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National Aeronautics and Space Administration Office of STEM Engagement FY 2021 NASA Cooperative Agreement Notice (CAN)

Established Program to Stimulate Competitive Research (EPSCoR)

Research Announcement

Announcement Number: NNH21ZHA004C
Catalog of Federal Domestic Assistance (CFDA) Number: 43.008

Release Date:	January 12, 2021
Notice of Intent Due:	February 26, 2021
Proposal Due Date:	April 19, 2021

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), Space Technology Mission Directorate (STMD), and the Human Exploration and Operations Mission Directorate (HEOMD), solicits proposals for the fiscal year 2021 NASA Established Program to Stimulate Competitive Research (EPSCoR) Research program.

Each funded NASA EPSCoR proposal is expected to establish research activities that will make significant contributions to NASA's strategic research and technology development priorities and contribute to the overall research infrastructure, science and technology capabilities of higher education, and economic development of the jurisdiction receiving funding.

NASA will assign a Technical Monitor (TM) to each award. The TM will monitor the progress of the research and collaborate as required to keep the research aligned with the approved project. The awardee will provide annual reports regarding the progress of the research; each report will be reviewed by the TM and approved by the NASA EPSCoR Project Manager. These reports will be shared with the NASA Mission Directorates, Centers, and NASA's Jet Propulsion Laboratory (JPL) as necessary.

The program parameters are:

- Jurisdictions responding to this Cooperative Agreement Notice (CAN) may submit one proposal in accordance with paragraph 2.0 of this CAN, NASA EPSCoR Eligibility and Proposal Acceptance. Proposals will be selected from this solicitation for FY 2021 funding.
- The maximum funding request per proposal is $750,000. This amount is to be expended over a three-year period.
- Cost-sharing by proposers is required at a level of at least 50% of the requested NASA funds. Also, in-kind cost-sharing is allowable. Limitations regarding acceptable cost-sharing are further discussed below at Section 2.2 and 2.3.
- Jurisdictions responding to this CAN may submit one proposal. It is anticipated that ten (10) to fifteen (15) awards of up to $750,000 each to be expended over a three-year period of performance may be made under this CAN in accordance with regulatory guidance found at Title 2 Code of Federal Regulations (CFR) Part 200, Uniform Administrative Requirements, Cost Principles and Audit Requirements for Federal Awards, as adopted and supplemented by NASA through Title 2 CFR Part 1800: Federal Agency Regulations for Grants and Agreements – NASA, and the NASA Grant and Cooperative Agreement Manual (GCAM), Appendix E. The exact number of awards depends on the available NASA EPSCoR Research Budget.
- The Government's obligation to make an award is contingent upon the availability of appropriated funds from which payment can be made.

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 the NASA mission;
- Improve the capabilities of the NASA EPSCoR jurisdictions to gain support from sources outside the NASA EPSCoR program;
- Develop partnerships among NASA research assets, academic institutions, and industry; and
- 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. Proposals will be evaluated by the Mission Directorate offices that are involved in this effort and accepted by the NASA EPSCoR Project Office.

Solicitation Availability

This announcement is accessible for a period of three (3) years through NSPIRES and through Grants.gov but will close on the proposal due date and no proposals will be accepted after that date.

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

While proposals can be accepted only from institutions where a NASA EPSCoR Jurisdiction Director is currently serving, all institutions of higher education within the jurisdiction shall be made aware of this CAN and given the opportunity to submit a proposal to the NASA EPSCoR Jurisdiction Director for competition for submission to NASA.

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/FY-2019-Eligibility.pdf

Proposals will be accepted from the resident institution of the NASA EPSCoR Jurisdiction Director in each jurisdiction. The 28 jurisdictions that are eligible for the opportunity in this solicitation 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.

The estimated funding and number of proposals anticipated to be funded, as shown in this CAN under the section entitled "Summary of Key Information," are subject to the availability of appropriated funds, as well as the submission of a sufficient number of proposals of adequate merit.

NASA EPSCoR awards will support a three-year cooperative agreement. It is anticipated that this period of performance will enable the researchers to achieve the performance task objectives stated in the original proposal and/or any amendments submitted with annual progress reports and accepted by the NASA EPSCoR project office.

It is anticipated that approximately (10-15) awards of up to $750,000 each for a period of performance not to exceed three years each may be made under this CAN pursuant to the authority of 2 CFR Part 200, 2 CFR Part 1800, and the NASA GCAM.

The research period of performance (start and end dates) are not fixed values, and are requested by the Jurisdiction for each submitted proposal. The official period of performance (start and end dates) are set forth 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 *Guidebook for Proposers Responding to a NASA Notice of Funding Opportunity (NOFO) effective June 23, 2020 Edition* (NASA Guidebook for Proposers). The latest PDF version is available at: http://www.hq.nasa.gov/office/procurement/nraguidebook

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 any other NASA 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

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

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

Jeppie R. Compton
National Project Manager, NASA EPSCoR
Kennedy Space Center, FL 32899-0001
E-mail: jeppie.r.compton@nasa.gov
Telephone: (321) 867-6988
Cell: (321) 360-6443

1.0 Description of Opportunity

1.1 NASA EPSCoR Program and Project Levels

The NASA EPSCoR is a component of the OSTEM at NASA Headquarters. NASA EPSCoR Program Management is closely coordinated with NASA Headquarters Mission Directorates, NASA Centers, and JPL.

The NASA EPSCoR Project Office is located at the Kennedy Space Center (KSC). This Project Office has the overall responsibility for oversight, evaluation, and reporting. Technical and scientific questions about programs in this solicitation may be directed to the NASA EPSCoR Project Manager.

1.2 Jurisdiction Level

The NASA EPSCoR Jurisdiction Director will serve as the managing Principal Investigator (PI) for the award, providing leadership and administrative direction for the team from an oversight role. The submitting and awardee institution will be that of the NASA EPSCoR Jurisdiction Director. The Director is responsible for oversight and overall administrative management of the project to assure compliance with NASA EPSCoR. The Director is responsible for ensuring the timely reporting of the team's progress and accomplishment of its work.

The investigator who will be responsible for the scientific direction and day-to-day management of the proposed work shall be listed as the Science-I (Sc-I). If the Sc-I's institution is different from the submitting institution, awards may be made to the Sc-I's institution through a subaward.

The Government's obligation to continue any award is based on satisfactory progress as detailed in the recipient's required annual progress reports. The research proposal may include an approved indirect cost rate if one has been negotiated with the Federal cognizant agency for funding of management, administrative, and oversight function of the NASA EPSCoR Jurisdiction Director.

For NASA to accept less than the approved indirect cost rate, a deviation is required. If a deviation is needed, the submitter shall include its proposed indirect cost amount as part of the $750,000 award cap.

The NASA EPSCoR Jurisdiction Director shall provide guidance and updates to the Sc-Is regarding NASA policy and direction from both an Agency technical perspective and from a NASA EPSCoR programmatic standpoint. The Director shall maintain an awareness of NASA research and technology development priorities and jurisdiction research priorities. As the primary point of contact for NASA regarding EPSCoR in the jurisdiction, the Director will identify and develop opportunities for collaboration within the jurisdiction with existing EPSCoR and EPSCoR-like programs from other federal agencies. Also, the NASA EPSCoR Jurisdiction Director will consult with appropriate jurisdiction organizations, such as the economic development commission, in addressing jurisdiction research priorities.

1.3 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 not historically 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 OSTEM.

Each NASA EPSCoR project shall perform scientific and/or technical research in areas that support NASA's strategic research and technology development priorities. Proposals shall emphasize developing capabilities to compete for funds from NASA and non-NASA sources outside of EPSCoR. The projects shall move increasingly towards gaining support from sources outside NASA EPSCoR by aggressively pursuing additional funding opportunities offered by NASA, industry, other federal agencies, and other sources.

This CAN solicits proposals that are expected to establish research activities that will make significant contributions to NASA's strategic research and technology development priorities and contribute to the overall research infrastructure, science and technology capabilities of higher education, and economic development of the jurisdiction receiving funding. 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 in the appendices. This will allow EPSCoR researchers to work alongside NASA and commercial partners for up to one year and is intended to strengthen the bonds among NASA EPSCoR jurisdictions, NASA, commercial partners, and other entities.

NASA will assign a Technical Monitor (TM) to each 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 JPL.

The program parameters are:

- Jurisdictions responding to this CAN may submit only one proposal in accordance with paragraph 1.3 of this CAN, NASA EPSCoR Eligibility and Proposal Acceptance. Proposals will be selected from this solicitation for FY 2021 funding.
- The maximum funding request per proposal is $750,000. This amount is to be expended over a three-year period.
- Cost-sharing by proposers is required at a level of at least 50% of the requested NASA funds. Also, in-kind cost-sharing is allowable. Limitations regarding acceptable cost-sharing are further discussed below at Section 2.2 and 2.3.
- Jurisdictions responding to this CAN may submit only one proposal. It is anticipated that ten (10) to fifteen (15) awards may be made under this CAN in accordance with regulatory guidance found at Title 2 CFR Part 200, Uniform Administrative Requirements, Cost Principles and Audit Requirements for Federal Awards, as adopted and supplemented by NASA through Title 2 CFR Part 1800: Federal Agency Regulations for Grants and Agreements – NASA, and the NASA GCAM.
- The Government's obligation to make an award is contingent upon the availability of appropriated funds from which payment can be made.
- This CAN is available in electronic form through the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) and Grants.gov. However, all proposals shall be submitted through NSPIRES.

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.

1.4 Award Information: Funding and Cost-Sharing

The maximum funding that a jurisdiction can request from NASA is $750,000 per proposal. This amount is to be spent in accordance with the budget details and narrative in the approved proposal.

Cost-sharing is required at a level of at least 50% of the requested NASA funds. Although the method of cost-sharing is flexible, NASA encourages the EPSCoR jurisdiction committees to consider methods that would add value to the jurisdiction's existing research capabilities. All contributions, including cash or in-kind, shall meet the criteria contained in 2 CFR 200 per the NASA GCAM.

1.5 Award Information: Restrictions

Awards from this funding announcement that are 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 GCAM, the following restrictions govern the use of the NASA-provided EPSCoR funds and are applicable to this CAN:

- 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 remuneration 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, see Section 3.2 of the *NASA Guidebook for Proposers* and the NASA FAR Supplement (NFS) part 1835.016-70.
- Travel, including foreign travel, is allowed for the meaningful completion of the proposed investigation, as well as for reporting results at appropriate professional meetings. Foreign travel to meetings and conferences in support of the jurisdiction's NASA EPSCoR research project is an acceptable use of NASA EPSCoR funds, with a limit of $3,000 per trip for up to two (2) separate years of a jurisdiction's proposal (i.e., the maximum amount the jurisdiction can request for foreign travel is $3,000 total in any one year and a limit of $6,000 total for each research proposal). NASA EPSCoR support shall be acknowledged by the NASA EPSCoR research project number in written reports and publications.
- 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 onlyfor 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, 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 Grants Officer).

- NASA EPSCoR funding shall not be used to support NASA civil service participation (i.e., full time equivalents (FTEs)) in a research project. That funding is provided through a funding vehicle between the jurisdiction and NASA Center, such as a Space Act Agreement or another reimbursable agreement. 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 NASA EPSCoR project. All activities charged under indirect costs shall be allowed under the cost principles set forth in 2 CFR 200.
- Grants and Cooperative Agreements shall not provide for the payment of fee or profit to the recipient.
- Non-Federal entities/the proposer may use one of the methods of procurement as prescribed in 2 CFR .1200.320. As defined in 2 CFR 200.67, 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 non-profit 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, whether higher or lower than 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.
- Any funds used for matching or cost sharing shall be allowable under 2 CFR 200.
- Procurement contracts shall not be awarded in conjunction with this solicitation.
- This solicitation is not for renewal or supplementation of existing projects, which are not eligible to compete with applications for new Federal awards within this solicitation, thus only new proposals will be considered.

1.6 Notice of Intent

Jurisdictions planning to prepare a proposal package for NASA EPSCoR shall submit a

Notice of Intent (NOI) to propose. To be useful to NASA EPSCoR Management for planning purposes, NOIs shall be submitted by the NASA EPSCoR Jurisdiction Director through NSPIRES at http://nspires.nasaprs.com by 11:59 p.m. Eastern Time**, February 26, 2021**.

NOIs shall be submitted via NSPIRES regardless of whether the solicitation was downloaded via NSPIRES or Grants.Gov. ***Information provided in the NOI shall identify the proposed research areas of interests (Nanotechnology, Oceanography, Biology, etc.) and any desired Center, JPL, and/or Mission Directorate alignment, if known*.)** See Appendix E, Section 3 of this announcement for additional details regarding NOIs.

1.7 Access to Research Results

Recipients receiving awards under this CAN shall comply with the provisions 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 designate 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 ITAR; 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 shall 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.

1.8 Foreign National Participation

All recipients shall work with NASA project/program staff to ensure proper credentialing for any individuals who need access to NASA facilities and/or systems. Such individuals include U.S. citizens and lawful permanent residents ("green card" holders). Please note that foreign nationals (individuals who are neither U.S. citizens nor permanent residents) are not normally allowed access to 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. 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, may be ineligible for award.

1.9 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, shall 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

While proposals can be accepted only from institutions where a NASA EPSCoR Jurisdiction Director is currently serving, all institutions of higher education within the jurisdiction shall be made aware of this CAN and given the opportunity to submit a proposal to the NASA EPSCoR Jurisdiction Director for competition for submission to NASA.

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/FY- 2019- Eligibility.pdf

Proposals will be accepted from the resident institution of the NASA EPSCoR Jurisdiction 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

The maximum funding that a jurisdiction can request from NASA is $750,000 per proposal. This amount is to be spent in accordance with the budget details and budget narrative in the approved proposal.

Cost-sharing is required at a level of at least 50% of the requested NASA funds. Although the method of cost-sharing is flexible, NASA encourages the EPSCoR jurisdiction committees to consider methods that would add value to the jurisdiction's existing research capabilities. All contributions, including cash or in-kind, shall meet the criteria contained in 2 CFR 200 per the NASA GCAM.

NASA-funded, in-kind services provided by Mission Directorates, NASA Centers, or JPL shall be identified as "NASA responsibilities" in the proposals and shall not be included in the 50% cost matching requirement.

Statements of commitment and letters of support are important components of the proposal. However, NASA does not solicit or evaluate letters of endorsement. Review the *NASA Guidebook for Proposers* for distinctions among statements of commitment, letters of support, and letters of endorsement.

3.0 Proposal Submission Instructions and Due Date/Time

All proposals in response 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 **April 19, 2021.**

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 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 or not to resubmit it in response to a subsequent solicitation.

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

- Every organization intending to submit a proposal to NASA in response to this CAN 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) at https://www.sam.gov/portal/public/SAM/
- 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 NSPIRES 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 NSPIRES 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. 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 shall check the box provided for this purpose.

REQUIRED SECTIONS OF THE PROPOSAL (in order of assembly)	**PAGE LIMIT**
Proposal Cover Page	NSPIRES proposal cover page that is available at http://nspires.nasaprs.com/
Proposal Summary (abstract)	4,000 characters including spaces
Data Management Plan	4,000 characters, including spaces
Table of Contents	As needed
Scientific/Technical/Management Plan	15*
References and Citations	As needed
Biographical Sketches for:	
the Science Investigator (Sc-I)	2
each Co-Investigator (Co-I)	1
Current and Pending Support	As needed
Statements of Commitment and Letters of Support	As needed
Budget Justification: Narrative and Details	As needed
• *Includes proposed budget, itemized list detailing expenses within major budget categories, detailed subawards and summary of personnel (User's Guide section 3.18 and Appendix C).*	
• *For grants/cooperative agreements, the table of personnel and work effort shall immediately follow the proposal budget and is not included in the budget.*	
Facilities and Equipment	As needed
Special Notifications and/or Certifications	As needed
** includes all illustrations, tables, and figures, where each "n-page" fold-out counts as n-pages and each side of a sheet containing text or an illustration counts as a page.*	

3.2 Announcement of Updates/Amendments to the Solicitation

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

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

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

3.3 Cancellation of Program Announcement

NASA OSTEM reserves the right to not make any awards under this CAN and/or to cancel this CAN. NASA assumes no liability (including for proposal costs) for cancelling the CAN 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 cooperative agreement announcement should be addressed to:

Mr. Jeppie Compton
National Project Manager, NASA EPSCoR
Office Phone: 321-867-6988
Cell Phone: 321-360-6443
E-mail: jeppie.r.compton@nasa.gov

Technical and scientific questions about programs in this CAN may be directed to the appropriate NASA POC listed in the attached appendices.

4.0 Proposal Review and Selection

All proposals submitted in response 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 **April 19, 2021.**

4.1 Evaluation Criteria

Evaluation by peer review will be used to assess each proposal's overall merit. The evaluation criteria are: Intrinsic Merit, NASA Alignment and Partnerships, Management and Evaluation, and Budget Justification: Narrative and Details. A NASA Headquarters Mission Directorate panel will use the results of the peer evaluation to make funding recommendations to the Selecting Official. See Section 5.0, Proposal Evaluation Criteria.

4.2 Review and Selection Process

Review of proposals submitted in response to this CAN 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 CAN under Section 5.0, Proposal Evaluation, take precedence over the evaluation criteria described in Section 5 of the *NASA Guidebook for Proposers*. The Selecting Official for this CAN is the NASA 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 200.205. For all proposals selected for award, the Grants Officer will review the submitting organization's information available through the Federal Awardee Performance and Integrity Information System (FAPIIS) and the System for Award Management (SAM) to include checks on entity core data, registration expiration date, active exclusions, suspension, debarment, and delinquent federal debt.

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 200.205. 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 (SAM.gov), FAPIIS, the Contractor Performance and Assessment Reporting System (CPARS), the Federal Audit Clearinghouse (FAC), USAspending.gov, and Grant Solutions Recipient Insight.

At its option, an applicant may review information about itself that NASA previously entered and that is currently in FAPIIS and may comment on such information.

NASA will consider any comments by the applicant, in addition to the other information in FAPIIS, in reaching a determination about the applicant's integrity, business ethics, and record of performance under Federal awards when completing the review of risk posed by applicants as described in 2 CFR 200.205, Federal awarding agency review of risk posed by applicants.

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.

Jurisdictions are strongly encouraged to submit proposals that demonstrate partnerships or cooperative arrangements among academia, government agencies, business and industry, private research foundations, jurisdiction agencies, and local agencies.

Limited Release of Proposers Confidential Business Information

For proposal evaluation and administrative processing, NASA may find it necessary to release proposal information to individuals who are not NASA employees (e.g., NASA support contractors). 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, subcontractors, and their employees are not eligible to submit a proposal in any capacity under this solicitation.

4.3 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 non-selected proposers should be aware that proposals of nominally high intrinsic and programmatic merits may be declined for reasons entirely unrelated to any scientific or technical weaknesses.

4.4 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 within 90 calendar days before an award are at the recipient's risk in accordance with 2 CFR § 1800.209.A

An anticipated award date announcement will be determined by the NASA EPSCoR Project Manager upon the conclusion of the review process.

4.5 Administrative and National Policy Requirements

All administrative and national policy requirements may be found at Title 2 CFR Part 200, Title 2 CFR Part 1800, and the NASA GCAM (all available at: http://prod.nais.nasa.gov/pub/pub_library/srba/index.html).

4.6 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 CAN will be consistent with the reporting requirements outlined in the NASA GCAM Appendix.

5.0 Proposal Evaluation

Successful research 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, as well as contribute to the overall research infrastructure, science and technology capabilities of higher education, and economic development of the jurisdiction.

Successful proposals shall also include pragmatic plans for generation of sustained non-

EPSCoR support.

Proposals will be evaluated based on the following criteria: Intrinsic Merit, 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. **Note:** *Each proposer shall provide specific information on how it determined the relevance of the proposed effort to NASA and the jurisdiction.*

5.1 Intrinsic Merit (35% of 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 detailed 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 shall provide baseline information about current research activities within the jurisdiction in the proposed research area, including projects currently funded under NASA EPSCoR.
- If the proposed research represents a new direction for the jurisdiction, the technical team's ability to conduct the research shall be explained. Other relevant research and technology development programs within the jurisdiction shall also be included.

5.2 NASA Alignment and Partnerships (35% of score)

- Proposals shall discuss the value of the proposed research to NASA and to the jurisdiction's research priorities.
- Proposals shall describe the use of NASA content, people, or facilities in the execution of the research activities.
- Proposals shall 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, Centers, and/or JPL 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.
- Proposals shall articulate clearly how the proposed research activities build capacity in the jurisdiction.
- In particular, proposers shall explain how this proposed research is related to the strategic plan for NASA EPSCoR-related research in the jurisdiction.
- Proposals shall state how they plan to develop research competitiveness both in

the jurisdiction and nationally.

- Proposals shall delineate mechanisms for building partnerships with universities, industry, and/or other government agencies to enhance the ability of the jurisdiction to achieve its objectives, to obtain and leverage sources of additional funding, and/or to obtain essential services not otherwise available.

5.3 Management and Evaluation (15% of score) NOTE: The following information does not count toward the 15-page limit for the Scientific, Technical, or Management section of the table on page 17.

This section shall describe the management structure for the proposed research and coordination with the jurisdiction's NASA EPSCoR project management. The following elements shall be included:

- Personnel: The proposal shall include a list of the personnel participating in this research program, including the Principal Investigator, Science-Investigator, and all Co-Investigators, Research Associates, Post-Doctoral Fellows, Research Assistants, and other research participants. The credentials of the researchers are important; however, EPSCoR includes the concept of encouraging and helping new researchers.
- Research Project Management: A description shall be included of the Science-I's management structure of the proposed research project, and the extent to which the project's management and research team will lead to a well-coordinated, efficiently-managed, and productive effort.
- Multi-Jurisdiction Projects: If the proposed research is a collaboration between more than one NASA EPSCoR jurisdiction, one jurisdiction shall be identified as the lead with additional partners identified as sub-awardees. The proposal shall detail the inter-jurisdiction management structure of the proposed research project, including a list of the participating jurisdictions, and the participating universities and agencies within each jurisdiction. Multi-jurisdictional proposals shall not exceed the $750,000 award limit.
- Project Evaluation: Proposals shall document the intended outcomes and offer metrics to demonstrate progress toward and achievements of these outcomes. They shall discuss metrics to be used for tracking and evaluating project progress. Milestones and timetables for achievement of specific objectives during the award period shall be presented. The proposal also shall describe an appropriate evaluation plan/process to document outcomes and demonstrate progress toward achieving objectives of proposed project elements. The evaluation methodology shall be based upon reputable models and techniques appropriate to the content and scale of the project. Projects shall implement improvements throughout the entire period of performance based on ongoing evaluation evidence.
- Results of Prior NASA EPSCoR Research Support: Examples of accomplishments commensurate with the managerial and administrative expectations of the award shall be provided. The EPSCoR Director will not be assessed on their expertise in the specific proposed research area since the

Science-PI is tasked with managing the scientific/technical development progress. The following information shall be provided: the NASA EPSCoR award number(s), the title of the projects(s); and period(s) of performance; primary outcomes resulting from the NASA EPSCoR award, including a summary discussion of accomplishments compared to the proposed outcomes from the original proposal; coordination with the research and technical development priorities of NASA, and contribution(s) to the overall research capacity of the jurisdiction.

- Proposals shall describe the use of NASA content, people, or facilities if involved in the execution of the research activities. Specifically, they shall 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.

5.4 Budget Justification: Narrative and Details (15% of 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.
- A detailed budget, including both NASA provided and cost-share funds, is required. This section shall include detailed budgets for each of the three years of the funding and a summary budget for all three years. All sources of cost-sharing shall be thoroughly described and documented.
- The budget will be evaluated based upon the clarity and reasonableness of the funding request. A budget narrative shall be included that discusses relevant budgetary issues such as the extent and level of jurisdiction, industrial, and institutional commitment and financial support, including resources (e.g., staff, facilities, laboratories, indirect support, waiver of indirect costs).

6.0 Certification of Compliance

As described in Section 1.4 above, recipients receiving awards under this CAN 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-

a. Submitting as approved peer-reviewed manuscripts and metadata to a designated repository; and
b. 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: http://naistst1.nais.nasa.gov/pub/pub_library/srba/certs.html.

Note: On February 2, 2019, the System for Award Management (SAM) implemented a new process that allows financial assistance registrants to submit common Federal Government-wide certifications and representations. This new process is required effective January 1, 2020. Guidance on the new process and system change is available at: https://interact.gsa.gov/blog/certifications-and-representation-improvements-sam.

Appendix A: NASA Mission Directorates and Center Alignment

NASA's Mission *to drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality and stewardship of Earth,* draws support from four Mission Directorates, nine NASA Centers, and NASA's Jet Propulsion Laboratory (JPL), each with a specific responsibility.

A.1 Aeronautics Research Mission Directorate (ARMD)

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

- Advanced Air Mobility
- Quiet Supersonic Flight Over Land
- Electrified Aircraft Propulsion
- Future Airspace and Transformative Tools

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

Areas of Interest - POC: Karen Rugg, karen.l.rugg@nasa.gov
Proposers are directed to the following:

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

A.2 Human Exploration & Operations Mission Directorate (HEOMD)

Human Exploration & Operations Mission Directorate (HEOMD) provides the Agency with leadership and management of NASA space operations related to human exploration in and beyond low-Earth orbit. HEO also oversees low-level requirements development, policy, and programmatic oversight. The International Space Station, currently orbiting the Earth with a crew of six, represents the NASA exploration activities in low-Earth orbit. Exploration activities beyond low Earth orbit include the management of Commercial Space Transportation, Exploration Systems Development, Human Space Flight Capabilities, and Advanced Exploration Systems. The directorate is similarly responsible for Agency leadership and management of NASA space operations related to Launch Services, Space Transportation, and Space Communications in support of both human and robotic exploration programs. Additional information on the HEOMD can be found at: (http://www.nasa.gov/directorates/heo/home/index.html)

Areas of Interest - Marc Timm marc.g.timm@nasa.gov
Human Research Program
The Human Research Program (HRP) is focused on investigating and mitigating the highest risks to human health and performance in order to enable safe, reliable, and productive human space

exploration. The HRP budget enables NASA to resolve health risks in order for humans to safely live and work on missions in the inner solar system. HRP conducts research, develops countermeasures, and undertakes technology development to address human health risks in space and ensure compliance with NASA's health, medical, human performance, and environmental standards.

Engineering Research

- Spacecraft: Guidance, navigation and control; thermal; electrical; structures; software; avionics; displays; high speed re-entry; modeling; power systems; interoperability/commonality; advanced spacecraft materials; crew/vehicle health monitoring; life support.
- Propulsion: Propulsion methods that will utilize materials found on the moon or Mars, "green" propellants, on-orbit propellant storage, motors, testing, fuels, manufacturing, soft landing, throttle-able propellants, high performance, and descent.
- Robotic Systems for Precursor Near Earth Asteroid (NEA) Missions: Navigation and proximity operations systems; hazard detection; techniques for interacting and anchoring with Near Earth Asteroids; methods of remote and interactive characterization of Near Earth Asteroid (NEA) environments, composition and structural properties; robotics (specifically environmental scouting prior to human arrival and later to assist astronauts with NEA exploration); environmental analysis; radiation protection; spacecraft autonomy, enhanced methods of NEA characterization from earth-based observation.
- Robotic Systems for Lunar Precursor Missions: Precision landing and hazard avoidance hardware and software; high-bandwidth communication; in-situ resource utilization (ISRU) and prospecting; navigation systems; robotics (specifically environmental scouting prior to human arrival, and to assist astronaut with surface exploration); environmental analysis, radiation protection.
- Data and Visualization Systems for Exploration: Area focus on turning precursor mission data into meaningful engineering knowledge for system design and mission planning of lunar surface and NEAs. Visualization and data display; interactive data manipulation and sharing; mapping and data layering including coordinate transformations for irregular shaped NEAs; modeling of lighting and thermal environments; simulation of environmental interactions including proximity operations in irregular micro-G gravity fields and physical stability of weakly bound NEAs.
- Research and technology development areas in HEOMD support launch vehicles, space communications, and the International Space Station. Examples of research and technology development areas (and the associated lead NASA Center) with great potential include:
  - *Processing and Operations*
    - Crew Health and Safety Including Medical Operations (Johnson Space Center (JSC))
    - In-helmet Speech Audio Systems and Technologies (Glenn Research Center (GRC))
    - Vehicle Integration and Ground Processing (Kennedy Space Center (KSC))
    - Mission Operations (Ames Research Center (ARC))
    - Portable Life Support Systems (JSC)
    - Pressure Garments and Gloves (JSC)
    - Air Revitalization Technologies (ARC)
    - In-Space Waste Processing Technologies (JSC)
    - Cryogenic Fluids Management Systems (GRC)
  - *Space Communications and Navigation*
    - Coding, Modulation, and Compression (Goddard Spaceflight Center (GSFC)

- Precision Spacecraft & Lunar/Planetary Surface Navigation and Tracking (GSFC)
- Communication for Space-Based Range (GSFC)
- Antenna Technology (Glenn Research Center (GRC))
- Reconfigurable/Reprogrammable Communication Systems (GRC)
- Miniaturized Digital EVA Radio (JSC)
- Transformational Communications Technology (GRC)
- Long Range Optical Telecommunications (Jet Propulsion Laboratory (JPL))
- Long Range Space RF Telecommunications (JPL)
- Surface Networks and Orbit Access Links (GRC)
- Software for Space Communications Infrastructure Operations (JPL)
- TDRS transponders for launch vehicle applications that support space communication and launch services (GRC)

– *Space Transportation*
- Optical Tracking and Image Analysis (KSC)
- Space Transportation Propulsion System and Test Facility Requirements and Instrumentation (Stennis Space Center (SSC)
- Automated Collection and Transfer of Launch Range Surveillance/Intrusion Data (KSC)
- Technology tools to assess secondary payload capability with launch vehicles (KSC)
- Spacecraft Charging/Plasma Interactions (Environment definition & arcing mitigation) (Marshall Space Flight Center (MSFC)

– *Commercial Space Capabilities*
- The goal of this area is to support research, development, and commercial adoption of technologies of interest to the U.S. spaceflight industry to further their space-related capabilities.
- These include capabilities for Moon, Mars, and Earth orbit. Such efforts are in pursuit of the goals of the National Space Policy and NASA's strategic plans, to foster developments that will lead to education and job growth in science and engineering, and spur economic growth as capabilities for new space markets are created.
- U.S. commercial spaceflight industry interests naturally vary by company. Proposers are encouraged to determine what those interests are by engagement with such companies in various ways, and such interests may also be reflected in the efforts of various NASA partnerships.
- Proposals shall discuss how the proposed effort aligns with U.S. commercial spaceflight company interest(s), and identify potential alignments with NASA interests.

A.3 Science Mission Directorate (SMD)

The Science Mission Directorate (SMD) leads the Agency in five areas of research: Biological and Physical Sciences (BPS), Heliophysics, Earth Science, Planetary Science, and Astrophysics. SMD, using the vantage point of space to achieve with the science community and our partners a deep scientific understanding of our planet, other planets and solar system bodies, the interplanetary environment, the Sun and its effects on the solar system, and the universe beyond. In so doing, we lay the intellectual foundation for the robotic and human expeditions of the future while meeting today's needs for scientific information to address national concerns, such as climate change and space weather. SMD's high-level strategic objectives are presented in the 2018 NASA Strategic Plan. Detailed plans by science area corresponding to the science divisions of SMD: Heliophysics, Earth Science, Planetary Science, and Astrophysics appear in *SCIENCE 2020-2024: A Vision for Scientific Excellence (the 2020 Science Plan),*"which is available at http://science.nasa.gov/about-us/science-strategy/. The best expression of specific research topics of interest to each Division within SMD are represented in by the topics listed in SMD's Research Opportunities in Space and Earth Science (ROSES) solicitation; see ROSES-2020 and the text in the Division research overviews of ROSES, i.e.:

Astrophysics Research Program Overview
Earth Science Research Overview
Heliophysics Research Program Overview
Planetary Science Research Program Overview
https://solicitation.nasaprs.com/ROSES2020table3
https://solicitation.nasaprs.com/ROSES2020table2

Please note, even if a particular topic is not solicited in ROSES this year, it is still a topic of interest and eligible for this solicitation. Additional information about the Science Mission Directorate may be found at: http://nasascience.nasa.gov.

SMD POC: Kristen Erickson kristen.erickson@nasa.gov

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

The mission of BPS is two-pronged:

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

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

BPS administers NASA's:

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

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

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

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

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

Research proposals are being solicited on the following topic:

- Organismal Biology – responses of whole organisms and their systems to ionizing radiation and/or other spaceflight-relevant stressors such as altered gravity simulators.
    - These will be ground-based studies.
    - Ionizing radiation and altered gravity regimes (partial gravity and microgravity) are a hallmark of the deep space environment. These stressors may cause direct physiological changes in the organisms or result in indirect effects such as loss of sleep in some organisms. Studies shall effectively delineate the biological effects of these factors, separately and/or in combination where possible.
    - Understand the mechanistic bases of the changes induced in these unique environments, preferably from a systems biology perspective, and could include genetic, cellular, or molecular biological effects.

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

Physical Science Program

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

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

The two NASA GRC drop towers described below are also available to augment research investigations. These facilities are typically used to conduct combustion or fluid physics experiments. Please go to link for further information. The Points of Contact for each research area are:
Fluid Physics: John McQuillen, john.b.mcquillen@nasa.gov
Combustion Science: Dan Dietrich, daniel.l.dietrich@nasa.gov
Since there is a cost involved to use these drop towers, please contact the appropriate POC for cost estimates for your proposal.

2.2 s tower
https://www1.grc.nasa.gov/facilities/drop/
The 2.2 Second Drop Tower has been used for nearly 50 years by researchers from around the world to study the effects of microgravity on physical phenomena such as combustion and fluid dynamics and to develop technology for future space missions. It provides rapid turnaround testing (up to 12 drops/day) of 2.2 seconds in duration.

5..2 s tower
https://www1.grc.nasa.gov/facilities/zero-g/
The Zero Gravity Research Facility is NASA's premier facility for ground based microgravity research, and the largest facility of its kind in the world. It provides researchers with a near weightless environment for a duration of 5.18 seconds. It has been primarily used for combustion and fluid physics investigations.

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

Heliophysics Division

Heliophysics encompasses science that improves our understanding of fundamental physical processes throughout the solar system, and enables us to understand how the Sun, as the major driver of the energy throughout the solar system, impacts our technological society. The scope of heliophysics is vast, spanning from the Sun's interior to Earth's upper atmosphere, throughout interplanetary space, to the edges of the heliosphere, where the solar wind interacts with the local interstellar medium. Heliophysics incorporates studies of the interconnected elements in a single system that produces dynamic space weather and that evolves in response to solar, planetary, and interstellar conditions.

The Agency's strategic objective for heliophysics is to **understand the Sun and its interactions with Earth and the solar system, including space weather.** The heliophysics decadal survey conducted by the National Research Council (NRC), *Solar and Space Physics: A Science for a Technological Society (http://www.nap.edu/catalog/13060/solar-and-space-physics-a-science-for-a-technological-society)*, articulates the scientific challenges for this field of study and recommends a slate of design reference missions to meet them, to culminate in the achievement of a predictive capability to aid human endeavors on Earth and in space. The fundamental science questions are:

- What causes the Sun to vary?
- How do the geospace, planetary space environments and the heliosphere respond?
- What are the impacts on humanity?

To answer these questions, the Heliophysics Division implements a program to achieve three overarching goals:

- Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system;
- Advance our understanding of the connections that link the Sun, the Earth, planetary space environment, and the outer reaches of our solar system; and
- Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Further information on the objectives and goals of NASA's Heliophysics Program may be found in the *2014 Science Plan and Our Dynamic Space Environment: Heliophysics Science and Technology Roadmap for 2014-2033* (download PDF). The Heliophysics research program is described in Chapter 4.1 of the *SMD Science Plan 2014* available at http://science.nasa.gov/about-us/science-strategy/. The program supports theory, modeling, and data analysis utilizing remote sensing and *in situ* measurements from a fleet of missions; the Heliophysics System Observatory (HSO). Frequent CubeSats, suborbital rockets, balloons, and ground-based instruments add to the observational base. Investigations that develop new observables and technologies for heliophysics science are sought.

Supported research activities include projects that address understanding of the Sun and planetary space environments, including the origin, evolution, and interactions of space plasmas and electromagnetic fields throughout the heliosphere. The program seeks to characterize these phenomena on a broad range of spatial and temporal scales, to understand the fundamental processes that drive them, to understand how these processes combine to create space weather events, and to enable a capability for predicting future space weather events.

The program supports investigations of the Sun, including processes taking place throughout the solar interior and atmosphere and the evolution and cyclic activity of the Sun. It supports investigations of the origin and behavior of the solar wind, energetic particles, and magnetic fields in the heliosphere and their interaction with the Earth and other planets, as well as with the interstellar medium.

The program also supports investigations of the physics of magnetospheres, including their formation and fundamental interactions with plasmas, fields, and particles and the physics of the terrestrial mesosphere, thermosphere, ionosphere, and auroras, including the coupling of these phenomena to the lower atmosphere and magnetosphere. Proposers may also review the information in the ROSES-19 Heliophysics Division Overview for further information about the Heliophysics Research Program.

Earth Science Division

The overarching goal of NASA's Earth Science program is to develop a scientific understanding of Earth as a system. The Earth Science Division (ESD) in SMD (https://science.nasa.gov/earth-science) contributes to NASA's mission, in particular, Strategic Objective 1.1: Understanding The Sun, Earth, Solar System, And Universe. This strategic objective is motivated by the following key questions:

- How is the global Earth system changing?
- What causes these changes in the Earth system?
- How will the Earth system change in the future?
- How can Earth system science provide societal benefit?

These science questions translate into seven overarching science goals to guide ESD's selection of investigations and other programmatic decisions:

- Advance the understanding of changes in the Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition (Atmospheric Composition)
- Improve the capability to predict weather and extreme weather events (Weather)
- Detect and predict changes in Earth's ecosystems and biogeochemical cycles, including land cover, biodiversity, and the global carbon cycle (Carbon Cycle and Ecosystems)
- Enable better assessment and management of water quality and quantity to accurately predict how the global water cycle evolves in response to climate change (Water and Energy Cycle)
- Improve the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land and ice in the climate system (Climate Variability and Change)
- Characterize the dynamics of Earth's surface and interior, improving the capability to assess and respond to natural hazards and extreme events (Earth Surface and Interior)
- Further the use of Earth system science research to inform decisions and provide benefits to society

In applied sciences, the ESD encourages the use of data from NASA's Earth-observing satellites and airborne missions to tackle tough challenges and develop solutions that improve our daily lives. Specific areas of interest include efforts that help institutions and individuals make better decisions about our environment, food, water, health, and safety (see http://appliedsciences.nasa.gov). In technological research, the ESD aims to foster the creation and infusion of new technologies – such as data processing, interoperability, visualization, and analysis as well as autonomy, modeling, and mission architecture design – in order to enable new scientific measurements of the Earth system or reduce the cost of current observations (see http://esto.nasa.gov). The ESD also promotes innovative development in computing and information science and engineering of direct relevance to ESD. NASA makes Earth observation data and information widely available through the Earth Science Data System program, which is responsible for the stewardship, archival and distribution of open data for all users

ESD places particular emphasis on the investigators' ability to promote and increase the use of space-based remote sensing through the proposed research. Proposals with objectives connected to needs identified in most recent Decadal Survey (2017-2027) from the National Academies of Science, Engineering, and Medicine, *Thriving on our Changing Planet: A Decadal Strategy for Earth Observation from Space* are welcomed. (see https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth).

NASA's ability to view the Earth from a global perspective enables it to provide a broad, integrated set of uniformly high-quality data covering all parts of the planet. NASA shares this unique knowledge with the global community, including members of the science, government, industry, education, and policy-maker communities.

Planetary Science Division

The Planetary Science Research Program, managed by the Planetary Science Division, sponsors research that addresses the broad strategic objective to "Ascertain the content, origin, and evolution of the Solar System and the potential for life elsewhere." To pursue this objective, the Planetary Science Division has five science goals that guide the focus of the division's science research and technology development activities. As described in Chapter 4.3 of the SMD 2014 Science Plan (https://science.nasa.gov/about-us/science-strategy), these are:

- Explore and observe the objects in the Solar System to understand how they formed and evolve.

- Advance the understanding of how the chemical and physical processes in the Solar System operate, interact and evolve.
- Explore and find locations where life could have existed or could exist today.
- Improve our understanding of the origin and evolution of life on Earth to guide our search for life elsewhere.
- Identify and characterize objects in the Solar System that pose threats to Earth or offer resources for human exploration.

In order to address these goals, the Planetary Research Program invites a wide range of planetary science and astrobiology investigations. Example topics include, but are not limited to:

- Investigations aimed at understanding the formation and evolution of the Solar System and (exo) planetary systems in general, and of the planetary bodies, satellites, and small bodies in these systems;
- Investigations aimed at understanding materials present, and processes occurring, in the early stages of Solar System history, including the protoplanetary disk;
- Investigations aimed at understanding planetary differentiation processes;
- Investigations of extraterrestrial materials, including meteorites, cosmic dust, presolar grains, and samples returned by the Apollo, Stardust, Genesis, and Hayabusa missions;
- Investigations of the properties of planets, satellites (including the Moon), satellite and ring systems, and smaller Solar System bodies such as asteroids and comets;
- Investigations of the coupling of a planetary body's intrinsic magnetic field, atmosphere, surface, and interior with each other, with other planetary bodies, and with the local plasma environment;
- Investigations into the origins, evolution, and properties of the atmospheres of planetary bodies (including satellites, small bodies, and exoplanets);
- Investigations that use knowledge of the history of the Earth and the life upon it as a guide for determining the processes and conditions that create and maintain habitable environments and to search for ancient and contemporary habitable environments and explore the possibility of extant life beyond the Earth;
- Investigations into the origin and early evolution of life, the potential of life to adapt to different environments, and the implications for life elsewhere;
- Investigations that provide the fundamental research and analysis necessary to characterize exoplanetary systems;
- Investigations related to understanding the chemistry, astrobiology, dynamics, and energetics of exoplanetary systems;
- Astronomical observations of our Solar System that contribute to the understanding of the nature and evolution of the Solar System and its individual constituents;
- Investigations to inventory and characterize the population of Near Earth Objects (NEOs) or mitigate the risk of NEOs impacting the Earth;
- Investigations into the potential for both forward and backward contamination during planetary exploration, methods to minimize such contamination, and standards in these areas for spacecraft preparation and operating procedures;
- Investigations which enhance the scientific return of NASA Planetary Science Division missions through the analysis of data collected by those missions;
- Advancement of laboratory- or spacecraft-based (including small satellites, e.g., CubeSats) instrument technology that shows promise for use in scientific investigations on future planetary missions; and

- Analog studies, laboratory experiments, or fieldwork to increase our understanding of Solar System bodies or processes and/or to prepare for future missions.

Proposers may also review the information in the ROSES-2019 Planetary Science Research Program Overview for further information about the Planetary Science Research Program.

Astrophysics Division

Astrophysics is the study of phenomena occurring in the universe and of the physical principles that govern them. Astrophysics research encompasses a broad range of topics, from the birth of the universe and its evolution and composition, to the processes leading to the development of planets and stars and galaxies, to the physical conditions of matter in extreme gravitational fields, and to the search for life on planets orbiting other stars. In seeking to understand these phenomena, astrophysics science embodies some of the most enduring quests of humankind.

NASA's strategic objective in astrophysics is to discover how the universe works, explore how it began and evolved, and search for life on planets around other stars. Three broad scientific questions flow from this objective:

- How does the universe work?
- How did we get here?
- Are we alone?

Each of these questions is accompanied by a science goal that shapes the Astrophysics Division's efforts towards fulfilling NASA's strategic objective:

- Probe the origin and destiny of our universe, including the nature of black holes, dark energy, dark matter and gravity
- Explore the origin and evolution of the galaxies, stars and planets that make up our universe
- Discover and study planets around other stars, and explore whether they could harbor life

The scientific priorities for astrophysics are outlined in the NRC decadal survey New Worlds, New Horizons in Astronomy and Astrophysics (http://www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics). These priorities include understanding the scientific principles that govern how the universe works; probing cosmic dawn by searching for the first stars, galaxies, and black holes; and seeking and studying nearby habitable planets around other stars.

The multidisciplinary nature of astrophysics makes it imperative to strive for a balanced science and technology portfolio, both in terms of science goals addressed and in missions to address these goals. All the facets of astronomy and astrophysics—from cosmology to planets—are intertwined, and progress in one area hinges on progress in others. However, in times of fiscal constraints, priorities for investments must be made to optimize the use of available funding. NASA uses the prioritized recommendations and decision rules of the decadal survey to set the priorities for its investments.

The broad themes of the Astrophysics Research Program are:

(i) Physics of the Cosmos:

To discover how the universe works at the most fundamental level; to explore the behavior and interactions of the particles and fundamental forces of nature, especially their behavior under the extreme conditions found in astrophysical situations; and to explore the processes that shape the structure and composition of the universe as a whole, including the forces which drove the Big Bang and continue to drive the accelerated expansion of the universe.

(ii) Cosmic Origins:

To discover how the universe expanded and evolved from an extremely hot and dense state into the galaxies of stars, gas, and dust that we observe around us today; to discover how dark matter clumped under gravity into the tapestry of large-scale filaments and structures which formed the cosmic web for the formation of galaxies and clusters of galaxies; to discover how stars and planetary systems form within the galaxies; and to discover how these complex systems create and shape the structure and composition of the universe on all scales.

(iii) Exoplanet Exploration:

To search for planets and planetary systems about nearby stars in our Galaxy; to determine the properties of those stars that harbor planetary systems; to determine the percentage of planets that are in or near the habitable zone of a wide variety of stars, and identify candidates that could harbor life.

(iv) Research Analysis and Technology Development:

A vital component of the astrophysics program is the development of new techniques that can be applied to future major missions: the test-beds for these new techniques are the balloons and rockets that are developed and launched from NASA's launch range facilities.

This program also supports technology development that includes detectors covering all wavelengths and fundamental particles, as well as studies in laboratory astrophysics. Examples of these studies could include atomic and molecular data and properties of plasmas explored under conditions approximating those of astrophysical environments.

Investigations submitted to the Astrophysics research program shall explicitly support past, present, or future NASA astrophysics missions. These investigations may include theory, simulation, data analysis, and technology development. The Astrophysics research program and missions are described in Chapter 4.4 of the SMD 2014 Science Plan available at https://science.nasa.gov/about-us/science-strategy.

Proposers may also review the information in the ROSES-19 Astrophysics Research Program Overview for further information about the Astrophysics Research Program.

A.4 The Space Technology Mission Directorate (STMD) is responsible for developing the crosscutting, pioneering, new technologies, and capabilities needed by the agency to achieve its current and future missions.

STMD rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise. STMD employs a merit-based competition model with a portfolio approach, spanning a range of discipline areas and technology readiness levels. By investing in bold, broadly applicable, disruptive technology that industry cannot tackle today, STMD seeks to mature the technology required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost for other government agencies and commercial space activities.

Research and technology development takes place within NASA Centers, at JPL, in academia and industry, and leverages partnerships with other government agencies and international partners. STMD engages and inspires thousands of technologists and innovators creating a community of our best and brightest working on the nation's toughest challenges. By pushing the boundaries of technology and innovation, STMD allows NASA and our nation to remain at the cutting edge. Additional information on STMD can be found at: (http://www.nasa.gov/directorates/spacetech/about_us/index.html).

Areas of Interest – POC: Damian.Taylor@nasa.gov
STMD expands the boundaries of the aerospace enterprise by rapidly developing, demonstrating, and infusing revolutionary, high-payoff technologies through collaborative partnerships. STMD employs a merit-based competition model with a portfolio approach, spanning a wide range of space technology discipline areas and technology readiness levels. Research and technology development takes place at NASA Centers, academia, and industry, and leverages partnerships with other government agencies and international partners.

STMD plans future investments to support the following strategic thrusts:

- ***Go***: *Rapid, Safe, & Efficient Space Transportation*
    - Provide safe, affordable, and routine access to space
    - Provide cost-efficient, reliable propulsion for long duration missions
    - Enable significantly faster, more efficient deep space missions
- ***Land***: *Expanded Access to Diverse Surface Destinations*
    - Safely and precisely deliver humans & payloads to planetary surfaces
    - Increase access to high-value science sites across the solar system
    - Provide efficient, highly-reliable sample return reentry capability
- ***Live***: *Sustainable Living and Working Farther from Earth*
    - Provide in-space habitation and enable humans to live on other planets
    - Provide efficient/scalable infrastructure to support exploration at scale
    - Providing ability to safely explore and investigate high-value sites
- ***Explore***: *Transformative Missions and Discoveries*
    - Expand access to new environments, sites, and resources
    - Develop new means of observation, exploration, and characterization
    - Enable new mission operations and increased science data

Current space technology topics of particular interest include:

- Autonomous in-space assembly of structures and spacecraft
- Methods for space and in space manufacturing
- Ultra-lightweight materials for space applications
- Materials, structures and mechanisms for extreme environments (low and high temperatures, radiation, etc.).
- Resource prospecting, mining, excavation, and extraction of in situ resources. Efficient in situ resource utilization to produce items required for long-duration deep space missions including fuels, water, oxygen, food, nutritional supplements, pharmaceuticals, building materials, polymers (plastics), and various other chemicals
- High performance space computing
- Smart habitats
- Extreme environment (including cryogenic) electronics for planetary exploration
- Advanced robotics for extreme environment sensing, mobility, manipulation and repair
- Advanced power generation, storage, and distribution for deep space missions and surface operations
- Advanced entry, decent, and landing systems for planetary exploration including materials response models and parachute models
- Radiation modeling, detection and mitigation for deep space crewed missions
- Biological approaches to environmental control, life support systems and manufacturing
- Autonomous systems for deep space missions
- Low size, weight, and power components for small spacecraft including high-bandwidth communication from space to ground, inter-satellite communication, relative navigation and control for swarms and constellations, precise pointing systems, power generation and energy storage, thermal management, system autonomy, miniaturized instruments and sensors, and in-space propulsion
- Technologies that take advantage of small launch vehicles and small spacecraft to conduct more rapid and lower-cost missions
- Advancements in engineering tools and models that support Space Technology advancement and development

Applicants are strongly encouraged to familiarize themselves with the roadmap document most closely aligned with their space technology interests. The roadmap documents may be downloaded at the following link: http://www.nasa.gov/offices/oct/home/roadmaps/index.html. Please note, however, that the 2015 technology taxonomy (outline structure for the roadmaps) currently found under this link is under revision. The 2020 revised technology taxonomy will be uploaded by 30 September 2019 under the same link.

NASA STMD's current year version of the NASA Research Announcement (NRA) entitled, "Space Technology Research, Development, Demonstration, and Infusion" has been posted on the NSPIRES web site at http://nspires.nasaprs.com(select "Solicitations" and then "Open Solicitations"). The NRA provides detailed information on specific proposals being sought across STMD program.

A.5 NASA Centers Areas of Interest

Examples of Center research interest areas include these specific areas from the following Centers. If no POC is listed in the Center write-up and contact information is needed, please contact the POC listed in Appendix D for that Center and request contacts for the research area of interest.

A.5.1 Ames Research Center (ARC)

POC: Krisstina Wilmoth (krisstina.wilmoth@nasa.gov)

Ames Research Center (ARC) enables exploration through selected development, innovative technologies, and interdisciplinary scientific discovery. Ames provides leadership in the following areas: astrobiology; small satellites; entry decent and landing systems; supercomputing; robotics and autonomous systems; life Sciences and environmental controls; and air traffic management.

- Entry systems: *Safely delivering spacecraft to Earth & other celestial bodies*
- Supercomputing: *Enabling NASA's advanced modeling and simulation*
- NextGen air transportation: *Transforming the way we fly*
- Airborne science: *Examining our own world & beyond from the sky*
- Autonomy & robotics: *Enabling complex air and space missions, and complementing humans in space*
- Low-cost missions: *Enabling high value science to low Earth orbit, the moon and the solar system*
- Biology & astrobiology: *Understanding life on Earth and in space*
- Exoplanets: *Finding worlds beyond our own*
- Autonomy & robotics: *Complementing humans in space*
- Lunar science: *Rediscovering our moon, searching for water*
- Human factors: *Advancing human-technology interaction for NASA missions*
- Wind tunnels**:** *Testing on the ground before you take to the sky*

Additional Center core competencies include:

- Space Sciences
- Applied Aerospace and Information Technology
- Biotechnology
- Synthetic biology.
- Biological Sciences
- Earth Sciences
- High Performance Computing,
- Intelligent Systems
- Quantum Computing
- Nanotechnology-electronics and sensors.
- Small Spacecraft and Cubesats
- Airspace Systems
- Augmented Reality
- Digital materials

A.5.2 Armstrong Flight Research Center (AFRC)

POC: Dave Berger, dave.e.berger@nasa.gov

AFRC's competencies include:
Autonomy (Collision Avoidance, Separation assurance, formation flight, peak seeking control)
(POC: Jack Ryan, AFRC-RC)

- Adaptive Control
  (POC: Curt Hanson, AFRC-RC)
- Hybrid Electric Propulsion
  (POC: Starr Ginn, AFRC-R)
- Control of Flexible Structures using distributed sensor feedback
  (POC: Marty Brenner, AFRC-RS; Peter Suh, AFRC-RC)
- Supersonic Research (Boom mitigation and measurement)
  (POC: Ed Haering, AFRC-RA)
- Supersonic Research (Laminar Flow)
  (POC: Dan Banks, AFRC-RA)
- Environmental Responsive Aviation
  (POC: Mark Mangelsdorf, AFRC-RS)
- Hypersonic Structures & Sensors
  (POC: Larry Hudson, AFRC-RS)
- Large Scale Technology Flight Demonstrations (Towed Glider)
  (POC: Steve Jacobson, AFRC-RC)
- Aerodynamics and Lift Distribution Optimization to Reduce Induced Drag
  (POC: Al Bowers, AFRC-R)

A.5.3 Glenn Research Center (GRC), POC: Mark David Kankam, Ph.D. mark.d.kankam@nasa.gov

Research and technology, and engineering engagements comprise GRC's competencies including:

- Acoustics / Propulsion Acoustics
- Advanced Energy (Renewable Wind and Solar, Coal Energy and Alternative Energy)
- Advanced Microwave Communications
- Networks, Architectures and Systems Integration
- Intelligent Systems-Smart Sensors and Electronic Systems Technologies
- Aeronautical and Space Systems Analysis
- Electrified Aircraft
- Computer Systems and Networks
- Electric (Ion) Propulsion
- Fluid and Cryogenic Systems / Thermal Systems
- Growth of Ice on Aircraft
- Aviation Safety Improvements
- Instrumentation, Controls and Electronics
- Fluids, Computational Fluid Dynamics (CFD) and Turbomachinery
- Materials and Structures, including Mechanical Components and Lubrication
- Mechanical and Drive Systems (Shape Memory Alloys-Base Actuation)
- Computational Modeling

- Microgravity Fluid Physics, Combustion Phenomena and Bioengineering
- Nanotechnology
- Photovoltaics, Electrochemistry-Physics, and Thermal Energy Conversion
- Propulsion System Aerodynamics
- Power Architecture, Generation, Storage, Distribution and Management
- Urban Air Mobility (UAM)
- Systems Engineering

The above engagement areas relate to the following key GRC Areas of Expertise:

- Aircraft Propulsion
- Communications Technology and Development
- Space Propulsion and Cryogenic Fluids Management
- Power, Energy Storage and Conversion
- Materials and Structures for Extreme Environment
- Physical Sciences and Biomedical Technologies in Space

A.5.4 Goddard Space Flight Center (GSFC), POC: James L. Harrington, james.l.harrington@nasa.gov

GSFC's competencies include:

Applied Engineering and Technology Directorate: POC: Danielle Margiotta, Danielle.V.Margiotta@nasa.gov

- **Advanced Manufacturing** - facilitates the development, evaluation, and deployment of efficient and flexible additive manufacturing technologies. (ref: NAMII.org)
- **Advanced Multi-functional Systems and Structures** - novel approaches to increase spacecraft systems resource utilization
- **Micro - and Nanotechnology - Based Detector Systems** - research and application of these technologies to increase the efficiency of detector and optical systems
- **Ultra-miniature Spaceflight Systems and Instruments** - miniaturization approaches from multiple disciplines - materials, mechanical, electrical, software, and optical - to achieve substantial resource reductions
- **Systems Robust to Extreme Environments** - materials and design approaches that will preserve designed system properties and operational parameters (e.g. mechanical, electrical, thermal), and enable reliable systems operations in hostile space environments.
- **Spacecraft Navigation Technologies**
  - Spacecraft GNSS receivers, ranging crosslink transceivers, and relative navigation sensors
  - Optical navigation and satellite laser ranging
  - Deep-space autonomous navigation techniques
  - Software tools for spacecraft navigation ground operations and navigation analysis
  - Formation Flying
- **Automated Rendezvous and Docking (AR&D) techniques**
  - Algorithm development

- Pose estimation for satellite servicing missions
- Sensors (e.g., LiDARs, natural feature recognition)
- Actuation (e.g., micro propulsion, electromagnetic formation flying)

- **Mission and Trajectory Design Technologies**
  - Mission design tools that will enable new mission classes (e.g., low thrust planetary missions, precision formation flying missions)
  - Mission design tools that reduce the costs and risks of current mission design methodologies
  - Trajectory design techniques that enable integrated optimal designs across multiple orbital dynamic regimes (i.e. earth orbiting, earth-moon libration point, sun-earth libration point, interplanetary)
- **Spacecraft Attitude Determination and Control Technologies**
  - Modeling, simulation, and advanced estimation algorithms
  - Advanced spacecraft attitude sensor technologies (e.g., MEMS IMU's, precision optical trackers)
  - Advanced spacecraft actuator technologies (e.g. modular and scalable momentum control devices, 'green' propulsion, micropropulsion, low power electric propulsion)
- **CubeSats** - Participating institutions will develop CubeSat/Smallsat components, technologies and systems to support NASA technology demonstration and risk reduction efforts. Student teams will develop miniature CubeSat/Smallsat systems for: power generation and distribution, navigation, communication, on-board computing, structures (fixed and deployable), orbital stabilization, pointing, and de-orbiting. These components, technologies and systems shall be made available for use by NASA for integration into NASA Cubesat/Smallsats. They may be integrated into complete off-the-shelf "CubeSat/Smallsat bus" systems, with a goal of minimizing "bus" weight/power/volume/cost and maximizing available "payload" weight/power/volume. NASA technologists will then use these components/systems to develop payloads that demonstrate key technologies to prove concepts and/or reduce risks for future Earth Science, Space Science and Exploration/Robotic Servicing missions. POC: Thomas P. Flatley (Thomas.P.Flatley@nasa.gov).

- **On-Orbit Multicore Computing** - High performance multicore processing for advanced automation and science data processing on spacecraft. There are multiple multicore processing platforms in development that are being targeted for the next generation of science and exploration missions, but there is little work in the area of software frameworks and architectures to utilize these platforms. It is proposed that research in the areas of efficient inter-core communications, software partitioning, fault detection, isolation & recovery, memory management, core power management, scheduling algorithms, and software frameworks be done to enable a transition to these newer platforms. Participating institutions can select areas to research and work with NASA technologists to develop and prototype the resulting concepts. POC: Alan Cudmore (Alan.p.cudmore@nasa.gov).

- **Integrated Photonic components and systems** - Integrated photonic components and systems for Sensors, Spectrometers, Chemical/biological sensors, Microwave, Sub-millimeter and Long-Wave Infra-Red photonics, Telecom- inter and intra satellite communications.

- **Quantum computing**

- **Artificial intelligence and machine learning**

- **(Big) data analytics**

- **Radiation Effects and Analysis**
  - Flight validation of advanced event rate prediction techniques
  - New approaches for testing and evaluating 3-D integrated microcircuits and other advanced microelectronic devices
  - End-to-end system (e.g., integrated component level or higher) modeling of radiation effects
  - Statistical approaches to tackle radiation hardness assurance (i.e., total dose, displacement damage, and/or single-event effects) for high-risk, low-cost missions.

Sciences and Exploration Directorate POC: Blanche Meeson, Blanche.W.Meeson@nasa.gov

The Sciences and Exploration Directorate at NASA GSFC (http://science.gsfc.nasa.gov) is the largest Earth and space science research organization in the world. Its scientists advance understanding of the Earth and its life-sustaining environment, the Sun, the solar system, and the wider universe beyond. All are engaged in the full life cycle of satellite missions and instruments from concept development to implementation, analysis and application of the scientific information, and community access and services.

- The **Earth Sciences Division** (ESD) plans, organizes, evaluates, and implements a broad program of research on our planet's natural systems and processes. Major focus areas include climate change, severe weather, the atmosphere, the oceans, sea ice and glaciers, and the land surface. To study the planet from the unique perspective of space, the ESD develops and operates remote-sensing satellites and instruments. ESD analyzes observational data from these spacecraft and make it available to the world's scientists and policy makers. The Division conducts extensive field campaigns to gather data from the surface and airborne platforms. The Division also develops, uses, and assimilates observations into models that simulate planetary processes involving the water, energy, and carbon cycles at multiple scales up to global. POC: Eric Brown de Colstoun (eric.c.browndecolsto@nasa.gov).
- The **Astrophysics Science Division** conducts a broad program of research in astronomy, astrophysics, and fundamental physics. Individual investigations address issues such as the nature of dark matter and dark energy, which planets outside our solar system may harbor life, and the nature of space, time, and matter at the edges of black holes. Observing photons, particles, and gravitational waves enables researchers to probe astrophysical objects and processes. Researchers develop theoretical models, design experiments and hardware to test theories, and interpret and evaluate observational data. POC: Rita Samburna (Rita.m.Sambruna@nasa.gov).
- The **Heliophysics Science Division** conducts research on the Sun, its extended solar-system environment (the heliosphere), and interactions of Earth, other planets, small bodies, and interstellar gas with the heliosphere. Division research also encompasses Geospace, Earth's magnetosphere and its outer atmosphere, and Space Weather—the important effects that heliospheric disturbances have on spacecraft and terrestrial systems. Division scientists develop spacecraft missions and instruments, systems to manage and disseminate heliophysical data, and theoretical and computational models to interpret the data. Possible heliophysics-related research include: advanced software environments and data-mining strategies to collect, collate and analyze data relevant to the Sun and its effects on the solar system and the Earth ("space weather"); and advanced computational techniques, including but not limited to parallel architectures and the effective use of graphics processing units, for the simulation of magnetized and highly dynamic plasmas and neutral gases in the heliosphere. POC: Doug Rabin (Douglas.Rabin@nasa.gov).

- The **Solar System Exploration Division** builds science instruments and conducts theoretical and experimental research to explore the solar system and understand the formation and evolution of planetary systems. Laboratories within the division investigate areas as diverse as astrochemistry, planetary atmospheres, extrasolar planetary systems, earth science, planetary geodynamics, space geodesy, and comparative planetary studies. To study how planetary systems form and evolve, division scientists develop theoretical models and experimental research programs, as well as mission investigations and space instruments to test them. The researchers participate in planetary and Earth science missions, and collect, interpret, and evaluate measurements. *POC: Brook Lakew (Brook.Lakew@nasa.gov)*

- **Quantum computing:** Quantum computing is based on quantum bits or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. As such, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer. *POC: Mike Little (m.m.little@nasa.gov)*

- **Artificial intelligence and machine learning**: Artificial Intelligence (AI) is a collection of advanced technologies that allows machines to think and act, both humanly and rationally, through sensing, comprehending, acting and learning. AI's foundations lie at the intersection of several traditional fields - Philosophy, Mathematics, Economics, Neuroscience, Psychology and Computer Science. Current AI applications include big data analytics, robotics, intelligent sensing, assisted decision making, and speech recognition just to name a few. *POCs: Mark Carroll (mark.carroll@nasa.gov) across the entire organization and in Heliophysics Barbara Thompson (Barbara.j.thompson@nasa.gov)*

- **(Big) data analytics:** Data Analytics, including Data Mining and Pattern Recognition for Science applications and with special emphasis on:
  - Quantification of uncertainty in inference from big data
  - Experiment design to create data that is AI/ML ready and robust against misleading correlations
  - Methods for prediction of new discovery spaces
  - Strength of evidence and reproducibility in inference from big data

  POC: Mark Carroll (mark.carroll@nasa.gov)

Scientists in all four divisions publish research results in the peer-reviewed literature, participate in the archiving and pubic dissemination of scientific data, and provide expert user support.

A.5.5 Jet Propulsion Laboratory (JPL), POC: Linda Rodgers, linda.l.rodgers@jpl.nasa.gov

JPL is NASA's sole Federally-Funded Research and Development Center, and is managed and operated by the California Institute of Technology (Caltech). JPL's areas of expertise include:

- Solar System Science

  Planetary Atmospheres and Geology

  Solar System characteristics and origin of life

  Primitive (1) solar systems bodies

Lunar (9) science
Preparing for returned sample investigations

- Earth Science
  Atmospheric composition and dynamics (Atmospheric Dynamics
  Land and solid earth processes (Solid Earth Processes
  Water and carbon cycles, Carbon Cycles, Water Cycles
  Ocean and ice
  Earth analogs to planets, Earth Analog
  Climate Science

- Astronomy and Fundamental Physics
  Origin, evolution, and structure of the universe, Origin Universe, Evolution Universe, Structure Universe
  Gravitational astrophysics and fundamental physics
  Extra-solar planets: Exoplanets; Star formation; Planetary formation
  Solar and Space Physics
  Formation and evolution of galaxies; Formation Galaxies; Evolution Galaxies

- In-Space Propulsion Technologies
  Chemical propulsion
  Non-chemical propulsion
  Advanced propulsion technologies
  Supporting technologies
  Thermal Electric Propulsion
  Electric Propulsion

- Space Power and Energy Storage
  Power generation
  Energy storage
  Power management & distribution
  Cross-cutting technologies
  Solar power, Photovoltaic
  Tethers
  Radioisotope
  Thermoelectric

- Robotics, Tele-Robotics, and Autonomous Systems
  Sensing (Robotic Sensing)
  Mobility
  Manipulation technology
  Human-systems interfaces
  Autonomy
  Autonomous rendezvous & docking
  Systems engineering
  Vision

Virtual reality
Telepresence
Computer Aided

- Communication and Navigation
  Optical communications & navigation technology
  Radio frequency communications, Radio Technologies
  Internetworking
  Position navigation and timing
  Integrated technologies
  Revolutionary concepts
  Communication technology
  Antennas
  Radar
  Remote Sensing
  Optoelectronics

- Human Exploration Destination Systems
  In situ resource utilization and Cross-cutting systems

Science Instruments, Observatories and Sensor Systems
Science Mission Directorate Technology Needs
Remote Sensing instruments/Remote Sensing Sensors
Observatory technologies
In-situ instruments, Sensor technologies
Sensors
In situ technologies
Instrument technologies
Precision frequency
Precision timing

- Entry, Descent and Landing Systems
  Aerobraking, Aerocapture and entry system; Descent; Engineered materials; Energy generation and storage; Propulsion; Electronics, devices and sensors; Nanotechnology; Microtechnology; Microelectronics; Microdevice; Orbital Mechanics; & Spectroscopy.
- Modeling, Simulation, Information Technology and Processing
  Flight and ground computing; Modeling; Simulation; Information processing
- Materials, Structures, Mechanical Systems and Manufacturing
  Materials; Structures; Mechanical systems; Cross cutting
- Thermal Management Systems
  Cryogenic systems; Thermal control systems (near room temperature); Thermal protection systems

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Other Research Areas

Small Satellite
Small Satellite Technologies
Balloons
Radio Science
MEMS
Advanced High Temperature
Spectroscopy
Magnetosphere
Plasma Physics
Ionospheres
Ground Data Systems
Laser
Drills
High Energy Astrophysics
Solar physics
Interstellar Astrophysics
Interstellar Medium
Astrobiology
Astro bio geochemistry
Life Detection
Cosmo chemistry
Adaptive Optics
Artificial Intelligence

A.5.6 Johnson Space Center (JSC)

POC: Kamlesh Lulla, kamlesh.p.lulla@nasa.gov

JSC's competencies include:

Active Thermal Control

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

ECLSS

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

EVA

- Portable Life Support System
- Power, Avionics and Software

- Pressure Garment

Entry, Descent, and Landing

- Innovative, Groundbreaking, and High Impact Developments in Spacecraft GN&C Technologies
- Deployable Decelerator Technologies
- High-Fidelity Parachute Fluid/Structure Interaction
- Mechanical Reefing Release Mechanism for Parachutes
- Next Generation Parachute Systems & Modeling
- Precision Landing & Hazard Avoidance Technologies
- Regolith – Rocket Plume Interaction: In-situ Measurements to Enable Multiple Landings at the Same Site
- Optical / Vision-Based Navigation for EDL Applications
- Sensors, including those embedded in thermal protection systems and proximity operations and landing
- Additive Manufacturing for Thermal Protection Systems
- Advanced Materials and Instrumentation for Thermal Protection Systems
- Predictive Material Modeling

Energy Storage technologies

- Batteries, Regenerative Fuel cells

In-Situ Resource Utilization

- Lunar/Mars regolith processing (Regolith collection and drying; Water collection and processing, water electrolysis)
- Mars atmosphere processing (CO2 collection; Dust filtering; Solid Oxide CO2 electrolysis; Sabatier; Reverse water gas shift)
- Methane/Oxygen liquefaction and storage

In-space propulsion technologies

Autonomy and Robotics

- Biomechanics
- Crew Exercise
- Human Robotic interface
- Robotics and TeleRobotics
- Simulation and modeling

Autonomous Rendezvous and Docking

- Integrated Solutions offering new vehicle & mission integration/architectural approaches
- Common Components solutions and strategies shared/used across attachment systems
- Strategies for docking system vehicle integration in the interest of mass savings and commonality of components
- Integration of Docking system into mobile and stationary surface assets

- Simplification of Soft Capture System Attenuation: less complex and lighter systems supporting vehicle assembly.
- Soft Capture Alignment Method Study: Studies and documents performance differences between peripheral and probe cone type SCS systems
- Surface Systems incorporating descent/ascent and surface environments requirements, (dust, gravity, crew transfer…)
- Low Cost / Low SWaP LIDAR Sensors
- Vision-Based Relative Navigation for RPOD

Computer Human Interfaces (CHI)

CHI - Human System Integration

- Human Computer Interaction design methods (Multi-modal and Intelligent Interaction) and apparatuses
- Human Systems Integration, Human Factors Engineering: state of the art in Usability and performance assessment methods and apparatus.
- Humans Systems Integration Inclusion in Systems Engineering
- Human-in-the-loop system data acquisition and performance modeling

CHI - Informatics

- Crew decision support systems
- Advanced Situation Awareness Technologies
- Intelligent Displays for Time-Critical Maneuvering of Multi-Axis Vehicles
- Intelligent Response and Interaction System
- Exploration Space Suit (xEMU) Informatics
- Graphic Displays to Facilitate Rapid Discovery, Diagnosis and Treatment of Medical Emergencies
- Imaging and information processing
- Audio system architecture for Exploration Missions

CHI - Audio

- Array Microphone Systems and processing
- Audio Compression algorithms implementable in FPGAs.
- COMSOL Acoustic modeling
- Front end audio noise cancellation algorithms implementable in FPGAs-example Independent Component Analysis
- Large bandwidth (audio to ultra-sonic) MEMs Microphones
- Sonification Algorithms implementable in DSPs/FPGAs
- Far-Field Speech Recognition in Noisy Environments

CHI - Imaging and Display

- Lightweight/low power/radiation tolerant displays
- OLED Technology Evaluation for Space Applications
- Radiation tolerant Graphics Processing Units (GPUs)
- Scalable software-implementable graphics processing unit

- Radiation-Tolerant Imagers
- Immersive Imagery capture and display
- H265 Video Compression
- Ultra High Video Compressions
- A Head Mounted Display Without Focus/Fixation Disparity
- EVA Heads-Up Display (HUD) Optics

Wearable Technology

- Tattooed Electronic Sensors
- Wearable Audio Communicator
- Wearable sensing and hands-free control
- Wearable Sensors and Controls

Wireless and Communications Systems

- Computational Electromagnetics (CEM) Fast and Multi-Scale Methods/Algorithms
- EPCglobal-type RFID ICs at frequencies above 2 G
- Radiation Hardened EPCglobal Radio Frequency Identification (RFID) Readers
- Robust, Dynamic Ad hoc Wireless Mesh Communication Networks
- Wireless Energy Harvesting Sensor Technologies
- Flight and Ground communication systems

Radiation and EEE Parts

- Mitigation and Biological countermeasures
- Monitoring
- Protection systems
- Risk assessment modeling
- Space weather prediction

A.5.7 Kennedy Space Center (KSC)

POC Jose Nunez, jose.l.nunez@nasa.gov

KSC's competencies include:

- **HEOMD – Commercial Crew systems development and ISS payload and flight experiments**
- Environmental and Green Technologies
- Health and Safety Systems for Operations
- Communications and Tracking Technologies
- Robotic, automated and autonomous systems and operations
- Payload Processing & Integration Technologies (all class payloads)
- R&T Technologies on In-Space Platforms (e.g., ISS, Gateway, Human Habitats)
- Damage-resistant and self-healing materials
- Plant Research and Production
- Water/nutrient recovery and management

- Plant habitats and Flight Systems
- Food production and waste management
- Robotic, automated and autonomous food production
- Robotic, automated and autonomous food production
- Damage-resistant and self-healing materials
- Automated and autonomous detection and repair
- Propulsion: Chemical Propulsion flight integration (human transportation)
- Space Environments Test: Right/West Altitude Chamber
- Launch technologies including propellant management, range & communications
- Vehicle, payload and flight science experiment integration and testing
- Landing & recovery operations
- Biological sciences (Plant research & production)
- Destination systems including ISRU, surface construction & dust mitigation
- Autonomous/robotic (unmanned) surface systems and operations
- Water resource utilization technologies
- Logistics reduction technologies

NOTE:

1. The above R&T Focus Areas are described in the KSC R&T Portfolio Data Dictionary

A.5.8 Langley Research Center (LaRC)

LaRC POC: Dr. Garnise Dennis, garnise.a.dennis@nasa.gov

LaRC's competencies include:

- Intelligent Flight Systems (POC: Charles "Mike" Fremaux 757-864-1193)
- Atmospheric Characterization – Active Remote Sensing (POC: Allen Larar 757.864.5328)
- Systems Analysis and Concepts - Air Transportation System Architectures & Vehicle Concepts (POC: Phil Arcara 757.864.5978)
- Advanced Materials & Structural System – Advanced Manufacturing (POC: David Moore 757-864-9169)
- Aerosciences - Trusted Autonomy (POC: Charles "Mike" Fremaux 757-864-1193)
- Entry, Decent & Landing - Robotic Mission Entry Vehicles (POC: Ron Merski – 757-864-7539)
- Measurement Systems - Advanced Sensors and Optical Measurement (POC: Tom Jones 757-864-4903)

A.5.9 Marshall Space Flight Center (MSFC)

POC: Frank Six, frank.six@nasa.gov

MSFC's competencies include:

Propulsion Systems

- Launch Propulsion Systems, Solid & Liquid
- In Space Propulsion (Cryogenics, Green Propellants, Nuclear, Fuel Elements, Solar-Thermal, Solar Sails, Tethers)
- Propulsion Testbeds and Demonstrators (Pressure Systems)
- Combustion Physics
- Cryogenic Fluid Management
- Turbomachinery
- Rotordynamics
- Solid Propellant Chemistry
- Solid Ballistics
- Rapid Affordable Manufacturing of Propulsion Components
- Materials Research (Nano Crystalline Metallics, Diamond Film Coatings)
- Materials Compatibility
- Computational Fluid Dynamics
- Unsteady Flow Environments
- Acoustics and Stability
- Low Leakage Valves

Space Systems

- In Space Habitation (Life Support Systems and Nodes, 3D Printing)
- Mechanical Design & Fabrication
- Small Payloads (For International Space Station, Space Launch System)
- In-Space Asset Management (Automated Rendezvous & Capture, De-Orbit, Orbital Debris Mitigation, Proximity Operations)
- Radiation Shielding
- Thermal Protection
- Electromagnetic Interference
- Advanced Communications
- Small Satellite Systems (CubeSats)
- Structural Modeling and Analysis
- Spacecraft Design (CAD)

Space Transportation

- Mission and Architecture Analysis
- Advanced Manufacturing
- Space Environmental Effects and Space Weather

- Lander Systems and Technologies
- Small Spacecraft and Enabling Technologies (Nanolaunch Systems)
- 3D Printing/Additive Manufacturing/Rapid Prototyping
- Meteoroid Environment
- Friction Stir and Ultrasonic Welding
- Advanced Closed-Loop Life Support Systems
- Composites and Composites Manufacturing
- Wireless Data & Comm. Systems
- Ionic Liquids
- Guidance, Navigation and Control (Autonomous, Small Launch Vehicle)
- Systems Health Management
- Martian Navigation Architecture/Systems
- Planetary Environment Modeling
- Autonomous Systems (reconfiguration, Mission Planning)
- Digital Thread / Product Lifecycle Management (for AM and/or Composites)
- Material Failure Diagnostics

Science

- Replicated Optics
- Large Optics (IR, visible, UV, X-Ray)
- High Energy Astrophysics (X-Ray, Gamma Ray, Cosmic Ray)
- Radiation Mitigation/Shielding
- Gravitational Waves and their Electromagnetic Counterparts
- Solar, Magnetospheric and Ionospheric Physics
- Planetary Geology and Seismology
- Planetary Dust, Space Physics and Remote Sensing
- Surface, Atmospheres and Interior of Planetary Bodies
- Earth Science Applications
- Convective and Severe Storms Research
- Lightning Research
- Data Informatics
- Disaster Monitoring
- Energy and Water Cycle Research
- Remote Sensing of Precipitation

A.5.10 Stennis Space Center (SSC)
POC: Dr. Mitch Krell, mitch.krell@nasa.gov

SSC's competencies include:

- Active and Passive Nonintrusive Remote Sensing of Propulsion Test Parameters
- Intelligent Integrated System Health Management (ISHM) in Rocket Test-Stands
- Advanced Non-Destructive Evaluation Technologies
- Advanced Propulsion Systems Testing
- Cryogenic Instrumentation and Cryogenic, High Pressure, and Ultrahigh Pressure Fluid Systems
- Ground Test Facilities Technology
- Propulsion System Exhaust Plume Flow Field Definition and Associated Plume Induced Acoustic & Thermal Environments
- Vehicle Health Management/Rocket Exhaust Plume Diagnostics

Propulsion Testing

Active and Passive Nonintrusive Remote Sensing of Propulsion Test Parameters

The vast amount of propulsion system test data is collected via single channel, contact, intrusive sensors and instrumentation. Future propulsion system test techniques could employ passive nonintrusive remote sensors and active nonintrusive remote sensing test measurements over wide areas instead of at a few discrete points. Opportunities exist in temperature, pressure, stress, strain, position, vibration, shock, impact, and many other measured test parameters. The use of thermal infrared, ultraviolet, and multispectral sensors, imagers, and instruments is possible through the SSC sensor laboratory.

Intelligent Integrated System Health Management (ISHM) in Rocket Test-Stands

SHM is a capability to determine the condition of every element of a system continuously. ISHM includes detection of anomalies, diagnosis of causes, and prognosis of future anomalies; as well as making available (to elements of the system and the operator) data, information, and knowledge (DIaK) to achieve optimum operation. In this context, we are interested in methodologies to embed intelligence into the various elements of rocket engine test-stands, e.g., sensors, valves, pumps, tanks, etc. Of particular interest is the extraction of qualitative interpretations from sensor data in order to develop a qualitative assessment of the operation of the various components and processes in the system. The desired outcomes of the research are: (1) to develop intelligent sensor models that are self-calibrating, self- configuring, self-diagnosing, and self- evolving (2) to develop intelligent components such as valves, tanks, etc., (3) to implement intelligent sensor fusion schemes that allow assessment, at the qualitative level, of the condition of the components and processes, (4) to develop a monitoring and diagnostic system that uses the intelligent sensor models and fusion schemes to predict future events, to document the operation of the system, and to diagnose any malfunction quickly, (5) to develop architectures/taxonomies/ontologies for integrated system health management using distributed intelligent elements, and (6) to develop visualization and operator interfaces to effectively use the ISHM capability.

Advanced Non-Destructive Technologies

Advances in non-destructive evaluation (NDE) technologies are needed for fitness-for-service evaluation of pressure vessels used in rocket propulsion systems and test facilities. NDE of ultra- high pressure vessels with wall thicknesses exceeding 10 inches require advanced techniques for the detection of flaws that may affect the safe use of the vessels.

Advanced Propulsion Systems Testing

Innovative techniques will be required to test propulsion systems such as advanced chemical engines, single- stage-to-orbit rocket plane components, nuclear thermal, nuclear electric, and hybrids rockets. New and more cost- effective approaches must be developed to test future propulsion systems. The solution may be some combination of computational- analytical technique, advanced sensors and instrumentation, predictive methodologies, and possibly subscale tests of aspects of the proposed technology.

Cryogenic Instrumentation and Cryogenic, High Pressure, and Ultrahigh Pressure Fluid Systems

Over 40 tons of liquefied gases are used annually in the conduct of propulsion system testing at the Center. Instrumentation is needed to precisely measure mass flow of cryogens starting with very low flow rates and ranging to very high flow rates under pressures up to 15,000 psi. Research, technology, and development opportunities exist in developing instruments to measure fluid properties at cryogenic conditions during ground testing of space propulsion systems. Both intrusive and nonintrusive sensors, but especially nonintrusive sensors, are desired.

Ground Test Facilities Technology

SSC is interested in new, innovative ground-test techniques to conduct a variety of required developmental and certification tests for space systems, stages/vehicles, subsystems, and components. Examples include better coupling and integration of computational fluid dynamics and heat transfer modeling tools focused on cryogenic fluids for extreme conditions of pressure and flow; advanced control strategies for non- linear multi-variable systems; structural modeling tools for ground-test programs; low-cost, variable altitude simulation techniques; and uncertainty analysis modeling of test systems.

Propulsion System Exhaust Plume Flow Field Definition and Associated Plume Induced Acoustic & Thermal Environments

Background: An accurate definition of a propulsion system exhaust plume flow field and its associated plume induced environments (PIE) are required to support the design efforts necessary to safely and optimally accomplish many phases of any space flight mission from sea level or simulated altitude testing of a propulsion system to landing on and returning from the Moon or Mars. Accurately defined PIE result in increased safety, optimized design and minimized costs associated with: 1. propulsion system and/or component testing of both the test article and test facility; 2. any launch vehicle and associated launch facility during liftoff from the Earth, Moon or Mars; 3. any launch vehicle during the ascent portion of flight including staging, effects of separation motors and associated pitch maneuvers; 4. effects of orbital maneuverings systems (including contamination) on associated vehicles and/or payloads and their contribution to space environments; 5. Any vehicle intended to land on and return from the surface of the Moon or Mars; and finally 6. The effects of a vehicle propulsion system on the surfaces of the Moon and Mars including the contaminations of those surfaces by plume constituents and associated propulsion system constituents. Current technology status and requirements to optimally accomplish NASA s mission: In general, the current plume technology used to define a propulsion system exhaust plume flow field and its associated plume induced environments is far superior to that used in support of the original Space Shuttle design. However, further improvements of this technology are required: 1. in an effort to reduce conservatism in the current technology allowing greater optimization of any vehicle and/or payload design keeping in mind crew safety through all mission phases; and 2. to support the efforts to fill current critical technology gaps discussed below. PIE areas of particular interest include: single engine and multi-engine plume flow field definition for all phases of any space flight mission, plume induced acoustic environments, plume induced radiative and convective ascent vehicle base heating, plume contamination, and direct and/or indirect plume impingement effects. Current critical technology gaps in needed PIE capabilities include: 1. An accurate analytical prediction tool to define convective ascent vehicle base heating for both single engine and multi- engine vehicle configurations. 2. An accurate analytical prediction tool to define plume induced environments associated with advanced chemical, electrical and nuclear propulsion systems. 3. A validated, user friendly free molecular flow model for defining plumes and plume induced environments for low density external environments that exist on orbit, as well as interplanetary and other planets.

Vehicle Health Management/Rocket Exhaust Plume Diagnostics
A large body of UV-Visible emission spectrometry experimentation is being performed during the 30 or more tests conducted each year on the Space Shuttle Main Engine at SSC. Research opportunities are available to quantify failure and wear mechanisms, and related plume code validation. Related topics include combustion stability, mixture ratio, and thrust/power level. Exploratory studies have been done with emission/absorption spectroscopy, absorption resonance spectroscopy, and laser induced fluorescence. Only a relatively small portion of the electromagnetic spectrum has been investigated for use in propulsion system testing and exhaust plume diagnostics/vehicle health management.

Appendix B: NASA Strategic Approach

B.1 NASA Strategic Plan

The NASA 2018 Strategic Plan focuses on the development of science, technology, engineering, and mathematics (STEM) disciplines along with the engagement of academic institutions and students in accomplishing the vision and mission of NASA. NASA contributes to national efforts for achieving excellence in STEM education through a comprehensive education portfolio implemented by the Office of STEM Engagement, the Mission Directorates, and the NASA Centers. NASA will continue the Agency's tradition of investing in the Nation's education programs and supporting the country's educators who play a key role in preparing, inspiring, exciting, encouraging, and nurturing the young minds of today that will manage and lead the Nation's laboratories and research centers of tomorrow.

<u>NASA Mission:</u>
Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

<u>NASA Strategic Goals:</u>

1. Expand the frontiers of knowledge, capability, and opportunity in space.
2. Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.
3. Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.

<u>NASA Strategic Goals and Objectives Relevant to Education</u>
Objective 1.2: *Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity*.
Objective 2.4: *Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets.*
Objective 3.1: *Attract and advance a highly skilled, competent, and diverse workforce, cultivate an innovative work environment, and provide the facilities, tools, and services.*

B.2 NASA Education Strategic Coordination Framework

NASA will continue the Agency's tradition of investing in the nation's education programs and supporting the country's educators who play a key role in preparing, inspiring, exciting, encouraging, and nurturing the young minds of today who will be the workforce of tomorrow.

<u>NASA will continue to pursue three major education goals</u>:

- Strengthening NASA and the Nation's future workforce
- Attracting and retaining students in science, technology, engineering and mathematics, or STEM, disciplines
- Engaging Americans in NASA's mission. The plan encompasses all education

efforts undertaken by NASA and guides the Agency’s relationships with external education partners.

Appendix C: Definitions

- Center – Refers to one of the nine NASA Centers plus the Jet Propulsion Laboratory (JPL). For purposes of collaboration in NASA EPSCoR, JPL is included in the NASA Center category.
- Cooperative Agreement – An award of federal assistance used to carry out a public purpose of support or stimulation authorized by a law. A cooperative agreement is similar to a grant with the exception that NASA and the award recipient are each expected to substantially involved for the performance of the project. Cooperative agreements are managed pursuant to the policies set forth in 2 CFR Part 200, 2 CFR Part 1800, and the NASA Grant and Cooperative Agreement Manual.
- Directorate – One of NASA's Mission Directorates—Aeronautics Research (ARMD), Human Exploration & Operations (HEOMD), Space Technology (STMD), and Science (SMD).
- Jurisdiction – States or commonwealths eligible to submit proposals in response to this CAN.
- NASA Research Contact – The NASA Research Contact is the primary NASA point of contact during the proposal writing stage for the proposed research area. If the proposer has contacted and received permission from a NASA scientific or technical person, that individual may be listed in the proposal as the NASA Research Contact. Otherwise, the NASA Research Contact is the University Affairs Officer at the Center, or the NASA Mission Directorate contact at NASA Headquarters. (See Appendix D.)
- Partnership – A reciprocal and voluntary relationship between the project personnel and NASA, industry, or other partners, to cooperatively achieve the goals of the proposed research.
- Principal Investigator (PI) – For this EPSCoR CAN, the Principal Investigator is the jurisdiction's EPSCoR director. The Principal Investigator has an appropriate level of authority and is responsible for proper conduct of the research, including appropriate use of funds and administrative requirements such as the submission of the scientific progress reports to the Agency. The PI is the administrator for the proposal.
  - Science-I – For this CAN, one Co-I shall be designated as the Science-I for those cases where the person leading the scientific direction of the proposed work is not the PI. The formally stated PI will still be held responsible for the overall direction of the effort and use of funds.
  - Co-Investigator (Co-I) – A Co-I is a member of the proposal's investigation team who is a critical "partner" for the conduct of the investigation through the contribution of unique expertise and/or capabilities.
  - Co-I/Institutional-PI – A Co-I at an organization other than that of the PI's institution, who is making a major contribution to the proposal and serves as the point of contact at the Co-I's institution, may also be designated as the Co- I/Institutional-PI. For this CAN, the Science-I may also serve as a Co-I/Institutional-PI. In these cases, the individual shall be identified as the

Science- I in the proposal cover page.

- Research area – One of the areas of research interest for the NASA Mission Directorate(s).
- Research Group – A group of researchers that undertakes one of the specific research areas proposed.
- Research Assistant – A student (undergraduate, graduate, or postdoctoral) who receives a research appointment in direct support of the NASA EPSCoR research in the research proposals.
- Technical Monitor – A NASA scientific or technical person designated by the NASA EPSCoR office to monitor the research project.

Appendix D: NASA Points of Contact

D.1 Additional information regarding NASA EPSCoR can be obtained from the following:

Mr. Jeppie R. Compton
Project Manager, NASA EPSCoR Office of STEM Engagement
Bldg. M6-0399, PX-E Kennedy Space Center, FL 32899-0001
Phone: (321) 867-6988
E-mail: Jeppie.R.Compton@nasa.gov

D.2 NASA Research Contacts

Technical and scientific questions about research opportunities in this announcement may be directed to the appropriate contact below. Discussions of research with appropriate NASA Center or JPL personnel are strongly encouraged.

D. 3 NASA Mission Directorate Liaisons

Aeronautics Research Mission Directorate *Karen Rugg* Lead, Communications and Education NASA Headquarters Phone: (202) 358-2197 karen.l.rugg@nasa.gov	Science Mission Directorate *Kristen Erickson* Director, Science Engagement & Partnerships NASA Headquarters Phone: (202) 358-1017 kristen.erickson@nasa.gov
Human Exploration & Operations Mission Directorate *Marc Timm* HEOMD Engineering Program Mgnt NASA Headquarters Phone: (202) 358-0373 marc.g.timm@nasa.gov	Space Technology Mission Directorate *Damian Taylor* SBIR and STTR Mission Directorate Liaison NASA Headquarters Phone: (202) 358-1432 damian.taylor@nasa.gov

D.4 NASA Center Liaisons

Ames Research Center *Krisstina Wilmoth* Education Specialist Phone: (650) 604-6137 krisstina.wilmoth@nasa.gov	Kennedy Space Center *Jeffery A. Kohler* Technology Transfer Office KSC Mail Stop: UB-T Phone: (321) 867-2462 jeffrey.a.kohler@nasa.gov
Armstrong Flight Research Center *Krisstina Wilmoth* Education Specialist Phone: (650) 604-6137 krisstina.wilmoth@nasa.gov	Langley Research Center *Kim Brush* LaRC OSTEM Integration Manager Phone: (757) 864-6454 kimberly.m.brush@nasa.gov
Goddard Space Flight Center *James L. Harrington* Computer Research and Development Phone: (301) 286-4063 james.l.harrington@nasa.gov	Glenn Research Center *Mark David Kankam, Ph.D.* University Affairs Officer Phone: (216) 433-6143 Mark.D.Kankam@nasa.gov
Jet Propulsion Laboratory *Linda Rodgers or Petra Kneissl* University Programs Administrators Linda - Phone: (818) 354-3274 Linda.L.Rodgers@jpl.nasa.gov Petra – Phone: (818) 201-8805 petra.a.kneissl-milanian@jpl.nasa.gov	Marshall Space Flight Center *Norman (Frank) Six* University Affairs Officer Office of Academic Affairs (HS30) Phone: (256) 961-0678 Norman.F.Six@nasa.gov
Johnson Space Center *Kamlesh Lulla* Director, University Research Collaborations and Partnership Office Phone: (281) 483-3065 Kamlesh.P.Lulla@nasa.gov	Stennis Space Center *Mitch Krell, Ph.D.* Data Analysis Phone: (228) 688-1821 mitch.krell@nasa.gov

Appendix E: Proposal and Submission Information

E.1 Proposal Instructions and Requirements

All information needed to respond to this solicitation is contained in this Cooperative Agreement Notice (CAN) and in the companion *NASA Guidebook for Proposers March 2018 Edition* located at
http://www.hq.nasa.gov/office/procurement/nraguidebook/proposer2018.pdf.

Proposers are responsible for understanding and complying with the *NASA Guidebook for Proposers*' procedures for the successful, timely preparation and submission of their proposals. Proposals that do not conform to its standards may be declared noncompliant and rejected without review.

The introductory material, as well as the appendices, of the *NASA Guidebook for Proposers* provide additional information about the entire CAN process, including NASA policies for the solicitation of proposals, guidelines for writing complete and effective proposals, and NASA's general policies and procedures for the review and selection of proposals and for issuing and managing the awards to the institutions that submitted selected proposals.

E.2 Content and Form of the Proposal Submission

- Electronic Proposal Submission

All proposals submitted in response to this CAN must be submitted in a fully electronic form. **No hard copy proposals will be accepted.** Electronic proposals shall be submitted by the authorized organization representative (AOR) at the proposal Principal Investigator's (PI) institution. Electronic submission by the AOR serves as the required original signature by an authorized official of the proposing institution.

Proposers shall submit proposals in response to this CAN via electronic proposal submission through NSPIRES, located at http://nspires.nasaprs.com (see below). NASA plans to use the NSPIRES system to facilitate the review process.

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

- Every institution intending to submit a proposal to NASA in response to this CAN shall be registered in NSPIRES. Registration for the proposal data system shall be performed by an institution's electronic business point-of-contact (EBPOC) having a valid registration with the System for Award Management (SAM) [formerly known as the Central Contractor Registry (CCR)].
- Any institution requesting NASA funds through the proposed investigation shall be listed on the Proposal Cover Page. NASA will not fund institutions that are not included on the Proposal Cover Page.
- Each individual team member named on the proposal's electronic cover page shall be individually registered in NSPIRES.
- Each individual team member named on the proposal's electronic cover page shall specify an institutional affiliation. The institutional affiliation specified shall be the institution through which the team member is participating in the proposed

investigation. If the individual has multiple affiliations, then this institution may be different from the individual's primary employer or preferred mailing address.

Generally, an electronic proposal consists of one or more electronic forms, including an electronic cover page and one or more attachments. The attachments contain all sections of the proposal, including the project description as well as all required and allowed appendices; see the "Proposal Format and Contents" section below for further requirements.

Submission of electronic proposals via NSPIRES requires several coordinated actions from the proposing institution. In particular, when the PI has completed entry of the data requested in the required electronic forms and attachment of the allowed PDF attachments, including the project description section, an official at the PI's institution who is authorized to make such a submission, referred to as the AOR, shall submit the electronic proposal (forms plus attachments). Coordination between the PI and his/her AOR on the final editing and submission of the proposal materials is facilitated through their accounts in NSPIRES. Note that if one individual is acting in both the PI and AOR roles, he/she shall ensure that all steps in the process are taken, including submitting the institution's proposal.

- Proposal Format and Contents

All proposals submitted in response to this CAN shall include the appropriate required electronic forms available through NSPIRES.

The project description and other required sections of the proposal shall be submitted as *SEARCHABLE*, unlocked PDF files that are attached to the electronic submission in NSPIRES. Proposers shall comply with any format requirements specified in this CAN and in the *NASA Guidebook for Proposers,* Section 3. Only appendices/attachments that are specifically requested in either this CAN or in the NASA *Guidebook for Proposers* for Proposers will be permitted; proposals containing additional appendices/attachments may be declared noncompliant. The *NASA Guidebook for Proposers*, Section 3, provides detailed guidelines on the content of proposals applicable to this CAN. Additionally, this CAN's Section 7.0. on Proposal Preparation provides a listing of required content elements.

In the event the information in this CAN is different from or contradicts the information in the *NASA Guidebook for Proposers,* the information in this CAN takes precedence.

Important note on creating PDF files for upload: It is essential that all PDF files generated and submitted meet the NASA requirements below. This will ensure that the submitted files can be transferred into NSPIRES. At a minimum, it is the proposer's responsibility to: (1) ensure that all PDF files are unlocked and that edit permission is enabled – this is necessary to allow NSPIRES to concatenate submitted files into a single PDF document; and (2) ensure that all fonts are embedded in the PDF file and that only Type 1 or TrueType fonts are used. In addition, any proposer who creates files using TeX or LaTeX is required to first create a DVI file and then convert the DVI file to Postscript and then to PDF. See http://nspires.nasaprs.com/tutorials/PDF_Guidelines.pdf for more information on creating PDF documents that are compliant with NSPIRES. PDF files that do not meet the NASA requirements may be declared noncompliant and not submitted to peer review for evaluation.

- Additional Requirement for Budget Format

In addition to the budget summary information provided in NSPIRES:

Cover Page forms: all proposers shall include more detailed budgets and budget justifications, including detailed subcontract/subaward budgets, in a format of their own choosing in the *Budget Justification*. For this CAN, this additional budget must be divided into two parts, the "*Budget Justification: Narrative*" and the "*Budget Justification: Details*," both as described in the *NASA Guidebook for Proposers,* Section 3.18.

The *Budget Justification: Narrative* includes the *Table of Proposed Work Effort* and the description of facilities and equipment, as well as the rationale and basis of estimate for all components of cost including procurements, travel (destination, purpose and number of travelers), publication costs, and all subawards/subcontracts. The *Table of Proposed Work Effort* shall include the names and/or titles of all personnel (including postdoctoral fellows and graduate students, where known) necessary to perform the proposed investigation, regardless of whether these individuals require funding from the current proposal. The number of person-months each person is expected to devote to the project must be given for each year.

The *Budget Justification: Details* shall include the detailed proposed budget including all of the Other Direct Costs, Total Cost Share/Match and Other Applicable Costs specified in the *NASA Guidebook for Proposers*.

A proposer's failure to provide sufficient budget justification and data in the *Budget Justification: Narrative* (including the *Table of Proposed Work Effort*) and the *Budget Justification: Details* will prevent the peer review from appropriately evaluating the cost realism of the proposed effort. A finding by the peer review of "insufficient information to properly evaluate cost realism" shall be considered a proposal weakness. Inconsistent information between these budget descriptions and the proposal text shall also be considered a proposal weakness.

- Submission of Proposals via NSPIRES, the NASA Proposal Data System

In order to submit a proposal via NSPIRES, this CAN requires that the proposer register key data concerning the intended submission with NSPIRES; NSPIRES is accessed at http://nspires.nasaprs.com. Potential applicants are strongly urged to access this site well in advance of the proposal due date(s) of interest to familiarize themselves with its structure and enter the requested identifier information.

It is especially important to note that every individual named on the proposal's electronic *Cover Page* form (see below) as a proposing team member in any role, including Co-Investigators (Co-I's), shall be registered in NSPIRES and that such individuals shall perform this registration themselves; no one may register a second party, even the Principal Investigator of a proposal in which that person is committed to participate. This data site is secure and all information entered is strictly for NASA's use only.

All proposals submitted via NSPIRES in response to this CAN shall include a required electronic *Cover Page* form that is accessed at http://nspires.nasaprs.com. This form comprises several distinct sections: a *Cover Page* that contains the identifier information for the proposing institution and personnel; a *Proposal Summary* that provides an overview of the proposed investigation that is suitable for release through a publicly accessible archive if the proposal is selected; and a *Budget Summary* of the proposed research effort. Unless specified in the program description itself, no other forms are required for proposal submission via NSPIRES. See the *NASA Guidebook for Proposers* for further details.

The required elements of the proposal, including the project description, shall be submitted as one PDF document that is attached to the *Cover Page* using the tools in NSPIRES. The complete proposal is submitted as a single, *SEARCHABLE*, unlocked PDF document that contains the complete proposal, including the project description section and budget justification, assembled in the order provided in this CAN and uploaded using the tools in NSPIRES. One advantage of submitting the proposal as one PDF document is that it is easy to upload.

NSPIRES will provide a list of all elements that make up an electronic proposal, and the system will conduct an element check to identify any item(s) that is (are) apparently missing or incomplete. The element check may produce warnings and/or identify errors. Uploading the proposal in one PDF file is likely to create warnings as part of the element check. Please ignore these warnings since such warnings do not prevent proposal submission.

Proposers are encouraged to begin their submission process early. Tutorials and other NSPIRES help topics may be accessed through the NSPIRES online help site at http://nspires.nasaprs.com/external/help.do. For any questions that cannot be resolved with the available on-line help menus, requests for assistance may be directed by e-mail to nspires- help@nasaprs.com or by telephone to (202) 479-9376, Monday through Friday (except Federal holidays), 8:00 a.m. – 6:00 p.m. Eastern Time.

E.3 Notice of Intent to Propose

A brief Notice of Intent (NOI) to propose is required for the submission of proposals to this CAN. The information contained in an NOI is used for planning purposes and to help expedite the proposal review activities and, therefore, is of considerable value to both NASA and the proposer. NOIs shall be submitted by the jurisdiction NASA EPSCoR Director through NSPIRES (http://nspires.nasaprs.com). Grants.gov does not support NOI submittal. Note that NOIs may be submitted within NSPIRES directly by the proposal's PI; no action by an organization's AOR is required to submit an NOI. The NOI, at a minimum, shall include a clear descriptive title and/or a scientific/technical summary of the anticipated research. The NOI shall:

- Identify the Mission Directorate(s)/Centers with which the proposal will be aligned (if known)
- Identify the areas of expertise required for the research
- Identify the Science-I

E.4 Certifications, Assurances, and Representations

The AOR's signature on the Proposal Cover Page automatically certifies that the proposing organization has read and is in compliance with all certifications, assurances, and representations as detailed in NASA Grant and Cooperative Agreement Manual (GCAM).

Appendix F: Useful Web Sites

- NASA http://www.nasa.govv
- NASA Office of STEM Engagement http://STEM Engagement.nasa.gov
- NASA EPSCoR http://www.nasa.gov/offices/education/programs/national/epscor/home/index.html
- Vision for Space Exploration http://www.nasa.gov/missions/solarsystem/explore_main.html
- NASA Centers & Facilities http://www.nasa.gov/offices/education/centers/index.html
- Guidebook for Proposers Responding to a NASA Research Announcement http://www.hq.nasa.gov/office/procurement/nraguidebook
- NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) http://nspires.nasaprs.com
- NASA Grants and Cooperative Agreement Manual (GCAM) https://prod.nais.nasa.gov/pub/pub_library/srba/documents/Grant_and_CooperativeAgreementManual.pdf
- NPR 5810.1A, Standard Format for NASA Research Announcement and Other Announcements for Grants and Cooperative Agreements https://nodis3.gsfc.nasa.gov/npg_img/N_PR_5810_001A_/N_PR_5810_001A_.pdf
- Electronic Code of Federal Regulations (2 CFR 200, 2 CFR 1800): https://www.ecfr.gov/cgi-bin/text-idx?SID=9c532e98bd83e32de3606f5bcd226be6&mc=true&tpl=/ecfrbrowse/Title02/2cfrv1_02.tpl#200

Appendix G: Research interests from the R3 solicitation

G.1: NASA SMD Planetary Division

Below is the SMD Planetary Science request. There has been no change. Please contact the POC listed in the solicitation for additional information.

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

Two examples of areas of technology development highlighted for an EPSCoR extreme environment call are described below:

A. High-Temperature Subsystems and Components for Long-Duration (months) Surface Operations: Advances in high-temperature electronics and power generation would enable long-duration missions on the surface of Venus operating for periods as long as a year, where the sensors and all other components operate at Venus' surface ambient temperature. These advances are needed for both the long-duration lander and the lander network. Development of high-temperature electronics, sensors, thermal control, mechanisms, and the power sources designed for operating in the Venus ambient would be enabling for future missions.

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

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

C. Extreme Environment Aerobot

- Venus provides an important scientific link to Earth, Solar System formation, and to Exoplanets. This EPSCoR call is made for technology projects, which take into consideration Venus' middle atmosphere conditions and its unique extreme environment. The call concentrates on the challenge to develop an aerial platform that would survive the 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

Reference material:
Further Information on Venus's challenging environment needs, for its exploration, can be found on the Venus Exploration Analysis Group (VEXAG) website: https://www.lpi.usra.edu/vexag /.
"Aerial Platforms for the Scientific Exploration of Venus" report (JPL) Aug 2018.

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

NASA Contact

Name: Adriana Ocampo

- Organization: SMD/Planetary Science
- Work Phone: 202.358.2152
- Cell Phone: 202 372 7058
- Email: adriana.c.ocampo@nasa.gov

Name: Carolyn Mercer

- Organization: SMD/Planetary Science
- Work Phone: 216.433.3411
- Cell Phone: 216.905.1987
- Email: cmercer@nasa.gov

(*) Reference papers:

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

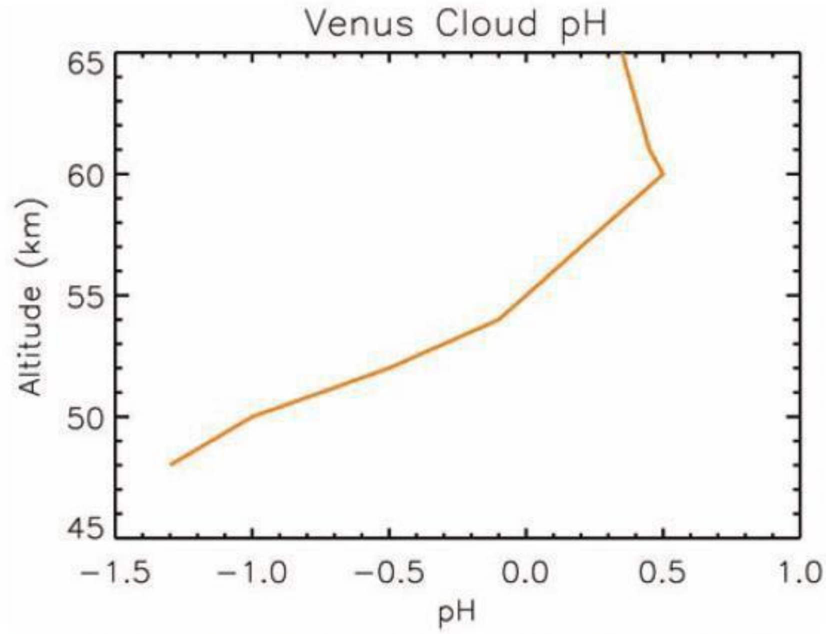

Plate 2. The pH of Venus' clouds as a function of altitude. The relatively water-rich aerosols in the upper cloud have a small range of positive pH, from 0.3 to 0.5. In the lower cloud, with its larger and more water-poor particles, pH can be as low as -1.3. Aerosol H_2SO_4 concentrations were calculated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

G2: Commercial Space Capabilities Office

Commercial Space Research
Research Request Number: CSCO-2021-01

1) Program: Commercial Space Capabilities Office (CSCO)

2) Research Title: Renewal of Previously Selected CSCO R3

3) Research Overview:
NASA is requesting renewal proposals for promising and current CSCO R3 efforts that received an initial R3 award ~ 9 months previously, and as otherwise adhering to *NASA Grant and Cooperative Agreement Manual* section 5.3.3. as follows:

a. **Renewals can only be proposed for CSCO Call Area Awards from Fall 2019 RAPID RESPONSE RESEARCH – CYCLE 2, which are: 18-EPSCoR R3-0022, 18-EPSCoR R3-0025, 18-EPSCoR R3-0034, 18-EPSCoR R3-0040, 18-EPSCoR R3-0053, 18-EPSCoR R3-0057, and 18-EPSCoR R3-0058**.
    i. Proposer may assume that (as applicable) that NASA provided materials will be similar to those in the predecessor award.
    ii. Proposer shall assume that all special conditions (e.g. ITAR) in the predecessor award remain in effect.

b. Proposed renewals shall support the same work of the predecessor award, or work that is a natural extension of and closely related to that work, **not** new projects unrelated to the predecessor award.

c. In addition to required proposal contents, the proposer shall provide the following in their renewal proposal:
    i. Brief statements regarding:
        1. why the work is still relevant, and
        2. how the work satisfies 3) b. above.
        3. why the work should be renewed rather than recompeted
    ii. Show that costs are reasonable and realistic
    iii. State which Co-I/Sci-I personnel and capabilities/facilities would be used to perform the proposed renewal work, and state which (if any) are new. [NOTE: Changes in research personnel supporting the Co-I/Sci-I do not need to be stated]

Proposers are to assume that technically knowledgeable NASA engineers and scientists will be reviewing proposals; accordingly, Proposers shall focus on technical/scientific specifics.

NOTE 1: For this Call, the Technical portion of the proposal may be up to five (5) pages.

NOTE 2: For this Call, due to impacts of COVID-19 and resulting No Cost Extensions of work, submitted proposals may be considered for an immediate R3 award, or at a following R3 award opportunity.

4) NASA Contact
Name: Warren Ruemmele
Organization: Commercial Space Capabilities Office (CSCO)/UA3

Work Phone: 281-483-3662
Cell Phone: 832-221-1367
Email: warren.p.ruemmele@nasa.gov

A NASA Technical Monitor (TM) will be assigned after award, but is anticipated to be the same TM as for the predecessor award.

5) 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 (Proposals shall 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 renewal work.

6) Other NASA-Coordinated Contributions to Proposed Work
The following contributions will be provided to the proposed work that would be in addition to NASA EPSCOR-awarded funding, and in the event of an award.

a. From NASA organization other than EPSCoR
None.

b. From Organization partnering with NASA
None.

7) Intellectual property management:
Proposer shall indicate any intellectual property considerations in its proposal.

8) Additional Agreement Clauses applicable to Cooperative Agreements awarded for this Call Area
None additional.

9) Additional Information:
NASA will support a telecon with the Proposer prior to the submission of proposals, to answer Proposer's questions and discuss each Proposer's anticipated approach towards this Research Request. Contact information is provided in section 4.

NASA CSCO will coordinate support from NASA as needed.

NASA will make resulting materials data available in its MAPTIS database https://maptis.nasa.gov/.

NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee. NASA's goal is for widest possible eventual dissemination of the results from this work, when other restrictions allow.

G2: Commercial Space Capabilities Office (continued)

Commercial Space Research
Research Request Number: CSCO-2021-02

1) **Program:** Commercial Space Capabilities Office (CSCO)

2) **Research Title:** Improvement of Space Suit State of Art

3) **Research Overview:**

NASA is requesting research proposals in this area to further future Moon and Mars exploration and commercialization efforts, by investigating improvements to current space suit state of art.

NASA is seeking proposals for improvements to current space suit design, implementation, and operation. These may apply to any space suit flight phase including: launch/landing Intra Vehicular Activity (IVA), Mars or Moon surface Extra Vehicular Activity (EVA) operation, and in-space EVA. Areas are:

a) Mobility (in spacecraft and on Mars or Lunar surface), ergonomics, fit, unassisted usability (ingress/egress, don/doff, prebreathe)
b) Suit environmental controls and life support (ECLS). In particular for long Suited durations such as for planetary surface EVAs
c) On-suit electronics/elements that aide suited crewmember's autonomy from Earth ground control centers, and/or that improve suited crewmember's performance/health/safety.
d) The Suit system's availability/readiness, maintainability, redundancy, producability, cost reduction. Especially for off-Earth maintenance and repair to enable long-duration surface operations when resupply from Earth is limited (e.g. Mars – 26 months between supply ship visits)
e) Softgoods/wovens materials and fabrication processes.

The proposed work shall:

a) Be projected to be applicable to flight designs (~TRL5) https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf) within a few years
b) Address an identified need and/or shortcoming in current state of art, rather than a "nice to have".
c) Describe the proposing institution's and Co-I/Sci-I's relevant capabilities and prior work. (weblinks preferred. This does not count against the Technical page limit.)
d) Provide references/links when presenting need and/or shortcoming in current state of art.
e) Compare and contrast proposed work against prior and existing work
f) Develop an engineering/scientific design concept and, if/as funding permits: fabricating key portions of the concept to an initial prototypic level, and/or perform testing.
g) Produce a final report and delivery of developed design concept and data
h) **For this Call the Technical portion of the proposal may be up to five (5) pages**. Proposers are to assume that technically knowledgeable NASA engineers and scientists will be reviewing proposals so each proposal shall focus on presenting technical/scientific specifics.

4) NASA Contact

Name: Warren Ruemmele
Organization: Commercial Space Capabilities Office (CSCO)/UA3
Work Phone: 281-483-3662
Cell Phone: 832-221-1367
Email: warren.p.ruemmele@nasa.gov

NASA Technical Monitor (TM) will be assigned after award

5) 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 (Proposals shall 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 contributions have been arranged for the proposed work.

6) Other NASA-Coordinated Contributions to Proposed Work

The following contributions will be provided to the proposed work that will be in addition to NASA EPSCoR-awarded funding, and in the event of an award.

a. **From NASA organization other than EPSCoR**
None.

b. **From Organization partnering with NASA**
None.

7) Intellectual property management:

Proposer shall indicate any intellectual property considerations in its proposal.

8) Additional Agreement Clauses applicable to Cooperative Agreements awarded for this Call Area

None additional.

9) Additional Information:

NASA will support a telecon with the Proposer prior to the submission of proposals, to answer Proposer's questions and discuss each Proposer's anticipated approach towards this research request. Contact information is provided in section 4.

NASA CSCO will coordinate support from NASA as needed.

NASA will make any resulting materials data available in its MAPTIS database https://maptis.nasa.gov/.

NASA welcomes opportunities to co-publish results proposed by EPSCoR awardee. NASA's goal is for widest possible eventual dissemination of the results from this work, when other restrictions allow.

G3: SMD Earth Sciences Division

NASA SMD Earth Science Division (ESD) Research Topics to Address Remote Sensing of Water Quality

SMD requests that EPSCoR include research opportunities focused on better understanding changes in water quality through the use of remote sensing.

Anthropogenic and natural environmental processes can influence water quality. For example, changes in land cover, such as deforestation or agricultural practices, have been linked in with increased erosion and changes in soil nutrient composition which in turn affect sediment, carbon, and nutrient fluxes to inland and coastal systems and water bodies. A large proportion of the global population lives near the coast, and whose livelihoods depend on coastal resources. It is thus imperative to better understand human-related effects on coastal water quality, and water quality impacts on ecological dynamics, ecosystem health, and biological diversity. Understanding changes and the drivers of changes in water quality requires the understanding of processes beyond lakes, rivers, and the coastal ocean; terrestrial and atmospheric processes, such as changes in land use and precipitation patterns, also need to be taken into account. Event-scale phenomena (e.g., hurricanes, wildfires, deforestation, and their frequency and intensity) can also impact water quality.

Remote sensing observations can play a critical role in addressing this intricate problem and have the capability to help resolve landscape processes that drive water quality outcomes. Observations, both from aircraft and satellite platforms, have been widely used to measure water quality parameters, which include chlorophyll-*a* (chl-*a*), colored dissolved organic matter (CDOM), turbidity, temperature, and total suspended sediments (TSS). Also, long term observations of LC and LUC, water stores and fluxes (i.e. precipitation, soil moisture, surface water, etc.) can also be used to understand what changes are occurring at the land surface and how these may influence and/or interact with water quality.

Proposals seeking to respond to this EPSCOR Research Topic shall focus on improving and leveraging the capability of Earth Observing Satellites and NASA airborne campaigns to remotely sense water quality from space, drivers of water quality changes, and/or the application of these capabilities and associated information into the decision making process of stakeholders. NASA also encourages proposals that assess the impacts of water quality on ecosystem and habitat health. Of particular interest is the advancement of the readiness of application science, especially future pertinent NASA satellite missions, such as PACE and SWOT. The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission. PACE science is expected to significantly advance aquatic ecology and biogeochemistry research both in the open ocean and in coastal and inland regions (including estuaries, tidal wetlands, and lakes). In 2020, NASA selected the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Science and Applications Team; more information about PACE applications can be found here. The Surface Water and Ocean Topography (SWOT) satellite will advance our understanding of freshwater fluxes to coastal environments, as well as measuring the size of inland water bodies, providing much needed information about inland water.

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/. In particular, water quality relevant data can be found at https://earthdata.nasa.gov/learn/pathfinders/water-quality-data-pathfinder. Instrument-specific airborne data in addition can be found through the different airborne data sites; examples suitable to this call include:

AVIRIS (Airborne Visible InfraRed Imaging Spectrometer): https://aviris.jpl.nasa.gov/data/get_aviris_data.html

PRISM: (Portable Remote Imaging SpectroMeter) https://prism.jpl.nasa.gov/

Commercial SmallSat Data Acquisition Program (CSDAP): Proposers are also welcome to use, in addition to NASA and non-NASA Earth observing satellite sensors currently in orbit, data acquired by the Commercial SmallSat Data Acquisition Program.

Proposals shall include clear statements as to what the significance and impact of proposed work will be, scientifically and/or to a stakeholder community, and a detailed plan on dissemination and sharing of data, products, and tools where applicable. This research opportunity will not fund the acquisition of new *in situ* data, but rather seeks to take advantage of the large quantities of data that NASA and other entities have already collected over the years (i.e., SeaBASS). Projects including citizen science are also welcome.

Examples of potential topics suitable for the EPSCOR remote sensing of water quality include:

1. Refinement of detection approaches for and drivers of harmful algal blooms
2. Employing remotely sensed water quality information to understand impacts on nearshore ecology and ecosystem health.
3. Impacts of wildfires and other natural hazards/episodic events on inland and coastal water quality.
4. Impacts of land use/change on inland and coastal water quality.
5. Improving description of the link between optical and biogeochemical properties with targeted applications of management.

G4: NASA SMD Biological and Physical Sciences (BPS)

1) Program:
Physical Sciences – Materials Science

2) Research Title:
Extraction of Materials from Regolith

3) Research Overview:
With NASA's renewed efforts to put astronauts on the moon and to develop a persistent human presence on the moon, the ability to utilize in-situ resources is paramount to the success of these future missions. Extraction of materials (e.g. metals, glasses and water ice) from extra-terrestrial regolith is necessary for NASA to be successful in the long term. The extracted materials could be used as feedstock for additive manufacturing processes, to construct habitats and/or other structures, to build infrastructure, for example, roads, walls, and landing pads, or to fabricate tools or other hardware. The water ice from regolith material could be used to augment life support systems for extended stay missions or produce liquid hydrogen and liquid oxygen for propellant production.

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

Proposed studies are expected to generate and test specific hypotheses to the extent possible in a terrestrial lab. Investigations shall be proposed that will 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.

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).

5) BPS Contact:

a. Name: Michael SanSoucie
b. Organization: NASA MSFC / EM41
c. Work Phone: 256-544-5269
d. Email: michael.p.sansoucie@nasa.gov

6) Additional Information:

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

G4: NASA SMD Biological and Physical Sciences (BPS) (continued)

1) (BPS) Program:
Physical Sciences – Complex Fluids

2) Research Title:
Foam Evolution and Stability

3) Research Overview:
Foams are present in many industrial, commercial and personal settings. The drainage of the liquid within foams is dominated by gravity, but other factors contribute towards evolution or aging of the final structure such as capillary pressure, evaporation and phase change. This time dependency impacts the rheology, coarsening and rearrangement of the cellular network and affects the successful utilization of foams for their intended purpose.

4) Research Focus:
While most practical foams are in the category of "dry" foams where the liquid content is less than 1% by volume, these ground-based studies will examine the behavior of foams at liquid contents up to 35 or 40% in order to determine other factors besides gravity that determine the structure, rate of evolution and stability criteria. Foams are comprised of polyhedral cells separated by thin films. In addition, these ground-based studies may also look at the behavior of foams in terms of the following:

- Impact on flow and heat transfer as the foams are stressed in different manners.
- Methods to increase their stability.
- Techniques to generate consistent cellular structure.

Novel methods for non-intrusively probing and characterizing the internal structure of these foams will also be considered.

5) BPS Contact:

a. Name: John McQuillen
b. Organization: NASA Glenn Research Center, Low-Gravity Exploration Technology Branch
c. Work Phone: 216-433-2876
d. Email: john.b.mcquillen@nasa.gov

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

G5: KSC Exploration Systems and Development

I. Research Project Info

1) Research Title: Gas Separation for Sabatier Reactor and other systems

2) Research Overview: Separate products (CH_4 and H_2O) from the reactants (H_2, CO_2) for the Sabatier reaction. The product will come from a reactor at ~350 degrees C. The separation can happen at elevated temperatures or cooler temperatures. The system shall be able to operate autonomously (no maintenance) for up to 18 months.
3) Organization: NASA, UB-E
4) Contact: Elspeth Petersen, Elspeth.petersen@nasa.gov, 321-867-3757
5) Mission Directorate(s) [Involved / Connected]: STMD
6) Intellectual property rights: -N/A
   a. Company information
   b. Desired process
7) Additional Information: N/A

II. Research Project Info

1) Research Title: Need improved VOC scrubbing techniques (addresses Space Crop Production Gap 1.B.2.b.1)

2) Research Overview: NASA has determined gaps in the area of VOC scrubbing for plant growth and crewed environments. While large-scale technology exists for VOC scrubbing in oil and gas and other industrialized applications, we require an effective small-scale VOC scrubber that could operate within limited space using limited power input and be positioned within a controlled environment plant growth chamber or crew quarters.
3) Organization: NASA, UB-A
4) Contact: NASA-KSC, UB-A
5) Mission Directorate(s) [Involved / Connected]: SMD (BPS), HEOMD (AES SCLT Habitation Systems and HRP)
6) Intellectual property rights: Negotiable
   a. Company information
   b. Desired process
7) Additional Information: N/A

III. Research Project Info

1) Research Title: Spaceflight-compatible Recycling of non-edible Biomass (addresses Space Crop Production Gap 1.D.1.0.1)

2) Research Overview: NASA has determined gaps in the area of inedible biomass recycling. Crop plants produce excess biomass that must be broken down into useful components. Finding methods of improving these processes of waste conversion to useful soil-like substrates, biochar, or materials that could be used by the crew for biofuels or additive manufacturing.
3) Organization: NASA, UB-A
4) Contact: NASA-KSC, UB-A
5) Mission Directorate(s) [Involved / Connected]: SMD (BPS), HEOMD (AES SCLT Habitation Systems and HRP)
6) Intellectual property rights: Negotiable
   a. Company information
   b. Desired process
7) Additional Information: N/A

IV. Research Project Info

1) Research Title: Pressure level effects on plant physiology for spaceflight candidate crops (addresses Space Crop Production Gap 2.A.4.b.1)

2) Research Overview: NASA has determined gaps in the area of pressure level effects on the plant physiology of spaceflight-relevant candidate crops. Plant physiology studies need to be conducted within controlled environment growth chambers with variable pressure that are hospitable to plant growth. With this funding line appropriate chambers could be grown, and studies conducted using applicable candidate crops.
3) Organization: NASA, UB-A
4) Contact: NASA-KSC, UB-A
5) Mission Directorate(s) [Involved / Connected]: SMD (BPS), HEOMD (AES SCLT Habitation Systems and HRP)
6) Intellectual property rights: Negotiable
   a. Company information
   b. Desired process
7) Additional Information: N/A

V. Research Project Info

1) Research Title: Improving Ethylene Sensor Technology for Space Crop Production (addresses Space Crop Production Gap 1.A.1.a.1)

2) Research Overview: NASA has determined gaps in the area of ethylene sensing to support space crop production for future exploration missions. We have a need for an ethylene sensor that is small enough to fit within the small confines of a growth chamber, drawing limited power, with data logging capability and remote operation. The material involved would need to be able to withstand periodic wetting and drying events and operate in elevated humidity.
3) Organization: NASA, UB-A
4) Contact: NASA-KSC, UB-A
5) Mission Directorate(s) [Involved / Connected]: SMD (BPS), HEOMD (AES SCLT Habitation Systems and HRP)
6) Intellectual property rights: Negotiable
    a. Company information
    b. Desired process
7) Additional Information: N/A

VI. Research Project Info

1) Research Overview: Research Title: Seed Handling Approaches for Space Crop Production (addresses Space Crop Production Gaps 2.C.1.a.2, 2.C.1.a.4, and 2.C.1.a.1)

2) Research Overview: NASA has gaps in the area of seed handling to support space crop production for future exploration missions. We have a need for a sacrificial seed container, possibly 3-D printed, where seeds could be planted/inserted in a correct orientation, and early germination and growth could occur. There would be a desire to periodically submerge or hydrate this container with water or nutrient solution, and a desire for the container to be consumed by the plant or broken down as the plant grows. There is interest for a seed coating or seed container to provide benefits to survival for seeds that might be stressed by the space environment (e.g. lack of natural convection, space radiation). There is also interest in new approaches to seed sanitization for long duration storage, and seed-specific radiation protection.
3) Organization: NASA, UB-A
4) Contact: NASA-KSC, UB-A
5) Mission Directorate(s) [Involved / Connected]: SMD (BPS), HEOMD (AES SCLT Habitation Systems and HRP)
6) Intellectual property rights: Negotiable
    a. Company information
    b. Desired process
7) Additional Information: N/A

G6: NASA SMD Computational and Information Sciences and Technology Office (CISTO)

Program: Computational and Information Sciences and Technology Office (CISTO) Computational and Technological Advances for Scientific Discovery via AI/ML Modeling and Development Hackathons

SMD requests that NASA EPSCoR include research opportunities in areas of Artificial Intelligence and Machine Learning (AI/ML) Modeling and Development Hackathons. NASA's scientific lines of business include Earth Sciences, Planetary Sciences, Astrophysics, and Heliophysics. While NASA seeks AI/ML solutions to increase science and technology returns from the SMD Science Fleet an additional major component for the design of the awarded Hackathons will be an execution model that clearly provides opportunities for underrepresented communities in NASA SMD AI/ML research and broadening the reach of NASA SMD AI/ML research participation across diverse geographical regions.

There are two primary objectives with a hackathon:

1. Through concentrated effort, enable advances on a scientific investigation via AI/ML algorithms and tools. This can range from the development of a software/code module (function or tool) to processing data to answer scientific questions or developing a method for analyzing the data.
2. Expand collaborations among research scientists, computer scientists and data scientists to find new ways of addressing science questions.

CISTO Artificial Intelligence and Machine Learning (AI/ML) Initiative:
Advent of new computational technologies such as Clouds and Graphical Processing Units (GPUs) for storing and processing massive data sets has significantly increased adoption of AI in the past decade even though many of the AI technologies originated in 1950s. Internet tools and technologies have also enabled ordinary citizens to participate in the scientific process via various Citizen Science applications and games. At the same time, NASA scientists are faced with large volumes of data from various missions on a daily basis. This makes it essential to take advantage of the latest technological and computational advances, as outlined in this call, for their analysis and scientific discovery.

Recent advances in AI infrastructure and tools calls for development of AI algorithms for various, yet unexplored, scientific data *classification, search, prediction, feature selection, and modeling* problems in different NASA scientific areas. Some past work includes classification of supernova to better measure cosmic distances and understand expansion of universe, classification of Planets to better predict probability of life, finding craters on moon, search for gravitational waves, and search for exoplanets. Similar techniques can be applied for finding different phenomena (e.g. feature detection for identifying safe landing sites, finding faint moving objects, etc.), environmental feature recognition (forest patches, water bodies, agriculture fields, etc.), or to other fields such as Earth Science and Heliophysics data. Another topic of interest is to apply AI/ML techniques to NASA data in time domain, or time-series analysis (e.g. when studying solar winds or various Earth observations).

In addition to these techniques often applied on the ground, there are compelling reasons for benefitting from AI capabilities onboard the spacecraft in deep space. Drivers for onboard AI capabilities include data transmission and downlink limitations, the desire to have near real time results (e.g. for spacecraft safety, planetary defense, etc.), or the nature of mission itself (e.g. in interferometry missions an image cube is constructed from data of multiple satellites via complex image registration and reconstruction algorithms).

While new scientific and technology discoveries are at the core of this solicitation; a major desired outcome is to support the diversity and inclusion vision for the agency. An excerpt from the NASA Administrator James Bridenstine communicates a critical view for how collaborative teaming should be designed:

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

Therefore, proposals that will be deemed responsive to this solicitation will design a year of AI/ML education, training, networking and building of machine learning models in close collaboration with NASA project senior science and engineering mentors that target documented science and technology data science case studies with multi-institutional and interdisciplinary teams.

A good proposal design supports; a spring semester (1-2 days) immersive machine learning model education and collaboration activity, followed by a summer (3-5 day) hackathon, followed by a fall semester (1-2 day) hackathon designed to improve results from the summer activity, finalizing with a collaborative final report.

There are two collaborative hackathon models we would like to introduce where NASA has implemented a researched best practice for collaborative machine learning modeling development:

1. **“Hack Weeks as a Model” (https://www.pnas.org/content/115/36/8872)**

Hackathons have become a popular way to bring together a group of people to a true working meeting where they can make substantive progress on a specific problem. The University of Washington has been hosting these events (Hack weeks) for a number of years with a great deal of success (see here for more information: https://www.nccs.nasa.gov/news-events/nccs-highlights/icesat2-hackathon).

The “Hack weeks as a Model” research from University of Washington identifies critical desirable outcomes for interdisciplinary team building and can facilitate broadening participation of underrepresented communities and diverse geographical regions in NASA AI/ML research:

- Education and Training - Tutorials as well as informal and peer learning is often a component. Furthermore, lateral knowledge through collaboration provides an opportunity to learn skills that are not described in papers and software implementations.
- Tool Development - Hack weeks present an opportunity for scientific software developers to meaningfully engage with users and critically evaluate applications to particular scientific issues.
- Community Building - Hack weeks are an opportunity to catalyze community development through a shared interest in solving computational challenges with open source software. They allow computationally minded researchers to break from the isolation of their institutions and spark new collaborations.

- Interdisciplinary Research - Intensive, time-bounded collaborative events are an opportunity to experiment with concepts, questions, and methods that span boundaries within and across disciplines.
- Recruitment and Networking - Hack weeks are a melting pot of participants from academia, government, and industry and provide numerous opportunities for networking. Close collaboration in diverse groups exposes skills that might be suitable for careers outside of a narrow domain.

2. **SMD FDL** - The NASA Science Mission Directorate (SMD) has also implemented a Hackathon model that can serve as an additional reference for proposal design with its development of the Frontier Development Laboratory (FDL) 2020 Program https://frontierdevelopmentlab.org/ that seeks to push the boundaries of what is possible in science and exploration through both the development and application of artificial intelligence (AI) and machine learning (ML) tools. Like the “Hack week as a Model” the Program engages interdisciplinary teams of computer scientists and discipline scientists who work together to solve problems that are important to NASA and humanity’s future. With the FDL model, each research team is made up of four participants (two computer scientists and two domain scientists). The teams are mentored by senior experts with a deep knowledge of the problems. Unlike the “Hack week as a Model” where the tools are developed in one week, the FDL teams perform the tasks in an eight-week time period. We are not suggesting that an eight week Hackathon time period should be proposed, the multi-day, multi-event over a year time frame is more appropriate for the outcomes being sought here. This reference is provided for increasing the understanding of how interdisciplinary teaming is strategically used by two very successful multi-day Hackathon models and serve as a best practice for a proposal response for this Appendix.

A successful summer and fall hackathon plan should typically span multiple days using open science tools (e.g. github, public data repositories, Jupyter notebooks), includes subject matter experts, computer scientists and data scientists. Events can be in person or virtual and participants should be provided with enough resources to fully participate. This can be facilitated with systems such as commercial cloud platforms or Jupyter hub environments, in both cases all necessary data should be pre-loaded into the compute environment so that participants do not have to spend time finding, acquiring and reformatting data. Any required software packages should also be pre-loaded into the compute environment.

There are two proposal category opportunities provided via this research Appendix to execute the modeling development hackathon award:

1. The proposal identifies senior experts with a deep knowledge of a data science case study that is responsive to the CISTO AI/ML Initiative described above where development of AI algorithms for various, yet unexplored, scientific data classification, search, prediction, feature selection, and modeling problems in different NASA scientific areas is identified:
    a. With this proposal category, awardees provide:
        i. Science concept (what is the overarching question to be addressed)
2. The proposal seeks to partner with the identified CISTO point of contact/technical lead? case studies listed later in this document.
    a. With this proposal category, awardees collaborate and are mentored by senior experts with a deep knowledge of the problems identified.

With both of these proposal categories, the proposal shall also respond to the following features:

- Logistics for the event including venue (physical or virtual), support staff (technical and "cat herders"), web services (Git, Jupyter, etc.)
- Advertising and management of participants, which shall explicitly communicate recruitment for participation of underrepresented communities and geographical diversity strategy or established relationships.

NASA will provide for both proposal categories a NASA EPSCoR Technical Monitor to assist with:

1. Training for awardee for hackathon best practices
2. Support for awardee making connections to NASA science mentors
3. Soft guidance through the process

NASA science senior case study expert mentors for hackathon provide:

1. Support for awardee developing answerable science questions in a hackathon framework
2. Support for advertisement of hackathon within the science community

NASA solicits proposals from the community to host a collaborative multi-event hackathon year that facilitates participation for underrepresented minorities and geographical diversity at their institution. Funds from this program may be used to support the development of the event including logistics, setting up compute environment (not for purchasing general purpose equipment), and archiving results post event. Proposers shall identify a NASA scientist or program that the hackathon will support/benefit. Case studies are provided. The GSFC AI Center of Excellence can provide some guidance for the formulation of the hackathon but implementation is the responsibility of the proposers.

The following are case studies facilitated by CISTO for proposers to collaborate with mentors who are senior experts with a deep knowledge of the problems identified.

G6: NASA SMD Computational and Information Sciences and Technology Office (CISTO) (continued)

1) Program: Artificial Intelligence and Machine Learning Capability

2) Research Title: Assessing and qualifying Citizen Science Labeling for Training Data for GLOBE Observer Mosquito and Land Cover protocols improving data quality within the GLOBE Observer community.

3) Research Overview:

NASA GSFC has an unparalleled heritage and commitment to fundamental scientific discovery through spaceflight missions. The use of machine learning is growing in the analysis of data and the construction of data-driven models. Developing training data for supervised machine learning is labor intensive and can be a major factor is the viability and accuracy of models. Since the model developer is typically the same person/team that acquires the labeling of the sample data, they have a general sense of the quality characteristics. However, as more training data is shared, some means of characterizing the quality is needed which would create confidence in the model capability as well as re-use of the data. Quality factors generally can be lumped into two categories:

- Characteristics of the labeling community workforce
- Characteristics of the data used for labeling

A number of problems with training data can reduce the value of their use. Many of these problems are not obvious to the analyst increasing the need for some consistent characterization. For example,

- training data, which is too uniform over trains the model, making it non-responsive to the full range of data that it might be used to analyze.
- Labeling performed by a single individual or uniform group of individuals can result in inherent bias.

Several questions need to be answered for any training data set to make it useful to others.

- Does the community of persons doing the labeling demonstrate inherent bias that might be reflected in the training data?
- How representative is the labeled data of the data to be analyzed, including edge and corner cases?

4) Research Focus:
The research shall propose a means for characterizing the quality of the labeled training data and a tool for quantifying those characteristics. The project shall then develop one, but not more than three, generalizable machine learning tools to perform this analysis and publish the results using a common vocabulary which would allow the analyst to share this information with other users of the model and for others to re-use the training data in an appropriate way. These tools shall be demonstrated against a specific use case. The project shall also explain how this proposed research could be expanded for other use cases.

5) NASA Contact:
a. Name: James Harrington/Michael Little/Ved Chirayath
b. Organization: NASA Goddard Space Flight Center/Ames Research Center
c. Work Phone: 301-286-4063
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6) Commercial Entity (Collaboration Infrastructure Support; AI/ML Training and Education Resources:
a. Microsoft Enterprise Services
b. Contact Name: Damon House, Senior Business Program Manager
c. Work Phone: +1 (425) 705-1576
d. Cell Phone: +1 (703) 628-1017
e. Amazon Web Services NASA Account
f. Contact: aws-nasa-notify@amazon.com

7) Partner Contribution:
GLOBE Observer Land Cover Senior Science Mentor

a. Peder Nelson, Science Lead for the land cover tool in GLOBE Observer mobile app; Nelson, Peder Vernon Peder.Nelson@oregonstate.edu; reference "Automatic land cover classification of geo-tagged field photos by deep learning." *Environmental Modelling & Software* 91 (2017): 127-134. https://doi.org/10.1016/j.envsoft.2017.02.004

GLOBE GO Mosquito Habitat Mapper Dataset Senior Science Mentors

a. Becky Bulger - Rebecca Boger beckyboger@gmail.com
b. Rusty Low rusty_low@strategies.org https://observer.globe.gov/toolkit/mosquito-habitat-mapper-toolkit

c. Additional References from Peter, Becky and Rusty addressing GLOBE Observer citizen science data:

in prep. Low, R., Boger, R. Nelson, P. Soeffing, C., Kimura, M and Ingle, P. Preparing citizen science data for use in research applications: an exploration of GLOBE Observer Mosquito Habitat Mapper Data 2017-2020. To be submitted end of September.

2020 Amos, H., Starke, M., Rogerson, T., Robles, M., Anderson, T., Boger, R., Campbell, B., Low, R., Overoye, D., Taylor, J., Weaver, K., Ferrell, T., Kohl, H., and Schwerin, T. GLOBE Observer Data: 2016-2019. Earth and Space Science 7(8). https://doi.org/10.1029/2020EA001175

2020 Boger, R., Low, R., and Nelson, P. Identifying hurricane impacts on Barbuda using citizen science ground observations, drone photography and satellite imagery. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences; Vol. XLII- 3/W11: 23-28. Gottingen: Copernicus GmbH. DOI:10.5194/isprs-archives-XLII-3-W11-23-2020

2019 Muñoz, J. Boger, R., Dexter, S., Low, R., and Li, J. Image recognition of disease-carrying insects: a system for combating infectious diseases using image classification techniques and citizen science. In Delivering Superior Health and Wellness Management with IoT and Analytics, Springer.

2018 Muñoz, J. Boger, R., Dexter, S., Low, R. and Li J. Image Recognition of Disease-Carrying Insects: A System for Combating Infectious Diseases using Image Classification Techniques and Citizen Science. Proceedings of the 51st Hawaii International Conference on System Sciences.

8) Intellectual Property management

No NASA Partner intellectual property concerns.

9) Additional Information

All publications that result from an awarded EPSCOR study shall acknowledge NASA and the GLOBE Observer Citizen Science Community.

G6: NASA SMD Computational and Information Sciences and Technology Office (CISTO) (continued)

1) Program: Artificial Intelligence and Machine Learning Capability

2) Research Title: Onboard Satellite Fault Diagnosis using Machine Learning

3) Research Overview:

NASA GSFC has an unparalleled heritage and commitment to fundamental scientific discovery through spaceflight missions. Although successful, NASA’s space scientific discovery efforts are sometimes limited by current fault mitigation and resolution techniques, which result in the loss of valuable science data that otherwise would have been retrieved if the fault were managed more gracefully. To address this specific limitation, next-generation autonomous methods for on board fault handling and mitigation need to be considered and developed.

Current onboard fault mitigation techniques utilize *automated* methods, where faults are triggered by canned, pre-determined logic and threshold-based rules, placing the spacecraft or instrument suite in a 'safe mode' state. In a safe mode, the C&DH (command and data handling subsystem) shuts down all non-essential functions and waits for a state exiting command sequence from ground control, after manual fault diagnosis and analysis. In the interim, all science data collection is halted and lost (since scientific instruments are shut down for health & safety reasons). Developing *autonomous* methods for onboard diagnosis of faults using spacecraft housekeeping telemetry data would save valuable science data, along with resources, cost, time due to post analysis of faults, etc.

4) Research Focus:

The research requests proposals to explore is the use of machine learning techniques for onboard diagnosis of spacecraft faults, which will help determine 1) causal structure in telemetry data, 2) context specific considerations for fault diagnosis, and 3) saliencies characterizing anomalies. Proposals shall focus on one of the following research objectives:

a. Is it possible to use machine learning algorithms on labelled telemetry data to classify the following?
    a. fault severity
    b. cause of fault
    c. anomalous faults
b. Is it possible to use machine learning to computationally capture associations in telemetry consistent with and/or exceed subject matter expert (SME) associations? Are these associations useful to diagnosis?
c. Explore the use of Generative Adversarial Networks (GANs) for providing rich data scenarios for fault classification.
d. Explore self-supervised methods for determining causal structure in telemetry faults.
e. Explore non-machine learning based AI methods for fault diagnosis, and/or in support of fault diagnosis.

All algorithms will be tested against SME diagnosis and against user injected faults and anomalies in an interactive simulation environment.

5) NASA Contact:

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b. Organization: NASA Goddard Space Flight Center
c. Work Phone: 781-8356404 (cell, due to remote work)
d. Email: Evana.Gizzi@nasa.gov; Evana13G@gmail.com

6) Commercial Entity (Collaboration Infrastructure Support; AI/ML Training and Education Resources:

a. Microsoft Enterprise Services
b. Contact Name: Damon House, Senior Business Program Manager
c. Work Phone: +1 (425) 705-1576
d. Cell Phone: +1 (703) 628-1017
e. Amazon Web Services NASA Account

f. Contact: aws-nasa-notify@amazon.com

7) Partner Contribution:
No NASA Partner contributions

8) Intellectual Property Management:
No NASA Partner intellectual property concerns

9) Additional Information:
All publications that result from an awarded EPSCOR study shall acknowledge the NASA EPSCoR research award.

G6: NASA SMD Computational and Information Sciences and Technology Office (CISTO) (continued)

1) Program: Artificial Intelligence and Machine Learning Capability

2) Research Title: Application of Machine Learning to High-Resolution Earth System Model Data

3) Research Overview:
The Global Modeling and Assimilation Office (GMAO) uses a Global Circulation Model (GCM) called the Goddard Earth Observing System (GEOS) high-performance application to produce high resolution atmospheric model data. The output of GEOS is used across a wide variety of applications, including the following:

- Short term (up to 10 days) research weather forecasts
- Seasonal to sub-seasonal (up to 3 months) forecasts
- Retrospective reanalysis from 1980 to the present
- Observing System Simulation Experiments (OSSEs)
- Ultra-high-resolution research experiments

In addition, the GMAO is currently working on a coupled ocean-atmosphere model that will be used for the next generation retrospective reanalysis. The amount of data generated across all of these runs is already on the order of petabytes, and with the expected increase in resolution of these model runs, the data will grow even more.

4) Research Focus

NASA is interested in using machine learning and/or deep learning models for the following types of activities.

- Create a near-real time analysis capability for the GEOS model output to rapidly identify various weather-related phenomena at multiple scales and multiple time frames, such as hurricanes, weather fronts, mesoscale convective cells, and more. This output will be used to create a searchable catalogue of

events that can be used to assist and guide researchers who are interested in specific weather events.
• Analysis of high-resolution data to predict localized extreme weather events, such as tornadoes, extreme winds, hail, and more. The resolution of the global models is still too coarse to predict these localized events. However, the combined use of model and observation data could provide some level of heightened predictably for these localized events.
• Super-scaling, or upscaling, the resolution in space and time. This will create a higher-resolution output of the models that can be trained against observation data. The idea would be to be able to quickly run the models at lower resolution, which requires less compute and storage resources, while generating high-resolution outputs on demand for specific variables or sets of variables.
• Creation of trained model components for GEOS. The introduction of a trained model to replace a physics-based component has the potential to rapidly speed up the model runs on high-performance computers. Given the trend toward higher resolutions with multi-ensemble runs, the introduction of trained components will enhance the capability of generating accurate, short-term weather forecasts.
• Use of ML/DL for parameterization studies. Models continue to use a large number of parameterized components, and as models are updated, parameterization studies take a large amount

5) NASA Contact

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d. Cell Phone: +1 (703) 628-1017
e. Amazon Web Services NASA Account
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7) Partner contribution

No NASA Partner contributions

8) Intellectual property management

No NASA Partner intellectual property concerns

9) Additional Information

All publications that result from an awarded EPSCOR study shall acknowledge NASA EPSCoR Award.

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G7: NASA ARMD Electric Aircraft Batteries & Crash Safety

1. **Research Title:** ***Materials and Processes for All Solid-State Batteries for Electric Aircraft***
2. **Research Overview:**
   All electric vertical take-off and landing vehicles (eVTOL) for urban air mobility (UAM) concepts face numerous challenging technical barriers before their introduction into service. The most challenging of these technical barriers is an energy storage system capable of meeting both the rigorous aerospace safety and performance criteria. Aircraft safety is essential for operation, and systems level analyses have indicated that there are five key properties to enable such vehicles; safety, energy density, power, packaging design and scalability. The battery systems must be constructed of nonflammable materials for safety and be able to achieve fast discharge rates as needed for the flight profiles (2C and higher). Current state-of-the-art (SOA) lithium-ion batteries meet or exceed the requirements for electric aviation in the areas of power and scalability, but are insufficient in energy, safety and packaging design. Proposals shall focus on materials and processes for battery technology that meets all five key performance criteria. As an example, the approach could utilize nonflammable electrolytes, solid-state electrolytes, novel battery chemistries and combinations thereof to meet the performance requirements.
3. **Organization:** LaRC, RD, AMPB (D307)
4. **Contact:** John W. Connell (john.w.connell@nasa.gov)
5. **Mission Directorate(s) [Involved / Connected]:** ARMD
6. **Intellectual property rights:** Negotiable
   a. Company information
   b. Desired process
7. **Additional Information:** N/A

Research Title: ***Mechanical Testing to Measure Composite Material Properties for the LS-DYNA MAT213 Model***

Research Overview:

A. Overview of MAT213

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

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

A limitation of the model is that currently the post-peak stress degradation response is based on correlation with structural level impact and/or crush tests. Research is required to develop a methodology to characterize this response based on coupon level tests.

For this task we are focused on characterizing the deformation and failure models for a composite material or materials that will be defined and supplied by NASA as well as a recommended approach for characterizing the post-peak stress degradation response. We will focus on only the shell element analysis.

To characterize the deformation and failure models, mechanical testing is required as described below. At least one material must be characterized, but additional weight will be given to proposals that address two or more materials.

B. Required Tests

For the shell element version of MAT213, at a minimum, seven stress-strain curves, with repeats as specified below, must be supplied. 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

In addition to the above tests, to characterize the interlaminar failure models, the following tests are required:

h. Double Cantilever Beam
i. End Notched Flexure

C. Test Requirements

i. Test coupons will be machined by the grant recipient from flat panels supplied by NASA.
ii. For all tests the tabulated full stress-strain curve, all the way to failure, must be recorded and supplied in electronic tabular format. Raw data such as loads must also be supplied.
iii. All specimens must be measured and weighed prior to testing
iv. Testing is to be conducted at nominal room temperature conditions
v. The test environmental conditions must be recorded and documented
vi. A minimum of three repeats for each loading condition must be conducted
vii. Full Field Digital Image Correlation (DIC) must be used to measure deformations and strains
viii. The tests must be based on ASTM Standard Test Methods, but modifications to the standard methods are allowable if necessary
ix. Testing at different strain rates is encouraged but not required

D. Post-Peak Stress Degradation

Based on the above tests, an effort should be made to define an approach to characterizing the post-peak stress degradation in a manner that can be applied in a MAT213 analysis. If this requires additional testing to validate the approach, material will be made available.

E. Deliverables
   a. Full tabulated stress strain data to failure supplied in electronic tabular format
   b. All DIC images and associated calibration files
   c. A proposed approach to characterize the post-peak stress degradation based on coupon level test data.

References:

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

Intellectual Property Rights: All data and analysis methods will be made publicly available.

G8: NASA Office of Chief Health and Medical Officer (OCHMO)

Areas of Research Interest:

1. Review previous Pre- and Post-Flight MRI/MRV and archived medical data related to long duration spaceflight induced brain and eye findings including papilledema, eye ball flattening and choroid and retinal folds, intracranial pressure, changes in ventricular brain size, identification of transverse sinus or other venous sinus stenosis to determine associations between the Imaging findings and the other medical signs. Post Flight MRI/MRV- In astronauts that have signs of VIIP/SANS performing postflight MRI/MRV to identify brain edema, clots that may have occurred in the collecting system on the central nervous system, and correlating those findings to a spinal pressure would be extremely useful clinically. We don't yet know the degree of edema, how that correlates to the intracranial pressure, and if there are any clots in the collecting system. The bulk of the collecting system is behind the skull and not visible with ultrasound. Doing this with MRI/MRV would be extremely useful clinically.

2. Part Two- We are looking for a treatment using drug(s) or mechanical devices which lowers intracranial pressure and CSF fluid in the brain. Ideally, we would want to trial this on the ground. Dovetailing to the study above, we would want to first do the MRI/MRV and spinal pressure on a returning astronaut with known symptoms of VIIP/SANS. Then we would want to give the drug for ten to 14 days and then repeat the MRI/MRV and spinal pressure to look for changes.

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G9: MSFC EPSCoR Research Areas

Top Ideas

Development of a non-chromated cryogenic primer
"Lauren Fisher (EM41) John Bloyer (EM41)"

A non-chromated cryogenic primer that can maintain its properties when exposed to a maximum lower limit cryogenic temperature of -410°F, and which can be applied by means of spray, roll, and brush methods

Additive manufacturing (AM) of ceramic matrix composites (CMCs) for liquid rocket engine components
"Pete Valentine (EM41) Brian West (EM42) Paul Gradl (ER13)"

Investigate various potential means of using AM to create CMC's (ex.: carbon fiber reinforced carbon or silicon carbide matrices) for small liquid rocket engines, such as those to be used on lunar lander descent/ascent stages. Emphasis shall be on fiber reinforced composites, which could include whisker reinforcement or continuous fiber reinforcement. Initial technology development can concentrate on small test articles, but ultimately the technology will need to be scalable to larger sizes. Minimum operating temperatures for the composites shall be at least 3000°F (1649°C).

Lunar Surface Sustainability Through Dust Resistance Materials
Malik Thompson (EM41)

The key to sustained lunar surface presence will be an optimization of materials, designs, and innovative techniques used to mitigate the effects of lunar regolith dust. This project will assess the durability of state of the art materials (i.e. seals, coatings, and structural materials) against simulated lunar environments. The objective will be to select combinations of these materials and surface preparations to better enable lunar surface missions

Next Generation Adhesives for Advanced Cryogenic Applications
Malik Thompson (EM41)

At present there is only one flight or mission qualified adhesive for deep space missions. To date it has not been evaluated for lunar environments that are considerably more unforgiving than applications to date. It also acts a source of a single point failure in production and procurement if it's manufacture elects to discontinue the product. New adhesive options better fitting for lunar surface environments (thermal and radiation) are required. The objective of this project will include identification and testing of a new series of adhesives developed for a sustained lunar presence for the production and maintenance of lunar cryogenic systems.

Development of three-directional (3D) carbon fiber reinforced composites for rocket nozzle extensions and/or combustion chambers
"Pete Valentine (EM41) Paul Gradl (ER13)"

The use of 3D fiber architectures for rocket engine nozzle extensions (both liquid and nuclear thermal propulsion systems) is of interest to enable more durable and fracture-resistant high temperature composites. The aim is to move towards woven, braided, needled, or stitched fiber architectures, and away from the current more common practice of using 2D ply hand lay-ups (gore, involute, etc.). Both carbon and ceramic (silicon carbide, zirconium carbide, etc.) matrices are of interest. While the focus shall be on assessing and developing the fiber architecture technology itself, please keep in mind that the technology needs to be compatible with the incorporation of high temperature matrices. Some examples of current weaving and braiding technology can be found on the websites of Bethlehem Advanced Materials (BAM), Fiber Materials Inc. (FMI), and Textile Engineering And Manufacturing (TEAM). Minimum operating temperatures for the ultimate applications (lander, in-space, upper-stage liquid propulsion) shall be at least 3000°F (1649°C).

Modeling of Manufacturing Processes in Micro and Reduced Gravity Environments
EM04/Prater

Modeling of manufacturing processes in micro and reduced gravity environments: focus on bound metal deposition, wire+arc additive manufacturing, laser welding, thin film deposition (3D printing of electronics)

AM In-Situ Monitoring Data Analysis and Correlation for NDE of Part Quality
EM21/Walker/Lanigan

The ultimate goal is an empirical understanding of the relationship between the AM machine parameters, process physics, microstructural evolution, defect formation, and how those defects manifest themselves in nondestructive evaluation, metallography, and mechanical testing.

Enhanced Welding and Printing of Next Generation Refractory Metals and Alloys
EM32/Sowards

Joining and 3D printing of these materials has proven difficult as the currently available alloys were designed for optimal hot working, not enhanced weldability/printability. Proposals that evaluate and optimize novel refractory alloys for enhanced weldability and printability through experiments and or simulations are of interest.

Physical Effects of In-Space Environment on High Energy Density Welding
EM32/Sowards

Proposals that explore the physical effects of microgravity and vacuum on welding including the transfer of heat, generation and control of debris (fume and spatter), in situ process monitoring, and real-time process control are of interest.

Other Ideas

In Space Metal Recycling Techniques
EM04/Prater

There is also interest from OSAM in assessing feasibility of metal recycling techniques for in-space applications

Computational Approaches to Understand Shape Memory Ionic Polyimides for AM
EM22/Jackson

This effort proposes to determine the relationship between the molecular structure, physical properties, and performance of ionic polyimides more specifically of its shape memory behaviors.

In-Situ In-Space and Additive Manufacturing and welding/Joining Mechanical Properties by Non-Destructive Ultrasonic Evaluation.
EM32/Michael/Sowards/Cobb

Develop methods to determine materials properties using nondestructive ultrasonic methods.

Large Scale Additive Construction Technologies
EM04/Prater

Exploration of large scale additive construction technologies and materials for planetary surface construction applications, specifically focusing on automation and use of ISRU-derived feedstock materials

A Combined Machine Learning/AI and Testing and Characterization Materials Discovery of NASA Relevant Light weight, Super-Alloys and Refractory Alloys: Connecting Microscopic Electronic & Thermodynamical Alloy Properties to Macroscopic Alloy Mechanical Properties Predictively. EM32/Michael/Sowards/Cobb

Computationally Aided Materials Discovery CAMDIS is achieving great strides and increasing success in areas of materials focused engineering and sciences. We MSFC? proposes that EPSCoR support and fund a program of research and development in CAMDIS that seeks to integrate Machine Learning/AI (artificial intelligence) ML/AI with experimental data acquisition and validation, this for light weight aerospace alloys, super-alloys and Refractory materials alloys.

Development of Process Pathways between ISRU and In-Space Manufacturing
EM04/Prater

Bridging technologies between in-situ resource utilization and in-space manufacturing, specifically development of process pathways to refine and process extracted material from regolith into feedstock for manufacturing systems (in particular additive manufacturing systems)