

Appendices A thru J

A.1.0 Biological and Physical Sciences (BPS)

POCs: See Topic Area

A.1.1 Research Topic 1

1) Program:

Fundamental Physics

2) Research Title:

Quantum Science

3) 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.

4) Research Focus:

Quantum physics is a cornerstone of our understanding of the universe. The importance of quantum mechanics is extraordinarily wide ranging, from explaining emergent phenomena such as superconductivity, to underpinning next-generation technologies such as quantum computers, quantum communication networks, and sensor technologies. Laser-cooled cold atoms are a versatile platform for quantum physics on Earth, and one that can greatly benefit from space-based research. The virtual elimination of gravity in the reference frame of a free-flying space vehicle enables cold atom experiments to achieve longer observation times and colder temperatures than are possible on Earth. The NASA Fundamental Physics program plans

to support research in quantum physics that will lead to transformational outcomes, such as the discovery of phenomena at the intersection of quantum mechanics and general relativity that inform a unified theory, the direct detection of dark matter via atom interferometry or atomic clocks, and the creation of exotic quantum matter than cannot exist on Earth. Proposals are sought for ground-based theory and experimental research that may help to develop concepts for future flight experiments. Research in field effects in quantum superposition and entanglement are of particular interest.

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6) Additional Information:

All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS).

A.1.2 Research Topic 2

1) Program:

Physical Sciences – Complex Fluids/Soft Matter

2) Research Title:

Soft Matter-Based Metamaterials

3) Research Overview:

Soft matter-based metamaterials possess unique physical properties, owing to their engineered structure, ranging from negative index material with regard to a multitude of physical properties (e.g.- viscosity, refractive index, acoustics etc.). While these are interesting properties, they can be limited to narrow range of operations (e.g.- frequency).

4) Research Focus:

Metamaterials have recently drawn the attention of soft-matter scientists and engineers with the possibility of designing metamaterials that have their functions governed, not by the specific substance out of which the material is constructed, but rather by its microstructure.

Some of the ground-based challenges that need to be answered are:

- Development of novel soft-matter based metamaterials
- Develop methodologies to encode multiple functions in soft-matter based metamaterials
- Understand the scalability of active materials & metamaterials and how that affects multiple functionality

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6) Additional Information:

All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS).

A.1.3 Research Topic 3

1) Program:

Physical Sciences – Fluid Physics

2) Research Title:

Oscillating Heat Pipes (OHP)

3) Research Overview:

NASA has a growing need for improved passive thermal management of electronics, batteries, high capability sensors, power system heat rejection, etc. for future spacecraft and planetary habitat systems. Due to the potential to extract heat at significantly higher heat flux levels, oscillating heat pipes (OHP) offer the promise of significantly higher efficiencies compared to conventional heat pipes used on today's spacecraft. However, the underlying liquid-vapor fluid dynamics (distinct liquid plugs and vapor plugs), interfacial phenomena, and two-phase heat transfer in the pulsating flows of OHPs are not well understood.

4) Research Focus:

It is imperative that a physical model that can predict the performance of an OHP be developed. As a first step, NASA is seeking proposals for an instrumented, ground-based OHP experiment to provide insight into the mechanisms, fundamental processes and governing equations. The resulting high-fidelity data will be used for computational fluid dynamics model validation to better predict OHP performance and limits of operation. NASA is currently funding the development of an advanced OHP computer model at JPL. The experimental data from this project will be provided to the JPL OHP numerical modeling team. Specifically, NASA is interested in fundamental experimental research to address some or all of the topics below. The list of needs is given in a somewhat prioritized order. Please note: all OHP proposals **must** include liquid film characterization.

- Liquid film characterization:
 - Liquid film on the wall surrounding vapor plugs

- Dynamics and heat transfer of the liquid film trailing an advancing liquid slug in adiabatic, heated and cooled, slug plug flow. Establish a method to predict liquid film thickness in OHPs with given channel geometry and operational conditions. This may include direct or indirect measurement and theoretical modeling of the liquid film.
- Oscillation Characteristics: frequency, velocity, etc.
- Measurement of the ratio of the net heat transfer attributable to latent heat transfer as compared to that from sensible heat transfer.
- Nucleate boiling characterization, including frequency measurements, and physics in a closed isochoric system.
- Experimental research that supports or refutes the OHP operational limits published by Drolen and Smoot.¹ This includes the effect of viscous losses on OHP operation, the OHP sonic limit, the swept length limit where the amplitude of oscillation is significantly smaller than the evaporator length, the heat flux limit, and the vapor inertia limit which attempts to define the maximum flow velocity that the slug meniscus can support.
- Experimental and physical research into OHP startup including the effects of surface roughness and initial fluid distribution prior to startup

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6) Additional Information:

All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS).

A.1.4 Research Topic 4

1) Program:

Physical Sciences – Combustion Science

2) Research Title:

High Pressure Transcritical Combustion (HPTC)

3) Research Overview:

Fundamental discoveries made by NASA researchers over the last 50 years has helped enable advances in fundamental combustion including low-temperature hydrocarbon oxidation, soot formation and flame stability, to name a few. One area of fundamental research that NASA

¹ B.L. Drolen and C.D. Smoot, "The Performance Limits of Oscillating Heat Pipes: Theory and Validation," Journal of Thermophysics and Heat Transfer, 31, 4, 2017, pp. 920-936.

wishes to emphasize in the future is the area of high pressure, transcritical combustions (HPTC). This includes transformative research to enable the design of future internal combustion engines that are moving to higher operating pressures (increasing efficiency while simultaneously reducing pollutant emissions) and novel applications such as supercritical water oxidation (SCWO) for waste incineration.

The microgravity environment provides an ideal experimental backdrop for probing many of the questions raised in high pressure supercritical research. Since the buoyant force scales with pressure squared, fundamental combustion studies in terrestrial laboratories are increasingly difficult because of the dominance of the buoyant force. The microgravity environment allows for extended length and/or time scales without the intrusion of a dominant buoyant flow. This in turn enables diagnostic techniques, that otherwise prove intractable in 1-g environments, to obtain transformative insights into supercritical phenomena. Using well designed experiments the aforementioned research topics can successfully be explored in microgravity and will serve to greatly enhance the developmental pace of a number of important technologies for both terrestrial and extraterrestrial application.

4) Research Focus:

This Combustion Science Emphasis requests proposals for hypothesis-driven experiments and/or analysis that that will help determine: 1) fundamental phase change and transport processes in the injection of a subcritical fluid into an environment in which it is supercritical; 2) ignition and combination of hydrocarbons under these conditions; and 3) how to optimize SCWO systems for waste management in extraterrestrial habitats.

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6) Additional Information:

Proposers are encouraged to include the use of drop tower facilities in their proposals. For more information about these facilities, they can contact Eric Neumann (eric.s.neumann@nasa.gov; 216-433-2608). These facilities provide either 2.2 or 5.2 seconds of low gravity. The possibility exists (and proposals encouraged) that investigators could take advantage of an existing experimental apparatus for the 5.2 second drop tower.

All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS).

A.1.5 Research Topic 5

1) Program:

Physical Sciences – Materials Science

2) Research Title:

Extraction and Utilization of Materials from Regolith

3) Research Overview:

NASA is successfully advancing the mission of returning humans to the Lunar surface and establishing a long-term presence. Critical to success of sustaining a human presence on the Lunar surface is the utilization of natural resources. Extraction of materials (e.g., metals, glasses, and water ice) from extra-terrestrial regolith and the subsequent use in manufacturing key infrastructure will enable humans to thrive on extra-terrestrial surfaces. The extracted materials could be used as feedstock for additive manufacturing processes to produce outfitting for habitats, to build infrastructure, for example, habitats, roads, walls, and landing pads, or to fabricate tools or other hardware. The water ice from regolith material could be used to augment life support systems for extended stay missions or produce liquid hydrogen and liquid oxygen for propellant production.

4) Research Focus:

The goal of this NASA Physical Sciences Program research emphasis is to develop and increase understanding of extraction techniques to generate useful materials (e.g., metals, glasses, water ice) from Lunar or Martian regolith.

Proposed studies are expected to generate and test specific hypotheses to the extent possible in a terrestrial lab. Investigations should be proposed that would study one or more of the following topics:

- a) Refinement of existing techniques to extract materials from regolith.
- b) Development of new techniques for extraction of materials from regolith.
- c) Studies of the extracted material to determine its properties or to investigate novel ways of utilizing it to support NASA's exploration goals.
- d) Investigations to determine manufacturing processes using regolith or materials extracted from regolith to produce infrastructure and/or outfitting critical to sustaining life on extra-terrestrial surfaces.

It is expected that regolith simulant, or equivalent, will be used for the proposed experiments. For example, crushed basalt could potentially be used in lieu of Lunar regolith simulant. Proposals are encouraged to use existing hardware.

More information on NASA's exploration goals can be found in the Decadal Survey (<http://www.nap.edu/catalog/13048.html>), specifically Translation to Space Exploration Systems (TSES) number 16 (TSES16).

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6) Additional Information:

All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences (BPS).

A.1.6 Research Topic 6

1) Program:

Space Biology

2) Research Title:

Effects of Chronic Radiation Exposure on Plant and Microbial interactions or Multigenerational Growth of Invertebrates

3) Research Overview:

Radiation and altered gravity regimes (partial gravity and microgravity) are a hallmark of the deep space environment. While much of the focus of past Space Biology-sponsored research has been on the effects of altered gravity on biological systems, the program is interested in understanding the impacts of all components of the deep space environment on living organisms. For example, ionizing space radiation is a concern for organisms on long-duration missions. While understanding the mechanisms of damage induced by ionizing radiation will be important to inform the risk to the living system and develop effective countermeasures, it is also important to understand how chronic exposure to radiation over prolonged periods of time impacts an organism's overall health, fitness, and vitality.

For this EPSCoR Rapid Research Response Topic, NASA is interested in proposals that will characterize the effects of chronic low-dose ionizing radiation exposure on plant and microbial interactions (over multiple microbial generations), or the multigenerational growth of invertebrates.

4) Research Focus:

Applicants may submit a proposal to the topic of chronic low-dose radiation exposure that is responsive to only one of the two emphases below.

Emphasis 1: Plant/Microbial Interactions

Fundamental discoveries made by NASA researchers over the last 50 years have enabled the successful growth of plants in space, as is demonstrated through current work being done on the ISS using [Veggie](#) and the [Advanced Plant Habitat](#). Despite these advances and the potential of this work to lead to the creation of space life-support systems, additional plant biology research is still needed. There is much to learn about how plants respond to environments within Low Earth Orbit (LEO) and those beyond Low Earth Orbit (BLEO), such as on the Martian and Lunar surfaces. Furthermore, we have little information on the role that the ecosystems surrounding plants, including microbial communities, play in plant growth and development in non-terrestrial environments. Therefore, the NASA Space Biology Program is soliciting research projects through this opportunity to increase our knowledge of what it will take to support long-duration plant growth and cultivation efforts during extended space exploration missions.

One area of fundamental research in which NASA wishes to focus is the impact of ionizing radiation on plant growth and development, with a specific focus on how it influences plant and microbial interactions. While the microbial contamination of plants grown in the closed environment of a spacecraft is always a potential concern, the interactions of these plants with beneficial microbes, such as those between leguminous plants and nitrogen-fixing bacteria, may also be altered in spaceflight environments (Foster et al., 2014: PMID: [25370197](#)). This Space Biology research emphasis aims to build a better understanding of how exposure to chronic low doses of ionizing radiation influences the fitness of relevant plants and microbes, and in turn, how these changes affect plant/microbial ecosystems over time.

To be responsive to this emphasis, proposals must encompass hypothesis-driven experiments that help determine: 1) the effects that exposure to chronic low-dose ionizing radiation has on plant-microbial interactions; and 2) how to optimize plant-microbial systems for growing and sustaining plants under these conditions. Fundamental plant-microbial biology research is needed to identify the space environmental factors or combination of factors that impact plant-microbial interactions. Applicants may propose to use any microbe/plant combination of their choosing but must include adequate rationale and justification for their selection in terms of space relevance.

Applicants may consider the following questions in the preparation of their proposal:

- Do plant and microbial interactions change over time under chronic low dose ionizing radiation exposure, and are processes such as commensalism, symbioses, nitrogen fixation, and biodegradation altered?
- If the proposed project involves a single microbial species, how does chronic radiation exposure influence the fitness of the microbe over time, and how does that in turn affect the fitness of the plant-microbe interaction?
- If the proposed project involves a community of microbial species, does radiation exposure influence the development and diversity of the microbial community when associated with plants? Does the microbial population from plant surfaces or plant growth media change over time in a radiation environment?

- Does chronic exposure to ionizing radiation cause beneficial microbes in plant growth to become less beneficial over time? What effect does radiation exposure have on the harmful effects of plant pathogens?

Proposers are free to use any source of ionizing radiation they choose; however, they must include the rationale and justification for this choice and its relevance to space-relevant environments.

Awarded projects will be for \$100,000 over a one-year duration. The intention of the Space Biology Program is that awarded projects produce preliminary data for an application to future NASA Life-Sciences funding opportunities.

Emphasis 2: Multigenerational Growth of Invertebrates

The goal of this Space Biology research emphasis is to solicit research projects that will examine the biological and physiological impacts that exposure to chronic low doses of ionizing radiation has on living systems using invertebrate models. Proposals must include hypothesis-driven experiments and may use any invertebrate model system of their choice, provided it has a short generation time so that multiple generations can be examined during the award performance period. Justification and rationale for the choice of the model should be included in the proposal.

Applicants may consider the following questions in the preparation of their proposal:

- What organ systems/tissues seem most impacted by the exposure to chronic low-dose radiation exposure?
- Does chronic radiation exposure alter gene/protein expression patterns over time (other omics approaches are acceptable). Are these changes limited to a single generation, or do they propagate across multiple generations? Are these changes the results of epigenetic modifications? Are these changes limited to specific organ/tissue systems?
- Is there a change in the frequency of mutation accumulation in the tested model, and if so, where in the genome do mutations occur?
- Does chronic radiation exposure effect neurobehavioral responses and result in changes of movement and activity of the model system over time? Does the organism become more or less active with each passing generation?
- If the model system tested has multiple life stages (i.e., undergoes metamorphosis), what impact does radiation exposure have on the transition between these stages? What happens to progeny numbers over time?
- How does progeny isolated after multiple generations of radiation exposure interact with organisms that have not been exposed? Are they able to produce viable offspring together?

Proposers are free to use any source of ionizing radiation that they choose, however, proposals must include the rationale and justification for this choice and its relevance to space-relevant environments.

Awarded projects will be for \$100,000 over a one-year duration. The intention of the Space Biology Program is that awarded projects produce preliminary data for an application to future NASA Life-Sciences funding opportunities.

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6) 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.

Appendix B

B.1.0: Ames Research Center

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

B.1.1 Research

1. **Organization/Program:** Entry Systems Modeling Project
2. **Research Title:** Thermal Conductivity Heat Transfer of Porous TPS Materials
3. **Research Overview:** Provide data to allow for the development of models for predicting the effective thermal conductivity of TPS materials of interest to Entry Descent and Landing projects and missions at NASA.
4. **Research Focus:** This proposal seeks heat transfer measurements that can isolate the contributions of solid conduction, gas conduction, and radiation to the overall effective thermal conductivity of porous thermal protection system (TPS) materials for a range of temperatures. These measurements should allow for the radiative heat transfer to be isolated from the conductive heat transfer through a TPS material, allowing for the contribution of each of these heat transfer mechanisms to be characterized independently. The data would then be made available to the TPS materials modeling groups at NASA to improve thermal conductivity models.
5. **Contact:** Aaron Brandis aaron.m.brandis@nasa.gov

B.1.2 Research

1. **Organization/Program:** Entry Systems Modeling Project
2. **Research Title:** Measurements for Characterizing In-Depth Spectral Radiative Properties of TPS Materials
3. **Research Overview:** Resolving the reflectance and transmission of radiative heating impinging on TPS materials as a function of wavelength
4. **Research Focus:** Data is needed to validate models for in-depth TPS radiative heating transport models. As radiative heating is specific to certain wavelengths (the relevant wavelengths of which change for different atmospheric compositions), these measurements need to be spectrally resolved to get data at relevant wavelengths. The proposal would need to offer techniques to measure the energy transmitted/reflected to provide an estimate for the flux of photons transmitted/reflected incident upon a TPS material. Materials of relevance could include FiberForm, and Silicon Carbon-based materials.
5. **Contact:** Aaron Brandis aaron.m.brandis@nasa.gov

B.1.3 Research

1. **Organization/Program:** Entry Systems Modeling Project
2. **Research Title:** NuSil Coated PICA Material Response in CO2 Environments

3. **Research Overview:** Provide experimental data to characterize the material response of NuSil coated PICA under simulated Martian entry conditions.
4. **Research Focus:** Data is needed to validate models for NuSil coated PICA under simulated Martian entry conditions, with the atmosphere being predominately CO₂ and aerothermal environments equivalent to that experienced by Mars 2020 or Mars Science Laboratory. Furthermore, a parametric sweep of conditions would be beneficial to inform model improvements. Relevant facilities for such measurements could include ArcJets or Plasma Torches. Data of interest would include thermocouples imbedded in the PICA and non-intrusive surface temperature measurements. Characterization of the post-test materials is also of interest. Understanding the material response of NuSil is important to maximize science return for the MEDLI and MEDLI2 instrumentation suites.
5. **Contact:** Aaron Brandis aaron.m.brandis@nasa.gov

B.1.4 Research

1. **Organization/Program:** Entry Systems Modeling Project
2. **Research Title:** Deposition of Ablation/Pyrolysis Products on Optical Windows
3. **Research Overview:** Provide experimental data to characterize the deposition of ablation/pyrolysis products on radiometer/spectrometer windows that reduce transmissivity.
4. **Research Focus:** Mars 2020 carried a radiometer on the backshell of the entry vehicle as part of the MEDLI2 instrumentation suite. Pyrolysis and ablation products can be deposited on the radiometer window during entry, and reduce the transmissivity. This reduction in transmissivity is a function of spectral wavelength, and can reduce the signal level reaching the radiometer sensing element. Such a test could be conducted in an ArcJet or Plasma torch either with a scaled approximate model of Mars 2020, or a simplified geometry (e.g. a wedge, backward facing step). Relevant materials for testing include PICA, RTV and SLA 561V. After products have been deposited on the window during a test, these products need to be characterized and the transmissivity of the window measured. These post-test results could either be measured as part of the proposal, or the post-test models sent back to NASA for characterization.
5. **Contact:** Aaron Brandis aaron.m.brandis@nasa.gov

B.1.5 Research

1. **Organization/Program:** Entry Systems Modeling Project
2. **Research Title:** Predictive Modeling of Plasma Physics Relevant to High Enthalpy Facilities
3. **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.
4. **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.

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Appendix C

C.1.0 Office of the NASA Chief Medical Officer (OCHMO) and Human Research Program/Space Radiation Element

POCs:

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C.1.1 OCHMO Areas Of Research Interest:

1. 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.
2. 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

C.1.2 Topics from Human Research Program/Space Radiation Element

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Sishc, Brock J. (JSC-SA211)[WYLE LABORATORIES, INC.] <brock.j.sishc@nasa.gov>

Topic 1: Pilot studies to examine the effects of whole-body irradiation on minipigs.

- 1) Program: Space Radiation Element/Human Research Program
- 2) Research Title: Pilot studies to examine the effects of whole-body irradiation on minipigs.
- 3) Research Overview

Human spaceflight involves exposure to galactic cosmic rays (GCR), solar particle events (SPE), and charged particles trapped in the magnetic field of Earth called the Van Allen Belts. The

intensity and quality of space radiation is different than that experienced in terrestrial environments and therefore uncertainties exist in the understanding of the consequences of space radiation exposure. Epidemiological studies of terrestrial radiation-exposed human cohorts such as the atomic bomb survivors, uranium miners, and occupational radiation workers provide insight into the health impacts of radiation exposure, most notably an increased risk of carcinogenesis and cardiovascular disease (CVD).

Because it is unethical to purposely expose human populations to radiation for experimental research, animal models are used to characterize differences between terrestrial radiation and components of the space radiation environment using ground-based analogs. Traditionally, rodent models are predominantly used to conduct this research, however, translation from rodents to human populations is limited due to multiple factors including anatomical, size, lifespan, and genetic differences. Interestingly, in these rodent models a new risk not observed in any human cohorts at relevant doses has emerged. Changes in the central nervous system (CNS) that negatively impact cognitive and behavioral performance have been demonstrated following relevant doses of charged particle irradiation.

Minipigs, which are more similar in lifespan, size, anatomy, and physiology to humans, provide a unique opportunity to better characterize the effects of space radiation exposure particularly for CVD pathogenesis and changes to the CNS that could impact cognitive and behavioral performance. Utilizing minipigs as a model for carcinogenesis is likely not practical due to their long lifespan compared to rodents. **This topic seeks proposals for preliminary pilot studies to establish functional clinically relevant endpoints to examine the health effects of whole-body ionizing radiation exposure in minipigs for CVD, and CNS related endpoints.**

4) Research Focus

The research topic focuses on ground-based proposals studying clinically relevant functional endpoints and relevant biomarkers to understand the effects of whole body ionizing radiation exposure on minipigs with a particular focus on cardiovascular disease (CVD) and central nervous system (CNS) effects that impact cognitive and behavioral performance.

Relevant endpoints include (but are not limited to):

- Cognitive and/or behavioral testing
- Qualitative and quantitative measurements of cardiovascular structure and function as well as microvascular functional changes is desirable.
- Changes in biomarkers of long-term health outcomes relevant to CVD, and CNS outcomes , and carcinogenesis following whole body radiation exposure.
- Functional outcomes relevant to specific human health conditions.

Due to limited time and budget, researchers are encouraged to utilize minimal animal numbers and radiation sources at space-relevant doses (0-5 Gy of photons or proton irradiation) available at home facilities. A successful proposal will not necessitate the use of the NASA Space Radiation Laboratory (NSRL), the ground analog for space radiation studies, at Brookhaven National Laboratory.

Topic 2: Development of tissue chip models to accelerate space radiation research.

1) Program: Space Radiation Element/Human Research Program

- 2) Research Title: Development of tissue chip models to accelerate space radiation research
- 3) Research Overview

Human spaceflight involves exposure to galactic cosmic rays (GCR), solar particle events (SPE), and charged particles trapped in the magnetic field of Earth, called the Van Allen Belts. The intensity and quality of this space radiation is different than that experienced in terrestrial environments and therefore uncertainties exist in the understanding of the consequences of space radiation exposure. Epidemiological studies of terrestrial radiation exposed human cohorts such as the atomic bomb survivors, uranium miners, and occupational radiation workers provide insight into the health impacts of radiation exposure most notably an increased risk of carcinogenesis, and cardiovascular disease (CVD). Additionally, a new risk not observed in any human cohorts at relevant doses has emerged. Changes in the central nervous system (CNS) that negatively impact cognitive and behavioral performance have been demonstrated in rodent models following relevant doses of charged particle radiation. However, no human data exists to help understand the effects of charged particle radiation environment experienced in space. Traditionally, NASA's risk models utilize experimental data generated in model systems (human cells, tissues, small animals, etc.) to "scale" radiation risks estimated from terrestrially-exposed human cohorts to the space radiation environment.

Recent breakthroughs in microfluidics, prolonged cell culture, material science, and the ability to differentiate genetically similar cells from induced pluripotent stem cell populations have led to the advancement of tissue- or organ-on-a chip technologies that more closely and accurately recapitulate human tissues *in vitro*. Chip technologies offer a unique opportunity to expand the knowledge base for space radiation exposures at the systems biology and organ levels, however functional endpoints have not yet been established following radiation exposure. Additionally, chip technology has the potential to vastly accelerate translation of animal data to human outcomes, thus providing improved fidelity to the data generated using animal models. **This topic seeks proposals that interrogate the effects of radiation on functional endpoints using human and/or animal tissue- or organ-on-a-chip technologies in one of three research emphases.**

4) Research Focus

This research topic focuses on ground-based proposals studying functional endpoints and relevant biomarkers to understand the effects of ionizing radiation exposure using chip technologies with a particular focus on CVD pathogenesis and/or carcinogenesis. Successful applications will address one of the following three research emphases and will establish appropriate functional endpoints and biomarkers necessary to accelerate space radiation research and its effects on human health.

- Radiation carcinogenesis (tissue/organ systems of interest: breast, lung, liver, colon, and hematopoietic system),
- Microvasculature physiology and functional changes, or
- Comparative translational endpoints between human and rodent tissues focusing on CVD, CNS, or carcinogenesis.

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.

Appendix D

D.1.0 Aeronautics Research Mission Directorate (ARMD)

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D.1.1 Research Title: Safety of Electro-mechanical Powertrains for Electrified Vertical Takeoff and Landing (eVTOL) Vehicles

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 increased automation and 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 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 combined with mechanical or magnetically-g geared transmissions. Research topics of particular interest are those that focus on:

- 1) high power density electro-mechanical powertrains;
- 2) application of advanced materials and manufacturing; and
- 3) high reliability and robustness for safety-critical propulsion systems.

The target application is eVTOL vehicles sized to carrying four to six passengers with missions as described in References 1-6. Research equipment is available at GRC to support experimental studies for collaborations. The facilities for experiments include full-scale helicopter

transmissions and electric motor evaluation test facilities as well as several test rigs for fundamental studies which pertain to lubrication, endurance and fatigue, efficiency, and windage.

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.

Organization: NASA Glenn Research Center

Contact: Dr. Timothy Krantz, timothy.l.krantz@nasa.gov, 216.433.3580

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

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.

A pre-proposal conference is desired.

Dr. Krantz and colleagues will support a pre-proposal conference. We believe that researchers from Arkansas, Kentucky and Oklahoma may have interest and expertise in this area and be ESPCoR eligible.

D.1.2 Research Title: Impact Testing to Support the Development of an Artificial Bird Material for Aircraft Certification

POCs: Dr. Robert K. Goldberg, Robert.K.Goldberg@nasa.gov, (216) 433-3330

Dr. Justin Littell, Justin.d.littell@nasa.gov, 757.864.5095

Dr. Michael Pereira, mike.pereira@nasa.gov, 216.287.7340

Research Overview:

A. Overview

The certification process for aircraft and engines involves a number of tests that make use of real birds as projectiles to verify that structures can safely withstand an impact. There are several disadvantages to using real birds, including a lack of repeatability, hygiene issues with testing and the requirement for sacrificing an animal. The NASA Glenn Research Center is involved in a process to develop an artificial material that responds in a similar manner as a real bird and that would be accepted by Civil Aviation Authorities as a substitute for real birds in certification testing.

The process for developing a qualified artificial bird material is being done through the SAE G-28 Committee, Simulants for Impact and Ingestion Testing Committee. The process requires conducting a number of tests at different levels of complexity with both real and artificial birds that demonstrate similarity in the two responses. The most basic of the tests, described in the SAE AS6940 Aerospace Standard [1], involves impacting the projectile into the end of a large aluminum cylindrical bar, called a Hopkinson bar, in an axial direction. The bar is in two sections, each 12-inches in diameter and 12-feet long. Strain gages located along the bar record the transient strains produced by the impact, allowing the computation of the impact force history.

NASA is soliciting proposals to conduct tests in accordance with SAE AS6940 with real birds over a range of impact energies (bird impact velocities and masses) that cover the range specified in the SAE G-28 Committee Technical Strategy (available by contacting the committee). Optionally, additional tests can be conducted using an artificial bird material, mutually agreed upon by NASA and the test proposer.

B. Required Tests

The tests involve accelerating a bird, typically with the use of a single stage gas gun, into one end of the Hopkinson bar described in SAE AS6940.

The tests being proposed should fall within the range of velocities and kinetic energies shown in figure 1 and, specifically, the conditions shown in the inset. For each condition three repeats should be conducted. It is recognized that all the conditions identified in figure 1 by may not be achievable within the supplied budget. The number of tests to

be conducted and the conditions must be specified in the proposal. Higher priority will be placed on proposals that address the lowest mass (1 kg) bird at the two lower kinetic energies, followed by the medium mass (1.8 kg) bird at higher velocities.

The same species of bird should be used for all tests at a given mass. Bird preparation should be done in accordance with the requirements in ASTM Standard Test Method F-330-16 [2] or its most recent revision. The proposal should include a description of the species of birds and the masses and velocities to be used. It should also include deviations, if any, from the Aerospace Standard.

The award recipient has the option of building and instrumenting the Hopkinson bar, as specified by the AS6940 standard, or including in the budget the cost of round-trip shipment of an existing bar located at the NASA Glenn Research Center.

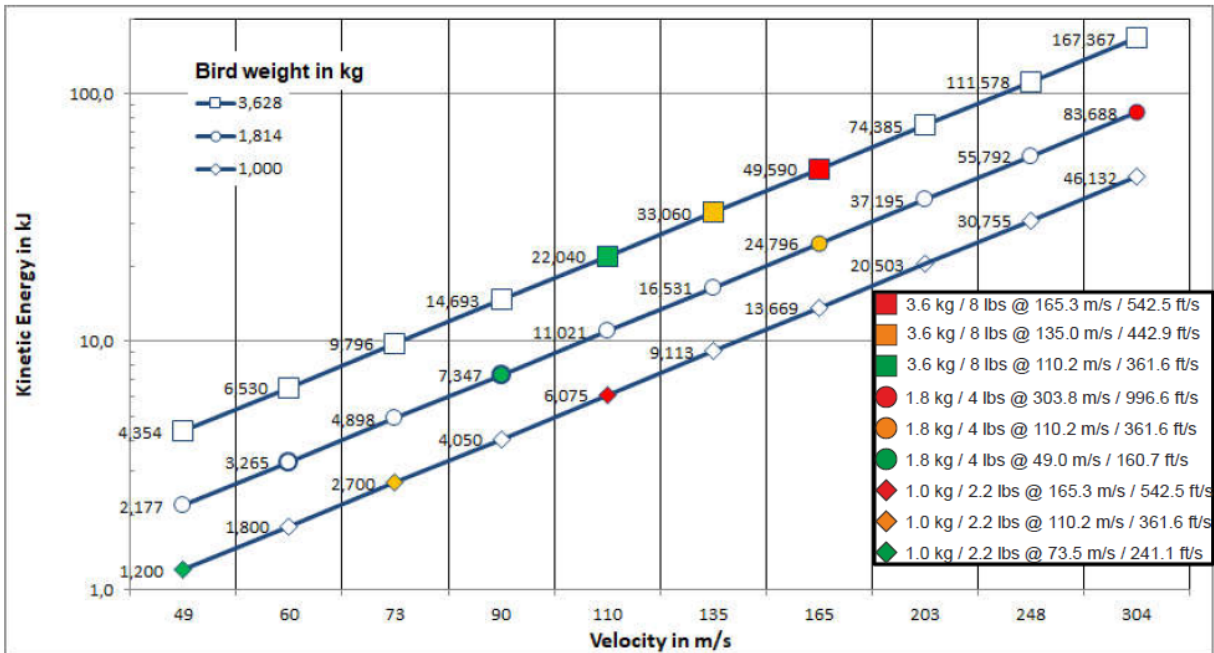


Figure 1. Range of Velocities and Kinetic Energies Relevant to Bird Strike Testing

C. Deliverables

- a. Raw data from the two strain gage bridges, either in the form of strain or converted to force. Data to be in tabulated form as a function of time.
- b. High speed video images from all cameras used in the test
- c. Report summarizing methods, results and conclusions in a format that would be submittable as a NASA Technical Memorandum.

References:

1. Aerospace Standard: “AS6940 Standard Test Method for Measuring Forces During Normal Impact of a Soft Projectile on a Rigid Flat Surface”, SAE International, Warrendale PA, 2021

2. ASTM. 2016, "F330-16, Standard Test Method for Bird Impact Testing of Aerospace Transparent Enclosures", West Conshohocken, PA: ASTM International. DOI: 10.1520/F0330-16

Organization: NASA Glenn Research Center/NASA Langley Research Center

Contact: Dr. Mike Pereira, Dr. Robert Goldberg, Dr. Justin Littell

Mission Directorate: Aeronautic Research Mission Directorate / Revolutionary Vertical Lift Technology Project

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.

D.1.3 Research Title: Development of Characterization Techniques to Determine Key Composite Material Properties for the LS-DYNA MAT213 Model

Research Overview:

A. 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.

There are several key material parameters required for input to the MAT 213 material model that are challenging to obtain via traditional coupon level testing techniques. Specifically, due to the fact that the plasticity flow law in the deformation portion of the material model is not coupled to the yield function, determining the coefficients required for the flow rule function requires the measurement of complex parameters such as the plastic Poisson's ratio. Developing a more straightforward and

reproducible approach to determining these flow rule coefficients would significantly improve the usability of the material model. Furthermore, to appropriately capture the full response of a composite under dynamic loading conditions, the ability to account for stress degradation after peak loading conditions are reached is required. Currently, however, the parameters required to characterize this post-peak stress degradation response are determined based on correlation with structural level impact and/or crush tests. Research is required to develop a methodology to characterize this stress-degradation response based on lower scale experiments such as coupon level tests.

For this task we are focused on developing techniques and recommended approaches to characterize the material parameters described above using tests at the coupon scale or similar fundamental types of tests. To carry out this task, we are interested in having a composite material or materials that will be defined and supplied by NASA tested. The focus of the effort is to develop test methods and conduct detailed tests to characterize the flow rule coefficients and the post-peak stress degradation response. Fundamental characterization data obtained from standard tension, compression and shear tests should be available for the chosen material. The primary focus of this task will be to characterize the material to a sufficient degree to allow for simulations of the material to be conducted using shell elements.

B. Required Tests

Specific tests will have to be developed and carried out to appropriately characterize the flow rule coefficients and the post-peak stress degradation response. However, it is expected that the following standard set of tests could provide a baseline from which the needed parameters can be determined. For the shell element version of MAT213, at a minimum, seven fundamental tests are required to appropriately characterize the material response. The loading directions are as follows:

- a. Tension in the 1-direction
- b. Compression in the 1-direction
- c. Tension in the 2-direction
- d. Compression in the 2-direction
- e. Shear in the 12-direction
- f. Shear in the 21-direction
- g. 45 degree off axis tension

While some or all of the tests listed above could form the basis of determining the flow rule coefficients and the post-peak stress degradation response, it is acknowledged that additional tests to be determined over the course of the research will likely be required to characterize the specified parameters.

C. Test Requirements

- i. Test coupons will be machined by the grant recipient from flat panels supplied by NASA.

- ii. For all tests the tabulated full stress-strain curve, all the way to failure, must be recorded and supplied in electronic tabular format. 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 nominal room 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
- viii. The tests should be based on ASTM Standard Test Methods if possible, but it is acknowledged that modifications to the standard methods may be required to obtain the specific data required to characterize the flow rule coefficients and the post-peak stress degradation response.
- ix. Testing at different strain rates is encouraged but not required

D. Deliverables

- a. Full tabulated stress strain data to failure supplied in electronic tabular format
- b. All DIC images and associated calibration files
- c. A proposed approach to characterize the plasticity flow rule coefficients based on coupon or similar low scale test data.
- d. A proposed approach to characterize the post-peak stress degradation based on coupon level or similar low scale test data

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.

Organization: NASA Glenn Research Center/NASA Langley Research Center

Contact: Dr. Robert Goldberg, Dr. Justin Littell, Dr. Mike Pereira

Mission Directorate: Aeronautic Research Mission Directorate / Revolutionary Vertical Lift Technology Project

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.

Appendix E

E.1.0 Marshall Space Flight Center (MSFC)

POC: Jhonathan Rosales (jhonathan.rosales@nasa.gov), 256.961.2491

E.1.1 Additive Manufacturing of Nuclear Fuels (ceramics)

- 7) Organization/Program: EM32/ Advanced Metals Processing and Technologies Team
- 8) Research Title: Additive Manufacturing of Nuclear Fuels (ceramics)
- 9) Research Overview:

The development of ceramics for high performance applications including energy, defense, aerospace, and nuclear applications is a challenging task in the engineering world. Advanced nuclear fuel designs may bring increased energy outputs, enhanced performance, and sometimes a greater accident tolerance. But some of these ceramic nuclear fuel architectures may not be fabricated under traditional processes employed to mass produce nuclear fuel. Thus, novel methods are being investigated to fabricate ceramic nuclear fuel.

In space nuclear propulsion, ceramic fuel is employed to heat the propellant (liquid hydrogen) to generate thrust and impulse the space vehicle. Some of the main challenges on fabricating this fuel concept are consolidation and the post-processing of near-net-shapes (complex geometries), where machining this robust material can be laborious and expensive, requiring diamond tools. Often times a large fraction of the fabrication has to be allocated to machining. In recent years additive manufacturing (AM) technologies have proved success in reducing production times, produce complex geometries, and bring significant economic savings. Additionally, fabrication of ceramic compounds via AM has been recently researched in different systems of interest including selective laser melting (SLS) and stereolithography (SLA) [1].

10) Research Focus:

Additive Manufacturing (AM) of ceramic nuclear fuels can be a long-term solution to produce the fuel's complex geometries in a scalable and cost-effective process. Direct ink writing (DIW) or Robocasting (RC), where a binder or colloidal gel is deposited on the sample feedstock to form the required geometry can be promising methods to explore AM of ceramic nuclear fuel [2]. Photocuring or heat treatment are crucial for sintering, allowing for densification and reducing porosity. During the heat treatment, the green bodies can significantly increase their density, which is crucial for optimum fuel performance.

A base step is to prove feasibility of fabricating UO_2 which is a highly demanded fuel for nuclear power plants to generate electricity. AM could demonstrate a representative density and microstructural features in surrogate materials including ZrO_2 and CeO_2 [3,4]. Additionally, NASA's Space Nuclear Propulsion program is exploring carbide fuel to generate propulsion for deep space missions, where UC can be the basis to explore AM feasibility with surrogate material ZrC.

Work with radioactive materials may require strict safety measures, material traceability, and a certified laboratory by the U.S. Nuclear Regulatory Commission (NRC). Due to the complexity of working with radioactive materials we will tailor this research effort to surrogate work, where non-radiological materials can be explored to arrive at a proof of concept. AM of nuclear fuels and ceramics can benefit other research areas at NASA, including nuclear electric propulsion, hypersonics, propulsion parts (nozzles), and piezo electric materials.

11) Contact: Jhonathan Rosales (jhonathan.rosales@nasa.gov)

12) References:

1. Travitzky, Nahum, Alexander Bonet, Benjamin Dermeik, Tobias Fey, Ina Filbert-Demut, Lorenz Schlier, Tobias Schlordt, and Peter Greil. "Additive manufacturing of ceramic-based materials." *Advanced engineering materials* 16, no. 6 (2014): 729-754.
2. Fu, Zongwen, Matthias Freihart, Larissa Wahl, Tobias Fey, Peter Greil, and Nahum Travitzky. "Micro-and macroscopic design of alumina ceramics by robocasting." *Journal of the European Ceramic Society* 37, no. 9 (2017): 3115-3124.
3. Hunt, Rodney Dale, John D. Hunn, J. F. Birdwell, T. B. Lindemer, and J. L. Collins. "The addition of silicon carbide to surrogate nuclear fuel kernels made by the internal gelation process." *Journal of nuclear materials* 401, no. 1-3 (2010): 55-59.
4. Roleček, Jakub, Štěpán Foral, Karel Katovský, and David Salamon. "A feasibility study of using CeO₂ as a surrogate material during the investigation of UO₂ thermal conductivity enhancement." *Advances in applied ceramics* 116, no. 3 (2017): 123-131.

Appendix F

F.1.0 NASA SMD Computational and Information Sciences and Technology Office (CISTO)

POCs: James Harrington, james.l.harrington@nasa.gov 301-286-4063
Elizabeth A. Macdonald, elizabeth.a.macdonald@nasa.gov, 301-286-6690

F.1.1. Program 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.

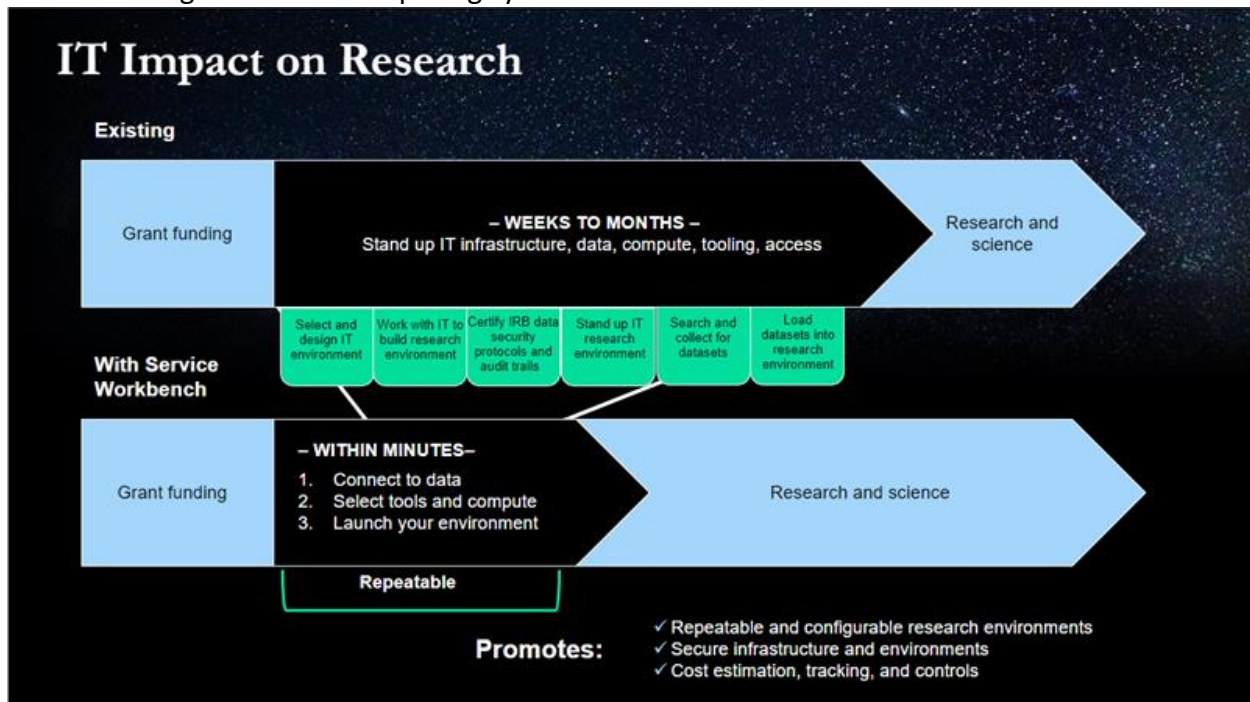
NASA open science promotes the availability of original source code and data to be available on the public domain to be repurposed for easier collaborations to be born among different groups or teams to work towards solving scientific problems that can benefit society. NASA SMD communicates a VISION via the SMD Big Data Working Group (SBDWG) 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).

The SBDWG report states that "SMD and the individual science divisions do not operate in isolation and therefore should recognize there is tremendous value in engaging with multiple stakeholder groups to identify opportunities to increase collaboration and use of advanced tools and techniques to drive scientific discovery. The decisions on when and how to collaborate should be made in such a way that SMD sets policies and facilitates sharing best practices, while providing the science divisions with responsibility and flexibility to manage their systems to meet the needs of their communities.

One such strategy to support this VISION is promoting a robust Citizen Science program recommended by the SMD Science Management Council approved by the SMD Associate Administrator. SMD citizen science projects shall be held to the same rigorous standards as any SMD science program. Documented project goals must include advances in science, the merit of which shall be determined by peer review.

Additionally, the SBDWG report communicates a goal to: Continuously Evolve Data and Computational Systems - SMD must therefore continuously evolve data and computational systems to realize the potential of innovative techniques to more efficiently manage data and computing resources and establish policies optimized to support investments in technology development and adoption. This will require investments in data systems, computational

approaches, and the workforce that harnesses technology are needed to support the evolution of data management and computing systems.



This Appendix opportunity is designed to facilitate the continuous progress towards the SMD goals for open science via targeting data analysis opportunities for Heliophysics Citizen Science, one of the SMD Science Themes to increase science returns that are to be held to the same rigorous standards as any SMD science program while facilitating advancements in agency resources for continuously optimizing techniques and computing resources for more efficient data science research. An additional responsiveness component is for broadening participation of underrepresented audiences.

Broadening Participation of traditionally underrepresented audiences

Former NASA Administrator James Bridenstine communicated a diversity agenda for the agency that is continued today: “We embrace the critical importance of cultivating and empowering a diverse and inclusive workforce and work environment-enabling NASA to attract the widest and deepest pools of talent, leverage the capabilities of our exceptional workforce; and empower all personnel to be authentic, to participate, and to fully contribute. We understand this provides NASA access to the highest levels of knowledge, capabilities, creativity, problem solving, decision making, and performance. And this will enable NASA to achieve the greatest mission success.”

A proposal that is fully responsive to this opportunity must establish a research, education, training and capacity building collaboration strategy that includes:

1. Majority/Minority lead institution partners with MSI (HBCU, HSI, Tribal College) within EPSCoR jurisdiction or across another EPSCoR jurisdiction;

2. Majority/Minority lead institution partners with a Community College within EPSCoR jurisdiction or across another EPSCoR jurisdiction;
3. Majority/Minority lead institution partners with another Majority/Minority institution with a focus on including ethnic minority students.

Or some type of mixture of any of the three.

NASA Contact:

- a. Name: James Harrington
- b. Organization: NASA Goddard Space Flight Center
- c. Work Phone: 301-286-4063
- d. Email: james.l.harrington@nasa.gov

F.1.2: Supporting Heliophysics Citizen Science Goals through Data Partnerships

POC: Elizabeth MacDonald, elizabeth.a.macdonald@nasa.gov, 505-920-7602

- 1) Program: Artificial Intelligence and Machine Learning Capability
- 2) Research Title: Supporting Heliophysics Citizen Science Goals through Data Partnerships

3) Research Overview:

The Science Mission Directorate Heliophysics Division studies the nature of the Sun, and how it influences the very nature of space — and, in turn, the atmospheres of planets and the technology that exists there. Space is not, as is often believed, completely empty; instead, we live in the extended atmosphere of an active star. Studying this system not only helps us understand fundamental information about how the universe works, but also helps protect our technology and astronauts in space. NASA seeks knowledge of near-Earth space, because -- when extreme -- space weather can interfere with our communications, satellites and power grids. The study of the Sun and space can also teach us more about how stars contribute to the habitability of planets throughout the universe.

Citizen science in Heliophysics has a balanced strategy and implementation plan that maximizes natural opportunities over the next five years. Our Vision is to leverage public participation in Heliophysics to help drive innovation and diversity in science, society, and education and our Mission is to build a robust, dynamic, and engaging Heliophysics citizen science portfolio that fuses natural phenomena, mission opportunities, and the power of people’s diverse viewpoints to fuel collective innovation. To achieve our Mission, a number of inter-related Objectives build momentum towards our goals to Grow, Execute, Innovate, Communicate, Optimize, and Partner. There is an opportunity to achieve this vector of opportunities in our strategic plan to its fullest implementation and we look forward to pursuing this here. We are looking to advance this Vision by building new partnerships and capacity between existing citizen science projects, achieving our vision and the data science interest of this call. More about our strategy can be found here: <https://science.nasa.gov/heliophysics/programs/citizen-science>.

4) **Research Focus:**

Citizen Science programs are a form of open collaboration in which individuals or organizations participate voluntarily in the scientific process. The current SMD Policy (<https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/SPD%2033%20Citizen%20Science.pdf>) on citizen science describes standards for evaluating proposed and funded SMD citizen science projects. For more information see the <https://science.nasa.gov/citizenscience> webpage, that provides information about existing launched SMD-funded projects. Other projects may be eligible if approved by the NASA Contact. Specific interests include the analysis of data that could lead to original discoveries from space Heliophysics missions or citizen science ground-based data. This could include the compilations of data catalogs, statistical studies, algorithms and pattern recognition, artificial intelligence applications, development of data pipelines, etc. These tools should be demonstrated against a specific use case. The proposal should also explain how this might be expanded for other use cases. Existing Heliophysics citizen science projects will be invited to the pre-proposal workshop to present their science target, existing project, and related data needs appropriate to the scope of this call. You may request the NASA Contact to put your team in contact with a specific project and to offer specific skills earlier if you wish. Existing Heliophysics citizen science projects involve solar data, solar observing, comets that orbit the sun, eclipse observing, solar radio data, ionospheric radio data, Jovian radio data, magnetospheric data analysis and sonification, the aurora, and sprite lights in the mesosphere.

5) **NASA Contact:** a. Name: James Harrington/Elizabeth MacDonald b.

Organization: NASA Goddard Space Flight Center c. Work Phone: 301-286-4063, 505-920-7602

d. Email: james.l.harrington@nasa.gov; elizabeth.a.macdonald@nasa.gov

6) **Additional Information:** In 2017, we saw millions in the US captivated by the first total solar eclipse of the millennium. In 2023-4, we have the opportunity to convert a generation to Heliophysics Science by experiencing two solar eclipses during solar maximum through citizen science as a gateway to our missions and science. As part of a larger strategic initiative called the “Heliophysics Big Year” to grow and innovate Heliophysics citizen science, we are planning a campaign designed to achieve a broader vision for Heliophysics utilizing these natural opportunities coinciding with the rise of citizen science within SMD. What is a “Big Year”? A big year is a birding term for maximizing a birder’s number of species. We envision utilizing the recognition of a big year(s) to tie the three major Heliophysics events together and encourage the maximization of participation and data collection in a coordinated incentivized branded campaign. Proposals with geographic or skills based alignment with this HBY opportunity may explain in the proposal.

Appendix G

G.1.0 SMD Astrophysics

POCs: Dr. Hashima Hasan, hhasan@nasa.gov, (202) 358-0692
Dr. Mario Perez, mario.perez@nasa.gov, 202.358.1535

G.1.1 Areas of Interest

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>

Appendix H

H.1.0 NASA SMD Planetary Science Division

POCs: Adriana C. Ocampo Uria, adriana.c.ocampo@nasa.gov,
(202) 358-2152
Carolyn Mercer, cmercerc@nasa.gov, (216) 433-3411

H.1.1 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/>.

Technology requirements and challenges related to Venus exploration are discussed in the Venus Technology Roadmap at:
<https://www.lpi.usra.edu/vexag/reports/Venus-Technology-Plan-140617.pdf>

Technology development is sought for the following two applications:

H.1.2 High-Temperature Subsystems and Components for Long-Duration (months) Surface Operations: 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, sensors, thermal control, mechanisms, and the 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.

H.1.3 Aerial Platforms for Missions to Measure Atmospheric Chemical and Physical Properties:

- Venus provides an important scientific link to Earth, Solar System formation, and to Exoplanets. This EPSCoR call is made for technology projects, which take into

consideration Venus' middle atmosphere conditions and its unique extreme environment. The call concentrates on the challenge to develop an aerial platform that would survive the 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:

- 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

Reference material:

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/reports/Venus-Technology-Plan-140617.pdf>

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(*) Reference papers:

Counselman C. C., Gourevitch S. A., King R. W., Lorient G. B., and Ginsberg E. S. (1980) Zonal and meridional circulation of the lower atmosphere of Venus determined by radio interferometry.

Journal of Geophysical Research, 85: 8026-8030.

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

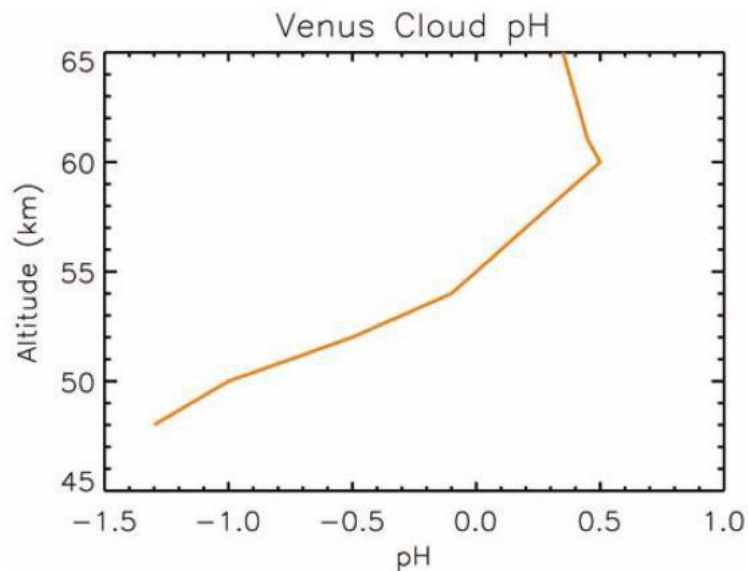


Plate 2. The pH of Venus' clouds as a function of altitude. The relatively water-rich aerosols in the upper cloud have a small range of positive pH, from 0.3 to 0.5. In the lower cloud, with its larger and more water-poor particles, pH can be as low as -1.3. Aerosol H_2SO_4 concentrations were calculated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

Appendix I

I.1.0 Commercial Space Capabilities (CSC) Research

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I.1.1 Scope of the Commercial Space Capabilities (CSC) Research Interest Area

The Commercial Space Capabilities area is under the Human Exploration & Operations Mission Directorate (HEOMD). The goal of the CSC area is to harness the capabilities of the U.S. research community to advance research, initial demonstration, and improvement of technologies of interest to the U.S. commercial spaceflight industry to further their space-related capabilities. A new emphasis of the CSC area is to encourage and facilitate a robust and competitive U.S. low Earth orbit economy. Efforts that benefit near Earth activities and are also extensible to Moon and/or Mars are also of interest.

U.S. commercial spaceflight industry interests naturally vary by company. Proposers are encouraged to determine what those interests are by engagement with such companies.

Proposals should discuss how the effort aligns with U.S. commercial spaceflight company interest(s), and identify potential alignments with NASA interests.

I.1.2 CSC Research Topics

A. In-Space Welding

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 would also be of 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 this operation also consider debris generation and how to control.

B. In-Space Fabrication

Propose and demonstrate fabrication for application in Earth orbit. Includes methods for metals, polymers, other non-metallics, and multi material components. Application can be for in-space fabrication of products for use in-space, or for products to be returned and used back on Earth. Extensibility to being used for Moon vac/g, and/or Mars atm/g environments would be of particular interest. For this topic, when a current SoA exists, identify the shortcoming in the current SoA that the proposal addresses. Aspects include:

1. Enable fabrication capabilities that can take advantage of the microgravity environment to improve products for subsequent on Earth.

2. Enable simple fabrication and repair methods to sustain in-space operations using bulk materials rather than having to launch spares from Earth.

C. Materials and Processes Improvements for Propulsion State of Art (SoA)

Propose and demonstrate improvements for launch, entry, and/or in-space 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.

D. Small Reentry Systems

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.

I.1.3 Additional Instructions for Proposals in this Interest Area

E. Content

1. Newly proposed concepts should be projected to be applicable to flight designs (so ~TRL5 https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf) within ~5 years
2. If there is an existing State of Art, then state how proposed work would address an identified need/shortcoming in current state of art, rather than a “nice to have”.
3. Must describe proposing Institution’s and Co-I/Sci-I’s relevant capabilities and prior work. (weblinks preferred. Does not count against the Technical page limit.)
4. Compare and contrast proposed work against prior and existing work. Use references and links to reduce space in proposal
5. Must develop an engineering/scientific design concept and, if/as funding permits: create a part of the concept to an initial practice level, and/or perform testing.
6. Must produce a final report and delivery of developed design concept and data
7. Proposers can assume that technically knowledgeable NASA engineers and scientists will be reviewing the Proposal – so Proposer should focus on technical/scientific specifics.
8. NOTE 1: For this Call, the Technical portion of the proposal may be up to five (5) pages.

F. Contributions to Proposed Work other than NASA EPSCoR

Proposer-coordinated contributions from Jurisdiction, or Organizations that would partner with the Jurisdiction, are encouraged but not required. If there are such contributions then the Proposer will state what has arranged, include funding or other in-kind contributions such as materials or services (Proposal should indicate the estimated value of the latter).

G. Intellectual Property

Proposer to indicate any intellectual property considerations in the Proposal.

H. Publishing of Results

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, 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/>.

I. NASA Contact

The CSC NASA Contact will support a telecon with the Proposer prior to the submission of Proposals, to answer Proposer's 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.

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Appendix J

J.1.0 NASA SMD Earth Science Division (ESD)

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J.1.1 NASA SMD Earth Science Division (ESD) Research Topics to improve our understanding of carbon fluxes across the land-ocean interface.

SMD requests that EPSCoR include research opportunities focused on better understanding carbon cycle dynamics across the land-ocean continuum using NASA's remotely sensed and in situ data collections.

J.1.2 Carbon cycling dynamics across landscapes, inland water, and coastal and open ocean are complex with many interconnected processes. There are significant gaps in our understanding of fluxes within and across ecosystems due to a combination of poor data coverage and methodological constraints; such gaps limit our ability to quantify accurately the global carbon budget and understand how ecosystems will respond to growing carbon dioxide levels in the atmosphere. Satellite remote sensing provides simultaneous global observations of fundamental physical, chemical, and biological processes that are needed to quantify large-scale carbon cycle processes. To understand carbon fluxes across the land-ocean interface, it is necessary to constrain 1) the transport and transformation of carbon in riverine systems and, 2) upon reaching the ocean, the impact/influence of adjacent land characteristics and their interdependencies to climate and weather.

Proposals seeking to respond to this EPSCOR Research Topic must address research that contributes to furthering our understanding of carbon as it moves from the land to the ocean. Research under this objective should be focused on furthering the understanding of present and future carbon fluxes across the land-ocean continuum, which may include carbon fluxes from land to rivers, freshwater wetlands, coastal wetlands, coastal areas, and/or marshlands. Research should consider projected changes in climate, environmental change, and/or human actions, including, but not limited to, management/decision making, urbanization, land use change, and sea level rise. Research should advance humanity's understanding of the potential feedback(s) of naturally- or anthropogenically-driven change in such zones. Activities that support key findings and recommendations of the [CCARS Science Plan](#) and the [Second State of the Carbon Cycle Report \(SOCCR2\)](#) are welcome.

Proposed investigations must utilize NASA remotely sensed observations (e.g., MODIS, Landsat, etc.) and/or existing NASA in situ data holdings (e.g., NASA OB.DAAC and SeaBASS data repositories, etc) for data mining and as a primary research tool. Proposers are also encouraged to use data acquired via the NASA Commercial SmallSat Data Acquisition Program ([CSDAP](#)). Research that further constrains uncertainties related to carbon and biogeochemical fluxes across the land-ocean continuum in preparation for future sensors, such as the Surface Water

and Ocean Topography ([SWOT](#)) and the Plankton, Aerosol, Cloud and ocean Ecosystem ([PACE](#)) missions, as well as the Geosynchronous Littoral Imaging and Monitoring Radiometer ([GLIMR](#)) instrument, is also welcome and encouraged.

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/>.

The proposals should include clear statements describing 1) the significance and impact of proposed work, 2) the relevance to scientific and/or stakeholder communities, and 3) a detailed plan for the dissemination and sharing of data, products, and tools, as applicable. 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 (i.e., the NASA OB.DAAC and SeaBASS data holdings).

Examples of potential topics suitable for the EPSCOR research on carbon fluxes across the land-ocean interface include:

1. Refinement of riverine organic carbon fluxes from the land to the ocean
2. Characterization of the impacts of land use change on carbon fluxes from the land to the ocean
3. Better quantification of the effects of climate change on carbon fluxes across the land-ocean interface
4. Improvements of terrestrial-aquatic carbon cycle models
5. Characterization of lateral transports of carbon between the land and ocean