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# National Aeronautics and Space Administration
# Office of STEM Engagement

# FY 2023 NASA Notice of Funding Opportunity (NOFO)

# Established Program to Stimulate Competitive Research (EPSCoR)

# Rapid Response Research (R3)

Announcement Number: NNH23ZHA002C
Assistance Listing/Catalog of Federal Domestic Assistance (CFDA) Number: 43.008

**Release Date:** **September 16, 2022**
**Proposal Due Date:** **December 15, 2022**

NASA Headquarters
Office of STEM Engagement
Washington, DC 20546-0001

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## Introduction

NASA's Office of STEM Engagement (OSTEM), in collaboration with the Aeronautics Research Mission Directorate (ARMD), Science Mission Directorate (SMD) Planetary Science Division, Earth Science Division, Biological and Physical Sciences Division, Space Technology Mission Directorate (STMD), Exploration Systems Development Mission Directorate(ESDMD), and the Space Operations Mission Directorate's (SOMD) Commercial Space Capabilities Office (CSCO), along with the Marshall Spaceflight Center (MSFC), Goddard Spaceflight Center (GSFC), and the Office of the Chief Health and Medical Officer (OCHMO), solicits proposals for the fiscal year (FY) 2023 NASA Established Program to Stimulate Competitive Research (EPSCoR) Rapid Response Research (R3) program.

The R3 program is a collaborative effort between NASA EPSCoR and the NASA Mission Directorate programs/offices listed above. The goals of R3 are to provide a streamlined method to address research issues important to NASA, and to enable NASA EPSCoR researchers to work with NASA to solve research issues impacting the Agency's programs/missions.

- This solicitation will remain open for one year or for as long as funds are available, whichever comes first.
- Amendments will be issued to add/close appendices which list specific research tasks.
- Amendments will be open for 90 days.
- No proposals for the listed research tasks will be accepted after 90 days.
- Jurisdictions may submit up to a total of six proposals. The proposals may come from one or multiple offices (i.e., six proposals for the same topic or office, or one proposal from each of six offices, or any combination). Renewals are allowed but must include their own external funding and will not be included in the total proposal count. Please remember to include the Research Identifier in your title (and be sure to include Renewal if the proposal is a renewal). Note that renewals will require a letter of commitment from the funding office.
- Proposals shall be two to three pages but may be slightly longer if specified in the appendix and *<u>must be submitted by the State NASA EPSCoR Director</u>* through the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). EPSCoR is only able to accept proposals submitted by the State NASA EPSCoR Director.
- Proposers are encouraged to contact the research task point of contact (POC) listed under the "Inquires" section of this solicitation for clarification/information on the requested research.

The NASA Authorization Act for Fiscal Year 1993, Public Law 102-588, and its Reauthorization Act of 2017 (Public Law 114-329 Section 103) authorizes NASA to initiate NASA EPSCoR to strengthen the research capability of jurisdictions that have not historically participated equably in competitive aerospace research activities. The goal of NASA EPSCoR is to provide funding that will enable jurisdictions to develop a research enterprise directed toward long-term, self-sustaining, nationally competitive capabilities in aerospace and aerospace-related research. This capability will, in turn, contribute to the jurisdiction's economic viability and expand the nation's base for aerospace research and development.

The following are the specific objectives of NASA EPSCoR:

- Contribute to and promote the development of research capability in NASA EPSCoR jurisdictions in areas of strategic importance to NASA's mission.
- Improve the capabilities of the NASA EPSCoR jurisdictions to gain support from sources outside the NASA EPSCoR program.
- Develop partnerships between and among NASA research assets, academic institutions, and industry.
- Contribute to the overall research infrastructure and economic development of the jurisdiction.

Based on the availability of funding, NASA will continue to help jurisdictions achieve these goals through NASA EPSCoR. Funded jurisdictions' proposals shall be selected through a merit-based, peer-review competition, evaluated by the Mission Directorate offices that are involved in this effort, and accepted by the EPSCoR Project Office.

**Solicitation Availability**

This announcement is accessible for a period of one year or as long as funds are available, whichever comes first, through NSPIRES and through Grants.gov.

To access this announcement through NSPIRES, go to http://nspires.nasaprs.com and click on Solicitations. For Grants.gov, go to https://www.grants.gov/web/grants/search-grants.html and select the link for NASA.

**Eligibility**

As stated in NASA EPSCoR legislation, jurisdictions eligible to compete for this opportunity are those jurisdictions eligible to compete in the National Science Foundation (NSF) EPSCoR Research Infrastructure Improvement Grant Program (RII). NSF eligibility is based on whether the most recent three-year level of NSF research support is equal to or less than 0.75 percent. The most recent eligibility table is located at:
https://www.nsf.gov/od/oia/programs/epscor/Eligibility_Tables/FY2022_Eligibility.pdf

Proposals will be accepted from the resident institution of the NASA EPSCoR Director in each jurisdiction. The 28 jurisdictions that are eligible for the opportunity in this NOFO are: Alabama, Alaska, Arkansas, Delaware, Guam, Hawaii, Idaho, Iowa, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Puerto Rico, Rhode Island, South Carolina, South Dakota, US Virgin Islands, Vermont, West Virginia, and Wyoming.

**Availability of Funds and Period of Performance**

NASA's ability to make awards is contingent upon the availability of appropriated funds from which payment can be made.

It is anticipated that approximately (30) cooperative agreement awards of up to $100,000 each for a period of performance not to exceed one year each may be made under this NOFO pursuant to the authority of Title 2 Code of Federal Regulations (CFR) Parts 200, 2 CFR 1800, and the *NASA Grant and Cooperative Agreement Manual* (GCAM).

The research period of performance (start and end dates) are not fixed at the time of proposal submission and are requested by the Jurisdiction for each submitted proposal. The official period of performance (start and end dates) are included in the Award document issued by the NASA Shared Services Center (NSSC).

### Proposal Submission

All information needed to respond to this solicitation is contained in this announcement and in the *NASA Guidebook for Proposers*. The latest PDF version of the *Guidebook* is available at: https://www.nasa.gov/sites/default/files/atoms/files/2021_ed._nasa_guidebook_for_proposers.pdf

Proposers are cautioned that only the Grants Officer at the NSSC has the authority to make commitments, obligations, or awards on behalf of NASA or authorize the expenditure of cooperative agreement funds. No commitment on the part of NASA should be inferred from technical or budgetary discussions with NASA managers, Mission Directorate employees, or other support staff. An organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement signed by a NASA NSSC Grants Officer does so at its own risk.

### Inquiries

Technical and scientific questions about programs in this NOFO may be directed to:

| EPSCoR Program | |
|---|---|
| *Jeppie R. Compton*<br>National Project Manager, NASA EPSCoR<br>Kennedy Space Center, FL 32899-0001<br>jeppie.r.compton@nasa.gov<br>P: (321) 867-6988 / M: (321) 360-6443 | *Dr. Mitch Krell*<br>*Deputy Project Manager, NASA EPSCoR*<br>*Stennis Space Center, MS 39529*<br>mitch.krell@nasa.gov<br>P: (228) 688-1821 / M: (228) 342-7462 |
| **SMD Planetary Science** | |
| Adriana C. Ocampo Uria PhD<br>Lead Program Executive<br>NASA HQ\SMD<br>Planetary Science Division<br>300 E Street SW, 3X74<br>Washington DC 20546<br>adriana.c.ocampo@nasa.gov<br>P: (202) 358-2152 | Carolyn Mercer, PhD<br>Program Executive<br>SMD/Planetary Science Division<br>Glenn Research Center<br>21000 Brookpark Road<br>Cleveland, OH, 44135<br>cmercer@nasa.gov<br>P: (216) 433-3411 |
| **Commercial Space Capabilities Office** | |
| Marc Timm<br>Program Executive<br>NASA HQ\Rm 7A77<br>marc.g.timm@nasa.gov<br>*P: (202) 358-0373 / M: (202) 372-5931* | Warren Ruemmele<br>Project Executive<br>NASA JSC\UA311<br>warren.p.ruemmele@nasa.gov<br>P: (281) 483-3662 / M: (832) 231-1367 |

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|---|---|
| **SMD Earth Science** | |
| Allison Leidner<br>Earth Science Remote Sensing<br>NASA HQ/RM 3Z53<br>allison.k.leidner@nasa.gov<br>P: (202) 358-0855 | Laura Lorenzoni<br>Earth Science Remote Sensing<br>NASA HQ/RM 3Y35<br>laura.lorenzoni@nasa.gov<br>P: (202) 358-0917 |
| **SMD Biological and Physical Sciences** | |
| Diane Malarik<br>Diane.C.Malarik@nasa.gov<br>202-358-2275 | Douglas Gruendel<br>Douglas.J.Gruendel@nasa.gov<br>321-867-2462 |
| **GSFC Computational and Information Sciences and Technology Office (CISTO)** | |
| James Harrington<br>Project Manager<br>Goddard Space Flight Center, MD<br>james.l.harrington@nasa.gov<br>P: (301) 286-4063 / M: (301) 806-2382 | Edward McLarney<br>Edward.l.mclarney@nasa.gov<br>Yuri Gawdiak<br>yuri.o.gawdiak@nasa.gov<br>Nikunj Oza<br>nikunj.c.oza@nasa.gov |
| **Aeronautics Research Mission Directorate** | |
| John M. Koudelka<br>Project Manager<br>NASA Glenn Research Center<br>E-mail: john.m.koudelka@nasa.gov<br>Phone: (216) 905.5139 | Susan A. Gorton<br>Project Manager<br>NASA Langley Research Center<br>E-mail: susan.a.gorton@nasa.gov<br>Phone: (757) 864-5059 |
| **Human Research Program (HRP)** | |
| Dr. Robin Elgart<br>HRP Radiation Element Scientist<br>JSC:SK4<br>shona.elgart@nasa.gov<br>P: 281.244.0596 | Brock Sishc brock.j.sishc@nasa.gov<br>Corey Theriot corey.theriot@nasa.gov |
| Janice Zawaski janice.zawaski@nasa.gov<br>Janapriya Saha janapriya.saha@nasa.gov | Carol Mullenax<br>carol.a.mullenax@nasa.gov |

| Office of Chief Health and Medical Officer (OCHMO) | |
|---|---|
| Dr Victor S. Schneider<br>Enterprise Scientist - Medical Research Officer<br>NASA HQ:BF016, HQ:2L25<br>vschneider@nasa.gov<br>P: (202)358-2204 | Kristin Fabre<br>Deputy Chief Scientist<br>JSC:SA111<br>kristin.m.fabre@nasa.gov |
| **Center for Design and Space Architecture** | |
| Robert L. Howard, Jr., Ph.D.<br>NASA Johnson Space Center<br>E-mail: robert.l.howard@nasa.gov | |

## 1.0 Description of Opportunity

### 1.1 Program Description

The NASA Authorization Act for Fiscal Year 1993, Public Law 102-588 and the Reauthorization Act of 2017 (Public Law 114-329 Section 103), authorized NASA to initiate NASA EPSCoR to strengthen the research capability of jurisdictions that have historically not participated equably in competitive aerospace research activities. The goal of NASA EPSCoR is to provide seed funding that will enable jurisdictions to develop an academic research enterprise directed toward long-term, self-sustaining, nationally competitive capabilities in aerospace and aerospace-related research. This capability will, in turn, contribute to the jurisdiction's economic viability and expand the nation's base for aerospace research and development. NASA EPSCoR is administered through NASA's Office of STEM Engagement (OSTEM).

This Notice of Funding Opportunity (NOFO) solicits proposals of two to three pages for the FY 2023 NASA EPSCoR Rapid Response Research (R3) program. Each funded NASA EPSCoR proposer shall work closely with a NASA researcher to focus on developing competitive research and technology for the solution of scientific and technical issues of importance to the NASA Mission Directorates as listed Section 7. The R3 program is an attempt to implement research within NASA and commercial partners to address technical issues. This opportunity will allow EPSCoR researchers to work alongside NASA and commercial partners for up to one year and is intended to strengthen the bonds among EPSCoR jurisdictions, NASA, commercial partners, and other entities. These awards will be made through a cooperative agreement.

NASA will assign a Technical Monitor (TM) to each cooperative agreement award. The TM will monitor the progress of the research and collaborate as required to keep the research aligned with the approved project's objective(s). Each awardee shall provide an annual report on the progress of the research, documenting expected performance goals, indicators, targets, baseline data, data collection, and other outcomes. These reports will be reviewed by the TM and approved by the NASA EPSCoR Project Manager, and will be shared with the NASA Mission Directorates, NASA Centers, and NASA's Jet Propulsion Laboratory (JPL). Jurisdictions shall submit electronic progress reports to the NSSC at NSSC-Grant- Report@mail.nasa.gov and the technical officer at agency-epscor@mail.nasa.gov. The reporting requirements for awards made through this NOFO shall be consistent with the NASA GCAM, Appendix D. Recipients also shall comply with reporting requirements at 2 CFR § 180.335, Financial Reporting, and 2 CFR §180.350, Monitoring and reporting program performance. Additionally, if the Federal share of any award issued under this NOFO is more than $500,000 over the total period of performance, additional reporting requirements shall apply. See 2 CFR § 200 Appendix XII—Award Term and Condition for Recipient Integrity and Performance Matters (http://www.ecfr.gov/cgi-bin/text-idx?SID=4b63b1740bdb186d3bf5d346f5ddf42c&mc=true&node=ap2.1.200_1521.xii&rgn=div9).

### 1.2 Award Information: Funding and Cost-Sharing

The maximum funding that a jurisdiction can request from NASA is $100,000 per proposal. This amount is to be spent in accordance with the budget details and budget narrative in the approved proposal. Jurisdictions may submit up to a total of six proposals. The proposals may come from one or multiple offices (i.e., six proposals for the same topic or office, or one proposal from each of six offices, or any combination). Renewals are allowed but must include their own external funding and will not be included in the total proposal count. Please remember to include the Research Identifier in your title (and be sure to include Renewal if the proposal is a renewal). Note that renewals will require a letter of commitment from the funding office.

EPSCoR plans to make approximately 30 awards from this announcement.

The period of performance for awards is one year. Cost-sharing is not required; however, any funds used for voluntary matching or cost-sharing shall be allowable under 2 CFR 200. Also see 2 CFR 200.306, cost sharing or matching.

The solicitation period of performance (start and end dates) are not fixed at the time of proposal submission and are initially requested by the Jurisdiction in each proposal. The official period of performance (start and end dates) are stated in the Award document issued by the NSSC.

### 1.3 Award Information: Restrictions

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

Awards of proposals related to this NOFO must comply with the National Environmental Policy Act (NEPA); thus, proposers are encouraged to plan and budget for any anticipated environmental impacts. While most research awards will not trigger action specific NEPA review, some activities will.

The majority of grant-related activities are categorically excluded as research and development (R&D) projects that do not pose any adverse environmental impact. A blanket NASA Grants Record of Environmental Consideration (REC) provides NEPA coverage for these anticipated activities. Section VIII includes a questionnaire to determine whether a specific proposal falls within the Grants REC and must be completed as part of the NOFO process. Activities outside of the bounding conditions of the Grants REC will require additional NEPA analysis. Examples of actions that will likely require NEPA analysis include but are not limited to: suborbital-class flights not conducted by a NASA Program Office (see Section V); activities involving ground-breaking construction/fieldwork; and certain payload activities such as the use of dropsondes.

Questions concerning environmental compliance may be addressed to Tina Norwood, NASA NEPA Manager, at tina.norwood-1@nasa.gov or (202) 358-7324.

Per the *NASA Guidebook for Proposers, Title 2 CFR* Parts *200 and 1800*, and the *NASA Grant* *and Cooperative Agreement Manual* (GCAM), the following restrictions govern the use of the NASA-provided EPSCoR funds and are applicable to this NOFO:

- Funds shall not be used to fund research carried out by non-U.S. institutions. However, U.S. research award recipients may directly purchase supplies and/or services that do not constitute research from non-U.S. sources. Subject to export control restrictions, a foreign national may receive payment through a NASA award for the conduct of research while employed either full or part time by a U.S. institution. For additional guidance on foreign participation in awards, see Section 3.2 of the *NASA Guidebook for Proposers* and the NASA FAR Supplement (NFS) Part 1835.016-70.
- Domestic travel, defined as travel that does not require a passport, does not have a funding limit and shall be appropriate and reasonable to conduct the proposed research.
- NASA EPSCoR funding shall not be used to purchase general purpose equipment, e.g. desktop workstations, office furnishings, reproduction and printing equipment as a direct charge. Special purpose equipment purchases (i.e., equipment that is used only for research, scientific, and technical activities directly related to the proposed research activities) are allowed and can be reflected as a direct charge as per cost principles cited in the GCAM Appendix D, Equipment and Other Property. Per 2 CFR 200.439, Equipment and other capital expenditures, special purchase equipment items with a unit cost of $5,000 or more must have the prior written approval of the Federal awarding agency (i.e., the NASA Grant Officer).
- NASA EPSCoR funding shall not be used to support NASA civil service participation (i.e., full time equivalents (FTEs)) in a research project. Rather, that funding is provided through a funding vehicle between the jurisdiction and NASA Center, such as a Space Act Agreement or another reimbursable agreement. However, NASA EPSCoR may set aside funding from an award to send to a Center for contractor support (including travel) and/or services as identified by the proposer.
- NASA EPSCoR funds shall be expended on NASA EPSCoR institutions. If a Co-Investigator (Sc-I/Co-I) with an NASA EPSCoR award transfers to a non-EPSCoR institution, the EPSCoR funding amount, or the portion of it that remains unobligated at the time of Sc-I/Co-I transfer, shall not be transferred to the non-EPSCoR institution.
- All proposed funds shall be allowable, allocable and reasonable. Funds may only be used for the EPSCoR project. All activities charged under indirect cost shall be allowed under the cost principles included in 2 CFR 200.
- Grants and cooperative agreements shall not provide for the payment of fee or profit to the recipient.
- Non-Federal entities, including proposers, may use one of the methods of procurement as prescribed in 2 CFR 200.320, Methods of procurement to be followed. As defined in 2 CFR 200.1, Definitions, the micro-purchase threshold for acquisitions of supplies or services made under grant and cooperative agreement awards issued to institutions of higher education, or related or affiliated nonprofit entities, or to nonprofit research

organizations or independent research institutes, is $10,000; or such higher threshold as determined appropriate by the head of the relevant executive agency and consistent with audit findings under chapter 75 of Title 31, United States Code, internal institutional risk assessment, or state law.

- Unless as otherwise directed in 2 CFR 200, for changes to the negotiated indirect cost rate that occur throughout the project period, the proposer/recipient shall apply the rate negotiated for that year of performance, whether it is higher or lower than the rate negotiated at the time the budget and application was awarded.
- Proposals shall not include bilateral participation, collaboration, or coordination with China or any Chinese-owned company or entity, whether funded or performed under a no-exchange-of-funds arrangement. Proposals including bilateral participation, collaboration, or coordination with China or any Chinese-owned company or entity will not be eligible for award.
- Cost sharing is not required, however, any funds used for voluntary matching or cost- sharing shall be allowable under 2 CFR 200. Also see 2 CFR 200.306, Cost sharing or matching.
- Procurement contracts shall not be awarded in conjunction with this solicitation.
- Pre-award costs are those incurred prior to the effective date of an award directly pursuant to the negotiation and in anticipation of the award where such costs are necessary for efficient and timely performance of the scope of work. Such costs are not allowed under this NOFO.

**1.4 Access to Research Results**

Recipients receiving awards under this NOFO shall comply with the provision set forth in the NASA Plan for Increasing Access to the Results of Scientific Research (http://www.nasa.gov/sites/default/files/files/NASA_Data_Plan.pdf) including the responsibility for—

- Submitting as approved peer-reviewed manuscripts and metadata to a designated repository: and
- Reporting publications with the annual and final progress reports.

All proposals shall include a Data Management Plan (DMP) or an explanation as to why one is not necessary given the nature of the work proposed. *The DMP shall be submitted by responding to the NSPIRES cover page question about the DMP (limited to 4000 characters)*. Any research project in which a DMP is not necessary shall provide an explanation in the DMP block. Example explanations:

- *This is a development effort for flight technology that will not generate any data that my entity can release, so a DMP is not necessary;*
- *The data that our entity will generate will be International Traffic in Arms (ITAR) compliant; or*
- *Explain why the proposed project is not going to generate data.*

The proposal type that requires a DMP is described in the *NASA Plan for Increasing Access to Results of Scientific Research* (see above link). The DMP shall contain the following elements, as appropriate to the project:

- A description of data types, volume, formats, and (where relevant) standards;
- A description of the schedule for data archiving and sharing;
- A description of the intended repositories for archived data, including mechanisms for public access and distribution;
- A discussion of how the plan enables long-term preservation of data; and
- A discussion of roles and responsibilities of team members in accomplishing the DMP (If funds are required for data management activities, these should be included in the budget and budget justification sections of the proposal.).

Proposers that include a plan to archive data shall allocate suitable time for this task. Unless otherwise stated, this requirement supersedes the data sharing plan included in the *NASA Guidebook for Proposers*.

In addition, as part of an award term and conditions, researchers submitting NASA-funded articles in peer-reviewed journals or papers from conferences now shall make their work accessible to the public.

### 1.5 Foreign National Participation

All recipients shall work with NASA project/program staff to ensure proper credentialing for any individuals requiring access to NASA facilities and/or systems. Such individuals include U.S. citizens and lawful permanent residents ("green card" holders). It should be noted that foreign nationals (individuals who are neither U.S. citizens nor permanent residents) are usually not allowed access to work at NASA facilities. Foreign nationals from "designated" countries or countries designated by the State Department and listed by NASA as being sponsors of terrorism cannot be allowed on any NASA facilities unless they are green card holders. As stated above, proposals involving bilateral participation, collaboration, or coordination in any way with China or any Chinese-owned company, whether funded or performed under a no exchange-of-funds arrangement, will be ineligible for award.

### 1.6 Flight Activities

Proposals that include flight activities (not normal passenger travel) such as aircraft or helicopter flight services, including Unmanned Aircraft Systems (UAS)/Drones operations or the acquisition or construction of such flight vehicles, must comply with NASA Policy Directive 7900.4. Questions concerning flight compliance requirements may be addressed to Norman Schweizer at norman.s.schweizer@nasa.gov.

## 2.0 Eligibility

### 2.1 Jurisdictions Eligible to Apply

As stated in NASA EPSCoR legislation, jurisdictions eligible to compete for this opportunity are those jurisdictions eligible to compete in the NSF EPSCoR Research Infrastructure Improvement Grant Program RII). NSF eligibility is based on whether the most recent three-year level of NSF research support is equal to or less than 0.75 percent. The most recent eligibility table is located at https://www.nsf.gov/od/oia/programs/epscor/Eligibility_Tables/FY2022_Eligibility.pdf.

Proposals will be accepted from the resident/home institution of the NASA EPSCoR Director in each jurisdiction. The 28 jurisdictions that are eligible for this opportunity are: Alabama, Alaska, Arkansas, Delaware, Guam, Hawaii, Idaho, Iowa, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Puerto Rico, Rhode Island, South Carolina, South Dakota, US Virgin Islands, Vermont, West Virginia, and Wyoming.

### 2.2 Cost Share

There is no cost share requirement to compete for this announcement.

## 3.0 Proposal Submission Instructions and Due Date/Time

All proposals responding to this announcement shall be submitted electronically via NSPIRES (http://nspires.nasaprs.com). Hard copies of the proposal will not be accepted. Electronic proposals shall be submitted in their entirety by 11:59 p.m., Eastern Time on the proposal due date of **December 15, 2022.**

Respondents without Internet access or that experience difficulty using the NSPIRES proposal site (http://nspires.nasaprs.com) may contact the Help Desk at nspires-help@nasaprs.com or call 202-479-9376 between 8:00 a.m. and 6:00 p.m. (ET), Monday through Friday, except Federal Government holidays. NSPIRES automatically identifies any proposals that are late. Proposals received after the due date may be returned without review. If a late proposal is returned, it is entirely at the proposer's discretion whether to resubmit it in response to a subsequent solicitation.

Please carefully note the following requirements for submission of an electronic proposal via NSPIRES:

- Every organization that intends to submit a proposal to NASA in response to this NOFO shall be registered in NSPIRES. Registration for the proposal data system shall be performed by an organization's electronic business point-of-contact (EBPOC) who holds a valid registration with the System for Award Management (SAM) and provides a Unique Entity Identifier (UEI) number with the proposal. https://sam.gov/content/home
- Each individual team member (e.g., PI, co-investigators), including all personnel named on the proposal's electronic cover page, shall be individually registered in NSPIRES.

While every effort is made to ensure the reliability and accessibility of the web site and to maintain a help center via e-mail and telephone, difficulty may arise at any point on the internet, including with the user's own equipment. Prospective proposers are strongly urged to familiarize themselves with the NSPIRES site and to submit the required proposal materials well in advance of the proposal submission deadline. Difficulty in registering with or using NSPIRES is not, in and of itself, a sufficient reason for NASA to consider a proposal that is submitted after the proposal due date.

### 3.1. Proposal Preparation

Required elements of the proposal are described below and shall be submitted as one or more PDF documents that are uploaded for proposal submission. In the *NASA Guidebook for Proposers*, please refer to Section 3.6 (provides guidelines for style formats) and Section 3.7(provides guidelines for proposal content).

NASA is implementing a process to collect demographic data from grant applicants for the purpose of analyzing demographic differences associated with its award processes. Information collected will include name, gender, race, ethnicity, disability status, and citizenship status. Submission of the information is voluntary and is not a precondition of award. Therefore, NASA EPSCoR is requesting the demographic data to ensure compliance with Title VI of the Civil Rights Act of 1964, 42 U.S.C. § 2000d et seq., Title IX of the Education Amendments of 1972, 20 U.S.C. § 1681 et seq., Section 504 of the Rehabilitation Act of 1973, 29 U.S.C. § 701 et. seq., Executive Order 2020-13926 and NASA's implementing regulations at 14 CFR. §§1250, 1251, and 1253. Submission of the requested information on NASA Form 1839 is voluntary and will not affect the organization's eligibility for an award. Any individual who does not want to submit some or all of the information should check the box provided for this purpose.

**Please identify in the Proposal Title which office the applicant is proposing against (Use Appendix identifier, i.e., Appendix A, Appendix B, Appendix C, Renewal) at the beginning of the proposal title.**

| Required Proposal Sections (in order of assembly) | Page Limit |
|---|---|
| Proposal Cover Page (NSPIRES web forms or Grants.gov forms) including:<br>• Proposal Summary – limit to 4000 characters (including spaces)<br>• Data Management Plant (per the NOFO) – limit to 4000 characters (including spaces)<br>• NSPIRES cover page budget<br>• Other required elements | Constrained by NSPIRES or Grants.gov |
| Table of Contents | As needed |
| Scientific/Technical/Management Plan | 2-3 pages |
| References and Citations | As needed |
| Biographical Sketches for:<br>• Principal Investigator(s) (PI)<br>• Science Investigator(s) (Sci-I)<br>• Each Co-Investigator (Co-I) | <br>2 (per PI)<br>2 (per Sci-I)<br>1 |
| Current and Pending Support | As needed |
| Statements of Commitment and Letters of Support | As needed |
| Proposal Budget – both the budget narrative and budget details | As needed |
| Facilities and Equipment | As needed |
| Table of Personnel and Work Effort | As needed |

### 3.2 Announcement of Updates/Amendments to Solicitation

Additional programmatic information for this NOFO may be made available before the proposal due date. If so, such information will be added as a formal amendment to this NOFO and posted at its homepage on http://nspires.nasaprs.com.

Also, any clarifications or questions and answers regarding this NOFO will be posted at its homepage on http://nspires.nasaprs.com.

Each prospective proposer has the responsibility to regularly check this NOFO's homepage for any updates.

### 3.3 Cancellation of Program Announcement

NASA OSTEM reserves the right to not make any awards under this NOFO and/or to cancel this NOFO at any time if it is in the Government's interest to do so. NASA assumes no liability (including for proposal costs) for cancelling the NOFO or for any entity's failure to receive such notice of cancellation.

### 3.4 Contacts

Inquiries regarding the submission of electronic proposal materials to NSPIRES should be addressed to:

Ms. Althia Harris
NASA Research and Education Support Services (NRESS) Phone:
202-479-9030 x310
E-mail: aharris@nasaprs.com

All other inquiries about this NOFO should be addressed to:

Dr. Mitch Krell
Deputy Project Manager, NASA EPSCoR Office
Phone: (228) 688-1821
Cell Phone: (228) 342-7462
E-mail: mitch.krell@nasa.gov

Technical and scientific questions about programs in this NOFO may be directed to the appropriate NASA POC listed in the Introduction under "Inquiries."

## 4.0 Review and Selection Process

Review of proposals submitted in response to this NOFO shall be consistent with the general policies and provisions contained in the *NASA Guidebook for Proposers*, Appendix D. Selection procedures will be consistent with the provisions of the *NASA Guidebook for Proposers*, *Section 5*. However, the evaluation criteria described in this NOFO under Section 5.0 of this document, Proposal Evaluation, takes precedence over the evaluation criteria described in Section 5 of the *NASA Guidebook for Proposers*. The selecting official for this NOFO is the EPSCoR Project Manager or their appointed representative. The NASA EPSCoR Grants Officer will conduct a pre-award review of risk associated with the proposer as required by 2 CFR 200.206, Federal awarding agency review of risk posed by applicants. For all proposals selected for award, the Grant Officer will review the submitting organization's information available through multiple government-wide repositories such as the System for Award Management (SAM.gov), Federal Awardee Performance and Integrity Information System (FAPIIS), the Contractor Performance and Assessment Reporting System (CPARS), the Federal Audit Clearinghouse (FAC), USAspending.gov, and Grant Solutions Recipient Insight.

Prior to making a Federal award with a total amount of Federal share greater than the simplified acquisition threshold (currently $250,000), NASA Grant Officers will conduct a pre-award review of risk associated with the proposer as required by 2 CFR 200.206. For all proposals selected for award, the Grant Officer will review the submitting organization's information available through multiple government wide repositories such as SAM.gov, FAPIIS, CPARS, the FAC, USAspending.gov, and Grant Solutions Recipient Insight.

Successful research proposals are likely to be those that provide sound contributions to both immediate and long-term scientific and technical needs of NASA as explicitly expressed in current NASA documents and communications, as well as those that contribute to the overall research infrastructure and economic development of the jurisdiction.

*Limited Release of Proposers Confidential Business Information*

For proposal evaluation and other administrative processing, NASA may find it necessary to release proposal information to individuals who are not NASA employees. Business information that would ordinarily be entitled to confidential treatment may be included in the information released to these individuals. Accordingly, by submission of its proposal, the proposer consents to this limited release of its confidential business information (CBI).

Except where otherwise provided by law, NASA will permit the limited release of CBI only pursuant to non-disclosure agreements signed by the assisting NASA support contractor or subcontractor, and their individual employees who may require access to the CBI to perform work under such support contract with NASA. Of course, these NASA support contractors are not eligible to submit a proposal in any capacity under this solicitation.

### 4.1 Selection Announcement

NASA's stated goal is to announce selections as soon as possible. However, NASA does not usually announce new selections until the funds needed for those awards are approved through the Federal budget process. Therefore, a delay in NASA's budget process may result in a delay of the selection date(s). After 180 days past the proposal's submitted date, proposers may contact the NASA EPSCoR Project Manager for a status.

A proposer has the right to be informed of the major factor(s) that led to the acceptance or rejection of the proposal. Debriefings will be available upon request. Again, it is emphasized that submitters of non-selected proposals should be aware that proposals of nominally high intrinsic and programmatic merits may be declined for reasons entirely unrelated to any scientific or technical finding.

### 4.2 Notice of Award

For selected proposals, the NASA Grants Officer will contact the business office of the proposer's institution. The Grants Officer is the only official authorized to obligate the Government. For a grant or cooperative agreement, any costs that the proposer incurs more than 90 calendar days before an award are at the recipient's own risk in accordance with 2 CFR §200.458, Pre-award costs. Also see 2 CFR 1800.210, Pre-award costs (NASA waives the approval requirement for pre-award costs of 90 days or less).

An anticipated award date announcement will be determined by the NASA EPSCoR Project

Manager upon the conclusion of the review process.

### 4.3 Administrative and National Policy Requirements

All administrative and national policy requirements are set forth at Title 2 CFR Part 200, Title 2 CFR Part 1800 (https://ecfr.federalregister.gov/current/title-2), and the NASA GCAM (https://www.nasa.gov/offices/ocfo/gpc/regulations_and_guidance).

### 4.4 Award Reporting Requirements

Recipients shall submit a report to the NASA Grants Officer at the NSSC, with copies to Agency-EPSCoR and to the supported organization on the results pertaining to this award no later than 120 days after the project's end date. The reporting requirements for awards made through this NOFO will be consistent with the reporting requirements outlined in the GCAM Appendix.

Each awardee shall provide an annual report on the progress of the research, documenting expected performance goals, indicators, targets, baseline data, data collection, and other outcomes. These reports will be reviewed by the TM and approved by the NASA EPSCoR Project Manager, and will be shared with the NASA Mission Directorates, NASA Centers, and NASA's Jet Propulsion Laboratory (JPL). Jurisdictions shall submit electronic progress reports to the NSSC at NSSC-Grant- Report@mail.nasa.gov and the technical officer at agency-epscor@mail.nasa.gov.

## 5.0 Proposal Evaluation

Successful R3 proposals shall provide sound contributions to both immediate and long-term scientific and technical needs of NASA as explicitly expressed in current NASA documents and communications.

Proposals will be evaluated based on the following criteria: Intrinsic Merit, Project Management, and Budget Justification. The bulleted lists after each criterion below should not be construed as any indication of priority or relative weighting. Rather, the bullets are provided for clarity and facilitation of proposal development.

### 5.1 Intrinsic Merit (65% of overall score)

- Proposed research shall have clear goals and objectives; address the expectations described in the announcement; and be consistent with the budget, effectively utilize the program management, and demonstrate a high probability for successful implementation.
- Proposals shall provide a narrative of the proposed research activity, including the scientific and/or technical merit of the proposed research, unique and innovative methods, approaches, concepts, or advanced technologies, and the potential impact of the proposed research on its field.
- Existing research proposals seeking a renewal shall provide baseline information about current research activities in the proposed research area currently funded under NASA EPSCoR R3.

### 5.2 Project Management (20% of overall score)

- This section shall describe the proposer's project management structure in reasonable detail.
- Proposals shall describe the use of NASA content, people, or facilities in the execution of the research activities. They should describe current and/or previous interactions, partnerships, and meetings with NASA researchers, engineers, and scientists in the area of the proposed research, and discuss how future partnerships between the institution's researchers and personnel at the Mission Directorates and/or Centers will be fostered. The name(s) and title(s) of NASA researchers with whom the proposers will partner shall be included. NASA shall consider the utilization of NASA venues for recipients to publish their accomplishments.

### 5.3 Budget Justification (15% of overall score)

- The proposed budget shall be adequate, appropriate, reasonable, and realistic, and demonstrate the effective use of funds that align with the content and text of the proposed project. Preparation guidelines for the budget can be found in the *NASA Guidebook for Proposers*, Section 3.18 and Appendix C.
- Because the budget will be evaluated based upon the clarity and reasonableness of the funding request, a budget narrative shall be included that discusses relevant issues such as the extent and level of jurisdiction, industrial, and institutional commitment and financial support, including resources (staff, facilities, laboratories, indirect support, waiver of indirect costs).

### 6.0 Certification of Compliance

Recipients receiving awards under this NOFO shall comply with the provision set forth in the NASA Plan for Increasing Access to the Results of Scientific Research (http://www.nasa.gov/sites/default/files/files/NASA_Data_Plan.pdf ), including the responsibility for-

- Submitting as approved peer-reviewed manuscripts and metadata to a designated repository: and
- Reporting publications with the annual and final progress reports.

The Authorized Organization's Representative (AOR's) signature on the Proposal Cover Page serves as a certification that the proposing organization has read and is in compliance with all certifications, assurances, and representations as detailed in the NASA GCAM Appendix C, Section C1. The GCAM is available at the following site: https://www.nasa.gov/offices/ocfo/gpc/regulations_and_guidance

**Note:** On February 2, 2019, SAM implemented a revised process that allows financial assistance registrants to submit common Federal Government-wide certifications and representations. This revised process was effective January 1, 2020. Guidance on this revised process and system change is available at:

https://interact.gsa.gov/blog/certifications-and-representation-improvements-sam.

### 6.1 Statement on Nondiscrimination

NASA recognizes and supports the benefits of having diverse and inclusive scientific, engineering, and technology communities and fully expects the reflection of such values in the composition of all panels and teams, including peer review panels, proposal teams, science definition teams, and mission and instrument teams. Per federal statutes and NASA policy, no eligible applicant shall experience exclusion from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving financial assistance from NASA on the grounds of their race, color, creed, age, sex, national origin, or disability. NASA welcomes proposals from all qualified and eligible sources, and strongly encourages proposals from Historically Black Colleges and Universities (HBCUs), Minority Serving Institutions (MSIs), small-disadvantaged businesses (SDBs), veteran-owned small businesses, service-disabled veteran-owned small businesses (SDVOSB), HUBZone small businesses, and women-owned small businesses (WOSBs), as eligibility requirements for a given opportunity allow.

### 6.2 Collection of Science, Technology, Engineering, and Math (STEM) Information

NASA is implementing a process to collect demographic data from grant applicants for the purpose of analyzing demographic differences associated with its award processes. Information collected will include name, gender, race, ethnicity, disability status, and citizenship status. Submission of the information is voluntary and is not a precondition of award.

Therefore, NASA requests additional demographic data to ensure compliance with Title VI of the Civil Rights Act of 1964, 42 U.S.C. § 2000d et seq., Title IX of the Education Amendments of 1972, 20 U.S.C. § 1681 et seq., Section 504 of the Rehabilitation Act of 1973, 29 U.S.C. § 701 et seq., and NASA's implementing regulations at 14 CFR §§1250, 1251, and 1253. Submission of the requested information on NASA Form 1839 is voluntary and will not affect the organization's eligibility for an award. Any individual not wishing to submit some or all the information should check the box provided for this purpose.

## 7.0 Research Focus Areas

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

Aeronautic Research Mission Directorate
NASA Glenn Research Center

POC: Timothy Krantz, timothy.l.krantz@nasa.gov

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

**Research Focus Area:** **H**igh power density power grids, power electronics, motors, and electro-mechanical powertrains
Research Identifier: **A-002**

**Research Focus Area:** High reliability and robustness for safety-critical propulsion systems including but not limited to a) arc fault protection; b) EMI/filtering; c) fault tolerant architectures; d) power management.
Research Identifier: **A-003**

**Research Focus Area:** Novel thermal management of the propulsion components and/or of the propulsion system.
Research Identifier: **A-004**

**Research Focus Area:** Application of advanced materials and manufacturing to achieve above
Research Identifier: **A-005**

**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 power grids and 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 of interest includes high-voltage (>540 V) bus and high-voltage DC protection devices, electric motors and associated power electronics, and mechanical or magnetically-geared powertrains and the associated sub-components and materials technologies. Research topics of particular interest are those that focus on:

1) high power density power grids, power electronics, motors, and electro-mechanical powertrains.
2) high reliability and robustness for safety-critical propulsion systems including but not limited to a) arc fault protection; b) EMI/filtering; c) fault tolerant architectures; d) power management.
3) novel thermal management of the propulsion components and/or of the propulsion system.
4) application of advanced materials and manufacturing to achieve items 1), 2) or 3).

The target application is eVTOL vehicles sized to carry four to six passengers with missions as described in References 1-6.

Reference 7 discusses Urban Air Mobility Electric Motor Winding Insulation Reliability Challenges.

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

**References:**


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


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

**Research Focus Area:** Development of Characterization Techniques to Determine Key Composite Material Properties for the LS-DYNA MAT213 Model

Research Identifier: **A-006**

POC: Robert Goldberg robert.goldberg@nasa.gov
Justin Littell justin.d.littell@nasa.gov
Mike Pereira mike.pereira@nasa.gov

**Research Overview:** Overview of MAT213 - MAT213 is an orthotropic macroscopic three-dimensional material model designed to simulate the impact response of composites which has been implemented in the commercial transient dynamic finite element code LS-DYNA [1-5]. The material model is a combined plasticity, damage and failure model suitable for use with both solid and shell elements. The deformation/plasticity portion of the model utilizes an orthotropic yield function and flow rule. A key feature of the material model is that the evolution of the deformation response is computed based on input tabulated stress-strain curves in the various coordinate directions.
The damage model employs a semi-coupled formulation in which applied plastic strains in one coordinate direction are assumed to lead to stiffness reductions in multiple coordinate directions. The evolution of the damage is also based on tabulated input from a series of load-unload tests. A tabulated failure model has also been implemented in which a failure surface is represented by tabulated single valued functions. While not explicitly part of MAT213, when using the model, interlaminar failure is modeled using either tie-break contacts or cohesive elements.

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 reproduceable approach to determining these flow rule coefficients would significantly improve the usability of the material model. Furthermore, to appropriate 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 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.

**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.

**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

**Deliverables**

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

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

## 7.2 Astrophysics

**Research Focus Area:** Astrophysics Technology Development
Research Identifier: **A-007**

**POCs:** Dr. Hashima Hasan, hhasan@nasa.gov, (202) 358-0692
Dr. Mario Perez, 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:**
- strophysics Documents: https://science.nasa.gov/astrophysics/documents

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

**CITIZEN SCIENCE PROJECTS:**
- Current projects: https://science.nasa.gov/citizenscience

**RESEARCH SOLICITATIONS:**

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

### 7.3 NASA Biological and Physical Sciences (BPS)

NASA Headquarters Biological and Physical Sciences Division

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

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

**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.

**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 inte **ion Sciences** rferometry 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.
Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

**NASA Biological and Physical Sciences (BPS)**

NASA Headquarters Biological and Physical Sciences Division

**Research Focus Area:** Complex Fluids/Soft Matter - Soft Matter-Based Materials
Research Identifier: **B-002**

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

**Research Overview:** Soft matter research examines materials with properties governed by relatively weak (compared to atomic bonds) interactions between the constituent particles. Classic soft matter systems include colloids, granular materials, polymers, and liquid crystals. Newer developments in soft matter physics include studies of cooperativity and self-assembly in non-equilibrium systems.

**Research Focus:** The focus of soft matter research in the Biological and Physical Sciences Division is the development and execution of concepts that use the unique characteristics of the space environment, in this case, near-absence of perceived gravity, to achieve results of transformative significance for science and technology. Research supported by the program must clearly identify how the work is related to past, current, or potential future space experiments.
Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

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

**NASA Biological and Physical Sciences (BPS)**
NASA Glenn Research Center, Low-Gravity Exploration Technology Branch

**Research Focus Area:** Fluid Physics - Oscillating Heat Pipes (OHP)
Research Identifier: **B-003**

POC: John McQuillen john.b.mcquillen@nasa.gov 216-433-2876

**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.

**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

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

**NASA Biological and Physical Sciences (BPS)**
NASA Glenn Research Center

**Research Focus Area:** Combustion Science - High Pressure Transcritical Combustion (HPTC)
Research Identifier: **B-004**

POC: Daniel L. Dietrich Daniel.L.Dietrich@nasa.gov, (216) 433-8759

**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. Two areas of fundamental research that NASA wishes to emphasize in the future are high pressure, transcritical combustion (HPTC) and the combustion of carbon-neutral and/or bio-derived fuels. These topics include 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 using more environmental friendly fuels. It also includes novel applications such as supercritical water oxidation (SCWO) for waste

[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.

incineration.

The microgravity environment provides an ideal experimental backdrop for probing many of the questions raised in high pressure supercritical research and providing fundamental data on renewable, carbon-neutral fuels. 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.

**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 combustion of hydrocarbons under these conditions; 3) ignition and combustion characteristics of bio-derived or carbon neutral fuels and 4) how to optimize SCWO systems for waste management in extraterrestrial habitats.

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

All publications that result from an awarded EPSCOR study shall acknowledge NASA Biological and Physical Sciences Division

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

**Research Focus Area:** Materials Science - Extraction and Utilization of Materials from Regolith
Research Identifier: **B-005**

POC: Michael SanSoucie michael.p.sansoucie@nasa.gov 256-544-5269

**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.

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

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

**NASA Biological and Physical Sciences (BPS)**
NASA Head Quarters, Space Biology Program

**Research Focus Area:** Effects of Regolith Simulant on Growth, Survival, and Fitness of Animal Models
Research Identifier: **B-006**

POC: Sharmila Bhattacharya SpaceBiology@nasaprs.com

**Research Overview:** As human exploration prepares to go beyond Earth Orbit, Space Biology is advancing its research priorities towards work that will enable organisms to Thrive In DEep Space (TIDES). These efforts will focus on determining the effects of deep-space stressors, including exposure to regolith, ionizing radiation, and reduced gravity, on multiple organisms. Space Biology-supported animal research will enable the study of the effects of environmental stressors in spaceflight on model animal systems, that will both inform future basic science work, as well as provide valuable information that will better enable human exploration of deep space. The ultimate goal of the TIDES initiative is to enable long-duration space missions and improve life on Earth through innovative research.

While some of the of the stressors associated with spaceflight in Low Earth Orbit, such as microgravity, are also found in deep space, stressors such as increased levels of space radiation and potentially toxic regolith are exclusive to deep space. The focus of this research element, therefore, is to gain a better understanding of how these deep space stressors, specifically regolith, impact the survival and fitness of animal models.

**Research Focus:** This Space Biology Research Emphasis requests proposals for hypothesis-driven experiments that will determine the effects of regolith (simulant) exposure on invertebrate or vertebrate animal model systems or cellular systems derived from such models. Studies may use lunar or Martian regolith simulant, or both. Proposed studies may be conducted over multiple generations but are not required to do so, and both acute and long/term consequences of regolith exposure will be characterized at the molecular and/or physiological levels.

Proposers can incorporate other deep space stressors into their experimental design if they choose, including the use of simulated micro/partial gravity and/or ionizing radiation, if feasible. While not required, applicants may propose to examine the effect that regolith exposure has on host/microbe interactions. Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

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

**NASA Biological and Physical Sciences (BPS)**
NASA Head Quarters, Space Biology Program

**Research Focus Area:** Effects of Space-Associated Stressors on Plant and Microbial Interactions
Research Identifier**:** **B-007**

POC: Sharmila Bhattacharya SpaceBiology@nasaprs.com

**Research Overview:** Fundamental discoveries made by NASA researchers over the last 50 years has helped enable successful growth of plants in spacecraft, as is demonstrated through current work being done on the ISS. Despite these advances, additional fundamental plant biology research is still needed. There is still much to learn about how plants respond to the spaceflight environments both in Low Earth Orbit (LEO) and in deep space, and what it will take to support long-duration, multiple generation plant growth and cultivation during extended space exploration missions. To fully support NASA's goals of conducting extended lunar and planetary exploration missions, it will be necessary to utilize the resources found within these environments, including regolith, to grow and cultivate plants.

One area of fundamental research that NASA wishes to focus on is the impact of the spaceflight environment on 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, may also be altered in the spaceflight-environment. Additionally, the impact of spacecraft-associated stressors on plant/microbial interactions, coupled with the use of regolith as a growth substrate, are topics of major interest to NASA.

The goal of this NASA Space Biology Program research emphasis, therefore, is to build a better understanding of the effects of spaceflight on microbial and plant ecosystems found both on spacecraft such as the ISS, and in deep space environments, which in turn will help us prepare for future exploration missions far from Earth.

**Research Focus:** This Space Biology Research Emphasis requests proposals for hypothesis-driven experiments that will help determine: 1) the effects of space-associated stressors on plant-microbial interactions; 2) the long-term, multigenerational effects of space-associated stressors on plant-microbial population dynamics; and 3) how to optimize plant-microbial systems for growing and sustaining plants in spacecraft and in deep space, including the lunar and Martian surfaces. Fundamental plant-microbial biology research is needed to specifically identity the driving space environmental factors or combination of factors that impact plant-microbial interactions.

Proposers are encouraged incorporate at least one of the following space-associated stressors in their experimental design: growth in regolith simulant, the use of microgravity analogs that simulate the effects of spaceflight (or partial gravity), and/or exposure to ionizing radiation. Investigators may also characterize the long terms effects of other spaceflight relevant stressors, including increased levels of $CO_2$ concentrations (e.g., 4000ppm) as experienced in enclosed space habitats etc.

The intention of the Space Biology Program is that awarded projects produce preliminary data for an application to future NASA Life Sciences funding opportunities. Additional information on BPS can be found at: https://science.nasa.gov/biological-physical

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

### 7.4 Center for Design and Space Architecture

Center for Design and Space Architecture
NASA Johnson Space Center

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

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

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

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

## Critical Failures Requiring RMAF Capability

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

**Generic RMAF Functions to Repair Critical Failures**

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

14. Welding

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

**References:**


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

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

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

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

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

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

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

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

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

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


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

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

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

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

### 7.5 Commercial Space Capabilities (CSC)

NASA Johnson Space Center
Commercial Space Capabilities Office

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3) Krypton Sputter Erosion: An evaluation of the sputter erosion of common thruster, spacecraft, and related materials from Krypton ion bombardment. The materials will be exposed to Krypton ion beams and the following will be determined:
    a. The dependence of the total yield with ion energies in the general range of tens to volts up to 1 kV
    b. Dependence of the total yield with ion incidence angles from normal to near grazing, and/or
    c. Differential yield profiles at various energies and incidence angles.

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

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

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

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

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

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

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

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

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

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

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

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

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

**A. Content**

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

**B. Contributions to Proposed Work other than NASA EPSCoR**

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

**C. Intellectual Property**

Proposer to indicate any intellectual property considerations in the Proposal.

**D. Publishing of Results**

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

**E. NASA Contact**

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

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

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

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

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

In 2019, a representative poll across NASA revealed over one hundred agency applications of AI in the past three years, with hundreds of AI projects planned across various missions, centers, and mission support activities from 2020 to 2022 and beyond. In November and December of 2020, the White House and Office of Management and Budget (OMB) published guidance3 regarding AI principles, policy, and governance. As an enthusiastic and forward leaning AI adopter, NASA must create and apply an evolving, living set of AI policies, principles, and guidelines to provide AI practitioners an ethical framework for their work.
**NASA Framework for the Ethical Use of Artificial Intelligence (AI) TM RDP Fillable 298.pdf (nasa.gov).**

The executive summary from the NASA Framework for the Ethical Use of AI guides the focus of this research opportunity:
The initial framework for NASA's ethical use of AI includes considerations applicable to today's simple Artificial Narrow Intelligence (ANI), as well as future human-level Artificial General Intelligence (AGI), and beyond to Artificial Super Intelligence (ASI). Considerations also include the ways humans may interact with machines, from using them as tools to augmenting humans with implants, to more speculative further-term topics such as the merging or melding of human and machine. This NASA framework draws from principles and frameworks of many other leading organizations, relating them to NASA's specific needs to provide an initial set of six ethical AI principles:

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

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

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

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

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

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

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

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

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

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

**Increasing awareness of inequitable impact and use of review/testing**

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

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

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

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

| | |
|---|---|
| **Research Focus Area:** | Document the Current State-of-the-Art/Practice of Ethical Decision Making by Humans in Operational Systems |
| Research Identifier**:** | **C-008** |
| POC: | James Harrington james.l.harrington@nasa.gov 301-286-4063<br>Edward McLarney Edward.l.mclarney@nasa.gov<br>Yuri Gawdiak yuri.o.gawdiak@nasa.gov<br>Nikunj Oza nikunj.c.oza@nasa.gov |

Document the Current State-of-the-Art/Practice of Ethical Decision Making by Humans in Operational Systems:

1. Document the historical evolution of operations ethical decision scenarios
    a. World and Cultural Views on Ethics and their possible impacts on values and priorities
    b. Evolution of operator and regulator responsibilities and ethical considerations as systems have gotten more complex and more automated.
2. Document current approaches to ethical decision-making training for professional operators:

a. Pilots
b. Ship Captains
c. Train Engineers
d. Truck Drivers
e. Doctors
f. Fire & Rescue
g. Others as appropriate

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

Research Identifier: **C-009**

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

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

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

Research Identifier: **C-010**

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Current & projected autonomous performance capabilities and limitations

a. Situational Awareness
b. Context Assessment/Lesson Learning Capabilities
c. Design/Implementation Characterizations
    i. Roles & Responsibilities
    ii. Training

iii. Processing Power Capabilities & Limitations
iv. Physical Performance Capabilities & Limitations
v. Learning Capabilities
vi. Distributed Network Characteristics

**Research Focus Area:** Document legal ecosphere of ethical decision making in off-nominal scenarios
Research Identifier**:** **C-011**

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

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

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

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Policy/Standards/Law Making Assessment

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

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

Research Identifier: **C-013**

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Design, Development, & Implementation of Highly Automated/Autonomous Systems to abide by ethical decision making policy, standards, guidelines, and laws

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

**Research Focus Area:** Societal ramifications of ethical decision making models

Research Identifier: **C-014**

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Societal ramifications of ethical decision making models

i. Inclusion of Multi-cultural/domain perspectives
ii. Prioritizations of lives and property
iii. Ranking of lives and property

iv. Tradeoffs of lives and property
v. Other collateral effects

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

### 7.7 Earth Science

NASA SMD Earth Science Division (ESD)

POC: Allison K. Leidner, allison.k.leidner@nasa.gov
Laura Lorenzoni, laura.lorenzoni@nasa.gov

**Research Focus Area:** Synthesis activities that combine multiple data sets to analyze the vulnerability and resilience of Arctic and boreal ecosystems in the Arctic Boreal Vulnerability Experiment (ABoVE) domain, across North America, and across the circumpolar region.
Research Identifier: **E-001**

**Research Focus Area:** Research that contributes to furthering our understanding of climate change impacts in high-latitude drainage basins, including coastal zones, and advance humanity's understanding of the potential feedback(s) of naturally- or anthropogenically-driven change in such zones
Research Identifier: **E-002**

**Research Focus Area:** Integration of research results and remote sensing data from ABoVE into a coherent modeling framework to diagnose and predict the impacts of environmental change on ecosystem dynamics and the consequent impacts on ecosystem services and society.
Research Identifier: **E-003**

**Research Focus Area:** Filling critical research gaps in our understanding of how environmental change impacts the dynamics of boreal and Arctic ecosystems within the ABoVE domain.
Research Identifier: **E-004**

**Research Overview:** NASA SMD Earth Science Division (ESD) Research Topics to better understanding climate change impacts on ecosystems and human in the Arctic-Boreal Zone (ABZ).
Climate change in the high northern latitudes of the Arctic-Boreal Zone (ABZ) is occurring faster than anywhere else on Earth, resulting in widespread transformation in landscape structure and ecosystem function. In addition to producing significant feedback to climate through changes in ecosystem processes, environmental change in this region is increasingly affecting ecosystem services, and these

changes in services can impact society. For example, increased frequency and intensity of ecological disturbance can negatively influence forest resources and air quality, thawing permafrost can negatively change local water quality and human infrastructure, and alterations to wildlife populations can negatively reshape traditional food sources for local human populations.

To better understand changes is the ABZ and related impacts, the NASA Terrestrial Ecology Program (https://cce.nasa.gov/terrestrial_ecology/) developed the Arctic Boreal Vulnerability Experiment (ABoVE). ABoVE is a 10-year field campaign focused on developing improved abilities to observe, understand, and model the complex, multiscale, and nonlinear processes that drive the region's natural and social systems. ABoVE's overarching science questions are:
1. How vulnerable or resilient are ecosystems and society to environmental change in the Arctic and boreal region of western North America?
2. How can insights gained from previous ABoVE efforts be used to extrapolate to the continental and circumpolar boreal and/or Arctic zones?

More information on ABoVE can be found at: https://above.nasa.gov.

Proposals seeking to respond to this EPSCOR Research Topic must address research that contributes to furthering our understanding of how climate change impacts ecosystems and humans in the ABZ. NASA is specifically interested in proposals that make significant use of remote sensing data to improve understanding of the vulnerability and resilience of ecosystems and society to environmental change in the Arctic and boreal regions of western North America. Examples of potential topics suitable for the EPSCOR research on the ABZ include:

1. Synthesis activities that combine multiple data sets to analyze the vulnerability and resilience of Arctic and boreal ecosystems in the ABoVE domain, across North America, and across the circumpolar region.
2. Research that contributes to furthering our understanding of climate change impacts in high-latitude drainage basins, including coastal zones, and advance humanity's understanding of the potential feedback(s) of naturally- or anthropogenically-driven change in such zones.
3. Integration of research results and remote sensing data from ABoVE into a coherent modeling framework to diagnose and predict the impacts of environmental change on ecosystem dynamics and the consequent impacts on ecosystem services and society.
4. Filling critical research gaps in our understanding of how environmental change impacts the dynamics of boreal and Arctic ecosystems within the ABoVE domain.

Proposed investigations must utilize remotely sensed observations (e.g., MODIS, Landsat, etc.) for data analysis and as a primary research tool. Proposers are also encouraged to use data acquired via the NASA Commercial SmallSat Data Acquisition Program (CSDAP). A description of NASA's fleet of Earth observing satellites and sensors can be found at https://science.nasa.gov/missions-page/, with more details about related airborne missions at https://airbornescience.nasa.gov/. Information about data access and discovery can be found at https://earthdata.nasa.gov/.
This research opportunity will not fund the acquisition of new in situ data, but seeks to further leverage the large quantities of remotely sensed and/or in situ data that NASA has already collected over the years, in particular through the ABoVE program (https://above.nasa.gov).

### 7.8 Entry Systems Modeling Project

NASA SMD Earth Science Division (ESD)

**Research Focus Area:** Nitrogen/Methane Plasma Experiments Relevant to Titan Entry
Research Identifier: **E-005**

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

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

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

**Research Focus Area:** Thermal Conductivity Heat Transfer of Porous TPS Materials
Research Identifier: **E-006**

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

**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.

**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.

**Research Focus Area:** Deposition of Ablation/Pyrolysis Products on Optical Windows
Research Identifier: **E-007**

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

**Research Overview:** Provide experimental data to characterize the deposition of ablation/pyrolysis products on radiometer/spectrometer windows that reduce transmissivity.
**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.

**Research Focus Area:** Predictive Modeling of Plasma Physics Relevant to High Enthalpy Facilities
Research Identifier**:** **E-008**

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

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

### 7.9 Human Research Program / Space Radiation

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

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

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

**Research Overview**: Research proposals are sought to accelerate risk characterization for high priority radiation health risks and inform mitigation strategies the NASA Human Research Program (HRP) Space Radiation Element (SRE) by sharing animal tissue samples and data. The proposed work should focus is on translational studies that support priority risk characterization (cancer, CVD, CNS), development of relative biological effectiveness (RBE) values, identification of actionable biomarkers, and evaluation of dose thresholds for relevant radiation-associated disease endpoints. Cross-species comparative analyses of rodent data/samples with higher order species (including human archival data and tissue banks) are highly encouraged.

- Data can include but is not limited to behavioral tasks, tumor data, physiological measurements, imaging, omics', etc. that has already been, or is in the process of being, collected.
- Tissue samples can include, but are not limited to, samples that have already been, or are in the process of, being collected and stored as well as tissues from other external archived banks (e.g., http://janus.northwestern.edu/janus2/index.php).
- Relevant tissue samples and data from other externally funded (e.g., non-NASA) programs and tissue repositories/archives for comparison with high linear energy transfer (LET), medical proton, neutron and other exposures can be proposed.
- A more detailed list of samples and tissues available from SRE can be found at our tissue sharing websites:
  - https://lsda.jsc.nasa.gov/Document/doc_detail/Doc13726
  - https://lsda.jsc.nasa.gov/Document/doc_detail/Doc13766
  - https://lsda.jsc.nasa.gov/Biospecimen by searching "NASA Space Radiation Laboratory (NSRL)" in the payloads field.
  - Instructions for accessing the tissue sharing information are posted at: https://spaceradiation.jsc.nasa.gov/tissue-sharing/.

**Research Focus Area:** Space radiation sex-differences
Research Identifier**:** **H-002**

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

**Research Overview**: Research proposals are sought to define the mechanisms underlying sexual dimorphism following exposure to space radiation. Research should focus on translational biomarkers relevant to changes in cognitive and/or behavioral performance, cardiovascular function, and the development of carcinogenesis **in non-sex-specific organs**. Due to limited time and budget, researchers are encouraged to utilize radiation sources located at home institutions at space relevant doses (0-5 Gy of photons or proton irradiation). A successful proposal will not necessitate the use of the NASA Space Radiation Laboratory (NSRL) at Brookhaven National Laboratory at this phase. Collaborations between investigators and institutions for the sharing of data and tissue samples are highly encouraged. Samples available for use by SRE, can be found at https://lsda.jsc.nasa.gov/Biospecimen by searching "NASA Space Radiation Laboratory (NSRL)" in the payloads field (SRE approval required). Instructions for accessing the tissue sharing information are posted at: https://spaceradiation.jsc.nasa.gov/tissue-sharing/.

**Research Focus Area:** Compound screening techniques to assess efficacy in modulating responses to radiation exposure
Research Identifier**:** **H-003**

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

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

**Research Focus Area:** Inflammasome role in radiation-associated health impacts
Research Identifier**:** **H-004**

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

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

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

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

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

**Human Research Program / Precision Health Initiative**

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

POC: Corey Theriot corey.theriot@nasa.gov , 281-244-7331
Carol Mullenax carol.a.mullenax@nasa.gov, 281-244-7068

The term "precision health" (also called personalized medicine, precision medicine, and individualized healthcare in clinical settings) refers to the strategy of collecting and analyzing individual medical data (clinical and molecular measures) along with environmental and lifestyle data to identify key factors that can improve the level of medical care for, and ultimately the health and performance of, the individual crewmember rather than the population. The term "technique" encompasses any clinical practice, strategy, test, or process that provides a clinically actionable medical outcome for an individual.

PHI seeks to maintain an individual astronaut's health and optimal mission performance, requiring in-depth understanding of individual molecular profiles and how they relate to health and performance. The practice of Precision Health encompasses the use of detailed phenotyping of an individual, using both clinical and molecular measures, along with the integrated analyses of those data to draw conclusions about an individual's response to the environment, diet, medications, exercise regimen, etc. **This topic seeks proposals for preliminary pilot studies that identify well-vetted and approved precision health techniques from terrestrial medicine that can be applied with little to no modification to crewmembers that will be exposed to the stressors of spaceflight: space radiation, altered gravity, isolation/confinement, distance from Earth, and hostile/closed environments.**

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

**Human Research Program / Systems Biology Translation**

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

POC: Corey Theriot corey.theriot@nasa.gov, 281-244-7331
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**Research Overview**: The environment astronauts are exposed to, particularly during future deep space missions, pose unique risks to human health and performance as well as research challenges that are fundamentally interdisciplinary. Systems biology frameworks offer inclusive approaches for the analysis and simulation of complex biological phenomena that in combination with the onset of new data sources and the availability of new tools for data analysis lead to a natural evolution towards the use of systems biology to understand complex biological responses. The anticipated outcome is a comprehensive understanding of the intricate interactions among biological system responses to spaceflight stressors by leveraging work across multiple disciplines. Additionally, improved identification of critical and influential system pathways corresponding to clinically and experimentally observed symptoms leads to the translation of results to human applications more quickly and economically. To develop these new capabilities and approaches, the NASA Human Research Program is interested in proof of concept development of systems biology research approaches: with particular interest in augmenting an existing HRP risk mitigation plan (such as Spaceflight Associated Neuro-ocular Syndrome) and developing a clean-sheet mitigation approach for a cross-cutting risk factor (such as inflammation). HRP human health and performance risks are described in the Human Research Roadmap (https://humanresearchroadmap.nasa.gov).
**This topic seeks proposals for preliminary pilot studies that establish systems biology frameworks that utilize omics datasets, biochemical data, bioinformatics, and computational modeling to evaluate responses in biological systems due to exposure to spaceflight environments.**

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

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

### 7.10 Office of Chief Health and Medical Officer (OCHMO)

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

Research Identifier: **H-008**

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

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

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

Research Identifier**:** **H-009**

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

**Research Overview**: Evaluation space capsule and spacesuit activity in stable and fit lower or upper extremity amputees and compare their responses to non-amputee fit individuals. The European Space Agency is establishing a parastronaut feasibility project. Since NASA offers its international partners access to NASA supported spacecraft and the International Space Station, NASA wants to obtain research data measuring the time it takes fit astronaut-like subjects compared to fit parastronaut subject to egress and exit simulated space capsules and simulated donning and doffing spacesuit. Research proposals are sought to obtain data measuring the functional testing indicated.

### 7.11 Planetary Division

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

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

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

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

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

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

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

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

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

**Research Focus Area:** Aerial Platforms for Missions to Measure Atmospheric Chemical and Physical Properties
Research Identifier: **P-002**

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

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

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

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

b. properties of the cloud particles in general;

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

d. the presence of lightning; and

e. properties of the surface mapped aerially.

Aerial vehicles that are able to operate at a variety of high and low altitudes in the middle atmosphere are needed to enable mid-term and far-term Venus missions addressing these issues. A platform able to operate close to the Venusian surface would be able to provide close surface monitoring but would require major development to operate in the hot dense lower atmosphere. Miniaturized guidance and control systems for aerial platform navigation for any altitudes are needed to track probe location and altitude.

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

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

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

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

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

References:

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

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

Counselman C. C., Gourevitch S. A., King R. W., Loriot 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

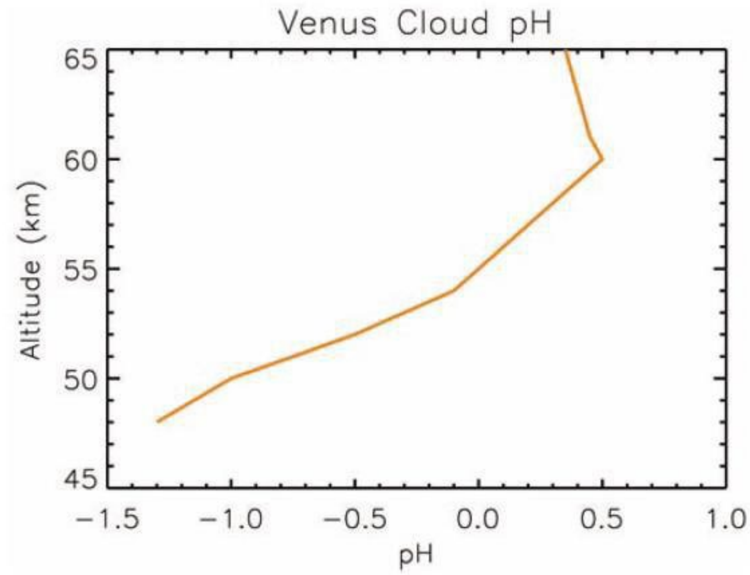


**Plate 2.** The pH of Venus' clouds as a function of altitude. The relatively water-rich aerosols in the upper cloud have a small range of positive pH, from 0.3 to 0.5. In the lower cloud, with its larger and more water-poor particles, pH can be as low as -1.3. Aerosol $H_2SO_4$ concentrations were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

### 7.12 Planetary Protection

**Office of Safety & Mission Assurance**

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

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

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

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

As NASA expands its exploration portfolio to include crewed missions beyond low Earth orbit, including

planning for the first crewed Mars mission, a new paradigm for planetary protection is needed. Together with COSPAR, the Committee on Space Research, NASA has been working with the scientific and engineering communities to identify gaps in knowledge that need to be addressed before an end-to-end planetary protection implementation can be developed for a future crewed Mars mission[2].
For this EPSCoR Rapid Research Response Topic, NASA is interested in proposals that will address identified knowledge gaps in planetary protection for crewed Mars mission concepts, facilitating a knowledge-based transition from current robotic exploration-focused planetary protection practice to a new paradigm for crewed missions.
Research Focus: The capability to detect, monitor and then (if needed) mitigate the effects of adverse microbial-based events, whether terrestrial or Martian in origin, is critical in the ability to safely complete a crewed return mission to and from the red planet.
OPP is interested in proposals that would be the first steps on a path to develop -omics based approaches (including downstream bioinformatic analyses) for planetary protection decision making, with a particular emphasis on assessing perturbations in the spacecraft microbiome as indicators of key events such as exposure to the Mars environment, or changes in crew or spacecraft health.
Additionally, OPP is interested in technologies and approaches for mitigation of microbial growth in space exploration settings. This includes remediation of microbial contamination (removal, disinfection, sterilization) in spacecraft environments in partial or microgravity as well as on planetary surfaces.

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

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

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

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

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

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

**Additional Information:** All publications that result from an awarded EPSCoR study shall acknowledge NASA OSMA. If the NASA GeneLab Data Systems (genelab.nasa.gov) is used, GeneLab shall be referenced in the resulting publication and included in the keyword list. All -omics data obtained from these studies shall be uploaded to the NASA GeneLab.

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

| Research Focus Area/Point of Contact (POC) | | |
|---|---|---|
| **Aeronautic Research Mission Directorate / Advanced Air Vehicles Program / Revolutionary Vertical Lift Technology Project** | | |
| **Research Focus Area** | **Point of Contact** | **Id** |
| Safety of Electro-mechanical Powertrains for Electrified Vertical Takeoff and Landing (eVTOL) Vehicles | Timothy Krantz, timothy.l.krantz@nasa.gov | A-001 |
| High power density power grids, power electronics, motors, and electro-mechanical powertrains | Timothy Krantz, timothy.l.krantz@nasa.gov | A-002 |
| High reliability and robustness for safety-critical propulsion systems including but not limited to: a) arc fault protection; b) EMI/filtering; c) fault tolerant architectures; d) power management | Timothy Krantz, timothy.l.krantz@nasa.gov | A-003 |
| Novel thermal management of the propulsion components and/or of the propulsion system | Timothy Krantz, timothy.l.krantz@nasa.gov | A-004 |
| Application of advanced materials and manufacturing to achieve above 3 items. | Timothy Krantz, timothy.l.krantz@nasa.gov | A-005 |
| Development of Characterization Techniques to Determine Key Composite Material Properties for the LS-DYNA MAT213 Model | Robert Goldberg robert.goldberg@nasa.gov Justin Littell justin.d.littell@nasa.gov Mike Pereira mike.pereira@nasa.gov | A-006 |
| **Astrophysics** | | |
| **Research Focus Area** | **Point of Contact** | **Id** |
| Astrophysics Technology Development | Hashima Hasan hhasan@nasa.gov Mario Perez mario.perez@nasa.gov | A-007 |
| **Biological and Physical Sciences** | | |
| **Research Focus Area** | **Point of Contact** | **Id** |
| Fundamental Physics - Quantum Science | Brad Carpenter bcarpenter@nasa.gov | B-001 |

| Research Focus Area/Point of Contact (POC) | | |
|---|---|---|
| Complex Fluids/Soft Matter - Soft Matter-Based Materials | Brad Carpenter<br>bcarpenter@nasa.gov | B-002 |
| Fluid Physics - Oscillating Heat Pipes (OHP) | John McQuillen<br>john.b.mcquillen@nasa.gov | B-003 |
| Combustion Science - High Pressure Transcritical Combustion (HPTC) | Daniel L. Dietrich<br>Daniel.L.Dietrich@nasa.gov | B-004 |
| Materials Science - Extraction and Utilization of Materials from Regolith | Michael SanSoucie<br>michael.p.sansoucie@nasa.gov | B-005 |
| Effects of Regolith Simulant on Growth, Survival, and Fitness of Animal Models | Sharmila Bhattacharya<br>SpaceBiology@nasaprs.com | B-006 |
| Effects of Space-Associated Stressors on Plant and Microbial Interactions | Sharmila Bhattacharya<br>SpaceBiology@nasaprs.com | B-007 |
| **Center for Design and Space Architecture** | | |
| **Research Focus Area** | **Point of Contact** | **Id** |
| Repair, Manufacturing, And Fabrication (RMAF) Facility for the Common Habitat Architecture | Robert L. Howard, Jr.<br>robert.l.howard@nasa.gov | C-001 |
| **Commercial Space Capabilities** | | |
| **Research Focus Area** | **Point of Contact** | **Id** |
| In-Space Welding | Warren Ruemmele<br>warren.p.ruemmele@nasa.gov | C-002 |
| Materials and Processes Improvements for Chemical Propulsion State of Art (SoA) | Warren Ruemmele<br>warren.p.ruemmele@nasa.gov | C-003 |
| Materials and Processes Improvements for Electric Propulsion State of Art (SoA) | Warren Ruemmele<br>warren.p.ruemmele@nasa.gov | C-004 |
| Improvements to Space Solar Power State of Art (SoA) | Warren Ruemmele<br>warren.p.ruemmele@nasa.gov | C-005 |
| Small Reentry Systems | Warren Ruemmele<br>warren.p.ruemmele@nasa.gov | C-006 |
| Other Commercial Space Topic | Warren Ruemmele<br>warren.p.ruemmele@nasa.gov | C-007 |

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

| Research Focus Area/Point of Contact (POC) | | |
|---|---|---|
| Design, Development, & Implementation of Highly Automated / Autonomous Systems to abide by ethical decision-making policy, standards, guidelines, and laws. | James Harrington<br>james.l.harrington@nasa.gov<br>Edward McLarney<br>Edward.l.mclarney@nasa.gov<br>Yuri Gawdiak<br>yuri.o.gawdiak@nasa.gov<br>Nikunj Oza<br>nikunj.c.oza@nasa.gov | C-013 |
| Societal ramifications of ethical decision-making models. | James Harrington<br>james.l.harrington@nasa.gov<br>Edward McLarney<br>Edward.l.mclarney@nasa.gov<br>Yuri Gawdiak<br>yuri.o.gawdiak@nasa.gov<br>Nikunj Oza<br>nikunj.c.oza@nasa.gov | C-014 |

**Earth Science**

| Research Focus Area | Point of Contact | Id |
|---|---|---|
| Synthesis activities that combine multiple data sets to analyze the vulnerability and resilience of Arctic and boreal ecosystems in the Arctic Boreal Vulnerability Experiment (ABoVE) domain, across North America, and across the circumpolar region. | Allison K. Leidner<br>allison.k.leidner@nasa.gov<br>Laura Lorenzoni<br>laura.lorenzoni@nasa.gov | E-001 |
| Research that contributes to furthering our understanding of climate change impacts in high-latitude drainage basins, including coastal zones, and advance humanity's understanding of the potential feedback(s) of naturally- or anthropogenically-driven change in such zones. | Allison K. Leidner<br>allison.k.leidner@nasa.gov<br>Laura Lorenzoni<br>laura.lorenzoni@nasa.gov | E-002 |
| Integration of research results and remote sensing data from ABoVE into a coherent modeling framework to diagnose and predict the impacts of environmental change on ecosystem dynamics and the consequent impacts on ecosystem services and society. | Allison K. Leidner<br>allison.k.leidner@nasa.gov<br>Laura Lorenzoni<br>laura.lorenzoni@nasa.gov | E-003 |
| Filling critical research gaps in our understanding of how environmental change impacts the dynamics of boreal and Arctic ecosystems within the ABoVE domain. | Allison K. Leidner<br>allison.k.leidner@nasa.gov<br>Laura Lorenzoni<br>laura.lorenzoni@nasa.gov | E-004 |

**Entry Systems Modeling Project**

| Research Focus Area | Point of Contact | Id |
|---|---|---|
| Entry Systems Modeling - Nitrogen/Methane Plasma Experiments Relevant to Titan Entry | Aaron Brandis<br>aaron.m.brandis@nasa.gov | E-005 |

| Research Focus Area/Point of Contact (POC) | | |
|---|---|---|
| Entry Systems Modeling - Thermal Conductivity Heat Transfer of Porous TPS Materials | Aaron Brandis<br>aaron.m.brandis@nasa.gov | E-006 |
| Entry Systems Modeling - Deposition of Ablation/Pyrolysis Products on Optical Windows | Aaron Brandis<br>aaron.m.brandis@nasa.gov | E-007 |
| Entry Systems Modeling - Predictive Modeling of Plasma Physics Relevant to High Enthalpy Facilities | Aaron Brandis<br>aaron.m.brandis@nasa.gov | E-008 |
| **Human Research Program (Space Radiation, Precision Health Initiative)** | | |
| **Research Focus Area** | **Point of Contact** | **Id** |
| Tissue and Data sharing for space radiation risk and mitigation strategies | Robin Elgart<br>shona.elgart@nasa.gov<br>Janice Zawaski<br>janice.zawaski@nasa.gov | H-001 |
| Space radiation sex-differences | Robin Elgart<br>shona.elgart@nasa.gov | H-002 |
| Compound screening techniques to assess efficacy in modulating responses to radiation exposure | Robin Elgart<br>shona.elgart@nasa.gov<br>Brock Sishc<br>brock.j.sishc@nasa.gov | H-003 |
| Inflammasome role in radiation-associated health impacts | Robin Elgart<br>shona.elgart@nasa.gov<br>Janapriya Saha<br>janapriya.saha@nasa.gov | H-004 |
| Portable, non-ionizing radiation based, high resolution disease detection imaging | Robin Elgart<br>shona.elgart@nasa.gov<br>Janice Zawaski<br>janice.zawaski@nasa.gov | H-005 |
| Pilot studies to adopt terrestrial precision health solutions for astronauts | Corey Theriot<br>corey.theriot@nasa.gov<br>Carol Mullenax<br>carol.a.mullenax@nasa.gov | H-006 |
| Pilot studies to demonstrate the utilization of full systems biology approaches in addressing human spaceflight risks | Corey Theriot<br>corey.theriot@nasa.gov<br>Carol Mullenax<br>carol.a.mullenax@nasa.gov | H-007 |

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

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