

## **Appendix G: Research Interests from the R3 solicitation**

### **G.1.0 Biological and Physical Sciences (BPS)**

In July 2020, NASA's biological and physical sciences research was transferred from the Space Life and Physical Sciences Research & Applications (SLPSRA) Division in the Human Exploration and Operations Mission Directorate (HEOMD) into the Biological and Physical Sciences (BPS) Division in the Science Mission Directorate (SMD).

The mission of BPS is two-pronged:

- Pioneer scientific discovery in and beyond low Earth orbit to drive advances in science, technology, and space exploration to enhance knowledge, education, innovation, and economic vitality
- Enable human spaceflight exploration to expand the frontiers of knowledge, capability, and opportunity in space

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

BPS administers NASA's:

- Space Biology Program, which solicits and conducts research to understand how biological systems accommodate to spaceflight environments
- Physical Sciences Program, which solicits and conducts research to understand how physical systems respond to spaceflight environments, particularly weightlessness

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

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

### **G.1.1 Space Biology Program**

The Space Biology Program within NASA's Biological and Physical Sciences Division focuses on pioneering scientific discovery and enabling human spaceflight exploration. Research in space biology has the following goals:

- To effectively use microgravity, radiation, and the other characteristics of the space environment to enhance our understanding of fundamental biological processes.
- To develop the scientific and technological foundations for a safe, productive human presence in space for extended periods and in preparation for exploration.
- To apply this knowledge and technology to improve our nation's competitiveness, education, and the quality of life on Earth.

Research proposals are being solicited on the following topics:

- Organismal Biology – responses of whole organisms and their systems to ionizing radiation and/or other spaceflight-relevant stressors such as altered gravity simulators.

- These will be ground-based studies.
  - Ionizing radiation and altered gravity regimes (partial gravity and microgravity) are a hallmark of the deep space environment. These stressors may cause direct physiological changes in the organisms or result in indirect effects such as loss of sleep in some organisms. Studies should effectively delineate the biological effects of these factors, separately and/or in combination where possible. See information on radiation facilities below.
  - Understand the mechanistic bases of the changes induced in these unique environments, preferably from a systems biology perspective, and could include genetic, cellular, or molecular biological effects.
- Advanced *in vitro* models: 3D Tissues and Tissue Chips or Microphysiological Systems – Using advanced *in vitro* models to investigate biological mechanisms associated with exposure to ionizing radiation.
    - These will be ground-based studies.
    - Ionizing radiation, specifically space radiation, is a concern for astronauts on deep space long duration missions. Understanding the mechanisms of damage induced by ionizing radiation will be important to inform risks to astronauts and develop effective countermeasures. Studies proposing ionizing radiation should use space relevant radiation exposures and doses. See information on radiation facilities below.

Information on radiation facilities:

- The NASA Space Radiation Laboratory (NSRL) is an irradiation facility capable of supplying particles from protons to gold with primary energies in the range of 50-2500 MeV for protons and 50-1100 MeV/n for high-mass, high-energy (HZE) particles. Selection of beam species and energies for experimental periods will be made by NASA officials in consultation with scientists proposing experiments for these beams. Activities at the NSRL are a joint effort of Brookhaven National Laboratory's Collider-Accelerator Department, providing accelerated particle beams, and the Biosciences Department, providing experimental area support, animal care, and cell and biology laboratories. The NSRL includes irradiation stations, beam controls, and laboratory facilities required for most radiobiological investigations. Additional information about NSRL may be found at <https://www.bnl.gov/nsrl/>.
- Colorado State University low dose rate neutron facility is another ionizing radiation facility that provides low dose rate neutrons. Details can be found at: <https://three.jsc.nasa.gov> under "IN THE NEWS– JULY 2018" or by email to michael.weil@colostate.edu. Gamma-rays (Cs or Co) should be used as the reference radiation for studies. Significant justification needs to be provided to use X-rays with energies below 300 peak kilovoltage (kVp) as a reference radiation. Gamma controls must be completed at BNL for comparison with heavy charged particles, specifically for the calculation of relative biological

effectiveness (RBE). Gamma ray exposures can also be performed at Colorado State University.

All proposals submitted to the EPSCoR Research Announcement are required to include a data management plan (DMP) that describes how data generated through the course of the proposed research will be shared and preserved, including timeframe, or explain why data sharing and/or preservation are not possible or scientifically appropriate, or why the data need not be made publicly available. Specifically, for this Research Announcement, award recipients are required to upload all relevant data in the GeneLab Data Systems (<https://genelab.nasa.gov>), as well as make all analytical models, tools, and software produced under the funded research, as well as related documentation, available to NASA. Furthermore, articles published in peer-reviewed scholarly journals and papers published in peer-reviewed conference proceedings, should be made publicly accessible via NASA's PubSpace website (Submit to PubSpace - Scientific and Technical Information Program ([nasa.gov](https://pubspace.nasa.gov))).

Further information for the Space Biology program are available at:

<https://science.nasa.gov/biological-physical/programs/space-biology>  
<https://science.nasa.gov/biological-physical/documents>

### **G.1.2 Physical Science Program**

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

- Fluid physics: two-phase flow, boiling, condensation, heat pipes, capillary and interfacial phenomena; cryogenic fluid storage and transfer
- Combustion science: spacecraft fire safety, solids, liquids and gasses, transcritical combustion, supercritical reacting fluids, and soot formation;
- Materials science: solidification in metal and alloys, crystal growth, electronic materials, glasses and ceramics, granular materials, extraction of material from regoliths;
- Complex Fluids: colloidal systems, emulsions, liquid crystals, polymer flows, foams and granular flows;
- Fundamental physics: space optical/atomic clocks, quantum test of equivalence principle, theory supporting space-based experiments in quantum entanglement, decoherence, cold atom physics, and dusty plasmas.

Areas of particular interest include:

- **Extraction of Materials from Regolith** - 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 Physical Sciences Program requests research 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:

- Refinement of existing techniques to extract materials from regolith.
- Development of new techniques for extraction of materials from regolith.
- Studies of the extracted material to determine its properties or to investigate novel ways of utilizing it to support NASA's exploration goals.
- 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.

- **Metamaterials in Soft Matter** - 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. Also, soft matter-based metamaterials possess unique physical properties, owing to their engineered structure, ranging from negative index material with regard to multitude of physical properties (e.g.- viscosity, refractive index, acoustics etc.). Some of the 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

In addition to laboratory experimentation of metamaterials, short duration microgravity experiments in drop towers or parabolic flights can be considered since metamaterial formation may involve phenomena such as phase separation, onset of interfacial instability, etc.

- **Oscillating Heat Pipes** - NASA has a growing need for improved passive thermal management of electronics, batteries, high capability sensors, power system heat rejection, etc. for future spacecraft and planetary habitat systems. Due to the potential to extract heat at significantly higher heat flux levels, oscillating heat pipes (OHP) offer the promise of significantly higher efficiencies compared to conventional heat pipes used on today's spacecraft. However, the underlying liquid-vapor fluid dynamics (distinct liquid plugs and vapor plugs), interfacial phenomena, and two-phase heat transfer in the pulsating flows of OHPs are not well understood. It is imperative that a physical model that can predict the performance of an OHP be developed. As a first step, NASA is seeking proposals for a highly 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.<sup>1</sup> 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

For any Physical Sciences proposal selected for award, including the three areas of particular interest ("Extraction of Materials from Regolith", "Metamaterials in Soft Matter", and "Oscillating Heat Pipes"),

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<sup>1</sup> 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.

all data must be deposited in the Physical Sciences Informatics Database starting one year after award completion.

The two NASA GRC drop towers described below are also available to augment research investigations. These facilities are typically used to conduct combustion or fluid physics experiments. Please go to link for further information. The Points of Contact for each research area are:

Fluid Physics: John McQuillen, [john.b.mcquillen@nasa.gov](mailto:john.b.mcquillen@nasa.gov)

Combustion Science: Dan Dietrich, [daniel.l.dietrich@nasa.gov](mailto:daniel.l.dietrich@nasa.gov)

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

### 2.2 second drop tower

<https://www1.grc.nasa.gov/facilities/drop/>

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

### 5.2 second drop tower

<https://www1.grc.nasa.gov/facilities/zero-g/>

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

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

<https://science.nasa.gov/biological-physical/programs/physical-sciences>

## G.2.0: Ames Research Center

**Chief Technologist:** Harry Partridge, [harry.partridge@nasa.gov](mailto:harry.partridge@nasa.gov)

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](mailto:aaron.m.brandis@nasa.gov)

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](mailto:aaron.m.brandis@nasa.gov)

1. **Organization/Program:** Entry Systems Modeling Project

2. **Research Title:** NuSil Coated PICA Material Response in CO<sub>2</sub> 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 CO<sub>2</sub> 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](mailto:aaron.m.brandis@nasa.gov)

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](mailto:aaron.m.brandis@nasa.gov)

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.
5. **Contact:** Aaron Brandis [aaron.m.brandis@nasa.gov](mailto:aaron.m.brandis@nasa.gov)

### ***G.3.0 Office of the NASA Chief Medical Officer (OCHMO) and Human Research Program/Space Radiation Element***

#### ***POCs:***

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Dr Victor S. Schneider; E: [vschneider@nasa.gov](mailto:vschneider@nasa.gov), P: (202)358-2204



### **G.3.1 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

### **G.3.2 Topics from Human Research Program/Space Radiation Element**

**POCs:** Elgart, S Robin (JSC-SK4)[IPA] <[shona.elgart@nasa.gov](mailto:shona.elgart@nasa.gov), (281)244-0596

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

#### **G.4.0 Aeronautics Research Mission Directorate (ARMD)**

**POC:** Dr. Timothy Krantz, [timothy.l.krantz@nasa.gov](mailto:timothy.l.krantz@nasa.gov), 216.433.3580

Dr. Cornell, Peggy A. (GRC-KM00), [peggy.a.cornell@nasa.gov](mailto:peggy.a.cornell@nasa.gov), 216.387.5138

Dr. Koudelka, John M. (GRC-KM00), [john.m.koudelka@nasa.gov](mailto:john.m.koudelka@nasa.gov), 216.905.5139

#### **G.4.1 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-gear 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](mailto: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.

#### **G.4.2 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](mailto:Robert.K.Goldberg@nasa.gov), (216) 433-3330  
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## 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.

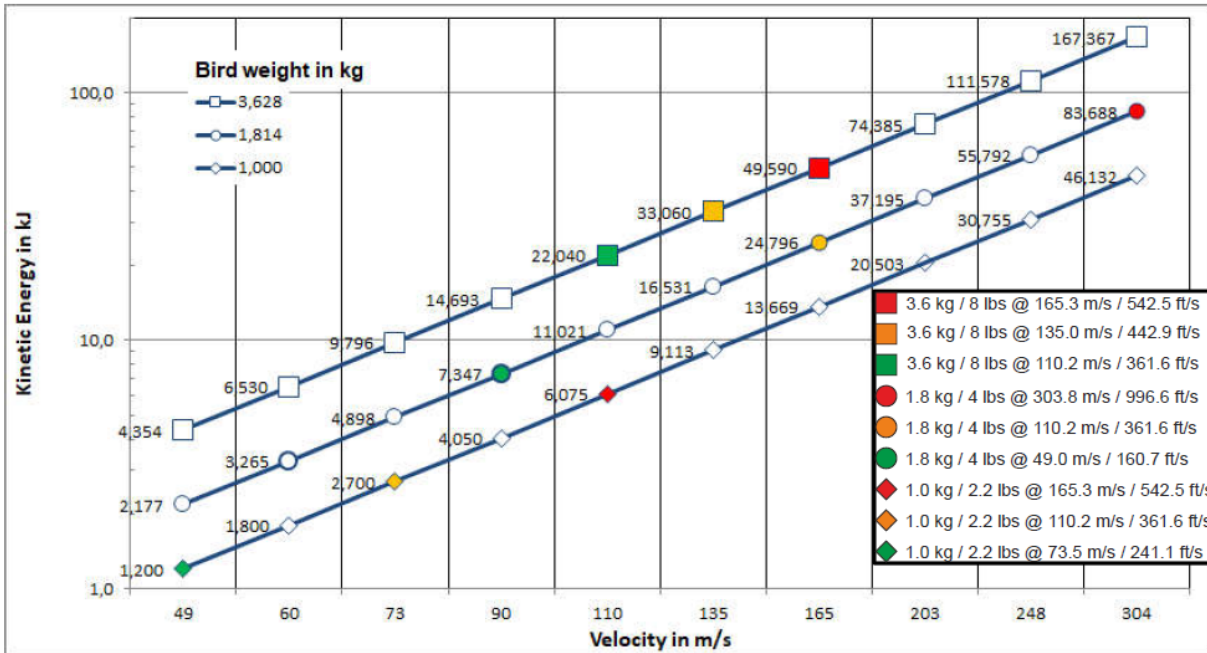


Figure 1. Range of Velocities and Kinetic Energies Relevant to Bird Strike Testing

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.

### **G.5.0 Additive Manufacturing of Nuclear Fuels (ceramics)**

**POC:** Jhonathan Rosales ([jhonathan.rosales@nasa.gov](mailto:jhonathan.rosales@nasa.gov)), 256.961.2491

**1)** Organization/Program: EM32/ Advanced Metals Processing and Technologies Team

**2)** Research Title: Additive Manufacturing of Nuclear Fuels (ceramics)

**3)** 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].

**4)** 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  $\text{UO}_2$  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  $\text{ZrO}_2$  and  $\text{CeO}_2$  [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.

5) Contact: Jhonathan Rosales ([jhonathan.rosales@nasa.gov](mailto:jhonathan.rosales@nasa.gov))

6) 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 CeO<sub>2</sub> as a surrogate material during the investigation of UO<sub>2</sub> thermal conductivity enhancement." *Advances in applied ceramics* 116, no. 3 (2017): 123-131.

### **G.6.0 Computational and Information Sciences and Technology Office (CISTO)**

**POC:** James Harrington, [james.l.harrington@nasa.gov](mailto:james.l.harrington@nasa.gov) 301-286-4063

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.

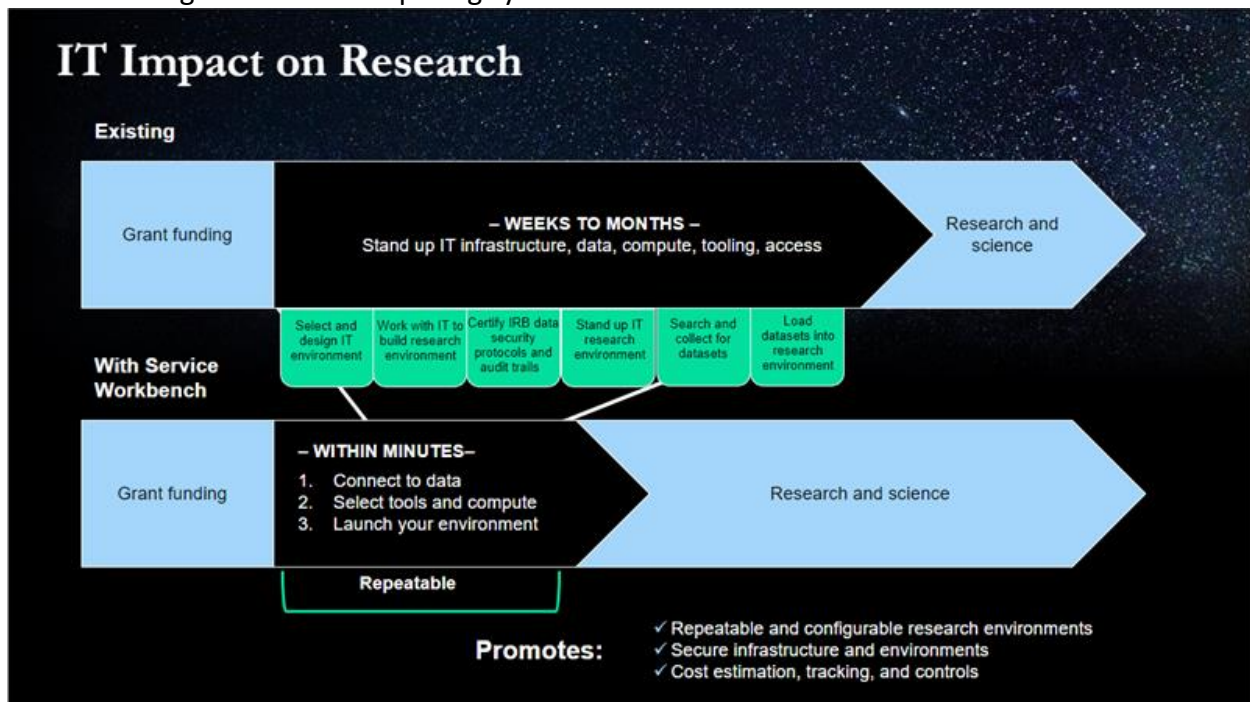
NASA SMD communicates a VISION via the SMD Big Data Working Group (SBDWG) to enable transformational open science through continuous evolution of science data and computing systems for NASA's Science Mission Directorate. SMD requests that NASA EPSCoR include research opportunities for data analysis that 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
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## **G.7.0: Supporting Heliophysics Citizen Science Goals through Data Partnerships**

**POC:** Elizabeth MacDonald, [elizabeth.a.macdonald@nasa.gov](mailto: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](mailto:james.l.harrington@nasa.gov); [elizabeth.a.macdonald@nasa.gov](mailto:elizabeth.a.macdonald@nasa.gov)

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.

### **G.8.0 SMD Astrophysics**

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

#### **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>

## G.9.0 NASA SMD Planetary Science Division

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

**H.1.0** 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:

### G.9.1 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.

### G.9.2 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>

#### **NASA Contact**

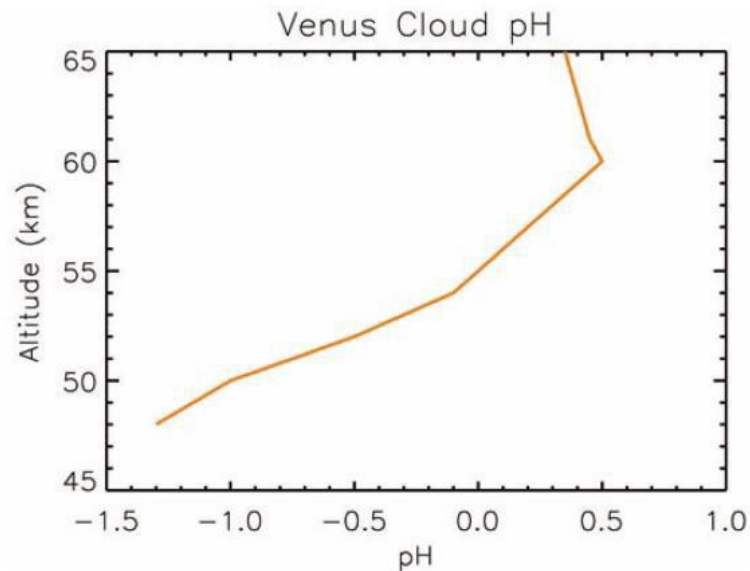
- a. Name: Adriana Ocampo
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(\* ) Reference papers:

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).