Montana, 2022.

Proposer-Coordinated Contributions to Proposed Work: Proposer to indicate any contributions to the proposed work that the Proposer has arranged, in the event of a NASA award, and that would be in addition to NASA EPSCoR awarded funding. This may include funding or other in-kind contributions such as materials or services (Proposal should indicate the estimated value of the latter)

a. **From Jurisdiction or Organization that would partner with the Jurisdiction**
   Encouraged but None are required. Proposer shall indicate if any has been arranged for the proposed work.

Intellectual Property Rights: All technologies developed through this research will be submitted through NASA's New Technology Reporting System prior to any public dissemination. Unless otherwise determined by the NASA New Technology Office, all data and analysis methods will be publicly available and no intellectual property rights will be assigned to any of the parties involved in this research. Proposer to indicate any specific intellectual property considerations in the Proposal.

Additional Information: NASA will support a telecon with the Proposer prior to the submission of Proposals, to answer Proposer's questions and discuss Proposers anticipated approach towards this Research Request. Contact information is provided in section (5). NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee. NASA goal is for widest possible eventual dissemination of the results from this work when other restrictions allow.

7.5 Commercial Space Capabilities (CSC)

NASA Johnson Space Center
Commercial Space Capabilities Office

The Commercial Space Capabilities (CSC) Research Interest area supports the Commercial Low Earth Orbit Development Program of NASA's Space Operations Mission Directorate (SOMD). This area's purpose is to harness the capabilities of the U.S. research community to advance research and perform initial proofs / validations, that improve technologies of interest to the U.S. commercial spaceflight industry. The intent is to address the commercially riskiest portion of implementing new and improved technologies ("Innovation Valley of Death") to advance science and technologies from TRL1 through to TRL4. U.S. commercial spaceflight industry can then assess and determine implementation.
The overall goal of this area is to encourage and facilitate a robust and competitive U.S. low Earth orbit economy. Efforts that primarily benefit near-Earth commercial activities but that may also be extensible Moon and/or Mars are also in scope.

Research Focus Area: In-Space Welding
Research Identifier**:** **C-002**

POC: Warren Ruemmele warren.p.ruemmele@nasa.gov

Research Overview: Research and initially demonstrate (in 1g) metal welding suitable for being directly exposed to space vacuum/0g. Metals of interest are those typically used for spacecraft structures and plumbing. (Extensibility to being used while exposed to Moon vac/g, and/or Mars atm/g environments could be a secondary interest.) Potential applications include the in-space assembly of very large structures that are too bulky or heavy to launch in one piece, and insitu repair or modifications. Consider weld processes suitable for incorporation into a robotic or EVA crew tool. A related secondary interest is for a metal cutting operation suitable for incorporation into a robotic or EVA crew tool. For cutting operations consider debris generation and how to control.

Research Focus Area: Materials and Processes Improvements for Chemical Propulsion State of Art (SoA)
Research Identifier**:** **C-003**

POC: Warren Ruemmele warren.p.ruemmele@nasa.gov

Research Overview: Propose and demonstrate improvements for launch, entry, and/or in-space chemical propulsion (of any type), to improve performance, reduce cost, enable new capabilities, and/or improve/simplify manufacturing. For this topic, when a current SoA exists, identify the shortcoming in the current SoA that the improvement addresses. NASA is specifically interested in proposed work in two subtopics:
Increase the knowledgebase of methane/natural gas/oxygen/air characteristics and combustion, pertinent to spaceflight applications. For this subtopic the Proposer should identify any current knowledge gaps that the work would try to address.
Develop new computational simulation tool(s) for Methane/Natural Gas Plume Combustibility modelling

specifically for spaceflight applications. Tool would use inputs for: vehicle/storage tank dimensions/ shape (e.g. IGES file), vent locations / separation distance, venting rate, species (Methane and Natural Gas mixtures, Oxygen, air) characteristics, and total propellant masses. Tool would then perform thermophysical calculations to estimate potential of developing combustible / explosive mixtures and the potential explosive force / quantity distance, and considering the effects of: ambient wind and atmospheric condition. Petroleum Industry and Governmental standards / procedures should also be considered. Scenarios to assess are:
Launch vehicle boiloff of cryogenic propellants while on pad prior to launch.
Launch site storage tank boiloff of liquified methane/natural gas and oxygen.

Research Focus Area: Materials and Processes Improvements for Electric Propulsion State of Art (SoA)
Research Identifier**:** **C-004**

POC: Warren Ruemmele warren.p.ruemmele@nasa.gov

Research Overview: Propose and demonstrate improvements for solar powered electric propulsion suitable for cislunar application, to improve performance, reduce cost, enable new capabilities, and/or improve/simplify manufacturing. For this topic; i) Proposer may contact NASA to schedule a pre-proposal telecon to discuss approach and understand details. ii) Proposer must describe the existing personnel skill and expertise, and facility capabilities to perform the work such as material finishing/processing, testing, inspection, and failure analysis.

NASA is specifically interested in proposed work to any of these three subtopics:

1) Material Properties: An evaluation of the bulk mechanical, thermal, and electrical properties of several common commercially available grades of material in environments relevant to thruster designs.
    a. Specific grades and in some cases samples can be provided by NASA and may include graphite, ceramics, refractories, aluminum, titanium, stainless steel, Inconel, Kovar, and other materials commonly used in thruster designs.
    b. Properties of interest include mechanical strength (flexural and compressive), low cycle fatigue, high cycle fatigue, toughness, slow crack growth, elastic modulus, Poisson's ratio, thermal conductivity, electrical conductivity, emissivity, thermal expansion, and outgas properties.
    c. Environments of interest include ambient temperature, low temperature (-40ºC), thruster temperature (600ºC), and cathode temperature (1100ºC).
    d. This work is intended to help fill gaps in open literature for common properties and materials used by the electric propulsion community to aid in design and analysis.

2) Material Deposition: An evaluation of material deposition resulting from ion beam sputtering of commonly used EP materials onto common spacecraft materials. Data shall include the following:
    a. Phase of the material deposited
    b. Whether the deposits are conductive or insulating
    c. Deposition rate compared to sputter yield based predictions,
    d. When/if spalling of the deposition occur.

3) Krypton Sputter Erosion: An evaluation of the sputter erosion of common thruster, spacecraft, and related materials from Krypton ion bombardment. The materials will be exposed to Krypton ion beams and the following will be determined:

a. The dependence of the total yield with ion energies in the general range of tens to volts up to 1 kV
b. Dependence of the total yield with ion incidence angles from normal to near grazing, and/or
c. Differential yield profiles at various energies and incidence angles.

Materials of interest include graphite, ceramics, coverglass, kapton, composites, and/or anodized coatings. This effort may be combined with the Material Deposition effort as appropriate including possibly measurement of sticking coefficients of the sputtered products

Research Focus Area: Improvements to Space Solar Power State of Art (SoA)
Research Identifier: **C-005**

POC: Warren Ruemmele warren.p.ruemmele@nasa.gov

Research Overview: Propose and demonstrate improvements for solar power generation (of any type) suitable for cis-lunar in-space application (e.g. space stations, satellites, power beaming), to improve performance, reduce cost, enable new capabilities, and/or improve/simplify manufacturing. NASA is especially interested in these two subtopics:

1) Improvements for in-space photovoltaics compared to current spaceflight solar array SoA.
2) Engineering trade studies of other solar power production methods (e.g. concentrators, thermodynamic cycles, etc) compared to current SoA space photovoltaic systems. Considerations would include: Technology readiness and gaps, launch volume and mass with respect to current US launch vehicles, peak/steady state power and characteristics, efficiency, operational considerations, in-space lifetime/performance degradation, energy storage, orbit and distance, and identifying break points and sweet spots.

Research Focus Area: Small Reentry Systems
Research Identifier: **C-006**

POC: Warren Ruemmele warren.p.ruemmele@nasa.gov

Research Overview: Design and demonstrate reentry systems that can be deployed from low Earth orbit to perform a self-guided intact reentry to return small cargo contained inside them intact to Earth. Cargo might include science samples, space-manufactured items, etc. An alternate use is to recover flight data recorders from destructively reentering technology demonstrators to allow retrieving large amounts of telemetry without the use of communications satellites. Passively guided systems are preferred. Such reentry systems might need to be safely storable inside crewed in-space platforms so preference is to not use hazardous materials. Hazards for people/property on the Earth resulting from reentry must be considered. Landing on ground is preferred to simplify and expedite recovery.

Research Focus Area: Other Commercial Space Topic
Research Identifier: **C-007**

POC: Warren Ruemmele warren.p.ruemmele@nasa.gov

NASA is receptive to topics in this Research Interest Area that it may not have already identified if a strong case can be made for these. The Proposer may therefore propose other topics as follows:

1) The proposed Topic must be consistent with the Intent and goal of this CSC Area.

2) The proposal must include a strong letter of support from a U.S. commercial company that describes the company's need for the work and any arrangements with the Proposer.
3) Before submitting the proposal for such a topic, the Proposer must discuss with NASA per CSC NASA Contact listed in the following page.

Additional Instructions for Proposals in this CSC Interest Area (C-002 through C-007):

A. Content

1. Proposals should discuss how the effort is anticipated to align with U.S. commercial spaceflight company interest(s). Proposers are encouraged to contact U.S. commercial spaceflight companies to understand current research challenges.
2. Proposals should identify the estimated starting and end point of the currently proposed effort in terms of Technology Readiness Level (TRL) https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf), and what subsequent work might be anticipated to achieve TRL5.
3. If there is an existing SoA, state how proposed work would address an identified need/shortcoming (not just a "nice to have").
4. Describe proposing Institution's and Co-I/Sci-I's relevant capabilities and prior work. Compare and contrast proposed work against prior and existing work by others. (Weblinks preferred. Does not count against the Technical page limit.)
5. Work must produce a final report and delivery of developed design concept and data (as applicable).
6. Proposers can assume that technically knowledgeable NASA engineers and scientists will be reviewing the Proposal – so Proposer should focus on technical/scientific specifics.
7. NASA anticipates that depending on the specifics of the proposed work, the Proposer *may* need to implement Export Controls (e.g. EAR or ITAR). Proposer should identify in their proposal whether they believe Export Control would apply, and identify (e.g. weblink) institutional export control methods/policy in the proposal's Data Management Plan. Proposer may contact NASA PoC to discuss prior to submitting proposal.
8. For Rapid Response Research (R3) proposals to this CSC interest area, the Technical portion of the proposal may be up to five (5) pages.

B. Contributions to Proposed Work other than NASA EPSCoR

Proposer-coordinated contributions from Jurisdiction, or Organizations (especially US commercial entities) that would partner with the Jurisdiction, are welcomed but not required. If there are such contributions then the Proposer must state what has been arranged, include funding or other in-kind contributions such as materials or services and indicate the estimated value of these.

C. Intellectual Property

Proposer to indicate any intellectual property considerations in the Proposal.

D. Publishing of Results

NASA welcomes opportunities to co-publish results as proposed by EPSCoR awardee, and its goal is for widest possible eventual dissemination of the results of the Researcher(s) work, to the extent other restrictions (e.g. Export Control) allow. For results that must be controlled, NASA will work with Researcher to present accordingly, and make data available in access controlled databases such as MAPTIS database https://maptis.nasa.gov/ .

E. NASA Contact
The CSC NASA Contact will support a telecon with the Proposer prior to the submission of their Proposal, to answer questions and discuss anticipated approach towards this Research Request. NASA Contact will coordinate support from within NASA as needed to provide subject matter expertise/limited consultation in event of award. (If Proposer has already discussed with and NASA or JPL personnel please identify so they might be able to support telecon.)

7.6 NASA SMD Computational and Information Sciences and Technology Office (CISTO)

NASA Goddard Space Flight Center
Ethical/Inclusive AI Research Opportunity
James Harrington james.l.harrington@nasa.gov 301-286-4063

Research Overview: Computational and Information Sciences and Technology Office (CISTO) Computational and Technological Advances for Scientific Discovery via AI/ML Modeling and Development implementing an open science approach.
NASA open science promotes the availability of original source code and data to be available on the public domain to be repurposed for easier collaborations to be born among different groups or teams to work towards solving scientific problems that can benefit society.
NASA SMD communicates a VISION via the SMD Big Data Working Group (Strategy for Data Management and Computing for Groundbreaking Science 2019-2024 Report) to enable transformational open science through continuous evolution of science data and computing systems for NASA's Science Mission Directorate. SMD requests that NASA EPSCoR include research opportunities for data analysis that provide tools and training to diverse communities to be better able to collaborate with all types of computational and computer scientists that enables the funding of successful collaborations, including Artificial Intelligence and Machine Learning (AI/ML).

Artificial intelligence technology is rapidly growing in capability, impact and influence. As designers and developers of AI systems, it is an imperative to understand the ethical considerations of our work. A tech-centric focus that solely revolves around improving the capabilities of an intelligent system doesn't sufficiently consider human needs. (credit: IBM everyday ethics)

In 2019, a representative poll across NASA revealed over one hundred agency applications of AI in the past three years, with hundreds of AI projects planned across various missions, centers, and mission support activities from 2020 to 2022 and beyond. In November and December of 2020, the White House and Office of Management and Budget (OMB) published guidance3 regarding AI principles, policy, and governance. As an enthusiastic and forward leaning AI adopter, NASA must create and apply an evolving, living set of AI policies, principles, and guidelines to provide AI practitioners an ethical framework for their work.
NASA Framework for the Ethical Use of Artificial Intelligence (AI) TM RDP Fillable 298.pdf (nasa.gov).
The executive summary from the NASA Framework for the Ethical Use of AI guides the focus of this research opportunity:
The initial framework for NASA's ethical use of AI includes considerations applicable to today's simple Artificial Narrow Intelligence (ANI), as well as future human-level Artificial General Intelligence (AGI), and beyond to Artificial Super Intelligence (ASI). Considerations also include the ways humans may interact with machines, from using them as tools to augmenting humans with implants, to more speculative further-term topics such as the merging or melding of human and machine. This NASA

framework draws from principles and frameworks of many other leading organizations, relating them to NASA's specific needs to provide an initial set of six ethical AI principles:

Fair. AI systems must include considerations of how to treat people, including scrubbing solutions to mitigate discrimination and bias, preventing covert manipulation, and supporting diversity and inclusion.

Explainable and Transparent. Solutions must clearly state if, when, and how an AI system is involved, and AI logic and decisions must be explainable. AI solutions must protect intellectual property and include risk management in their construction and use. AI systems must be documented.

Accountable. Organizations and individuals must be accountable for the systems they create, and organizations must implement AI governance structures to provide oversight.

Secure and Safe. AI systems must respect privacy and do no harm. Humans must monitor and guide machine learning processes. AI system risk tradeoffs must be considered when determining benefit of use.

Human-Centric and Societally Beneficial. AI systems must obey human legal systems and must provide benefits to society. At the current state of AI humans must remain in charge, though future advancements may cause reconsideration of this requirement.

Scientifically and Technically Robust. AI systems must adhere to the scientific method NASA applies to all problems, be informed by scientific theory and data, robustly tested in implementation, well-documented, and peer reviewed in the scientific community.

Need for involvement of underrepresented communities

A common issue of interest is the need for direct involvement of underrepresented communities in building, using, and testing datasets for bias and AI applications for fairness and disparate impact. Some specific questions noted include the following:

- How do we reach underrepresented communities?
- Can we involve underrepresented communities into user-centered design at every stage of data collection and AI design and usage?
- How do we support the need for creativity in identifying potential biases?
- How do we keep data secure so that people will trust data collection?
- Can we involve underrepresented communities to correct bias in AI apps and use "human-in-the-loop?

Supporting increasing diversity

Methods and suggestions for involving underserved communities in STEM and development of technical skills to increase diversity of AI developers:

- Include / recruit from diverse institutions - HBCUs, HSIs, and MSIs
- Involve Subject Matters Experts (e.g., social scientists, not just technologists) for diversity of thought

Increasing awareness of inequitable impact and use of review/testing

- Adopt equity impact assessments
- Educate developers in testing for inclusive AI
- Involve acquisition in training to spot inclusive AI
- Assign dedicated roles for reviewing AI applications for equity (e.g, scientific review officers)

Today's markets, including NASA missions, are relying every more increasingly on highly automated and

autonomous systems for the wide range of benefits they provide. Many of these systems have or will be taking over some of roles that human previously were responsible for. Some of those key roles include independent decision-making and learning. Independent, autonomous decision-making & learning carry with them significant implications, both of which include ensuring ethical behavior and beliefs.
At this time, there are no formal ethics standards with detailed parameters highly automated and autonomous systems to use. Executive Order 13960 and the Federal Data Strategy Action Plan provide a starter set of Federal AI ethics principles, and direct Federal organizations to begin taking action to guide responsible use of AI.
This current gap in ethical standards for highly automated and autonomous system means that industry and agencies need interim approaches to provide the best possible means of ensuring ethical behaviors and learning from our advanced systems until standards have been adopted. The goal of the research is to help provide key information to support formulation of such interim approached. Exploration of ethics challenges in designing, testing, implementing, and maintaining highly automated and autonomous systems.

Note: While holistic research across all the above topics is encouraged, applicants may propose research into focused subsets of the overall AI ethics solution space. NASA seeks both depth and breadth of research into this emerging area.

In all cases a report should be provided that documents the findings; identifies key risks and possible mitigations; and proposes possible next steps.

Research Focus Area: Document the Current State-of-the-Art/Practice of Ethical Decision Making by Humans in Operational Systems
Research Identifier**:** **C-008**

POC: James Harrington james.l.harrington@nasa.gov 301-286-4063
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Document the Current State-of-the-Art/Practice of Ethical Decision Making by Humans in Operational Systems:

1. Document the historical evolution of operations ethical decision scenarios
    a. World and Cultural Views on Ethics and their possible impacts on values and priorities
    b. Evolution of operator and regulator responsibilities and ethical considerations as systems have gotten more complex and more automated.
2. Document current approaches to ethical decision-making training for professional operators:
    a. Pilots
    b. Ship Captains
    c. Train Engineers
    d. Truck Drivers
    e. Doctors
    f. Fire & Rescue
    g. Others as appropriate

Research Focus Area: Explore and document the parameters in play in the transition of ethical decision making from humans to autonomous systems

Research Identifier: **C-009**

POC:
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Explore and document the parameters in play in the transition of ethical decision making from humans to autonomous systems. Human performance capabilities and limitations:

a. Situational Awareness
b. Context/Lessons Learned
c. Training
d. Biological Characterizations
    i. Cognitive Processing Power & Speed (decisions per second)
    ii. Physical Performance Capabilities & Limitations (i.e. reflexes)
    iii. Learning Capabilities
    iv. Social Characteristics

Research Focus Area: Current & projected autonomous performance capabilities and limitations

Research Identifier: **C-010**

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Current & projected autonomous performance capabilities and limitations

a. Situational Awareness
b. Context Assessment/Lesson Learning Capabilities
c. Design/Implementation Characterizations
    i. Roles & Responsibilities
    ii. Training
    iii. Processing Power Capabilities & Limitations
    iv. Physical Performance Capabilities & Limitations
    v. Learning Capabilities
    vi. Distributed Network Characteristics

Research Focus Area: Document legal ecosphere of ethical decision making in off-nominal scenarios

Research Identifier: **C-011**

POC:
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Document legal ecosphere of ethical decision making in off-nominal scenarios:

a. Multi-Culture/Tradition/Industry Domains
b. Precedents
c. Statutes
d. Laws, Regulations, Guidelines
e. Methods for: Tests, Certifications, Verification & Validations
f. Current Society Performance/Challenges on Ethical Decision Making
    i. Ability to make explicit historically implicit roles and responsibilities in ethical decision making to explicit parameters
    ii. Ability to get consensus on (why do we have 40 million lawsuits a year in the US?):
        1. Values
        2. Beliefs
        3. Fairness
        4. Equitable
        5. Unbiased
        6. Trade-offs/Priorities
        7. Etc.

Research Focus Area: Policy/Standards/Law Making Assessment
Research Identifier**:** **C-012**

POC: James Harrington james.l.harrington@nasa.gov 301-286-4063
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Policy/Standards/Law Making Assessment

a. Explore where policy, standards, and laws for Ethical Decision Making for Operations should considered/developed.
b. Requirements for each venue
c. Challenges for each venue
d. Estimated ability of development and schedule for each venue

Research Focus Area: Design, Development, & Implementation of Highly Automated / Autonomous Systems to abide by ethical decision making policy, standards, guidelines, and laws
Research Identifier**:** **C-013**

POC: James Harrington james.l.harrington@nasa.gov 301-286-4063
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Design, Development, & Implementation of Highly Automated/Autonomous Systems to abide by ethical decision making policy, standards, guidelines, and laws

a. Availability & challenges of appropriate (certified) data sets
b. Abstraction & modeling of policy, standards, guidelines, and laws
    i. Roles, Responsibilities, Liabilities
    ii. Cross Domain/Industry: Commonalities, Inter-operabilities, Hierarchies, Dependencies, etc..
    iii. Testing
    iv. Certification
    v. Learning Auditing
    vi. Maintenance

Research Focus Area: Societal ramifications of ethical decision making models
Research Identifier: **C-014**

POC: James Harrington james.l.harrington@nasa.gov 301-286-4063
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Societal ramifications of ethical decision making models
- i. Inclusion of Multi-cultural/domain perspectives
- ii. Prioritizations of lives and property
- iii. Ranking of lives and property
- iv. Tradeoffs of lives and property
- v. Other collateral effects

Additional Information: All publications that result from an awarded EPSCOR study shall acknowledge NASA

7.7 Earth Science

NASA SMD Earth Science Division (ESD)

POC: Laura Lorenzoni, laura.lorenzoni@nasa.gov
Nancy Searby, nancy.d.searby@nasa.gov

Research Focus Area: Impacts of human activity on coastal physical, geomorphological and ecological variability;
Research Identifier: **E-001**

Research Focus Area: Sea level rise, coastal erosion/retreat, and salt-water intrusion, and their impacts on ecosystems;
Research Identifier: **E-002**

Research Focus Area: Linkages between aquatic dynamics and land subsidence and its impacts on aquatic ecosystems;
Research Identifier: **E-003**

Research Focus Area: The role of urban development on land subsidence and aquatic ecosystems; biophysical coupling and feedbacks within the aquatic-land interface;
Research Identifier**:** **E-004**

Research Focus Area: Impacts of hazards related to climate extremes, such as storms and heat waves, on biogeophysical aspects of the coast; etc.
Research Identifier**:** **E-005**

Research Focus Area: Impacts of upstream activities on coastal communities
Research Identifier**:** **E-006**

Research Focus Area: Integration of existing and upcoming observational and modeling assets into a conceptual or (better) digital aquatic-land framework that enables the dynamical coupling of key processes within the aquatic-land interface.
Research Identifier**:** **E-007**

Research Focus Area: Exposure and vulnerability to geohazards (e.g., infrastructure and flooding, landslides, etc.), land cover/use change and their impacts on water
Research Identifier**:** **E-008**

Research Overview: NASA SMD Earth Science Division (ESD) seeks topics to address coastal and ecosystem resilience, and equity and environmental justice.
This research focus area seeks to expand and build on the recently-established Coastal Resilience program, selected under ROSES22, and the work solicited under ROSES21 equity and environmental justice and ROSES22 IDS environmental and climate justice. Climate change impacts all aspects of the Earth and human systems, and highly-populated coastal communities (adjacent to inland water bodies and the ocean) are among those experiencing its most disruptive consequences. Extreme weather events on land (droughts/floods), erosion, loss of marshes and wetlands, rising oceans and other direct human-induced changes threaten coastal communities, ecosystems, national and global economies. Furthermore, land changes from human activities such as groundwater/hydrocarbon extraction/injection, levee construction, river/sediment management, and urban development can have compounding effects with the naturally-occurring land processes such as tectonics, sediment compaction, erosion, etc, with each process modifying the land surface elevation and coastal geomorphology. Combined, these complex and interconnected aquatic-land processes impact biogeochemistry and ecology, affect ecosystem structure and function, and threaten biodiversity.

NASA ESD recognizes a need to develop and learn from relationships with environmental justice (EJ) and climate justice (CJ) and underserved communities, as well as organizations familiar with working alongside these communities. EJ and CJ refer to communities in geographic locations around the globe with significant representation of minoritized populations, low-income persons, and/or indigenous persons or members of Tribal nations, where such individuals experience, or are at risk of experiencing, more adverse human health, environmental, and/or climate change impacts.

NASA Earth Science and satellite-based Earth observations can play an important role in addressing questions at the intersection of Earth observations and EJ/CJ, and are critical to understanding and predicting land/aquatic interface environments that undergo natural and human-induced changes. Understanding both direct and indirect human-induced changes is equally important in informing studies of coastal resilience and addressing high priority EJ/CJ needs.

Proposals seeking to respond to this EPSCoR Research Topic must address research that contributes to furthering support priorities related to coastal resilience and EJ/CJ, and will provide the foundational information and evidence-based knowledge that will help inform solutions to increase resilience of coastal communities and high priority needs as exemplified below. NASA is specifically interested in proposals that make significant use of remote sensing data to advance our understanding of key physical, biological, biogeochemical, geological, and hydrological coastal processes and their interactions within the interface of the aquatic-land-human system, and to enhance our understanding of how these processes will be compounded in rapidly changing coastal environments.
Examples of potential topics suitable for the EPSCoR research on coastal resilience include the exploration of the underlying physical, biological, and/or geological mechanisms within the aquatic-land framework and potential feedback processes and impacts on coastal ecosystems and underserved communities. Examples of coupled coastal processes may include but are not limited to:

1. Impacts of human activity on coastal physical, geomorphological and ecological variability;
2. Sea level rise, coastal erosion/retreat, and salt-water intrusion, and their impacts on ecosystems;
3. Linkages between aquatic dynamics and land subsidence and its impacts on aquatic ecosystems;
4. The role of urban development on land subsidence and aquatic ecosystems; biophysical coupling and feedbacks within the aquatic-land interface;
5. Impacts of hazards related to climate extremes, such as storms and heat waves, on biogeophysical aspects of the coast; etc.
6. Impacts of upstream activities on coastal communities
7. Integration of existing and upcoming observational and modeling assets into a conceptual or (better) digital aquatic-land framework that enables the dynamical coupling of key processes within the aquatic-land interface.
8. Exposure and vulnerability to geohazards (e.g., infrastructure and flooding, landslides, etc.), land cover/use change and their impacts on water

The proposed investigations should be of regional (beyond local, 1,000+ km) focus, preferably in areas of high potential population growth, e.g. U.S. East, West, or Gulf coasts, Island Nations, and other low-lying regions across the globe that are impacted by climate change and/or socio-economic disadvantages. Proposals must provide a rationale for their region of choice. Proposals targeting the EJ/CJ topics are encouraged to integrate socio-economic data in their proposal.

Proposed investigations must utilize remotely sensed observations (e.g., MODIS, Landsat, etc.) for data analysis and as a primary research tool; however, other NASA data products from airborne campaigns, ground-based stations, or model output may be used for the proposed research. Proposers are also encouraged to use data acquired via the NASA Commercial SmallSat Data Acquisition Program (CSDAP). A description of NASA's fleet of Earth observing satellites and sensors can be found at https://science.nasa.gov/missions-page/, with more details about related airborne missions at https://airbornescience.nasa.gov/. Information about data access and discovery can be found at https://earthdata.nasa.gov/.

This research opportunity will not fund the acquisition of new in situ data, but seeks to further leverage the large quantities of remotely sensed and/or in situ data that NASA has already collected over the years.

7.8 Entry Systems Modeling Project

NASA SMD Earth Science Division (ESD)

Research Focus Area: Nitrogen/Methane Plasma Experiments Relevant to Titan Entry
Research Identifier**:** **E-009**

POC: Aaron Brandis aaron.m.brandis@nasa.gov

Research Overview: Provide experimental data to characterize TPS material response under simulated Titan entry conditions.

Research Focus: Research Focus: Data is needed to validate models for the material response of thermal protection system (TPS) materials under simulated Titan entry conditions, with the atmosphere being predominately nitrogen (N2) and a small amount of methane (CH4). The conditions should be traceable to conditions relevant to the upcoming Dragonfly mission. Furthermore, an understanding of how coatings, e.g. NuSil, are impacted (or not) by the presence of methane and in a non-oxidizing environment is of interest. Relevant facilities for such measurements could include ArcJets or Plasma Torches. Data of interest would include thermocouples imbedded in TPS materials (e.g. PICA, SLA) and non-intrusive surface temperature measurements. Characterization of the post-test materials is also of interest. Understanding the material response of NuSil/PICA in a Titan atmosphere is important to maximize the science return for the DrEAM instrumentation suite.

Research Focus Area: Predictive Modeling of Plasma Physics Relevant to High Enthalpy Facilities
Research Identifier**:** **E-010**

POC: Aaron Brandis aaron.m.brandis@nasa.gov

Research Overview: Develop predictive models for arc and plasma processes used in the generation of high enthalpy flows in shock tube and arcjet facilities at NASA.
Research Focus: This proposal seeks predictive modeling of processes occurring in facilities that generate high-enthalpy flows at NASA, including Arcs and Plasma Torches. The objectives may differ depending on facilities being modeled. For instance, the Electric Arc Shock tube uses an Arc to produce a high velocity shock waves. Acoustic modes in the arc driver may determine velocity profiles in the tube while ionization processes produce radiating species that may heat driven freestream gases. In plasma torches, studies of recombination of Nitrogen and Air plasma flows have relevance for predicted backshell radiation modeling. Modeling in arc jets may improve estimates of enthalpy profile uniformity and mixing of arc gas with add air.

Research Focus Area: Mechanical Properties of Ablative TPS Materials during Char Formation
Research Identifier**:** **E-011**

POC: Aaron Brandis aaron.m.brandis@nasa.gov

Research Overview: Provide mechanical property data to enable models that couple pyrolysis and char formation with thermostructural analysis for predicting the stress state of ablative TPS materials of interest to Entry Descent and Landing projects and missions at NASA.

Research Focus: This proposal seeks mechanical and/or strength measurements of ablative, porous thermal protection system (TPS) materials. The properties should be determined as a function of char conversion, with the char conversion occurring under controllable, repeatable conditions. Both degree and rate of char formation on the final properties would be desirable. The data would be made available to the TPS materials modeling groups at NASA to improve coupled ablative and thermostructural models.

7.9 Human Research Program / Space Radiation

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.

Research Focus Area: Tissue and Data sharing for space radiation risk and mitigation strategies
Research Identifier**:** **H-001**

POC: Robin Elgart shona.elgart@nasa.gov, (281)244-0596
Janice Zawaski janice.zawaski@nasa.gov

Research Overview: 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/.

Research Focus Area: Space radiation sex-differences

Research Identifier: **H-002**

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

Research Overview: 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/.

Research Focus Area: Compound screening techniques to assess efficacy in modulating responses to radiation exposure

Research Identifier: **H-003**

POC: Robin Elgart shona.elgart@nasa.gov, (281)244-0596
Brock Sishc brock.j.sishc@nasa.gov

Research Overview: 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.

Research Focus Area: Inflammasome role in radiation-associated health impacts

Research Identifier: **H-004**

POC: Robin Elgart shona.elgart@nasa.gov, (281)244-0596
Janapriya Saha janapriya.saha@nasa.gov

Research Overview: 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.

Research Focus Area: Portable, non-ionizing radiation based, high resolution disease detection imaging
Research Identifier**:** **H-005**

POC: Robin Elgart shona.elgart@nasa.gov, (281)244-0596
Janice Zawaski janice.zawaski@nasa.gov

Research Overview: Research proposals are sought to develop portable, non-ionizing radiation based, high resolution imaging technologies for disease detection in rodent models with potential scalability to humans. Conventional imaging modalities including 2D planar x-rays, micro computed tomography (CT), positron emission tomography (PET), magnetic resonance (MR), ultrasound, and bioluminescence/fluorescence imaging require either large-scale equipment that is generally immobile, or require highly trained personnel to accurately identify disease. Furthermore, the resolution of these standard techniques limits detectability of small changes in small-animal models. To accelerate radiation risk characterization and mitigation the NASA Human Research Program Space Radiation Element is seeking development of portable, non-ionizing radiation-based, high resolution imaging modalities for the early detection and continuous monitoring of disease development and progression for use in rodent models with potential scalability to human systems and use in space flight.

Human Research Program / Precision Health Initiative

Research Focus Area: Pilot studies to adopt terrestrial precision health solutions for astronauts
Research Identifier**:** **H-006**

POC: Corey Theriot corey.theriot@nasa.gov , 281-244-7331

The term "precision health" (similar to precision or personalized medicine in clinical settings) refers to the strategy of collecting and analyzing an individual's unique health status along with environmental and lifestyle data to identify key factors that can ultimately improve the health and performance of each crewmember in an individualized manner.

The Precision Health Initiative seeks to identify innovative methods to maintain an individual astronaut's health and optimal mission performance, requiring in-depth understanding of individual molecular profiles and how they relate to health and performance. The practice of Precision Health encompasses the use of detailed phenotyping of an individual, using both clinical and molecular measures, along with the integrated analyses of those data to draw conclusions about an individual's response to the environment, diet, medications, exercise regimen, etc. **This topic seeks proposals for preliminary pilot studies that identify vetted and approved precision health techniques from terrestrial settings that can be applied with little to no modification to crewmembers that will be exposed to the stressors of spaceflight: space radiation, altered gravity, isolation/confinement, distance from Earth, and hostile/closed environments.** For this solicitation, the term "technique" encompasses any clinical practice, strategy, test, or process that provides a clinically actionable medical outcome or unique knowledge of an individual's health status.

Research Focus: While most terrestrial precision medicine techniques focus on diagnosis and treatment of disease states, NASA is most interested in preventive measures that maintain crew health and performance during exposure to spaceflight stressors resulting in human health and performance risks as described in the Human Research Roadmap (https://humanresearchroadmap.nasa.gov). Proposed precision health techniques should have compelling evidence of efficacy for the crew population and be approved for terrestrial clinical practice by appropriate governing bodies, and proposals should address incorporation into the existing NASA operations, workflow, and infrastructure. Any proposed precision health techniques using genetic information must comply with the Genetic Information Nondiscrimination Act of 2008 (GINA) rules that preclude use of genetic information in employment decisions, which for NASA means that genetic data cannot be used to inform or influence crew selection or crew mission assignments.

Human Research Program / Systems Biology Translation

Research Focus Area: Pilot studies to demonstrate the utilization of full systems biology approaches in addressing human spaceflight risks
Research Identifier**:** **H-007**

POC: Corey Theriot corey.theriot@nasa.gov, 281-244-7331

Research Overview: The environment astronauts are exposed to, particularly during future deep space missions, pose unique risks to human health and performance as well as research challenges that are fundamentally interdisciplinary. Systems biology frameworks offer inclusive approaches for the analysis and simulation of complex biological phenomena. The onset of new data sources and the availability of new tools for data analysis lead to a natural evolution towards the use of systems biology to understand complex biological responses to spaceflight. The anticipated outcome is a comprehensive understanding of the intricate interactions among biological system responses to spaceflight stressors by leveraging work across multiple disciplines. Additionally, improved identification of critical and influential system pathways corresponding to clinically and experimentally observed symptoms leads to the translation of results to human applications more quickly and economically. To develop these new capabilities and approaches, the NASA Human Research Program is interested in proof of concept development of systems biology research approaches: with particular interest in augmenting an existing HRP risk mitigation plan (such as Spaceflight Associated Neuro-ocular Syndrome) and developing a clean-sheet mitigation approach for a cross-cutting risk factor (such as inflammation). HRP human health and performance risks are described in the Human Research Roadmap (https://humanresearchroadmap.nasa.gov).
This topic seeks proposals for preliminary pilot studies that establish systems biology frameworks that utilize omics datasets, biochemical data, bioinformatics, and computational modeling to evaluate responses in biological systems due to exposure to spaceflight environments.

Research Focus: The research topic focuses on proposals that establish the use of comprehensive systems biology approaches to understand biological responses to spaceflight. Particular focus should address (but not limited to) one of the following topics:

- Resolving aspects of the Spaceflight Associated Neuro-ocular Syndrome (SANS) risk to include multiple tissue (i.e., ocular and brain) responses.
- Assessment of the cross-risk factor of spaceflight-induced inflammation and inflammatory responses to include systemic as well as tissue specific responses in acute and chronic phases.

7.10 Office of Chief Health and Medical Officer (OCHMO)

Research Focus Area: Development and elaboration of Functional aids and testing paradigms to measure activity for use by parastronauts during spaceflight
Research Identifier**:** **H-008**

POC: Victor S. Schneider vschneider@nasa.gov
Kristin Fabre kristin.m.fabre@nasa.gov

Research Overview: 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.

Research Focus Area: Evaluation space capsule and spacesuit activity in stable and fit lower or upper extremity amputees and compare their responses to non-amputee fit individuals
Research Identifier**:** **H-009**

POC: Victor S. Schneider vschneider@nasa.gov
Kristin Fabre kristin.m.fabre@nasa.gov

Research Overview: 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.

7.11 Planetary Division

SMD requests that EPSCoR includes research opportunities in the area of Extreme Environments applicable to Venus, Io, Earth volcanoes. and deep-sea vents.

Venus has important scientific relevance to understanding Earth, the Solar System formation, and Exoplanets. For EPSCoR technology projects, Venus' highly acidic surface conditions are also a unique extreme environment with temperatures (~900F or 500C at the surface) and pressures (90 earth atmospheres or equivalent to pressures at a depth of 1 km in Earth's oceans). Furthermore, information on Venus' challenging environmental needs for its exploration can be found on the Venus Exploration Analysis Group (VEXAG) website: https://www.lpi.usra.edu/vexag/.

In particular, the technology requirements and challenges related to Venus exploration are discussed in the Venus Technology Roadmap at:

https://www.lpi.usra.edu/vexag/documents/reports/VEXAG_Venus_Techplan_2019.pdf

Research Focus Area: High-Temperature Subsystems and Components for Long-Duration (months) Surface Operations

Research Identifier**:** **P-001**

POC: Adriana Ocampo aco@nasa.gov W:202.358.2152/M:202.372.7058
Michael Lienhard michael.a.lienhard@nasa.gov 216.433.8932

Research Overview: Advances in high-temperature electronics and power generation would enable long-duration missions on the surface of Venus operating for periods as long as a year, where the sensors and all other components operate at Venus' surface ambient temperature. These advances are needed for both the long-duration lander and the lander network. Development of high-temperature electronics, memory, transmitters, sensors, thermal control, actuators, and power sources designed for operating in the Venus ambient would be enabling for future missions.

For example, Venus surface landers could investigate a variety of open questions that can be uniquely addressed through in-situ measurements. The Venus Exploration Roadmap describes a need to investigate the structure of Venus's interior and the nature of current activity, and potentially conduct the following measurements: a. Seismology over a large frequency range to constrain interior structure; b. Heat flow to discriminate between models of current heat loss; and c. Geodesy to determine core size and state.
Landers with sample return capability would be of great interest.

Research Focus Area: Aerial Platforms for Missions to Measure Atmospheric Chemical and Physical Properties

Research Identifier**:** **P-002**

POC: Adriana Ocampo aco@nasa.gov W:202.358.2152/M:202.372.7058
Michael Lienhard michael.a.lienhard@nasa.gov 216.433.8932

Research Overview: More than three decades ago, two small (3.5 m) VEGA balloons launched by the Soviet Union completed two-day flights around Venus, measuring wind speeds, temperature, pressure, and cloud particle density. The time is ripe for modern NASA efforts to explore the Venus atmosphere with new technology.

Aerial platforms have a broad impact on science for Venus. Examples of science topics to be investigated include:

a. the identity of the unknown UV absorber and atmospheric chemistry (i.e. phosphine);

b. properties of the cloud particles in general;

c. abundances atmospheric gas species (including trace gases and noble gases);

d. the presence of lightning; and

e. properties of the surface mapped aerially.

Aerial vehicles that are able to operate at a variety of high and low altitudes in the middle atmosphere are needed to enable mid-term and far-term Venus missions addressing these issues. A platform able to operate close to the Venusian surface would be able to provide close surface monitoring but would require major development to operate in the hot dense lower atmosphere.

Miniaturized guidance and control systems for aerial platform navigation for any altitudes are needed to track probe location and altitude.

Other topics of interest would include high pressure and acidic environments for technology development, which would be of interest to include in the $750K level EPSCoR call.

Research Focus Area: Extreme Environment Aerobot
Research Identifier**:** **P-003**

POC: Adriana Ocampo aco@nasa.gov W:202.358.2152/M:202.372.7058
Michael Lienhard michael.a.lienhard@nasa.gov 216.433.8932

Research Overview: Venus provides an important scientific link to Earth, Solar System formation, and to Exoplanets. This EPSCoR call is made for technology projects, which take intoconsideration Venus' middle atmosphere conditions and its unique extreme environment. The call concentrates on the challenge to develop an aerial platform that would survive the extreme conditions of the Venusian middle atmosphere. It is worth noting that in the middle atmosphere of Venus (79km to 45Km), the conditions are considerably more benign than its surface conditions. This EPSCoR call will focus on Variable Manurable (horizontally and vertically) altitude balloons or hybrid airship, or aerobots (buoyancy + lift). The top technical parameters to consider for the Extreme Environment Aerobot for Venus conditions are (* see references below):

- Altitude: Maintain 79km to 45km Altitude (avoids high temps)
- Structure: Airframe & Materials compatible with acids (PH -1.3 to 0.5). The cloud pH varies from about 0.5 at the top (65 km) to -1.3 at the base (48 km).
- Power source: Solar and/or Batteries
- Navigation: provide, Guidance & Control concepts
- Science Instruments: for atmosphere and ground remote sensing
- Lifetime: weeks to months
- Pressure and temperature range: 80mb-1.3bar, with pressure at 65 km (245Kelvin or -28C) from Pioneer Large probe measured 80 mb and at 48 km (385 Kelvin or 112C) is approximately 1.3 bar. At 60 deg. latitude the pressure at 65 km is about 70 mb and temperature is about 222 K (-51C).
- Winds: Vertical shear of horizontal wind, up to 5-10 m/s per km

References:

Further Information on Venus's challenging environment needs, for its exploration, can be found on the Venus Exploration Analysis Group (VEXAG) website:
https://www.lpi.usra.edu/vexag/.
"Aerial Platforms for the Scientific Exploration of Venus" report (JPL) Aug 2018.
In particular, the technology requirements and challenges related to Venus exploration are discussed in the Venus Technology Roadmap at:

https://www.lpi.usra.edu/vexag/documents/reports/VEXAG_Venus_Techplan_2019.pdf

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Kerzhanovich V. V., Aleksandrov Y. N., Andreev R. A., Armand N. A., Bakitko R. V., Blamont J.,

Bolgoh L., Vorontsov V. A., Vyshlov A. S., Ignatov S. P. et al. (1986) Small-scale turbulence in the Venus middle cloud layer. *Pisma v Astronomicheskii Zhurnal*, 12: 46-51.
Kerzhanovich V. V., and Limaye S. S. (1985) Circulation of the atmosphere from the surface to 100 KM. *Advances in Space Research*, 5: 59-83

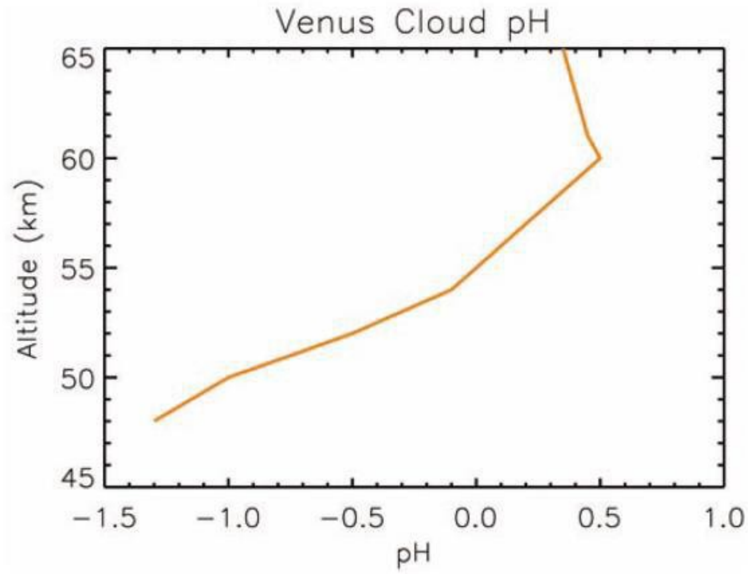

Plate 2. The pH of Venus' clouds as a function of altitude. The relatively water-rich aerosols in the upper cloud have a small range of positive pH, from 0.3 to 0.5. In the lower cloud, with its larger and more water-poor particles, pH can be as low as -1.3. Aerosol H_2SO_4 concentrations were calculated using the cloud model of Bullock and Grinspoon (2001), constrained by PV data. Correction for high activities is from Nordstrum et al. (2000).

7.12 Planetary Protection

Office of Safety & Mission Assurance

Research Focus Area: Addressing Knowledge Gaps in Planetary Protection for Crewed Mars Mission Concepts - Microbial and Human Health Monitoring

Research Identifier**:** **P-004**

POC: J Nick Benardini James.N.Benardini@nasa.gov

Research Overview: Planetary Protection is the practice of protecting solar system bodies from contamination by Earth life and protecting Earth from possible life forms that may be returned from other solar system bodies. NASA's Office of Planetary Protection (OPP) promotes the responsible exploration of the solar system by implementing and developing efforts that protect the integrity of scientific discovery, the explored environments, and the Earth.

As NASA expands its exploration portfolio to include crewed missions beyond low Earth orbit, including planning for the first crewed Mars mission, a new paradigm for planetary protection is needed. Together with COSPAR, the Committee on Space Research, NASA has been working with the scientific and engineering communities to identify gaps in knowledge that need to be addressed before an end-to-end

planetary protection implementation can be developed for a future crewed Mars mission1.
For this EPSCoR Rapid Research Response Topic, NASA is interested in proposals that will address identified knowledge gaps in planetary protection for crewed Mars mission concepts, facilitating a knowledge-based transition from current robotic exploration-focused planetary protection practice to a new paradigm for crewed missions.
Research Focus: The capability to detect, monitor and then (if needed) mitigate the effects of adverse microbial-based events, whether terrestrial or Martian in origin, is critical in the ability to safely complete a crewed return mission to and from the red planet.
OPP is interested in proposals that would be the first steps on a path to develop -omics based approaches (including downstream bioinformatic analyses) for planetary protection decision making, with a particular emphasis on assessing perturbations in the spacecraft microbiome as indicators of key events such as exposure to the Mars environment, or changes in crew or spacecraft health.
Additionally, OPP is interested in technologies and approaches for mitigation of microbial growth in space exploration settings. This includes remediation of microbial contamination (removal, disinfection, sterilization) in spacecraft environments in partial or microgravity as well as on planetary surfaces.

Research Focus Area: Addressing Knowledge Gaps in Planetary Protection for Crewed Mars Mission Concepts - Natural Transport of Contamination on Mars
Research Identifier**:** **P-005**

POC: J Nick Benardini James.N.Benardini@nasa.gov

Research Overview: The threat of harmful biological contamination at Mars is a balance between the release and spread of terrestrial biota resulting from the spacecraft surface operations, and the lethality of the Martian environment to these organisms. To understand and manage the risk of such contamination, the OPP is interested in studies of the following:

- Modeling and experimentation to describe the surface/atmospheric transport of terrestrial microorganisms as they would be released from spacecraft hardware at the Martian surface.
- Modeling and experimentation to describe the subsurface transport of terrestrial microorganisms as they would be released from spacecraft hardware onto the Martian surface.
- Modeling and experimentation to describe the lethality of the Mars environment to terrestrial organisms as they would be released from spacecraft hardware at the Martian surface.

Proposed research could focus in individual (indicator) organisms or populations of organisms. Of particular interest is the resistance of terrestrial organisms to the Martian UV environment under conditions relevant to release from crewed spacecraft (in clumps, attached to dust particles, or as part of a biofilm matrix).

Additional Information: All publications that result from an awarded EPSCoR study shall acknowledge NASA OSMA. If the NASA GeneLab Data Systems (genelab.nasa.gov) is used, GeneLab shall be

[1] Further information on the COSPAR meeting series on planetary protection knowledge gaps for crewed Mars missions can be found in the Conference Documents section of the OSMA Planetary Protection web site, in particular the report of the 2018 meeting at: https://sma.nasa.gov/docs/default-source/sma-disciplines-and-programs/planetary-protection/cospar-2019-2nd-workshop-on-refining-planetary-protection-requirements-for-human-missions-and-work-meeting-on-developing-payload-requirements-for-addressing-planetary-protection-gaps-on-nat.pdf?sfvrsn=507ff8f8_8

referenced in the resulting publication and included in the keyword list. All -omics data obtained from these studies shall be uploaded to the NASA GeneLab.

8.0 Table 1: Research Focus Area/Point of Contact (POC)

Research Focus Area/Point of Contact (POC)		
Aeronautic Research Mission Directorate / Advanced Air Vehicles Program / Revolutionary Vertical Lift Technology Project		
Research Focus Area	**Point of Contact**	**Id**
Safe and Efficient Electro-mechanical Powertrains for Electrified Vertical Takeoff and Landing (eVTOL) Vehicle	Timothy Krantz, timothy.l.krantz@nasa.gov Dr. Mark J. Valco, mark.j.valco@nasa.gov	A-001
Electric motor technologies appropriate for eVTOL with high torque density and, concurrently, such motors being free of partial discharge and having a continuous power rating in the range 50 – 400 kW.	Timothy Krantz, timothy.l.krantz@nasa.gov Dr. Mark J. Valco, mark.j.valco@nasa.gov	A-002
High reliability, robustness, and fault-tolerance for inverter-motor systems as needed for safety-critical eVTOL propulsion.	Timothy Krantz, timothy.l.krantz@nasa.gov Dr. Mark J. Valco, mark.j.valco@nasa.gov	A-003
Lubrication and cooling technologies specifically optimized for long life and highly efficient eVTOL motors, including interest in single-fluid approaches for inverters, motors, and gearboxes.	Timothy Krantz, timothy.l.krantz@nasa.gov Dr. Mark J. Valco, mark.j.valco@nasa.gov	A-004
Development of Characterization Techniques to Determine Rate and Temperature Dependent Composite Material Properties for the LS-DYNA MAT213 Model	Robert Goldberg robert.goldberg@nasa.gov Justin Littell justin.d.littell@nasa.gov Mike Pereira mike.pereira@nasa.gov	A-005
Astrophysics		
Research Focus Area	**Point of Contact**	**Id**
Astrophysics Technology Development	Hashima Hasan hhasan@nasa.gov Mario Perez mario.perez@nasa.gov	A-006
Biological and Physical Sciences		
Research Focus Area	**Point of Contact**	**Id**

Research Focus Area/Point of Contact (POC)		
Fundamental Physics	Mike Robinson; michael.p.robinson@nasa.gov	B-001
Soft Matter Physics	Mike Robinson; michael.p.robinson@nasa.gov	B-002
Fluid Physics	Brad Carpenter bcarpenter@nasa.gov	B-003
Combustion Science	Brad Carpenter bcarpenter@nasa.gov	B-004
Materials Science	Brad Carpenter bcarpenter@nasa.gov	B-005
Growth of plants in inhospitable “deep space-relevant” Earth soils or conditions	Sharmila Bhattacharya SpaceBiology@nasaprs.com	B-006
Commercially Enabled Rapid Space Science Project (CERISS)	Dr. Lisa Carnell; lisa.a.scottcarnell@nasa.gov	B-007
Center for Design and Space Architecture		
Research Focus Area	**Point of Contact**	**Id**
Repair, Manufacturing, And Fabrication (RMAF) Facility for the Common Habitat Architecture	Robert L. Howard, Jr. robert.l.howard@nasa.gov	C-001
Commercial Space Capabilities		
Research Focus Area	**Point of Contact**	**Id**
In-Space Welding	Warren Ruemmele warren.p.ruemmele@nasa.gov	C-002
Materials and Processes Improvements for Chemical Propulsion State of Art (SoA)	Warren Ruemmele warren.p.ruemmele@nasa.gov	C-003
Materials and Processes Improvements for Electric Propulsion State of Art (SoA)	Warren Ruemmele warren.p.ruemmele@nasa.gov	C-004
Improvements to Space Solar Power State of Art (SoA)	Warren Ruemmele warren.p.ruemmele@nasa.gov	C-005
Small Reentry Systems	Warren Ruemmele warren.p.ruemmele@nasa.gov	C-006
Other Commercial Space Topic	Warren Ruemmele warren.p.ruemmele@nasa.gov	C-007
Computational and Information Sciences and Technology Office (CISTO) Program		
Research Focus Area	**Point of Contact**	**Id**

Research Focus Area/Point of Contact (POC)		
Document the Current State-of-the-Art/Practice of Ethical Decision Making by Humans in Operational Systems.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-008
Explore and document the parameters in play in the transition of ethical decision making from humans to autonomous systems.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-009
Current & projected autonomous performance capabilities and limitations.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-010
Current & projected autonomous performance capabilities and limitations.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-011
Policy/Standards/Law Making Assessment.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-012

Research Focus Area/Point of Contact (POC)		
Design, Development, & Implementation of Highly Automated / Autonomous Systems to abide by ethical decision-making policy, standards, guidelines, and laws.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-013
Societal ramifications of ethical decision-making models.	James Harrington james.l.harrington@nasa.gov Edward McLarney Edward.l.mclarney@nasa.gov Yuri Gawdiak yuri.o.gawdiak@nasa.gov Nikunj Oza nikunj.c.oza@nasa.gov	C-014
Earth Science		
Research Focus Area	**Point of Contact**	**Id**
Impacts of human activity on coastal physical, geomorphological and ecological variability	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-001
Sea level rise, coastal erosion/retreat, and salt-water intrusion, and their impacts on ecosystems	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-002
Linkages between aquatic dynamics and land subsidence and its impacts on aquatic ecosystems	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-003
The role of urban development on land subsidence and aquatic ecosystems; biophysical coupling and feedbacks within the aquatic-land interface	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-004
Impacts of hazards related to climate extremes, such as storms and heat waves, on biogeophysical aspects of the coast	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-005
Impacts of upstream activities on coastal communities	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-006

Research Focus Area/Point of Contact (POC)		
Integration of existing and upcoming observational and modeling assets into a conceptual or (better) digital aquatic-land framework that enables the dynamical coupling of key processes within the aquatic-land interface	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-007
Exposure and vulnerability to geohazards (e.g., infrastructure and flooding, landslides, etc.), land cover/use change and their impacts on water	Laura Lorenzoni, laura.lorenzoni@nasa.gov Nancy Searby, nancy.d.searby@nasa.gov	E-008
Entry Systems Modeling Project		
Research Focus Area	**Point of Contact**	**Id**
Nitrogen/Methane Plasma Experiments Relevant to Titan Entry	Aaron Brandis aaron.m.brandis@nasa.gov	E-009
Predictive Modeling of Plasma Physics Relevant to High Enthalpy Facilities	Aaron Brandis aaron.m.brandis@nasa.gov	E-010
Mechanical Properties of Ablative TPS Materials during Char Formation	Aaron Brandis aaron.m.brandis@nasa.gov	E-011
Human Research Program (Space Radiation, Precision Health Initiative)		
Research Focus Area	**Point of Contact**	**Id**
Tissue and Data sharing for space radiation risk and mitigation strategies	Robin Elgart shona.elgart@nasa.gov Janice Zawaski janice.zawaski@nasa.gov	H-001
Space radiation sex-differences	Robin Elgart shona.elgart@nasa.gov	H-002
Compound screening techniques to assess efficacy in modulating responses to radiation exposure	Robin Elgart shona.elgart@nasa.gov Brock Sishc brock.j.sishc@nasa.gov	H-003
Inflammasome role in radiation-associated health impacts	Robin Elgart shona.elgart@nasa.gov Janapriya Saha janapriya.saha@nasa.gov	H-004
Portable, non-ionizing radiation based, high resolution disease detection imaging	Robin Elgart shona.elgart@nasa.gov Janice Zawaski janice.zawaski@nasa.gov	H-005
Pilot studies to adopt terrestrial precision health solutions for astronauts	Corey Theriot corey.theriot@nasa.gov	H-006

Research Focus Area/Point of Contact (POC)		
Pilot studies to demonstrate the utilization of full systems biology approaches in addressing human spaceflight risks	Corey Theriot corey.theriot@nasa.gov	H-007
Office of the Chief Health and Medical Officer (OCHMO)		
Research Focus Area	**Point of Contact**	
Development and elaboration of Functional aids and testing paradigms to measure activity for use by parastronauts during spaceflight	Victor S. Schneider vschneider@nasa.gov Kristin Fabre kristin.m.fabre@nasa.gov	H-008
Evaluation space capsule and spacesuit activity in stable and fit lower or upper extremity amputees and compare their responses to non-amputee fit individuals	Victor S. Schneider vschneider@nasa.gov Kristin Fabre kristin.m.fabre@nasa.gov	H-009
Planetary Science		
Research Focus Area	**Point of Contact**	**Id**
High-Temperature Subsystems and Components for Long-Duration (months) Surface Operations	Adriana Ocampo aco@nasa.gov Michael Lienhard michael.a.lienhard@nasa.gov	P-001
Aerial Platforms for Missions to Measure Atmospheric Chemical and Physical Properties	Adriana Ocampo aco@nasa.gov Michael Lienhard michael.a.lienhard@nasa.gov	P-002
Extreme Environment Aerobot	Adriana Ocampo aco@nasa.gov Michael Lienhard michael.a.lienhard@nasa.gov	P-003
Planetary Protection		
Research Focus Area	**Point of Contact**	**Id**
Addressing Knowledge Gaps in Planetary Protection for Crewed Mars Mission Concepts	J Nick Benardini James.N.Benardini@nasa.gov	P-004
Natural Transport of Contamination on Mars	J Nick Benardini James.N.Benardini@nasa.gov	P-005

Table 1: **Research Focus Area and Point of Contacts**