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National Aeronautics and Space Administration
Office of STEM Engagement

FY 2020 NASA Cooperative Agreement Notice (CAN)

Established Program to Stimulate Competitive Research (EPSCoR)

Research Announcement

Announcement Number: NNH20ZHA005C
Catalog of Federal Domestic Assistance (CFDA) Number: 43.008

Release Date:	**December 11, 2019**
Notice of Intent Due:	**January 24, 2020**
Proposals Due:	**March 6, 2020**

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

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1.0 Description of Opportunity

1.1 Technical Description

The National Aeronautics and Space Administration (NASA) Office of STEM Engagement, in cooperation with NASA's Aeronautics Research Mission Directorate (ARMD), Human Exploration & Operations Mission Directorate (HEOMD), Science Mission Directorates (SMD), the Space Technology Mission Directorate (STMD), and NASA's nine Centers, plus the Jet Propulsion Laboratory (JPL), solicit proposals for the NASA Established Program to Stimulate Competitive Research (EPSCoR).

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 as to the progress of the research that 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 JPL as necessary.

The program parameters are:

- Jurisdictions responding to this Cooperative Agreement Notice (CAN) may submit one proposal in accordance with paragraph 1.3 of this CAN, *EPSCoR Eligibility and Proposal Acceptance*. Proposals will be selected from this solicitation for FY 2020 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 three (3) to five (5) awards of up to $750,000 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. The exact number of awards depends on the available EPSCoR Research Budget. **Note**: *The 2 CFR 1800 was recently updated and everything above 2 CFR 1800.400 (Mostly terms and conditions) was moved to the NASA Grant and Cooperative Agreement Manual (GCAM), Appendix E*
- 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 the CAN through NSPIRES, go to http://nspires.nasaprs.com and click on Solicitations.

To access the CAN through Grants.gov, go to http://www.grants.gov/search/agency.do and select the link for NASA.

1.2 EPSCoR Background

Public Law 102-588, passed in 1992 and implemented in 1993, authorized NASA to initiate NASA EPSCoR to strengthen the research capability of jurisdictions that have not in the past 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.

Based on the availability of funding, NASA will continue to help jurisdictions achieve these goals through NASA EPSCoR. Funded jurisdictions will be selected through a merit-based, peer-review competition.

The specific objectives of NASA EPSCoR are to:

- 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.
- Contribute to the overall research infrastructure, science and technology capabilities of higher education, and economic development of the jurisdiction.

1.3 EPSCoR Eligibility and Proposal Acceptance

While proposals can be accepted only from institutions where a NASA EPSCoR 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 EPSCoR Director for competition for submission to NASA.*

The latest available National Science Foundation (NSF) eligibility tables are used to determine overall jurisdiction eligibility for NASA EPSCoR. Note that the eligibility process was recently changed. It is important that all proposers review the new requirements. The latest NSF eligibility table is available at:

https://www.nsf.gov/od/oia/programs/epscor/Eligibility_Tables/FY-2019-Eligibility.pdf

The following jurisdictions are eligible to submit a proposal in response to this NASA EPSCoR solicitation: 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, U.S. Virgin Islands, Vermont, West Virginia, and Wyoming.

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.

1.4 Period of Performance

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.

1.5 Role of NASA EPSCoR Director

Cooperative Agreements will be awarded to the institution of the NASA EPSCoR Director. Therefore, the NASA EPSCoR Director shall serve as the administrative Principal Investigator (PI) for, and administer, all of the jurisdiction's NASA EPSCoR projects (see *Section 3.0, Program Management, Subsection 3.2. Jurisdiction Level* for a discussion of management responsibilities).

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 Director through NSPIRES at http://nspires.nasaprs.com by 11:59 p.m. Eastern Time**, January 24, 2020**.

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.

2.0 Project Overview and Guidelines

2.1 General

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 should 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.

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.

2.2 Funding and Cost-Sharing

A jurisdiction may request a maximum of $750,000 from NASA per proposal. This amount is to be expended over a three (3) year performance period 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 NASA Grant and Cooperative Agreement Manual (GCAM).

2.3 Restrictions

In addition to the funding guidelines and requirements in the *NASA Guidebook for Proposers March 2018 Edition* located at http://www.hq.nasa.gov/office/procurement/nraguidebook/proposer2018.pdf.

and the NASA Grant and Cooperative Agreement Manual (GCAM), the following restrictions govern the use of the federally-provided and the cost-shared portion of funds for this opportunity (referred to collectively as NASA 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. Also, 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 the *NASA Guidebook for Proposers*.
- 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). EPSCoR support shall be acknowledged by the EPSCoR research project number in written reports and publications. Please note that domestic travel does not have a limit. Domestic travel, which is defined as travel that does not require a passport, shall be appropriate and reasonable to conduct the proposed research.
- The construction of facilities is not an allowable cost in any of the programs solicited in this CAN. For further information on allowable costs, refer to the cost principles cited in 2 CFR 200.
- NASA EPSCoR funding shall not be used to purchase general purpose equipment, e.g., desktop workstations, office furnishings, reproduction and printing equipment, etc. as a direct charge. Special purpose equipment purchases (i.e., equipment that is used only for research, scientific, and technical activities directly related to the proposed research activities) are allowed and can be reflected as a direct charge as per 2 CFR 200.
- NASA EPSCoR funding shall not be used to support NASA civil service participation (FTE) in any research project. That funding is provided through a funding vehicle between the jurisdiction and NASA Center, such as a Space Act Agreement or other reimbursable agreement using non-EPSCoR funds. NASA EPSCoR cannot withhold funding from an award to send to a NASA Center for FTE support (including travel).
- NASA EPSCoR funds shall be expended in 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 part of it that remains unobligated at the time of Sc-I/Co-I transfer, cannot be transferred to the non-EPSCoR institution.

- All proposed funding requests must be for expenditures that are allowable, allocable, and reasonable. Funds may only be used for the awarded project. All activities charged under indirect costs shall be allowable under 2 CFR 200, Subpart E, Cost Principles.
- Grants and Cooperative Agreements shall not provide for the payment of fee or profit to the recipient.
- Unless otherwise directed in 2 CFR 200, for changes to the negotiated indirect cost rate that occur throughout the project period, the recipient shall apply the rate negotiated for that year, regardless of whether it is higher or lower than at the time the cooperative agreement 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.
- A non-Federal entity shall use one of the methods of procurement as prescribed in 2 CFR 200.320. 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 nonprofit research organizations or independent research institutes is $10,000; or such higher threshold as determined appropriate by the head of the relevant executive agency and consistent with audit findings under chapter 75 of Title 31, United States Code, internal institutional risk assessment, or State law.

2.4 NASA Research Areas of Interest

NASA EPSCoR research priorities are defined by the Aeronautics Research, Human Exploration & Operations, Science, and Space Technology Mission Directorates, and NASA's nine Centers plus JPL. Each Mission Directorate, Center, and JPL covers a major area of the Agency's research and technology development efforts.

Information about current NASA research solicitations can be found on NSPIRES at http://nspires.nasaprs.com (select "Solicitations" and then "Open Solicitations").

Research priorities for each of the Mission Directorates, Centers, and JPL are summarized in Appendix A; also see Appendix D for detailed contact information for the NASA Point of Contact (POC) for each Mission Directorate, Center, and JPL. *The Nasa Offices That Participated In The EPSCoR R3 Solicitation Have Requested That The Areas Listed In The R3 Solicitation Be Allowed To Be Proposed Against In This Research Can. Proposers May View Those Topics In Appendix G.*

Also Note: *EPSCoR was contacted by the Office of the NASA Chief Medical Officer who would like to add two areas of research interest. Those two areas are at the beginning of Appendix G.*

2.5 Partnerships and Interactions

All institutions of higher education within an eligible jurisdiction shall be made aware of this NASA EPSCoR CAN and given the opportunity to compete. *However, all proposals shall be submitted through the jurisdiction's NASA EPSCoR Director's office*. 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.

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.

2.6 Environmental Statement

All awards must comply with the [National Environmental Policy Act (NEPA)](). NASA has an obligation under the National Environmental Policy Act (NEPA) to consider potential environmental effects of proposed projects. This includes projects that NASA funds which are implemented by grantees. The majority of grant related activities are categorically excluded as research and development projects that do not pose any adverse environmental impact. These are covered by a NASA Grants Record of Environmental Consideration (REC). The following questions enable NASA to identify grant proposals that do not fall within this blanket REC. Proposals that could result in a potential adverse environmental effect may require additional NEPA analysis if awarded (e.g., preparation of an Environmental Assessment). "Yes" responses are not grant selection criteria.

		Yes*	No
1	Would the proposal involve any activity that includes: a. Construction of new facilities or modification to the footprint of an existing-facility, or b. Ground disturbance (e.g., excavation, clearing of trees, installation of equipment, etc.), or c. Outdoor discharges of water (e.g., waste water runoff), air emissions (e.g., ozone-depleting substances) or generation of noise exceeding 115 dBA (excluding those associated with aircraft operations)?		
2	Would the proposal involve any field activity that would: a. Release equipment (e.g., dropsondes, sensors, etc.) or chemicals (e.g., dyes, tracers, etc.) into the air, bodies of water or on the ground, or b. Release a parachute or use equipment that would not be recovered, or c. Involve equipment or a payload that contains hazardous (e.g., petroleum, hypergols, oxidizers, solid propellants, etc.) or radioactive materials?		
3	Would the proposal involve the launch of a payload, equipment, or instrument (e.g., via launch vehicle, sounding rocket, balloon, etc.)?		
4	Would the proposal involve any activity to be conducted outside the United States or its territories?		

Proposers should plan and budget accordingly if environmental impacts are anticipated. Anticipated environmental impacts should be documented in Section VIII – Other Project Information of the proposal cover page submitted to NASA. Questions concerning environmental compliance requirements may be addressed to Tina Norwood, NASA NEPA Manager, at tina.norwood-1@nasa.gov.

3.0 Program Management

3.1 NASA EPSCoR Program and Project Levels

The NASA EPSCoR is a component of the Office of STEM Engagement 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.

3.2 Jurisdiction Level

The jurisdiction's NASA EPSCoR 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 jurisdiction's NASA EPSCoR 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 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 jurisdiction's NASA EPSCoR 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 cap.

The jurisdiction's NASA EPSCoR 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 Director will consult with appropriate jurisdiction organizations, such as the economic development commission, in addressing jurisdiction research priorities.

3.3 Data Management Plan - Increasing Access to the Results of Scientific Research

In keeping with the NASA Plan for Increasing Access to Results of Scientific Research, *new* terms and conditions consistent with the Rights in Data clause (GCAM, Annex E) in the award, which make manuscripts and data publically accessible, may be attached to NASA EPSCoR Research awards. All proposals shall provide 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 I can release, so a DMP is not applicable.*
- *The data that we will generate will be ITAR.*
- *Or, the submitter may explain why its project will not generate any data.*

The type of proposal that requires a DMP is described in the NASA Plan for increasing access to results of federally funded research. The DMP shall contain the following elements, as appropriate to the project:

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

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

In addition, researchers submitting NASA-funded articles in peer-reviewed journals or papers from conferences now shall make their work accessible to the public through NASA's *PubSpace* at https://www.nihms.nih.gov/db/sub.cgi. *PubSpace* provides free access to NASA-funded and archived scientific publications. Research papers will be available within one year of publication to download and read.

EPSCoR has also implemented the Research Performance Progress Report (RPPR) process to collect demographic data from grant applicants for the purpose of analyzing demographic differences associated with its award processes. Information collected will include name, gender, race, ethnicity, and disability status. Submission of this information is voluntary, only available to NASA in aggregate form, and is not a pre-condition of award.

3.4 Schedule

The schedule for the review and selection of proposals for this CAN is:

Notices of Intent Due: **January 24, 2020**
Proposals Due: **March 6, 2020**

3.5 Cancellation of Program Announcement

The NASA Office of STEM Engagement reserves the right to not make any awards under this CAN and/or to cancel this CAN. NASA assumes no liability (including proposal costs) for cancelling the CAN or for any entity’s failure to receive such notice of cancellation.

3.6 Inquiries

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

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

Inquiries regarding the submission of proposal materials may be addressed to:

Ms. Althia Harris
NASA Research and Education Support Services (NRESS)

2345 Crystal Drive, Suite 500
Arlington, VA 22202-4816
E-mail: aharris@nasaprs.com
Telephone: (202) 479-9030 x310
Fax: (202) 479-0511

4.0 Proposal Review and Selection

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 8.0, Proposal Evaluation Criteria.

4.2 Review and Selection Processes

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. The evaluation criteria described in this CAN under Section 8.0, Proposal Evaluation Criteria, takes precedence over the evaluation criteria described in Section 5 of the *NASA Guidebook for Proposers*. However, selection procedures shall be consistent with the provisions of the *NASA Guidebook for Proposers*, Section 5. The selecting official for this CAN is the Associate Administrator for STEM Engagement at NASA Headquarters or his appointed representative.

The NASA 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 the entity's (applicant's) core data, registration expiration date, active exclusions, 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 is required to review and consider any information about the applicant that is in the designated integrity and performance system (currently FAPIIS, which is accessible through SAM at https://www.sam.gov) (see 41 U.S.C. 2313).

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.

Limited Release of Proposers Confidential Business Information

For proposal evaluation and other administrative processing actions, NASA may find it necessary to release information submitted by the proposer to individuals not employed by NASA. 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 submitter hereby consents to a 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 contractor or subcontractor, and their individual employees who may require access to the CBI to perform the assisting contract.

4.3 Selection Announcement

NASA's stated goal is to announce selections as soon as possible. However, generally NASA does not 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 update.

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

5.0 Award Administration Information

5.1 Administrative, National Policy Requirements, and Intellectual Property Information

2 C.F.R. 200 *Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards (Uniform Guidance)* at http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title02/2cfr200_main_02.tpl

2 C.F.R. 1800 NASA supplement to 2 C.F.R. 200 (open word file) https://prod.nais.nasa.gov/pub/pub_library/srba/index.html

Grants and Cooperative Agreement Manual *– Appendix E, Terms and Conditions* *https://prod.nais.nasa.gov/pub/pub_library/Grant_and_CooperativeManual.doc*

Award and intellectual property information is available here: https://prod.nais.nasa.gov/pub/pub_library/srba/Award_and_IP_Information_for_Proposers.docx

5.2 Notice of Award

For selected proposals, a NASA Grants Officer will contact the business office of the proposer's institution. The NASA 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 200.458, & 1800.209.

5.3 Award Reporting Requirements

The reporting requirements for awards made through this CAN shall be consistent with the GCAM.

5.4 Access to NASA Facilities/Systems

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).

6.0 Updates and Submission Information

6.1 Announcement of Updates/Amendments to 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 as posted at its homepage on http://nspires.nasaprs.com.

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 updates.

6.2 Electronic Submission of Proposal Information

On-time electronic submission via NSPIRES (http://nspires.nasaprs.com) is required for every proposal. Please note carefully the following requirements for submission of an electronic proposal via NSPIRES:

- Every organization that intends to submit a proposal to NASA in response to this 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) https://www.sam.gov/portal/public/SAM/.
- Each individual team member (e.g., PI, co-investigators, etc.), 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 website and to maintain a help center via e-mail and telephone, technical difficulties may arise at any time with the Internet, including with the user's own equipment. Thus, prospective proposers are strongly urged to familiarize themselves with the NSPIRES site and to submit the required proposal materials well in advance of the proposal submission deadline. Difficulty in registering with or using a proposal submission system (NSPIRES) is not, in and of itself, a sufficient reason for NASA to consider a proposal that is submitted after the proposal due date (see Appendix E).

6.3 Proposal Submission Date and Time

All proposals in response to this CAN 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 **March 6, 2020.**

Respondents without Internet access or that experience difficulty using the NSPIRES proposal site (http://nspires.nasaprs.com) may contact the Help Desk at nspires-help@nasaprs.com or call 202-479-9376 between 8:00 a.m. and 6:00 p.m. (ET), Monday through Friday, except Federal Government holidays. NSPIRES automatically identifies any proposals that are late. Proposals received after the due date may be returned without review. If a late proposal is returned, it is entirely at the proposer's discretion whether or not to resubmit it in response to a subsequent solicitation.

7.0 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. Please refer to Appendix E of this announcement for NSPIRES instructions on proposal submission procedures. Section 3.6 of the

NASA Guidebook for Proposers provides guidelines for style formats, and Section 3.7 provides guidelines for proposal content.

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 should 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.*	

8.0 Proposal Evaluation Criteria

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.

Jurisdictions responding to this CAN may submit proposals per paragraph 1.3 above. Proposals will be evaluated based on the following criteria: Intrinsic Merit, NASA Alignment and Partnerships, Management and Evaluation, and Budget Justification: Narrative and Details. 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.*

8.1 Intrinsic Merit (35% of score)

- Proposed Research. 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 relevant, the narrative shall include a brief history of NASA EPSCoR Research projects in the jurisdiction, and shall include a discussion of how these previous NASA EPSCoR research projects or Research Infrastructure Development (RID) activities have helped prepare the institution and jurisdiction for and contributed to the proposed research activities. 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.

8.2 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. They should describe current and/or previous interactions, partnerships, and meetings with NASA researchers, engineers, and scientists in the area of the proposed research, and discuss how future partnerships between the institution's researchers and personnel at the Mission Directorates, 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.

8.3 Management and Evaluation (15% of score) NOTE: This information does not count toward the 15 page limit for the Scientific, Technical, or Management section.

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 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 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 shall be included.

- 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 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 shall describe an appropriate evaluation plan/process to document outcomes and demonstrate progress toward achieving objectives of proposed project elements. 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 his/her 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.

8.4 Budget Justification: Narrative and Details (15%)

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 (staff, facilities, laboratories, indirect support, waiver of indirect costs, etc.).

Appendix A: NASA Mission Directorates and Center Alignment

NASA's Mission *to pioneer the future in space exploration, scientific discovery, and aeronautics research,* draws support from four Mission Directorates, nine NASA Centers, and JPL, each with a specific responsibility.

NOTICE:

EPSCoR was contacted by the Office of the NASA Chief Medical Officer who would like to add two areas of research interest. POCs:

Dr James D. Polk; E: james.d.polk@nasa.gov, P: (202)358-1959

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

Those two areas are:

1. 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. So 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.

The Nasa Offices That Participated In The EPSCoR R3 Solicitation Have Requested That The Areas Listed In The R3 Solicitation Be Allowed To Be Proposed Against In This Research Can. Proposers May View Those Topics In Appendix G Below.

A.1 Aeronautics Research Mission Directorate (ARMD) conducts high-quality, cutting-edge research that generates 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 four research programs develop advanced technologies to reduce aviation's environmental impact & transform the way we fly.

- Advanced Air Vehicles
- Airspace Operations and Safety
- Integrated Aviation Systems
- Transformative Aeronautics Concepts Program

Additional information on the Aeronautics Research Mission Directorate (ARMD) can be found at: https://www.nasa.gov/aeroresearch.

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) 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, Advanced Exploration Systems, and Space Life Sciences Research & Applications. 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 Human Exploration & Operations Mission Directorate (HEOMD) can be found at: (http://www.nasa.gov/directorates/heo/home/index.html)

Areas of Interest - POC: Bradley Carpenter, bcarpenter@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.

Space Life Sciences
The Space Life Sciences, Space Biology Program has three primary goals:

- To effectively use microgravity 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.

These goals will be achieved by soliciting research using its three program elements:

- Cell and Molecular Biology and Microbial Biology - studies of the effect of gravity and the space environment on cellular, microbial and molecular processes;
- Organismal & Comparative Biology - studies and comparisons of responses of whole organisms and their systems; and
- Developmental Biology – studies of how spaceflight affects reproduction, development, maturation and aging of multi-cellular organisms, as described in NASA's Fundamental Space Biology Science Plan (PDF, 7.4 MB).

Further details about ongoing activities specific to Space Biology are available at: Space Biosciences website

Physical Science Research

The Physical Science Research Program, along with its predecessors, has conducted significant fundamental and applied research, both which have led to improved space systems and produced new products offering benefits on Earth. NASA's experiments in various disciplines of physical science reveal how physical systems respond to the near absence of gravity. They also reveal how other forces that on Earth are small compared to gravity, can dominate system behavior in space. The Physical Science Research Program also benefits from collaborations with several of the International Space Station international partners—Europe, Russia, Japan, and Canada—and foreign governments with space programs, such as France, Germany and Italy. The scale of this research enterprise promises new possibilities in the physical sciences, some of which are already being realized both in the form of innovations for space exploration to improve the quality of life on Earth.

Research in physical sciences spans from basic and applied research in the areas of:

- Fluid physics: two-phase flow, phase change, boiling, condensation and capillary and interfacial phenomena;
- Combustion science: spacecraft fire safety, solids, liquids and gasses, supercritical reacting fluids, and soot formation;
- Materials science: solidification in metal and alloys, crystal growth, electronic materials, glasses and ceramics;
- Complex Fluids: colloidal systems, liquid crystals, polymer flows, foams and granular flows; and
- Fundamental Physics: critical point phenomena, atom interferometry and atomic clocks in space.

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/

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)

A.3 Science Mission Directorate (SMD) leads the Agency in four areas of research: Earth Science, Heliophysics, 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 Chapter 4 of the 2014 NASA Science Plan. The best expression of specific research topics of interest to each Division within SMD are represented in by the topics listed in SMD's "ROSES" research solicitation, see Table 3 of ROSES-2019 and the text in the Division research overviews of ROSES, i.e., the Earth Science Research Overview, the Heliophysics Division Overview, the Planetary Science Research Program Overview and the Astrophysics Research Program Overview. Please note, even if 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

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
- 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

Our planet is changing on all spatial and temporal scales and studying the Earth as a complex system is essential to understanding the causes and consequences of global change. The Earth Science Division of the Science Mission Directorate (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 the Earth Science Division’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

The 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*, serves as a foundational document to guide the overall approach to the Earth science program (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 should explicitly support past, present, or future NASA astrophysics missions. These investigations can 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

Space Technology Mission Directorate (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:

- Methods for space and in space manufacturing
- Autonomous in-space assembly of structures and spacecraft
- 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.

The National Aeronautics and Space Administration (NASA) Space Technology Mission Directorate (STMD) 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: Brenda Collins (brenda.j.collins@nasa.gov)

Ames research Center 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*
- 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*
- 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

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 including:

- Acoustics / Propulsion Acoustics
- Advanced Energy (Renewable Wind and Solar, Coal Energy and Alternative Energy)
- Advanced Microwave Communications
- Aeronautical and Space Systems Analysis
- Electrified Aircraft
- Computer Systems and Networks
- Electric (Ion) Propulsion
- Icing and Cryogenic Systems/Engine and Airframe Icing
- Instrumentation, Controls and Electronics
- Fluids, Computational Fluid Dynamics (CFD) and Turbomachinery
- Materials and Structures, including Mechanical Components and Lubrication
- Microgravity Fluid Physics, Combustion Phenomena and Bioengineering
- Nanotechnology
- Photovoltaics, Electrochemistry-Physics, and Thermal Energy Conversion
- Propulsion System Aerodynamics
- Space Power Generation, Storage, Distribution and Management
- Urban Air Mobility (UAM)
- Systems Engineering

The above engagement areas relate to the following key Glenn 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 Harrington
james.l.harrington@nasa.gov

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.
- **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 Goddard Space Flight Center (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** 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 Earth Science Division develops and operates remote-sensing satellites and instruments. We analyze 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: Amber Straughn (Amber.n.Straughn@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 as well as the investigations and space instruments to test them. The researchers participate in planetary and Earth science missions, and collect, interpret, and evaluate measurements. POC: Lora Bleacher (Lora.V.Bleacher@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..
- **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

- **(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

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
Petra Kneissl, petra.a.kneissl-milanian@jpl.nasa.gov

- **Solar System Science**
  Planetary Atmospheres and Geology
  Solar System characteristics and origin of life
  Primitive solar systems bodies
  Lunar science
  Preparing for returned sample investigations
- **Earth Science**
  Atmospheric composition and dynamics
  Land and solid earth processes
  Water and carbon cycles
  Ocean and ice
  Earth analogs to planets
  Climate Science
- **Astronomy and Fundamental Physics**
  Origin, evolution, and structure of the universe
  Gravitational astrophysics and fundamental physics
  Extra-solar planets and star and planetary formation
  Solar and Space Physics
  Formation and evolution of galaxies
- **In-Space Propulsion Technologies**
  Chemical propulsion
  Non-chemical propulsion
  Advanced propulsion technologies
  Supporting technologies
- **Space Power and Energy Storage**
  Power generation
  Energy storage
  Power management & distribution
  Cross-cutting technologies
- **Robotics, Tele-Robotics and Autonomous Systems**
  Sensing
  Mobility
  Manipulation technology

Human-systems interfaces
Autonomy
Autonomous rendezvous & docking
Systems engineering

- **Communication and Navigation**
  Optical communications & navigation technology
  Radio frequency communications
  Internetworking
  Position, navigation and timing
  Integrated technologies
  Revolutionary concepts
- **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/sensors
  Observatory technology
  In-situ instruments/sensor technologies
- **Entry, Descent and Landing Systems**
  Aerobraking, aerocapture, and entry systems
  Descent
  Landing
  Vehicle system technology
- **Nanotechnology**
  Engineered materials
  Energy generation and storage
  Propulsion
  Electronics, devices and sensors
- **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

A.5.6 Johnson Space Center (JSC), POC: Kamlesh Lulla, kamlesh.p.lulla@nasa.gov

- In-space propulsion technologies
  - Energy Storage technologies-Batteries, Fuel cells
  - Robotics and TeleRobotics
  - Crew decision support systems
  - Immersive Visualization

- Virtual windows leading to immersive environments and telepresence systems
  - Human Robotic interface
  - Flight and Ground communication systems

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

- Video
  - Ultra High Video Compressions
  - H265 Video Compression
  - Rad-Tolerant Imagers
  - Lightweight/low power/radiation tolerant displays

- Advanced habitat systems
  - GN&C for descent systems
  - Large body GN&C
  - Human-in-the-loop system data acquisition and performance modeling
  - Imaging and information processing

- Lightweight/Low power Display Technology
  - Scalable software-implementable graphics processing unit

- Simulation and modeling
  - Materials and structures
  - Lightweight structure
  - Human Spaceflight Challenges
  - http://humanresearchroadmap.nasa.gov/explore

- Human System Interfaces
  - OLED Technology Evaluation for Space Applications
  - Far-Field Speech Recognition in Noisy Environments
  - Radiation-Tolerant/ Hardened Graphics Processing
  - Machine-Learning human interfaces and methods
  - 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

- ECLSS
  - Air Revitalization
  - Advanced water, O2 and CO2 monitoring and sensors
  - Advance thermally regenerated ionic fluids for CO2 and Humidity Control
  - Water Recovery and Management

- Brine water recovery systems and wastewater treatment chemical recover for reuse or repurpose
- Waste Management
- Advance wastewater treatment systems (lower toxicity, recoverable)
- Advanced trace contaminant monitoring and control technology
- Quiet fan technologies

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

- EVA
  - Pressure Garment
  - Portable Life Support System
  - Power, Avionics and Software

- Autonomous Rendezvous and Docking
  - Crew Exercise

- Small form Equipment
  - Biomechanics

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

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

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

- In-Situ Resource Utilization
  - Mars atmosphere processing
  - CO_2 collection, dust filtering, Solid Oxide CO_2 electrolysis, Sabatier
  - Reverse water gas shift
  - Lunar/Mars regolith processing

- Regolith collection and drying
- Water collection and processing, water electrolysis (PEM and Solid Oxide)
- Carbothermal reduction of regolith
- Solar concentrator heat collection
- Methane/Oxygen liquefaction and storage

A.5.7 Kennedy Space Center (KSC), by Roadmap Technical Area (TA), POC Jose Nunez, jose.l.nunez@nasa.gov

- 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

NOTE:

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

A.5.8 Langley Research Center (LaRC), POC: Dr. Kimberly Brush, kimberly.m.brush@nasa.gov

- Intelligent Flight Systems – Revolutionary Air Vehicles (POC: Guy Kemmerly 757-864-5070) – retired, awaiting new POC
- 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 Dress 757-864-5126)
- Aerosciences - Trusted Autonomy (POC: Sharon Graves 757-864-5018) –retired, awaiting new POC
- Entry, Decent & Landing - Robotic Mission Entry Vehicles (POC: Jeff Herath or Ron Merski)
- 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

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

- 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 needed to conduct NASA's missions.*

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 should 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 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 should 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
NASA Kennedy Space Center, 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 *Bradley Carpenter* Space Life and Physical Sciences Research and Applications Division NASA Headquarters Phone: (202) 358-0826 BCarpenter@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 *Brenda Collins* Chief, Education and Public Outreach Phone: (650) 604-3540 brenda.j.collins@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 *Dave Berger* University Affairs Officer Phone: (661) 276-5712 dave.e.berger@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 that intends 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. These warnings should be ignored as such warnings do not preclude 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 should 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.gov

- 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:
    https://www.ecfr.gov/cgi-bin/text-idx?SID=637ebfe1e02b1f0d8234914d77fe72de&mc=true&tpl=/ecfrbrowse/Title02/2chapterII.tpl
  - 2 CFR 1800:
    https://www.ecfr.gov/cgi-bin/text-idx?SID=637ebfe1e02b1f0d8234914d77fe72de&mc=true&node=pt2.1.1800&rgn=div5

Appendix G1: NASA SMD Planetary Division

Below is the SMD Planetary Science request. It is the same as before as they seek additional proposals. Please contact the POC listed in the solicitation for additional information.

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

Specifically for the planet Venus which has important scientific relevance to understanding Earth, the Solar System formation, and Exoplanets. For EPSCoR technology projects Venus highly acidic surface conditions is 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). 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/.

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:

G1.1. High-Temperature Subsystems and Components for Long-Duration (months) Surface Operations: Advances in high-temperature electronics and power generation would enable long-duration missions on the surface of Venus operating for periods as long as a year, where the sensors and all other components operate at Venus surface ambient temperature. These advances are needed for both the long-duration lander and the lander network. Development of high-temperature electronics, sensors, thermal control, mechanisms, and the power sources designed for operating in the Venus ambient would be enabling for future missions.

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

G1.2. 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 they could investigate include: a. the identity of the unknown UV absorber; b. properties of the cloud particles in general; c. abundances atmospheric gas species (including trace gases and noble gases); d. the presence of lightning; e. properties of the surface mapped aerially. Aerial vehicles 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.

G1.3. 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. 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

Appendix G2.1: Commercial Space Capabilities Office

Commercial Space Research
Research Request Number: CSCO-2020-02

1) Program: Commercial Space Capabilities Office (CSCO)
2) Research Title: Landed Sensing of Mars Ice
3) Research Overview:

NASA is requesting research proposals in this area to further Mars exploration and commercialization efforts, by investigating landed sensing capabilities to characterize Mars ice deposits with the goal of better understanding the availability of water ice, including:

- Composition of the ice, including possible mixed in salts, dust, pebbles, and rocks
- Heterogeneity of ice deposits: both for mixed in materials as well as any distinct layering
- Spatial distribution within an area of about 10 km^2 (e.g. localized vs uniform)
- Depth, density, and nature of overburden over the area of interest (e.g. loose sand vs large rocks)

NASA has not identified specific tasks in this area but is seeking proposals that consider the following:

a) Sensing capabilities that would be landed on Mars surface or operate near the surface (not in orbit)

b) Sensing capability would be deployed from a single large vehicle that will soft land at specific mid-latitude location(s) on Mars that have been identified from orbit as likely to have accessible water ice in the subsurface.
   i. Sensing capability shall be scientifically/geologically sound, and ideally with the underlying methodology being proven terrestrially in analogous environment. Methods include, but are not limited to: seismic, drill/melt probe, ground penetrating radar, neutron spectrometer.
   ii. Sensing capability elements may remain on, and/or deploy from, the large vehicle. Elements can be centralized or spread among these.
   iii. If deployment, a feasible method needs to be included in this proposal. Methods include, but are not limited to: flying, ejecting/shooting (non-explosive preferred), fully autonomous rover, tethered/cabled, combinations, etc.
   iv. The proposed sensing capability can be of much greater mass/volume than current NASA rovers. NASA telecon to discuss.
   v. Sensing capability electrical power can be provided by direct connection or cable to the large vehicle. NASA telecon to discuss.
   vi. Sensing capability commanding/data can be provided by direct connection, cable, or wireless from/to the large vehicle. Direct-To-Earth is allowed but not recommended. Commanding/data would be from Earth.
   vii. Goal of being able to sense an area ~10 km^2 centered on the large vehicle.
   viii. Goal of being able to operate on/in Mars environments between +35º and +50º latitude, for ~one Mars year.
   ix. Sensing capability shall not require any crew interaction on/near Mars.

c) Sensing capability is intended to provide ground truth to build upon the large amount of prior and ongoing data collection by other Mars systems (landers, rovers, remote sensors) and assessments by the Mars science/engineering community. Proposal should indicate relevance to, alignment with, and usage of these. Some references are:
   i. https://swim.psi.edu/

i. https://astrogeology.usgs.gov/geology/mars-ice
ii. http://www.antarcticglaciers.org/glacial-geology/glaciers-mars/
iii. https://mepag.jpl.nasa.gov/
iv. https://mepag.jpl.nasa.gov/reports/ICESAG_Report_FINAL.pdf

The proposed work shall include performing the following at minimum:

a) Developing an engineering design concept and, as funding permits, fabricating all or part of the design to prototypic level, that would be suitable for testing in suitable terrestrial analog.
b) Producing a final report and delivery of developed design concept and data.

Proposals for this Research Title must include:

a) Describe proposing Institution's and Co-I/Sci-I's relevant capabilities and prior work. (weblinks preferred. Does not count against the 2-3 page limit.)
b) Identify the underlying scientific principles.
c) Compare and contrast proposed work against prior and existing work.
d) If data is needed from NASA to perform the proposed work, identify what it is needed and a contact/source if known

Proposers can assume that technically knowledgeable NASA engineers and scientists will be reviewing the Proposal – so Proposer should focus on technical/scientific specifics. NASA welcomes opportunities to co-publish results proposed by EPSCOR awardee. NASA goal is for widest possible eventual dissemination of the results from this work, when other restrictions allow.

Appendix G2.2: Commercial Space Capabilities

Commercial Space Research
Research Request Number: CSCO-2020-03

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 has not identified specific tasks in this area but is seeking proposals that consider the following:

a) Improvement(s) to current space suit design, implementation, and operation. Areas include: soft goods/woven materials and fabrication processes, mobility (spacecraft and surface), ergonomics and crew performance/health/safety, usability (don/doff, pre-breathe), suit life support, suit autonomy aids, availability/maintainability/redundancy (e.g. for repeated surface operations), and produce-ability/cost reduction.
b) Improvement may apply to any space suit flight phase including: launch/landing Intra Vehicular Activity (IVA), surface Extra Vehicular Activity (EVA) operation, and in-space EVA .
c) Improvement should address an identified need and/or shortcoming in current state of art, rather than a "nice to have".
d) Reasonably projected to be applicable to flight designs (so ~TRL7 https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf) within ~2 years.

The proposed work shall include performing the following at minimum:

a) Developing an engineering design concept and, as funding permits, fabricating all or part of the design to prototypic level, that would be suitable for testing in suitable terrestrial analog. NASA would work with Proposer to identify suitable terrestrial analog facilities and/or sites.
b) Producing a final report and delivery of developed design concept and data.

Proposals for this Research Title must include:

a. Describe proposing Institution's and Co-I/Sci-I's relevant capabilities and prior work. (weblinks preferred. Does not count against the 2-3 page limit.)
b. Provide references/links when presenting need and/or shortcoming in current state of art.
c. Compare and contrast proposed work against prior and existing work.

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

Appendix G3: SMD Earth Sciences Division

NASA SMD Earth Science Division (ESD) Research Topics to Address Earth System response to disasters

SMD requests that EPSCoR include research opportunities focused on understanding the response of the Earth System to disasters. The ESD, in order to address its strategic goals and core near-term objectives, regularly collects data on unforeseen events or events of unique and novel character (scale, extent, complexity or impact) in the Earth system using remote sensing measurements from on-orbit satellites and airborne platforms. Such events may include wild fires, hurricanes and tropical storms, volcanic eruptions, floods, earthquakes, tsunamis, landslides, environmental emissions, pollution and toxic releases, oil spills, harmful algal blooms, coral bleaching events, crop failure, energy and transport disruption, and other large-scale, extraordinary, events. These data are used to address specific science questions in response to the event; improve the understanding related to natural or anthropogenic extreme events or similar unanticipated or unpredictable disasters and cascading impacts; and/or advance application readiness, disaster risk management, and disaster resilience. However, there is vast and untapped potential in science and applications of those data even after the event has long passed, which can significantly advance the understanding of the Earth System, and provide societal benefits.

Proposals seeking to respond to this EPSCOR Research Topic should focus on utilizing existing data (including outputs and predictive capabilities from models associated NASA products) relating to past unforeseen events or events of unique and novel character to further the understanding of such events within the Earth System, advancing the readiness of application science, and/or provide advancements in risk management and disaster resilience. 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/.

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

UAVSAR (Uninhabited Aerial Vehicle Synthetic Aperture Radar):
https://www.asf.alaska.edu/sar-data/uavsar/

G-LiHT (Goddard's LiDAR, Hyperspectral & Thermal Imager): https://gliht.gsfc.nasa.gov/
Please check the above mentioned websites to see if observational data are available for the time period and area of interest.

The proposals should include clear statements as to what the significance and impact of proposed work will be, scientifically and/or to a stakeholder community, and a plan on dissemination and sharing of data, products, and tools where applicable. This research opportunity seeks to take advantage of the large quantities of data that NASA has already collected over the years in response to unforeseen or unpredictable Earth system events. Scientists cannot propose to collect new airborne or satellite observations; we may consider collection of limited and targeted field data on a case by case basis.

Examples of potential topics suitable for the EPSCOR Earth System response to natural disasters include:

1. Oil spills (e.g. improved mitigation strategies; further understanding of oil distribution through time; comparison between spills in similar settings)
2. Hurricanes (e.g. impacts on coastal communities/ecosystems and subsequent recovery; comparison of storm types and ecosystem damage)
3. Wildfires (linkages of various wildfires (type, extent) to climatic conditions; societal impacts; recurrence and ecosystem response)
4. Harmful algal blooms (e.g. impacts on air/water quality; comparison of climatic conditions for different blooms; comparison of blooms across regions)
5. Volcanic eruptions (e.g. atmospheric composition/distribution of plumes of same volcano through time)

Appendix G4.1: NASA Space Life and Physical Sciences and Research Applications

SLSPRA has 11 topics listed below and on the following pages for your consideration and possible involvement.

1) **Program:** Physical Sciences Program
2) **Research Title:** Dusty Plasmas
3) **Research Overview:**

Dusty plasma research uses dusty plasmas – mixtures of electrons, ions, and charged micron-size particles as a model system to understand astronomical phenomena involving dust-laden plasmas, and as a simplified system modelling the behavior of many-body systems in problems of statistical and condensed matter physics. Dusty plasma research also addresses practical questions of dust management in planetary exploration missions.

Proposals are sought for research on dusty plasmas, particularly on the transport of particles in dusty plasmas.

Appendix G4.2: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Fluids Physics and Combustion Science
2) **Research Title:** Drop Tower Studies
3) **Research Overview**:

Fundamental discoveries made by NASA researchers over the last 50 years in fluids physics and combustion have helped enable advances in fluids management on spacecraft water recovery and thermal management systems, spacecraft fire safety, and fundamental combustion and fluids physics including low-temperature hydrocarbon oxidation, soot formation and flame stability.

The microgravity environment provides an ideal experimental backdrop for probing many of the questions raised in boiling, capillary effects and combustion research. Because the microgravity environment allows for extended length and/or time scales certain diagnostic techniques, that otherwise prove intractable in 1-g environments, show promise in obtaining new experimental insights. Using well designed experiments the aforementioned research topics can successfully be explored in microgravity and will serve to greatly enhance the developmental pace of a number of important technologies for both terrestrial and extraterrestrial application.

Research Focus

This Fluids Physics and Combustion Science emphasis requests proposals for hypothesis-driven experiments and/or analysis that that will help address fundamental issues in these fields or will address important issues in spacecraft life-support.

Proposers are encouraged to include the use of NASA GRC drop tower facilities in their proposals. For more information about these facilities, please contact Eric Neumann (eric.s.neumann@nasa.gov; 216-433-2608). These facilities provide either 2.2 or 5.2 seconds of low-gravity. Work Phone: 202-358-0693.

Appendix G4.3: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Combustion Science
2) **Research Title:** Transcritical Combustion
3) **Research Overview:**

Fundamental discoveries made by NASA researchers over the last 50 years has helped enable advances in fundamental combustion including low-temperature hydrocarbon oxidation, soot formation and flame stability. One area of fundamental research that NASA wishes to focus on is combustion at supercritical conditions. This study has two major applications: super critical water oxidation (SCWO) and hydrocarbon combustion processes as seen in diesel and jet engines.

The microgravity environment provides an ideal experimental backdrop for probing many of the questions raised in high pressure combustion research. Because the microgravity environment allows for extended length and/or time scales certain diagnostic techniques, that otherwise prove intractable in 1-g environments, show promise in obtaining new experimental insights. Using well designed experiments the aforementioned research topics can successfully be explored in microgravity and will serve to greatly enhance the developmental pace of a number of important technologies for both terrestrial and extraterrestrial application.

Research Focus

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

Proposers are encouraged to include the use of drop tower facilities in their proposals. For more information about these facilities, they can contact Eric Neumann (eric.s.neumann@nasa.gov ; 216-433-2608). These facilities provide either 2.2 or 5.2 seconds of low-gravity. The possibility exists that investigators could take advantage of an existing test rig for the 5.2 second drop tower. To learn about its capabilities contact: Daniel Dietrich (Daniel.l.dietrich@nasa.gov; 216-433-8759)

Appendix G4.4: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Physical Sciences Program
2) **Research Title:** Quantum Effects
3) **Research Overview:**

Space offers a unique environment for experimental physics in many areas. Current areas of focus for NASA's Fundamental Physics program are cold atom physics, the application of cold atom technologies to research in quantum science and general relativity, and the physics of dusty plasmas.

Quantum physics is a cornerstone of our understanding of the universe. The importance of quantum mechanics is extraordinarily wide ranging, from explaining emergent phenomena such as superconductivity, to underpinning next-generation technologies such as quantum computers, quantum communication networks, and sensor technologies. Laser-cooled cold atoms are a versatile platform for quantum physics on Earth, and one that can greatly benefit from space-based research. The virtual elimination of gravity in the reference frame of a free-flying space vehicle enables cold atom experiments to achieve longer observation times and colder temperatures than are possible on Earth. The NASA Fundamental Physics program plans to support research in quantum physics that will lead to transformational outcomes, such as the discovery of phenomena at the intersection of quantum mechanics and general relativity that inform a unified theory, the direct detection of dark matter via atom interferometry or atomic clocks, and the creation of exotic quantum matter than cannot exist on Earth.

Research Focus:
Proposals are sought for ground-based theory and experimental research that may help to develop concepts for future flight experiments. Research in distance effects in quantum superposition and entanglement are of particular interest.

Appendix G4.5: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Fluid Physics
2) **Research Title:** Flow Boiling in Reduced Gravity
3) **Research Overview:**

Study of two-phase flow instabilities began in the late 1920s, and in the nearly 100 years since, progress has been made in both experimental and theoretical understanding of them. Despite these advances, many key deficiencies remain, solution of which will provide appreciable value for system designers looking to leverage phase change heat transfer technologies in a safe and repeatable manner. There are several types of instabilities that are prevalent in flow boiling applications, but few modeling tools are available to predict operating conditions leading to their occurrence, or methods for mitigating their negative effects on flow boiling. These issues are especially concerning for flow boiling systems employed in space, given the added complexity of reduced gravity environment.

Research Focus:
The most prevalent and important forms of two-phase instability are (1) ***Density Wave Oscillations*** (DWOs) and (2) ***Parallel Channel Instability*** (PCI), both are *dynamic instability* types. The former is manifest by a liquid surge along a flow boiling channel, and precipitates fluctuations in both flow rate and wall temperature. The latter is encountered in cold plates containing parallel flow channels, where differences in interfacial behavior and void fraction between channels also causes fluctuations in both flow rate and wall temperature. A third important instability topic is ***Two-phase Choking***, which is a *static instability* limit. This phenomenon is the outcome of appreciable changes in specific volumes and enthalpies of liquid and vapor, and is known to both greatly increase pressure drop and/or impose upper limits on flow rate through the boiling channel. This focused flow boiling research emphasis requests ground-based, laboratory proposals for hypothesis-driven experiments and/or analysis to investigate and help determine: 1) Density wave oscillations 2) Parallel Channel Instability and 3) Two phase chocking instability.

Appendix G4.6: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Physical Sciences
2) **Research Title:** Physical Sciences Informatics System
3) **Research Overview:**

This call for proposals is for ground-based research proposals to utilize NASA's Physical Sciences Informatics (PSI) system (https://psi.nasa.gov/) to develop new analyses and scientific insights. The PSI system is designed to be a resource for researchers to data mine information generated from completed reduced-gravity physical sciences experiments performed on the

International Space Station (ISS), Space Shuttle flights, Free Flyers, commercial cargo flights to and from the ISS, or from related ground-based studies. Specifically, this call is for the utilization of data from investigations that are currently available in the PSI system.

Research Focus
The call solicits ground-based research proposals that present a compelling case of how the experimental data from the PSI system (https://psi.nasa.gov/) will be used to promote the advancement of further research. Proposers must show a clear path from the scientific data obtained from the PSI system to the proposed investigation. In addition, the project must address an important problem in the proposed area of research and advance scientific knowledge or technology. The scope of the proposed work is unrestricted except that the use of data in the PSI database must comprise a substantial portion of the research.

This call solicits proposals in the following five research areas: 1) Combustion Science, 2) Complex Fluids, 3) Fluid Physics, 4) Fundamental Physics, and 5) Materials Science. The call specifically solicits proposals that utilize data from investigations listed in the table below. Of the eligible 63 investigations, 47 are from the ISS, eight from the Space Shuttle (Space Transportation System; STS), one from a Free Flyer experiment, three from commercial cargo flights to and from the ISS (Commercial Resupply Services; CRS), and four selected through PSI NRA (denoted with “PSI NRA science” in the table). Proposals that do not utilize data from investigations listed in the table below may be declared without further review.

#	Research Area	Investigation	Carrier / Source
1	Combustion Science	BASS (Burning and Suppression of Solids)	ISS
2	Combustion Science	BASS-II (Burning and Suppression of Solids - II)	ISS
3	Combustion Science	CFI (Cool Flames Investigation)	ISS
4	Combustion Science	DAFT (Dust and Aerosol Measurement Feasibility Test)	ISS
5	Combustion Science	DAFT-2 (Dust and Aerosol Measurement Feasibility Test - 2)	ISS
6	Combustion Science	FLEX (Flame Extinguishment Experiment)	ISS
7	Combustion Science	FLEX-2 (Flame Extinguishment Experiment - 2)	ISS
8	Combustion Science	Quantitative Studies of Cool Flame Transitions at Radiation/Stretch Extinction Using Counterflow Flames (PSI NRA science)	PSI-A
9	Combustion Science	SAFFIRE I (Spacecraft Fire Experiment I)	Cygnus CRS OA-6

10	Combustion Science	SAFFIRE II (Spacecraft Fire Experiment II)	Cygnus CRS OA-5
11	Combustion Science	SAFFIRE III (Spacecraft Fire Experiment III)	Cygnus CRS OA-7
12	Combustion Science	SAME (Smoke Aerosol Measurement Experiment)	ISS
13	Combustion Science	SAME-R (Smoke Aerosol Measurement Experiment - Reflight)	ISS
14	Combustion Science	SLICE (Structure and Liftoff in Combustion Experiment)	ISS
15	Combustion Science	SPICE (Smoke Point in Coflow Experiment)	ISS
16	Complex Fluids	ACE-M1 (Advanced Colloids Experiment - Microscopy 1)	ISS
17	Complex Fluids	ACE-M2 (Advanced Colloids Experiment - Microscopy 2)	ISS
18	Complex Fluids	BCAT-3 (Binary Colloidal Alloy Test - 3)	ISS
19	Complex Fluids	BCAT-4 (Binary Colloidal Alloy Test - 4)	ISS
20	Complex Fluids	BCAT-5 (Binary Colloidal Alloy Test - 5)	ISS
21	Complex Fluids	BCAT-6 (Binary Colloidal Alloy Test - 6)	ISS
22	Complex Fluids	InSPACE (Investigating the Structure of Paramagnetic Aggregates from Colloidal Ellipsoids)	ISS
23	Complex Fluids	InSPACE-2 (Investigating the Structure of Paramagnetic Aggregates from Colloidal Ellipsoids - 2)	ISS
24	Complex Fluids	InSPACE-3 (Investigating the Structure of Paramagnetic Aggregates from Colloidal Ellipsoids - 3)	ISS
25	Complex Fluids	InSPACE-3+ (Investigating the Structure of Paramagnetic Aggregates from Colloidal Ellipsoids - 3+)	ISS
26	Complex Fluids	PCS (Physics of Colloids in Space)	ISS
27	Complex Fluids	PHaSE (Physics of Hard Spheres Experiment)	STS-94
28	Complex Fluids	SHERE (Shear History Extensional Rheology Experiment)	ISS
29	Complex Fluids	SHERE II (Shear History Extensional Rheology Experiment II)	ISS
30	Complex Fluids	SHERE-R (Shear History Extensional Rheology Experiment - Reflight)	ISS
31	Complex Fluids	Structure Evolution During Phase Separation in Colloids Under Microgravity, (PSI NRA science)	PSI-B

32	Fluid Physics	CCF-EU1-CV (Capillary Channel Flow - Experiment Unit 1 - Critical Velocities)	ISS
33	Fluid Physics	CCF-EU2-CV (Capillary Channel Flow - Experiment Unit 2 - Critical Velocities)	ISS
34	Fluid Physics	CCF-EU2-PS (Capillary Channel Flow - Experiment Unit 2 - Phase Separation	ISS
35	Fluid Physics	CFE (Capillary Flow Experiment)	ISS
36	Fluid Physics	CFE-2 (Capillary Flow Experiment – 2)	ISS
37	Fluid Physics	Computational Framework for Capillary Flows, (PSI NRA science)	PSI-A
38	Fluid Physics	CVB (Constrained Vapor Bubble)	ISS
39	Fluid Physics	CVB-2 (Constrained Vapor Bubble – 2)	ISS
40	Fluid Physics	Gravity Scaling of Pool Boiling Heat Transfer: Numerical Simulations and Validation with MABE and NPBX, (PSI NRA science)	PSI-B
41	Fluid Physics	MABE (Microheater Array Heater Boiling Experiment)	ISS
42	Fluid Physics	NPBX (Nucleate Pool Boiling Experiment)	ISS
43	Fluid Physics	PBE (Pool Boiling Experiment)	STS-47, STS-57, STS-60, STS-72, STS-77
44	Fluid Physics	PBRE (Packed Bed Reactor Experiment)	ISS
45	Fluid Physics	STDCE-1 (Surface Tension Driven Convection Experiment) - First United States Microgravity Payload on Columbia (USML-1)	STS-52
46	Fundamental Physics	DECLIC-ALI (Device for the Study of Critical Liquids and Crystallization - Alice Like Insert)	ISS
47	Fundamental Physics	GRADFLEX (Gradient Driven Fluctuation Experiment)	Free Flyer
48	Fundamental Physics	PKE-Nefedov & PK-3+ (Plasma Kristall Experiment; Dusty Plasma)	ISS
49	Materials Science	CSLM (Coarsening in Solid-Liquid Mixtures)	STS-83, STS-94
50	Materials Science	CSLM-2 (Coarsening in Solid-Liquid Mixtures - 2)	ISS
51	Materials Science	CSLM-2R (Coarsening in Solid-Liquid Mixtures - 2 Reflight)	ISS

52	Materials Science	CSLM-3 (Coarsening in Solid-Liquid Mixtures - 3)	ISS
53	Materials Science	CSLM-4 (Coarsening in Solid-Liquid Mixtures - 4)	ISS
54	Materials Science	DECLIC-DSI (Device for the Study of Critical Liquids and Crystallization - Directional Solidification Insert)	ISS
55	Materials Science	IDGE-STS-62 (Isothermal Dendritic Growth Experiment) - Second United States Microgravity Payload on Columbia (USMP-2)	STS-62
56	Materials Science	IDGE-STS-75 (Isothermal Dendritic Growth Experiment) - Third United States Microgravity Payload on Columbia (USMP-3)	STS-75
57	Materials Science	IDGE-STS-87 (Isothermal Dendritic Growth Experiment) - Fourth United States Microgravity Payload on Columbia (USMP-4)	STS-87
58	Materials Science	ISSI (In-Space Soldering Investigation)	ISS
59	Materials Science	MICAST/CSS (Microstructure Formation in Casting of Technical Alloys under Diffusive and Magnetically Controlled Convective Conditions/Comparison of Structure and Segregation in Alloys Directionally Solidified in Terrestrial and Microgravity Environments)	ISS
60	Materials Science	PFMI (Pore Formation and Mobility Investigation)	ISS
61	Materials Science	Strata-1	ISS
62	Materials Science	SUBSA (Solidification Using a Baffle in Sealed Ampoules)	ISS
63	Materials Science	TEMPUS (Tiegelfreies Elektromagnetisches Prozessieren Unter Schwerelosigkeit; Electromagnetic Containerless Processing in Microgravity)	STS-65, STS-83, STS-94

Proposers must review the data in the PSI system before preparing their proposal. The proposal must clearly demonstrate how the PSI data will be used in the project. Furthermore, prior to the submission of the proposal, it is highly recommended that the proposers take at least one representative sample set of PSI data to perform numerical modeling or sample experiments and present the findings as part of the proposal.

Research results from proposals selected under this call for proposals will be entered into the PSI system for use by future investigators.

Appendix G4.7: NASA Space Life and Physical Sciences and Research Applications

1. **Research Title:**
   Bioinformatic Analysis of Space Biology Data in the NASA GeneLab Data System

2. **Research Overview:**

With humans pushing to live further off Earth for longer periods of time, it is increasingly important to understand the changes that occur in biological systems during spaceflight --- whether these be astronauts, their microbial commensals, or their plant-based life support systems.

The NASA GeneLab data system contains decades of genomic, metabolomic, proteomic, transcriptomic, and microbiome profiling data from biological experiments performed in space or exposed to spaceflight-like conditions. Curation and aggregation of this data within GeneLab enables re-use and cross comparison of these rare opportunities for experimentation in space.

NASA is requesting proposals from investigators who wish to perform bioinformatic analyses of the data within GeneLab. These analyses could include single or multiple datasets. Investigators are encouraged to include data from other databases. Investigators are encouraged to utilize pre-processed data provided on GeneLab when possible, but are welcome to suggest improvements to this data to the GeneLab team.

All proposers are required to interact with various GeneLab Analysis Working Groups (AWGs) to receive input on their work and to strengthens these communities with new ideas (https://genelab.nasa.gov/awg/charter).

Proposals must translate the spaceflight derived data in the GeneLab database into new knowledge that addresses the objectives of NASA's Space Biology Program and its principal scientific elements (https://www.nasa.gov/sites/default/files/atoms/files/16-03-23_sb_plan.pdf).

Appendix G4.8: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Space Biology Program
2) **Research Title:** Biofilms and the Built Environment
3) **Research Overview:**

NASA needs to optimize the design of future human-occupied space craft for exploration to manage the microbial environment for sustained human utilization. Exploration missions include destinations to the moon and Mars as well as enabling a better understanding of continued long duration occupation of the International Space Station. Included in this design are. To identify and understand key factors required to optimize spacecraft and habitat design, an in-depth understanding of how the healthy and disease-causing microbes of this enclosed and sealed space will evolve and interact with the crew and plants over the mission duration is required. Areas for potential biofilm interactions include: life support subsystems, such as water recovery, spacecraft structural materials, and chambers for growing crops for crew food and nutrition. Additional microbiology research is needed to expand our understanding of spaceflight environmental factors that impact microbial growth, physiology, reproduction, evolution, community dynamics, and virulence.

Early studies with microorganisms showed that they reached higher population densities when grown under microgravity conditions than were obtained from cultures grown under similar conditions on the ground. The higher cell densities were likely due to a more homogeneous distribution of cells in the culture medium, as opposed to the crowded and more nutrient– depleted conditions that occurs at 1g as the cells settle (Klaus et al., 1997; PMID 9043122). Additional studies also showed that spaceflight caused some bacterial species to become more resistant to common antibiotics. (Klaus and Howard, 2006: PMID 16460819). Other studies demonstrated that spaceflight or simulated microgravity promoted biofilm formation (Kim et al., 2013; PIMD 23658630, Searles et al., 2011; PMID 21936634). These biofilms have been found to cause significant biofouling of water recovery system fluidic systems and serve as potential agents for biocorrosion of spacecraft materials.

Research Focus

The goal of this NASA Space Biology Program research emphasis is to build a better understanding of fungal and bacterial biofilm biology, its development, and interactions with spacecraft materials and hardware through hypothesis-driven experiments that will answer basic questions about how individual and mixed microbial biofilms respond to changes in gravity and other environmental factors (e.g., radiation) associated with spaceflight and methods for mitigating their development. Overall, the results of the proposed investigations should contribute to a broader, systems level understanding of biofilm biology in the spaceflight environment and its interaction with the built environment.

For this research emphasis, NASA requests proposals to determine the effect of simulated microgravity on microbial biofilm biology and community dynamics to advance findings and hypotheses derived from spaceflight investigations. Such studies are expected to generate and test specific ground-based hypotheses that will lead to hypotheses testable in spaceflight.

The proposed investigation is expected to simulate elements of the spaceflight conditions, such as microgravity, in ground-based analogs such as clinostats, High Aspect Rotating Vessels (HARVs), or other Low- Shear Model-Microgravity (LSMM) systems. Studies that investigate combine microgravity and radiation are encouraged, but the proposal must adhere to the funding and duration requirements of this EPSCoR CAN. Ground-based investigations should be proposed that will study one or more of the following topics:

a. Develop fundamental knowledge about how simulated microgravity influences biofilm biology. Space Biology studies will determine the effects of this environment on the dynamics of microbes in mono or mixed microbe biofilms with respect to cell processes (including biofilm development, biofilms structural and functional changes, and virulence and antibiotic resistance). The proposed investigation may study fungal- and/or bacterial-based biofilms.
b. Determine how biofilms interact with and affect built environment surfaces in simulated microgravity. The built environment is defined as spacecraft hardware and materials. Space Biology studies will determine the role different material types and surface features play in facilitating or inhibiting biofilm formation (including microbe-to-surface interactions and biocorrosion). The proposed investigation may study fungi, bacteria, or mixed microbe communities. It is encouraged that the studies use materials or hardware subsystems that are representative of those used on ISS and its hardware, such water recovery systems and material surfaces exposed to high humidity.
c. Develop fundamental knowledge to develop methods for mitigating biofilm formation on built surfaces and hardware systems, such as the ISS water recovery system and other fluidics systems. Methods for preventing biofilm formation may consider, but are not limited to, surface coatings, material surface topology, biocides, UV radiation, chemicals, mechanical disruption, bio-based antimicrobial treatments. It is anticipated that the studies will examine individual methods or combination of methods.

Proposers are expected to be familiar with the Decadal Survey Priorities (http://www.nap.edu/catalog/13048.html) and the NASA Space Biology Plan (https://www.nasa.gov/sites/default/files/atoms/files/16-05-11_sb_plan_2.pdf) to understand the specific space bioscience research topics that can be affected by non-space-associated variables.

Appendix G4.9: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Space Biology Program
2) **Research Title:** Plant and Microbial Interactions
3) **Research Overview:**

Fundamental discoveries made by NASA researchers over the last 50 years has helped enable successful growth of plants in space, as is demonstrated through current work being done on the ISS using Veggie and the Advanced Plant Habitat. In spite of these forward advances, and the potential of this work to lead to the creation of space life-support systems, additional fundamental plant biology research is still needed. There still much to learn about how plants respond to the spaceflight environment, and what it will take to support long-duration, multiple generation plant growth and cultivation during extended space exploration missions.

One area of fundamental research that NASA wishes to focus on is the impact of the spaceflight environment on plant and microbial interactions. While the microbial contamination of plants grown in the closed environment of a spacecraft is always a potential concern, the interactions of these plants with beneficial microbes, such as those between leguminous plant and nitrogen fixing bacteria, may also be altered in spaceflight-environment (Foster et. al., 2014: PMID: 25370197). The goal of this NASA Space Biology Program research emphasis is to build a better understanding of the effects of spaceflight on microbial and plant ecosystems found spacecraft such as the ISS, which in turn will help us prepare for future exploration missions to the moon and Mars.

Research Focus

This Space Biology Research Emphasis requests proposals for hypothesis-driven experiments that will help determine: 1) the effects of the spaceflight-like environment on plant-microbial interactions; 2) the long-term, multigenerational effects of the spaceflight-like environment on plant-microbial population dynamics; and 3) how to optimize plant-microbial systems for growing and sustaining plants in space. Fundamental plant-microbial biology research is needed to specifically identity the driving space environmental factors or combination of factors that impact plant-microbial interactions. Applicants should consider at least one of the following questions in the preparation of their proposal:

- How do space-environmental conditions influence the development and diversity of microbial communities associated with plants? How do microbial population from plant surfaces or plant growth media change over time in a spaceflight-like environment?
- Which plant-microbial interactions effect important processes (e.g., commensalisms, symbioses, nitrogen fixation, biodegradation) and how do the processes change in response to the multiple stimuli encountered in space environments?
- What environmental conditions are needed for optimal plant-microbial interactions in spacecraft (e.g., temperature, humidity, light wavelengths, light intensity, concentration and ratio of gases)? What is the optimal microbial composition for plant growth media needed to sustain plants in space environments?
- Can beneficial microbes in plant growth media be grown successfully through multiple life cycles in a space environment?

Proposers are encouraged to incorporate the use of microgravity analogs that simulate the effects of spaceflight (or partial gravity) on their plant/microbial system in their experimental design, or to use centrifuges to conduct hyper-gravity studies that characterize how their proposed system(s) responds to a downshift in gravity levels from 2g to 1g (as a surrogate for a 1g to 0g downshift).

Investigators may also propose studies that characterize the long terms effects of isolation similar to those experience in a closed built environment such as a spacecraft on plant/microbial ecosystems.

Proposers are expected to be familiar with the Decadal Survey Priorities (http://www.nap.edu/catalog/13048.html) and the NASA Space Biology Plan (https://www.nasa.gov/sites/default/files/atoms/files/16-05-11_sb_plan_2.pdf) to understand the specific space bioscience research topics that can be affected by non-space-associated variables.

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

Appendix G4.10: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Physical Sciences Program
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.

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 or reduced gravity aircraft. Investigations should be proposed that would study one or more of the following topics:

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

It is expected that regolith simulant will be used for the proposed experiments. 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).

Appendix G4.11: NASA Space Life and Physical Sciences and Research Applications

1) **Program:** Space Biology Program
2) **Research Title:** In-Situ Food Safety Monitoring
3) **Research Overview:** (General overview – no more than a couple of paragraphs)

NASA has identified in situ crop production as a technology gap that needs to be filled to enable deep space exploration. Current solutions to this technological gap utilize growing "pick and eat" crops during missions in plant growth chambers that are exposed to the cabin environment and crew interaction. Produce grown in situ is consumed without cooking or other processing techniques, leaving the produce susceptible to contamination during growth or post-harvest handling. Produce grown on ISS is currently cleaned post-harvest with produce sanitizing wipes to minimize crew exposure to potentially harmful pathogens. This procedure of cleaning produce post-harvest on-orbit is time consuming for the crew and requires the use of consumable sanitizing wipes that may be burdensome to stow on long-duration exploration missions.

There are currently no in situ techniques or procedures in place to detect or identify potential pathogens and opportunistic pathogens in crop production systems on spacecraft. This is especially concerning in the microgravity environment, where numerous changes in microbial behavior in response to microgravity are documented, such as findings of higher microbial population densities when grown under microgravity conditions (Klaus et al., 1997; PMID 9043122) and increased virulence in space-grown cultures of the pathogen *Salmonella* enterica serovar Typhimurium (Wilson et al., 2007; PMID 17901201).

There are numerous microbial monitoring programs on ISS that utilize molecular techniques to identify microbial populations on ISS (e.g. Venkateswaran et al., 2014: PMID 25130881). In their current form, none of these techniques are employed as a diagnostic tool for in-situ food safety monitoring of freshly grown produce. Molecular techniques could be employed as a diagnostic tool to detect specific human pathogens on produce prior to crew consumption. Current research at NASA and USDA into hyperspectral and multispectral imaging is advancing the capability to detect plant stress in real-time, which could be useful for identifying potential food safety concerns as plants are cultivated. Additionally, these advanced imaging systems are able to detect microbial growth, though it is still to be determined at what level of sensitivity microbes can be detected (i.e. colony size). It is likely a multi-faceted in-situ food safety monitoring approach may ultimately be deployed in space crop production systems on spacecraft. One where advanced plant health imaging systems are able to detect biofilm growth or changes in plant health that are most conducive to pathogen and opportunistic pathogen establishment, which is then followed up with targeted molecular techniques capable of detecting pathogens to the genus or species levels.

Research Focus:
The goal of this NASA Space Biology Program research emphasis is to build a better understanding of non-destructive in situ techniques that can be deployed to advance food safety specific microbial monitoring on spacecraft such as ISS to prepare for future exploration missions far from Earth.

The proposed investigation is expected to simulate elements of spaceflight crop production, to include use of light emitting diode (LED) lighting systems, controlled environmental conditions, and analogous water and nutrient delivery systems. Studies that use simulated microgravity are welcomed but may not be feasible with larger crops and must adhere to the funding and duration requirements of this EPSCoR CAN. Ground-based studies should be proposed that will:

a. Grow a range of "pick and eat" crops similar to those proposed to support future deep space exploration missions, including leafy greens, tomatoes, and peppers, and demonstrate the effectiveness of the proposed In-Situ Food Safety Monitoring technology to detect and measure the amount of microbes associated with these crops. An effective system will provide a visual cue for measurements that exceed a specific user defined quantity, which may be user adjustable based on health requirements.

b. Determine the false positive and false negative rate of the technology for different crop types and measure what other factors, such as gravity environment, humidity levels, ambient lighting, etc, may have on the false detection rates.
c. Determine microbial detection capabilities of food safety monitoring technique. Beyond knowing total microbial levels, differentiating individual strains of pathogens and beneficial microbes can enable targeted reduction of pathogens to ensure Food Safety while minimizing the negative impact of any sanitation techniques on the healthy microbiome of the grow system or potentially beneficial probiotic effect of the produce for the crew.

Proposers are expected to be familiar with the Decadal Survey Priorities (http://www.nap.edu/catalog/13048.html) and the NASA Space Biology Plan (https://www.nasa.gov/sites/default/files/atoms/files/16-05-11_sb_plan_2.pdf) to understand the specific space bioscience research topics that can be affected by non-space-associated variables.

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

Appendix G.5.1: KSC Partnerships Office

Research Title:

Conver

sion of CO_2 into Fuel

Research Overview: The original research at NASA aimed to investigate and demonstrate the conversion of CO_2 in the presence of H_2O vapor to fuel (i.e. CH_4) using novel photocatalysts in a photocatalytic reactor under Mars and Earth simulated solar spectrums. Results demonstrated production of hydrocarbon fuel, which was likely CH_4, as observed by GC and FTIR data. If peak performance parameters can be isolated and then honed in on, better understanding of the kinetics and mechanisms can aide in making the reaction more efficient for future scale up purposes.

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Related Publications: *Photocatalytic Conversion of CO_2 on Mars,* September 21, 2016.

Carbon Dioxide Methanation for Human Exploration of Mars: A Look at Catalyst Longevity and Activity Using Supported Ruthenium, April 18, 2018, Great Plains Catalysis Society Symposium, Manhattan KS.

Additional Information: The photocatalyst materials tested in the photoreactor were initially generated from the Science Innovation Fund Project "An In-Depth Study of Photocatalytic Charge Transport and Material Development through Synthesis, Characterization, and Photocatalytic Properties for In Situ Resource Utilization and Fuel Production on Mars". Further developments at Kennedy Space Center (KSC) continued during this project where photocatalyst materials were synthesized at KSC and the University of South Florida (USF) for photoreactor testing at KSC. The photocatalyst materials underwent structural/morphology analysis and optical characterization and were believed to have bandgap values in the regime for photocatalytic H_2O splitting and CO_2 conversion. The hydrogen evolution reaction produces available hydrogen that may react with CO_2 in a series of reduction and oxidation (redox) reactions for the production of fuels such as CH_4, which is a necessity for liquid O_2 and liquid CH_4 propulsion systems of deep space, as well as fuels used on earth. The data in this work looked at MoS_2, $(ZnO)_{1-x}(GaN)_x$, $(ZnO)_{1-x}(AlN)_x$ materials in the photoreactor under Earth and Mars conditions.

Appendix G.5.2: KSC Partnerships Office

Research Title: Evaluation of Low Pressure Air Plasma for Passivation of Metal Components

Research Overview: Currently there is no International Space Station capability for disinfecting pick and eat crops, food utensils and production areas, or medical devices. This deficit is extended to projected long duration missions. Small, portable, Cold Plasma (CP) devices would provide an enhanced benefit to crew health and address issues concerning microbial cross contamination. New technology could contribute to the reduction of solid waste since currently crews utilize benzalkonium chloride wet wipes for cleaning surfaces and might use organic acid based wipes for cleaning vegetables.

Previoulsy an innovation was designed to allow for passivation of aerospace components using a low-pressure air plasma system. The system operates as it is designed to (functional operation of low-pressure plasma system) but instead of the normal feed gases (hydrogen, oxygen, or argon) a k-bottle of breathing air is utilized. The compressed air is fed into the plasma system and ionized, allowing for cleaning of all available surfaces within the chamber. Plasma cleaning is a dry, non-thermal process which can provide broad-spectrum antimicrobial activity. It is microgravity compatible since cold plasma uses no liquids and is able to penetrate event eh smallest cracks and crevices. This innovation eliminates hazardous solvents and hazardous waste stream while reducing a multi-step process into single-step process. CP is a technology that could be used in medical facilities in remote areas and third world countries.

Since the cleaning process developed at KSC uses air as the plasma gas, this technology could be used in remote areas for sterilization without any consumables. In Food Science, CP has the potential to be used to disinfect vegetables and reduce considerably the number of foodborne illnesses per year in the world (deaths, medical costs, industry costs) and represents an alternative to the common disinfection method with bleach.

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Related Publications: *Evaluation of Low-Pressure Cold Plasma for Disinfection of ISS Grown Produce and Metallic Instrumentation,* July 16, 2017, 47th International Conference on Environmental Systems, Charleston, SC.

Additional Information: Aerospace components undergo a passivation process to ensure contaminants are removed from the surface of the metals/alloys and to form an inert, protective oxide layer to enhance the corrosion resistance of the material. Current methods require the use of hazardous chemicals, involve multiple steps, and produce hazardous waste streams that must be disposed of. Currently, passivation of corrosion-resistant steels for aerospace applications follows an SAE International Standard, AMS2700, where parts are submerged in either a nitric acid or nitric acid/sodium dichromate bath at predetermined temperatures and contact times. These baths require constant testing to ensure effective treatment, use corrosive and carcinogenic chemicals, and produce hazardous waste.

Appendix G6.1: GSFC Computational and Information Sciences and Technology Office (CISTO)

Program: Computational and Information Sciences and Technology Office (CISTO)
Research Title: Computational and Technological Advances for Scientific Discovery
Research Overview:
SMD requests that EPSCoR include research opportunities in areas of a) Artificial Intelligence and Machine Learning (AI/ML), b) High Performance Computing, c) Augmented Reality/Virtual Reality/Mixed Reality (AR/VR/MR), and d) Citizen Science to enable and accelerate scientific discovery and technological innovations for NASA's scientific missions. NASA's scientific lines of business include Earth Sciences, Planetary Sciences, Astrophysics, and Heliophysics.

G6.2 Artificial Intelligence and Machine Learning (AI/ML)

Advent of new technologies such as Clouds and 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. Similarly, in recent years AR/VR consumer-friendly software and hardware tools have become available at affordable prices. 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).

While these techniques are 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).

G6.3 High Performance Computing; Evolving Applications to Exascale

High Performance Computing (HPC) applications across NASA have seen a significant increase in computational capability over the past decade using cluster systems with traditional CPU-only based capabilities. The architectures being deployed across the US and abroad to reach the next milestone of computing, Exascale, have a significantly different architecture based on accelerated computing using Graphical Processing Units (GPUs). NASA applications, such as atmospheric models, will require Exascale computational capabilities over the next decade. Research investigations addressing the porting and scaling of HPC applications on accelerated based HPC are encouraged. Furthermore, the use of Domain Specific Languages (DSLs), such as Kokkos or GridTools, to create portable and optimized applications for different architectures is of high interest.

In addition to scaling applications using accelerator based computing platforms, NASA is interested in replacing model components and augmenting models with artificial intelligence. In General Circulation Models of the atmosphere, components are written based on physical models and algorithms are then written to compute those physics or chemistry based models. In some cases, the computational requirements for these physical based algorithms take too many resources for current HPC platforms. Replacing these model components with trained algorithms has the potential to dramatically reduce the computational requirements for these models while not reducing accuracy beyond acceptable limits. Research investigations addressing the replacement of model components with trained models for use in HPC applications is of high interest as well.

G6.4 Augmented Reality/Virtual Reality/Mixed Reality (AR/VR/MR)

AR/VR applications allow scientists to experience being in environments that are hard, impossible, or too costly in person. For example, existing NASA AR/VR applications enable immersive exploration of places deep in the ocean, to distant planetary surfaces and galaxies or to experiment with various robotic or spacecraft assembly and integration processes in AR/VR before taking high risks on the actual expensive hardware.

G6.5 Citizen Science

Various NASA projects have used Internet tools and technologies not only as a public outreach and education tool but as a means to engage ordinary citizens in their projects and most importantly to contribute to their scientific discoveries. Examples of such NASA citizen science projects are GLOBE Observer (https://observer.globe.gov), Planet Hunters (www.planethunters.org), Backyard Worlds: Planet 9 (www.backyardworlds.org), Moon Zoo (www.moonzoo.org) and Galaxy Zoo (www.galaxyzoo.org).

Research investigations addressing more than one of the above-mentioned areas (hybrid solutions) are encouraged. Examples include: onboard HPC AI/ML data processing and volume reduction algorithms; Citizen Science applications for generating labeled training data as input to AI/ML software, or to validate AI/ML output results.

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Intellectual property management:

Additional Information:

NASA GSFC CISTO will provide NCCS support as needed.

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