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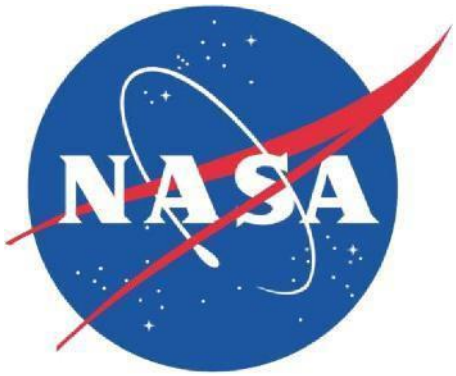

National Aeronautics and Space Administration
Office of STEM Engagement
FY 2021 NASA Cooperative Agreement Notice (CAN)

Established Program to Stimulate Competitive Research (EPSCoR)

Rapid Response Research (R3)

Announcement Number: NNH21ZHA002C
Catalog of Federal Domestic Assistance (CFDA) Number: 43.008

Release Date: **October 30, 2020**
Proposal Due Date: **February 5, 2021**

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

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Introduction

NASA's Office of STEM Engagement (OSTEM), in collaboration with the Aeronautics Research Mission Directorate (ARMD), Science Mission Directorate (SMD) Planetary Science Division, Earth Science Division, Biological and Physical Sciences Division, Space Technology Mission Directorate (STMD), and the Human Exploration and Operations Mission Directorate (HEOMD) Commercial Space Capabilities Office (CSCO), along with the Marshall Spaceflight Center (MSFC), Goddard Spaceflight Center (GSFC), and the Office of the Chief Health and Medical Officer (OCHMO), solicits proposals for the fiscal year 2021 NASA Established Program to Stimulate Competitive Research (EPSCoR) Rapid Response Research (R3) program.

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

- This solicitation will remain open for one year or for as long as funds are available.
- Amendments will be used to add/close appendices that list research tasks.
- Amendments will be open for 90 days.
- No proposals for the listed research tasks will be accepted after 90 days.
- Jurisdictions may submit one proposal per each NASA office, i.e., if there are four participating offices, the Jurisdiction may submit a maximum of four proposals. *Please include the appendix letter for the NASA office the applicant is proposing to support (i.e. SMD Planetary i.e. one of the NASA SMD Divisions: Planetary, Earth Sciences, Biological and Physical Sciences, or the CSCO) or NASA Center in the proposal title.* This will make it much easier for proposals to be sent to the correct NASA office for review/evaluation.
- Proposals should be two to three pages but may be up to 5 pages for several of the tasks (CSCO) and *must be submitted by the State NASA EPSCoR Director* through the NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). EPSCoR only accepts proposals submitted by the State NASA EPSCoR Director.
- Proposers are encouraged to contact the research task point of contact (POC) listed under the "Inquires" section of this solicitation on pages XX to XX for clarification/information on the requested research.

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

The following are the specific objectives of NASA EPSCoR:

- Contribute to and promote the development of research capability in NASA EPSCoR jurisdictions in areas of strategic importance to 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 and economic development of the jurisdiction

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

Solicitation Availability
This announcement is accessible for a period of one (1) year through NSPIRES and through Grants.gov.

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

Eligibility
As stated in NASA EPSCoR legislation, jurisdictions eligible to compete for this opportunity are those jurisdictions eligible to compete in the National Science Foundation (NSF) EPSCoR Research Infrastructure Improvement Grant Program (RII). The NSF eligibility is based on whether the most recent three-year level of NSF research support is equal to or less than 0.75 percent. The most recent eligibility table is located at: https://www.nsf.gov/od/oia/programs/epscor/Eligibility_Tables/FY-2019-Eligibility.pdf

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

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

It is anticipated that approximately (20) awards of up to $100,000 each for a period of performance not to exceed one year each may be made under this CAN pursuant to the authority of Title 2 Code of Federal Regulations (CFR) Parts 200, 2 CFR 1800, and the NASA Grant and Cooperative Agreement Manual (GCAM).

The research period of performance (start and end dates) are not fixed values, and are requested by the Jurisdiction for each submitted proposal. Official period of performance (start and end dates) are delineated by the Award document issued by the NSSC.

Proposal Submission
All information needed to respond to this solicitation is contained in this announcement and in the *Guidebook for Proposers Responding to a NASA Notice of Funding Opportunity (NOFO) effective June 23, 2020 Edition* (hereafter referred to as the *NASA Guidebook for Proposers*). The latest PDF version is available at: http://www.hq.nasa.gov/office/procurement/nraguidebook

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

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

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1.0 Description of Opportunity

1.1 Program Description

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

This Cooperative Agreement Notice (CAN) solicits proposals of two (2) to three (3) pages for the FY 2021 NASA EPSCoR Rapid Response Research (R3) program. Each funded NASA EPSCoR proposer shall work closely with a NASA researcher to focus on developing competitive research and technology for the solution of scientific and technical issues of importance to the NASA Mission Directorates as listed in Appendices A through I. The Rapid Response Research (R3) program is an attempt to implement research within NASA and commercial partners to address technical issues. It will allow EPSCoR researchers to work alongside NASA and commercial partners for up to one year and is intended to strengthen the bonds among EPSCoR jurisdictions, NASA, the commercial partners, and other entities.

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

1.2 Award Information: Funding and Cost-Sharing

The maximum funding that a jurisdiction can request from NASA is $100,000 per proposal. This amount is to be spent in accordance with the budget details and budget narrative in the approved proposal. Jurisdictions may submit one proposal consisting of two (2) to three (3) pages per NASA office listed. Multiple awards may be given for a particular task, depending on availability of funds. Proposers may resubmit proposals from previous R3 solicitations or submit proposals for renewal(s) of existing award(s).

EPSCoR plans to make approximately 20 awards from this announcement.

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

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

1.3 Award Information: Restrictions

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

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

The majority of grant-related activities are categorically excluded as research and development (R&D) projects that do not pose any adverse environmental impact. A blanket NASA Grants Record of Environmental Consideration (REC) provides NEPA coverage for these anticipated

activities. Section VIII includes a questionnaire to determine whether a specific proposal falls within the Grants REC and must be completed as part of the NOFO process. Activities outside of the bounding conditions of the Grants REC will require additional NEPA analysis. Examples of actions that will likely require NEPA analysis include but are not limited to: suborbital-class flights not conducted by a NASA Program Office (see Section V); activities involving ground-breaking construction/fieldwork; and certain payload activities such as the use of dropsondes.

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

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

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

- Non-Federal entities may 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.
- Unless as otherwise directed in 2 CFR 200, for changes to the negotiated indirect cost rate that occur throughout the project period, the proposer/recipient shall apply the rate negotiated for that year, whether higher or lower than at the time the budget and application was awarded.
- Proposals shall not include bilateral participation, collaboration, or coordination with China or any Chinese-owned company or entity, whether funded or performed under a no-exchange-of-funds arrangement.
- Cost sharing is not required, however, any funds used for voluntary matching or cost-sharing shall be allowable under 2 CFR 200.
- Procurement contracts shall not be awarded in conjunction with this solicitation.
- The proposer 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**.**

1.4 Access to Research Results

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

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

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

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

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

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

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

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

1.5 Foreign National Participation

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

1.6 Flight Activities

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

2.0 Eligibility

2.1 Jurisdictions Eligible to Apply

As stated in NASA EPSCoR legislation, jurisdictions eligible to compete for this opportunity are those jurisdictions eligible to compete in the NSF EPSCoR Research Infrastructure Improvement Grant Program RII). The NSF eligibility is based on whether the most recent three-year level of NSF research support is equal to or less than 0.75 percent. The most recent eligibility table is located at: https://www.nsf.gov/od/oia/programs/epscor/Eligibility_Tables/FY- 2019-Eligibility.pdf

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

2.2 Cost Share

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

3.0 Proposal Submission Instructions and Due Date/Time

All proposals in response to this announcement shall be submitted electronically via NSPIRES (http://nspires.nasaprs.com). Hard copies of the proposal will not be accepted. Electronic proposals shall be submitted in their entirety by 11:59 p.m., Eastern Time on the proposal due date of **February 5, 2021.**

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

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

- Every organization 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) at https://www.sam.gov/portal/public/SAM/
- Each individual team member (e.g., PI, co-investigators), including all personnel named on the proposal's electronic cover page, shall be individually registered in NSPIRES.

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

3.1. Proposal Preparation

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

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

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

Required Parts of a Proposal (in order of assembly)	Page Limit
Proposal Cover Page (NSPIRES web forms or Grants.gov forms) including: • Proposal Summary – limit to 4000 characters (including spaces) • Data Management Plan (per the NOFO) – limit to 4000 characters (including spaces) • NSPIRES cover page budget • Other required elements	Constrained by NSPIRES or Grants.gov
Table of Contents	As needed
Scientific/Technical/Management Plan	2-3 Pages*
References and Citations	As needed
Biographical Sketches for: See Section 3.15	
The Principal Investigator(s)	2 (per PI)
Each Co-Investigator	1
Current and Pending Support	As needed
Statements of Commitment and Letters of Support	As needed
[1]Proposal Budget (budget) – both the budget narrative and budget details	As needed
Facilities and Equipment	As needed
The Table of Personnel and Work Effort	As needed

3.2 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 and posted at its homepage on http://nspires.nasaprs.com.

Also, any clarifications or questions and answers regarding this CAN will be posted at its

homepage on http://nspires.nasaprs.com.

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

3.3 Cancellation of Program Announcement

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

3.4 Contacts

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

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All other inquiries about this cooperative agreement announcement should be addressed to:

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

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

4.0 Review and Selection Process

Review of proposals submitted in response to this CAN shall be consistent with the general policies and provisions contained in the *NASA Guidebook for Proposers*, Appendix D. Selection procedures will be consistent with the provisions of the *NASA Guidebook for Proposers*, Section 5. However, the evaluation criteria described in this CAN under Section 4.0, Proposal Evaluation, takes precedence over the evaluation criteria described in Section 5 of the *NASA Guidebook for Proposers*. The selecting official for this CAN is the EPSCoR Project Manager or their appointed representative. The NASA EPSCoR Grants Officer will conduct a pre-award review of risk associated with the proposer as required by 2 CFR 200.205. For all proposals selected for award, the Grants Officer will review the submitting organization's information available through the Federal Awardee Performance and Integrity Information System (FAPIIS) and the System for Award Management (SAM) to include checks on entity core data, registration expiration date, active exclusions, suspension, debarment, and delinquent federal debt.

Prior to making a Federal award with a total amount of Federal share greater than the simplified

acquisition threshold (currently $250,000), NASA Grant Officers will conduct a pre-award review of risk associated with the proposer as required by 2 CFR 200.205. For all proposals selected for award, the Grant Officer will review the submitting organization's information available through multiple government wide repositories such as the System for Award Management (SAM.gov), Federal Awardee Performance and Integrity Information System (FAPIIS), the Contractor Performance and Assessment Reporting System (CPARS), the Federal Audit Clearinghouse (FAC), USAspending.gov, and Grant Solutions Recipient Insight.

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

Limited Release of Proposers Confidential Business Information

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

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

4.1 Selection Announcement

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

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

4.2 Notice of Award

For selected proposals, the NASA Grants Officer will contact the business office of the proposer's institution. The Grants Officer is the only official authorized to obligate the Government. For a grant or cooperative agreement, any costs that the proposer incurs within 90 calendar days before an award are at the recipient's risk in accordance with 2 CFR § 1800.209.A

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

4.3 Administrative and National Policy Requirements

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

4.4 Award Reporting Requirements

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

5.0 Proposal Evaluation

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

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

5.1 Intrinsic Merit (65% of score)

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

5.2 Management (20% of score)

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

to publish their accomplishments.

5.3 Budget (15% of score)

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

6.0 Certification of Compliance

As described in Section 1.4 above, recipients receiving awards under this CAN shall comply with the provision set forth in the NASA Plan for Increasing Access to the Results of Scientific Research (http://www.nasa.gov/sites/default/files/files/NASA_Data_Plan.pdf), including the responsibility for-

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

The Authorized Organization's Representative (AOR's) signature on the Proposal Cover Page serves as a certification that the proposing organization has read and is in compliance with all certifications, assurances, and representations as detailed in the GCAM Appendix C, Section C1. The GCAM is available at the following site: http://naistst1.nais.nasa.gov/pub/pub_library/srba/certs.html.

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

Appendix A: NASA SMD Planetary Division

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

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

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

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

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

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

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

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

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

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

b. properties of the cloud particles in general;

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

d. the presence of lightning; and

e. properties of the surface mapped aerially.

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

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

C. Extreme Environment Aerobot

- Venus provides an important scientific link to Earth, Solar System formation, and to Exoplanets. This EPSCoR call is made for technology projects, which take into consideration Venus' middle atmosphere conditions and its unique extreme environment. The call concentrates on the challenge to develop an aerial platform that would survive the extreme conditions of the Venusian middle atmosphere. It is worth noting that in the middle atmosphere of Venus (79km to 45Km), the conditions are considerably more benign than its surface conditions. This EPSCoR call will focus on Variable Manurable (horizontally and vertically) altitude balloons or hybrid airship, or aerobots (buoyancy + lift). The top technical parameters to consider for the Extreme Environment Aerobot for Venus conditions are (* see references below):
- Altitude: Maintain 79km to 45km Altitude (avoids high temps)
- Structure: Airframe & Materials compatible with acids (PH -1.3 to 0.5). The cloud pH varies from about 0.5 at the top (65 km) to -1.3 at the base (48 km).
- Power source: Solar and/or Batteries
- Navigation: provide, Guidance & Control concepts
- Science Instruments: for atmosphere and ground remote sensing
- Lifetime: weeks to months
- Pressure and temperature range: 80mb-1.3bar, with pressure at 65 km (245Kelvin or -28C) from Pioneer Large probe measured 80 mb and at 48 km(385 Kelvin or 112C) is approximately 1.3 bar. At 60 deg. latitude the pressure at 65 km is about 70 mb and temperature is about 222 K (-51C).
- Winds: Vertical shear of horizontal wind, up to 5-10 m/s per km
- Reference material:

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

in the Venus Technology Roadmap at:
https://www.lpi.usra.edu/vexag/reports/Venus-Technology-Plan-140617.pdf

NASA Contact

a. Name: Adriana Ocampo
b. Organization: SMD/Planetary Science
c. Work Phone: 202.358.2152
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c. Work Phone: 216.433.3411
d. Cell Phone: 216.905.1987
e. Email: cmercer@nasa.gov

(*) Reference papers:

Counselman C. C., Gourevitch S. A., King R. W., Loriot G. B., and Ginsberg E. S. (1980) Zonal and meridional circulation of the lower atmosphere of Venus determined by radio interferometry. *Journal of Geophysical Research*, 85: 8026-8030.

Kerzhanovich V. V., Aleksandrov Y. N., Andreev R. A., Armand N. A., Bakitko R. V., Blamont J., Bolgoh L., Vorontsov V. A., Vyshlov A. S., Ignatov S. P. et al. (1986) Small-scale turbulence in the Venus middle cloud layer. *Pisma v Astronomicheskii Zhurnal*, 12: 46-51.

Kerzhanovich V. V., and Limaye S. S. (1985) Circulation of the atmosphere from the surface to 100 KM. *Advances in Space Research*, 5: 59-83

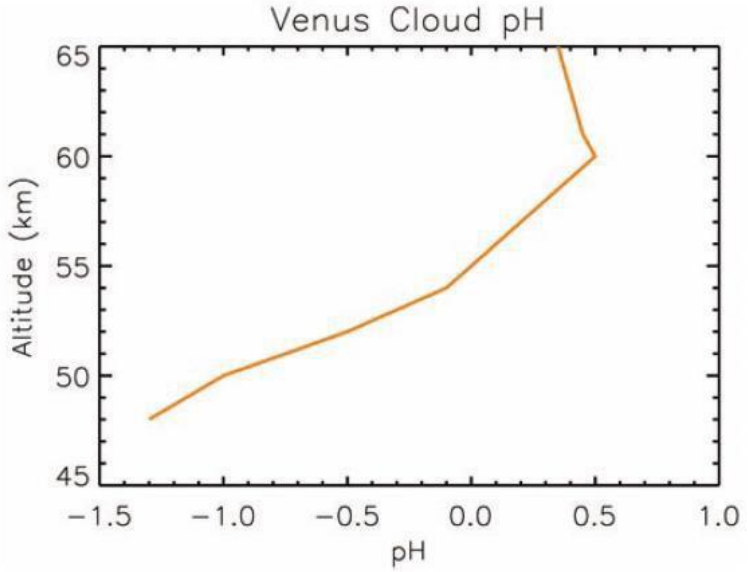

Plate 2. The pH of Venus' clouds as a function of altitude. The relatively water-rich aerosols in the upper cloud have a small range of positive pH, from 0.3 to 0.5. In the lower cloud, with its larger and more water-poor particles, pH can be as low as -1.3. Aerosol H_2SO_4 concentrations were calculated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

Appendix B: Commercial Space Capabilities Office

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

1) Program: Commercial Space Capabilities Office (CSCO)

2) Research Title: Renewal of Previously Selected CSCO R3

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

a. **Renewals can only be proposed for CSCO Call Area Awards from Fall 2019 RAPID RESPONSE RESEARCH – CYCLE 2, which are: 18-EPSCoR R3-0022, 18-EPSCoR R3-0025, 18-EPSCoR R3-0034, 18-EPSCoR R3-0040, 18-EPSCoR R3-0053, 18-EPSCoR R3-0057, and 18-EPSCoR R3-0058**.
    i. Proposer may assume that (as applicable) NASA provided materials will be similar to those in predecessor award.
    ii. Proposer shall assume that all special conditions (e.g ITAR) in predecessor award remain in effect.
b. Proposed renewals shall support the same work of the predecessor award, or work that is a natural extension of and closely related to that work, **not** new projects unrelated to the predecessor award.
c. In addition to normal Proposal contents, the proposer shall provide the following in their renewal proposal:
    i. Brief statements about:
        1. why the work is still relevant, and
        2. how the work satisfies 3) b. above.
        3. why the work should be renewed rather than recompeted
    ii. Show that costs are reasonable and realistic
    iii. State which Co-I/Sci-I personnel and capabilities/facilities would be used to perform the proposed renewal work, and state which (if any) are new. [NOTE: Changes in research personnel supporting the Co-I/Sci-I do not need to be stated]

Proposers can assume that technically knowledgeable NASA engineers and scientists will be reviewing the Proposal – so Proposer should focus on technical/scientific specifics.

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

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

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

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

5) Proposer-Coordinated Contributions to Proposed Work:

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

a. From Jurisdiction or Organization that would partner with the Jurisdiction

Encouraged but None are required. Proposer shall indicate if any has been arranged for the proposed renewal work.

6) Other NASA-Coordinated Contributions to Proposed Work

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

a. From NASA organization other than EPSCoR

None.

b. From Organization partnering with NASA

None.

7) Intellectual property management:

Proposer to indicate any intellectual property considerations in the Proposal.

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

None additional.

9) Additional Information:

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

NASA CSCO will coordinate support from within NASA as needed.

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

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

Appendix B: Commercial Space Capabilities Office (continued)

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

1) Program: Commercial Space Capabilities Office (CSCO)

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

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

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

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

The proposed work:

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

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

NASA Technical Monitor (TM) will be assigned after award

5) Proposer-Coordinated Contributions to Proposed Work:

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

a. From Jurisdiction or Organization that would partner with the Jurisdiction

Encouraged but None are required. Proposer shall indicate if any has been arranged for the proposed work.

6) Other NASA-Coordinated Contributions to Proposed Work

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

c. From NASA organization other than EPSCoR

None.

d. From Organization partnering with NASA

None.

7) Intellectual property management:

Proposer to indicate any intellectual property considerations in the Proposal.

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

None additional.

9) Additional Information:

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

NASA CSCO will coordinate support from within NASA as needed.

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

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

Appendix C: SMD Earth Sciences Division

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

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

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

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

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

A description of NASA's fleet of Earth observing satellites and sensors can be found at https://science.nasa.gov/missions-page/, with more details about related airborne missions at https://airbornescience.nasa.gov/. Information about data access and discovery can be found at https://earthdata.nasa.gov/. In particular, water quality relevant data can be found at

https://earthdata.nasa.gov/learn/pathfinders/water-quality-data-pathfinder. Instrument-specific airborne data in addition can be found through the different airborne data sites; examples suitable to this call include:
AVIRIS (Airborne Visible InfraRed Imaging Spectrometer):
https://aviris.jpl.nasa.gov/data/get_aviris_data.html
PRISM: (Portable Remote Imaging SpectroMeter) https://prism.jpl.nasa.gov/

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

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 detailed plan on dissemination and sharing of data, products, and tools where applicable. This research opportunity will not fund the acquisition of new in situ data, but rather seeks to take advantage of the large quantities of data that NASA and other entities have already collected over the years (i.e., SeaBASS). Projects including citizen science are also welcome.

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

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

Appendix D: NASA SMD Biological and Physical Sciences (BPS)

1) Program:
Physical Sciences – Fundamental Physics

2) Research Title:
Quantum Science

3) Research Overview:
Quantum mechanics is one of the most successful theories in physics. It describes the very small, such as atoms and their formation into the complex molecules necessary for life, to structures as large as cosmic strings. The behavior of exotic matter such as superfluids and neutron stars is explained by quantum mechanics, as are everyday phenomena such as the transmission of electricity and heat by metals.

The frontline of modern quantum science involves cross-cutting fundamental and applied research. For example, world-wide efforts concentrate on harnessing quantum coherence and entanglement for applications such as the enhanced sensing of electromagnetic fields, secure communications, and the exponential speed-up of quantum computing. This area is tightly coupled to research on the foundations of quantum mechanics, which involves exotica such as many-worlds theory and the interface between classical and quantum behavior. Another frontier encompasses understanding how novel quantum matter—such as high-temperature superconductivity and topological states—emerges from the interactions between many quantum particles. Quantum science is also central to the field of precision measurement, which seeks to expand our knowledge of the underlying principles and symmetries of the universe by testing ideas such as the equivalence between gravitational and inertial mass.

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

5) BPS Contact:
a. Name: Brad Carpenter
b. Organization: NASA Headquarters Biological and Physical Sciences Division
c. Work Phone: (202) 358-0826
d. Email: bcarpenter@nasa.gov

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

Appendix D: NASA SMD Biological and Physical Sciences (BPS) (continued)

6) Program:

Physical Sciences – Materials Science

7) Research Title:

Extraction of Materials from Regolith

8) 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.

9) Research Focus:

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

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

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

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

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

10) BPS Contact:

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

11) Additional Information:

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

Appendix D: NASA SMD Biological and Physical Sciences (BPS) (continued)

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

2) Research Title:
Foam Evolution and Stability

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

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

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

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

5) BPS Contact:

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

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

Appendix D: NASA SMD Biological and Physical Sciences (BPS)(continued)

1) Program:
Space Biology

2) Research Title:
Crop Plant Stress Tolerance for Space Exploration

3) Research Overview:
As NASA advances human space exploration back to the moon and then on to Mars, crop plants will play an essential role to enable sustained, long duration human space travel and presence at these destinations. Crop plants have recently become the focus of basic science investigations and astronaut food nutrition efforts. The goal of this work is to enable productive space horticulture and agriculture in the closed environment of the spaceflight vehicle and lunar and planetary human habitats. In addition, these studies will advance basic scientific knowledge of seed and plant physiology that will allow for characterizing and selecting varieties of renewable, nutritious crop plants to supplement the packaged diet. In order to meet this goal, a considerable amount of fundamental science knowledge, from the level of omics through the entire plant and to mixed cropping systems, needs to be gained to understand how crop plants respond and adapt to extreme spaceflight and extraterrestrial environments. Of particular high priority is determining how stress factors (e.g. radiation, water and nutrient delivery challenges, low relative humidity, high CO_2 levels, etc.) and stress tolerance, alone or in combination with microgravity, impact plant germination, growth, propagation, physiological structures and associated functions, yield, nutritional value, and production of beneficial secondary metabolites. The investigations into plant stress responses and stress tolerances are essential for providing the scientific data and findings essential for breeding hearty, nutritious crop plants capable of withstanding extreme environments and developing applications and technologies for crop plant space horticulture.

4) Research Focus:
This NASA research topic focuses on crop plant stress tolerance. Specifically, NASA is requesting ground-based proposals designed to gain new understanding of crop plant environmental stress tolerance (e.g. water and nutrient delivery challenges, low relative humidity, high CO_2 levels, etc.) and its impacts on plant yields, nutritional composition, and secondary metabolism. The proposed investigation will study one or more of the leafy greens or tomato plant listed below. Each of these crop plants were the focus of previous NASA studies on ISS and ground research. The seeds are all commercially available.

- Leafy greens:
    - 'Outredgeous' red lettuce
    - 'Dragoon' lettuce
    - Waldmann's Green' lettuce,
    - Mizuna mustard green
    - 'Wasabi' mustard green
    - Amara mustard green
    - 'Red Russian' Kale
    - 'Extra Dwarf" Pak cho
- 'Red Robin' tomato

It is anticipated that the data gained from the proposed study will provide the scientific knowledge necessary for guiding approaches, such as horticulture methods, environmental control, and crop plant breeding, which will result in practical methods and technologies to produce healthy, hearty, and nutritious crop plants in any exploration environment and return Earth benefits.

If the time and funding are available within the EPSCoR award, systems biology analyses may be included to investigate the genetics of stress tolerance of these crop plants and to acquire data for omics analyses to identify

underlying biochemical and molecular mechanisms and networks. These data will provide essential foundational knowledge to identify the specific genes and biological networks that respond to or govern crop plant stress responses and tolerance, which will guide crop plant breeding and horticultural methods.

5) BPS Contact:

e. Name: Sharmila Bhattacharya
f. Organization: NASA Headquarters, Space Biology Program
g. Work Mobile Phone: Sharmila Bhattacharya: 650-269-5865
h. Email: sharmila.bhattacharya@nasa.gov

6) Additional Information:

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

References:

https://www.nasa.gov/sites/default/files/atoms/files/veggie_fact_sheet_508.pdf

Burgner et al. (2020) Growth and photosynthetic responses of Chinese cabbage (Brassica rapa L. cv. Tokyo Bekana) to chronically super-elevated carbon dioxide in a simulated Space Station "Veggie" crop-production environment. *Life Sciences in Space Research* 27. https://doi.org/10.1016/j.lssr.2020.07.007

Khodadad et. al. (2020). Microbiological and Nutritional Analysis of Lettuce Crops Grown on the International Space Station. *Front. Plant Sci*. 11. https://doi.org/10.3389/fpls.2020.00199

Massa et. al. (2017). VEG-01: Veggie Hardware Validation Testing on the International Space Station. *Open Agriculture*. 2. https://doi.org/10.1515/opag-2017-0003

Appendix E: KSC Exploration Systems and Development

Research Project Info

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

2) Research Overview: Separate products (CH4 and H2O) from the reactants (H2, CO2) for the Sabatier reaction. The product will come from a reactor at ~350 degrees C. The separation can happen at elevated temperatures or cooler temperatures. The system should be able to operate autonomously (no maintenance) for up to 18 months.

3) Organization: NASA, UB-E

4) Contact: Elspeth Petersen, Elspeth.petersen@nasa.gov, 321-867-3757

5) Mission Directorate(s) [Involved / Connected]: STMD

6) Intellectual property rights: Notional-N/A

a. Company information

b. Desired process

7) Additional Information: N/A

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

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

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

There are two primary objectives with a hackathon:

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

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

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

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

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

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

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

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

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

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

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

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

- Education and Training - Tutorials as well as informal and peer learning is often a component. Furthermore, lateral knowledge through collaboration provides an opportunity to learn skills that are not described in papers and software implementations.
- Tool Development - Hack weeks present an opportunity for scientific software developers to meaningfully engage with users and critically evaluate applications to particular scientific issues.
- Community Building - Hack weeks are an opportunity to catalyze community development through a shared interest in solving computational challenges with open source software. They allow computationally minded researchers to break from the isolation of their institutions and spark new collaborations.
- Interdisciplinary Research - Intensive, time-bounded collaborative events are an opportunity to experiment with concepts, questions, and methods that span boundaries within and across disciplines.
- Recruitment and Networking - Hack weeks are a melting pot of participants from academia, government, and industry and provide numerous opportunities for networking. Close collaboration in diverse groups exposes skills that might be suitable for careers outside of a narrow domain.

2. **SMD FDL** - The NASA Science Mission Directorate (SMD) has also implemented a Hackathon model that can serve as an additional reference for proposal design with its development of the Frontier Development Laboratory (FDL) 2020 Program https://frontierdevelopmentlab.org/ that seeks to push the boundaries of what is possible in science and exploration through both the development and application of artificial intelligence (AI) and machine learning (ML) tools. Like the "Hack week as a Model" the Program engages interdisciplinary teams of computer scientists and discipline scientists who work together to solve problems that are important to NASA and humanity's future. With the FDL model, each research team is made up of four participants (two computer scientists and two domain scientists).

The teams are mentored by senior experts with a deep knowledge of the problems. Unlike the "Hack week as a Model" where the tools are developed in one week, the FDL teams perform the tasks in an eight-week time period. We are not suggesting that an eight week Hackathon time period should be proposed, the multi-day, multi-event over a year time frame is more appropriate for the outcomes being sought here. This reference is provided for increasing the understanding of how interdisciplinary teaming is strategically used by two very successful multi-day Hackathon models and serve as a best practice for a proposal response for this Appendix.

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

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

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

With both of these proposal categories, the proposal should also be responsive to the following features:

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

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

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

NASA science senior case study expert mentors for hackathon provide:

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

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

implementation is the responsibility of the proposers.

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

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

1) Program: Artificial Intelligence and Machine Learning Capability

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

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

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

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

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

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

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

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

5) NASA Contact:
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6) Commercial Entity (Collaboration Infrastructure Support; AI/ML Training and Education Resources:
a. Microsoft Enterprise Services
b. Contact Name: Damon House, Senior Business Program Manager
c. Work Phone: +1 (425) 705-1576
d. Cell Phone: +1 (703) 628-1017
e. Amazon Web Services NASA Account
f. Contact: aws-nasa-notify@amazon.com

7) Partner Contribution:

GLOBE Observer Land Cover Senior Science Mentor

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

GLOBE GO Mosquito Habitat Mapper Dataset Senior Science Mentors

a. Becky Bulger - Rebecca Boger beckyboger@gmail.com
b. Rusty Low rusty_low@strategies.org https://observer.globe.gov/toolkit/mosquito-habitat-mapper-toolkit
c. Additional References from Peter, Becky and Rusty addressing GLOBE Observer citizen science data:

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

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

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

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

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

8) Intellectual Property management

No NASA Partner intellectual property concerns

9) Additional Information

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

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

1) Program: Artificial Intelligence and Machine Learning Capability

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

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

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

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

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

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

5) NASA Contact:

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

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

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

7) Partner Contribution:

No NASA Partner contributions

8) Intellectual Property Management:

No NASA Partner intellectual property concerns

9) Additional Information:

All publications that result from an awarded EPSCOR study shall acknowledge the NASA EPSCoR research award.

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

1) Program: Artificial Intelligence and Machine Learning Capability

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

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

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

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

4) Research Focus

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

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

5) NASA Contact
a. Name: Dan Duffy/Mark Carroll; Computational and Information Science Technology Office (CISTO)
b. Organization: NASA Goddard Space Flight Center Code 606

c. Work Phone: TBD
d. Email: Daniel.Q.Duffy@nasa.gov; Mark.L.Carroll@nasa.gov;

6) Commercial entity (Collaboration Infrastructure Support; AI/ML Training and Education Resources:
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d. Cell Phone: +1 (703) 628-1017
e. Amazon Web Services NASA Account
f. Contact: aws-nasa-notify@amazon.com

7) Partner contribution
No NASA Partner contributions

8) Intellectual property management
No NASA Partner intellectual property concerns

9) Additional Information
All publications that result from an awarded EPSCOR study shall acknowledge NASA EPSCoR Award.

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Appendix G: NASA ARMD Electric Aircraft Batteries & Crash Safety

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

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

Research Overview:

A. Overview of MAT213

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

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

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

For this task we are focused on characterizing the deformation and failure models for a composite material or materials that will be defined and supplied by NASA as well as a recommended approach

for characterizing the post-peak stress degradation response. We will focus on only the shell element analysis.

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

B. Required Tests

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

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

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

h. Double Cantilever Beam
i. End Notched Flexure

C. Test Requirements

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

D. Post-Peak Stress Degradation

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

E. Deliverables

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

References:

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2. T. Achstetter, "Development of a composite material shell-element model for impact applications", *PhD Dissertation,* George Mason University, 2019
3. Goldberg, R.K.; Carney, K.S.; DuBois, P.; Hoffarth, C.; Harrington, J; Rajan, S.; and Blankenhorn, G.: "Development of an Orthotropic Elasto-Plastic Generalized Composite Material Model Suitable for Impact Problems", *Journal of Aerospace Engineering*, Vol. 29, no. 4, 04015083, 2016.
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5. Goldberg, R.K.; Carney, K.S.; DuBois, P.; Hoffarth, C.; Khaled, B.; Shyamsunder, L.; Rajan, S.; and Blankenhorn, G.: "Implementation of a tabulated failure model into a generalized composite material model", *Journal of Composite Materials*, Vol. 52, Issue 25, pp. 3445-3460.

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

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

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

Areas of Research Interest:

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

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

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Appendix I: MSFC EPSCoR Research Areas

Top Ideas

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

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

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

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

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

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

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

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

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

The use of 3D fiber architectures for rocket engine nozzle extensions (both liquid and nuclear thermal propulsion systems) is of interest to enable more durable and fracture-resistant high temperature composites. The aim is to move towards woven, braided, needled, or stitched fiber architectures, and away from the current more common practice of using 2D ply hand lay-ups (gore, involute, etc.). Both carbon and ceramic (silicon carbide, zirconium carbide, etc.) matrices are of interest. While the focus should be on assessing and developing the fiber architecture technology itself, it needs to be

kept in mind that the technology needs to be compatible with the incorporation of high temperature matrices. Some examples of current weaving and braiding technology can be found on the websites of Bethlehem Advanced Materials (BAM), Fiber Materials Inc. (FMI), and Textile Engineering And Manufacturing (TEAM). Minimum operating temperatures for the ultimate applications (lander, in-space, upper-stage liquid propulsion) should be at least 3000°F (1649°C).

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

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

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

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

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

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

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

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

Other Ideas

In Space Metal Recycling Techniques
EM04/Prater

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

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

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

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

Develop methods to determine materials properties using nondestructive ultrasonic methods.

Large Scale Additive Construction Technologies
EM04/Prater

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

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

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

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

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