LOUISIANA NASA EPSCoR

Research Awards Program (RAP)

A NASA EPSCoR Research Infrastructure Development (RID) Project

Sponsored by NASA & the Louisiana Board of Regents (BoR)
With Technical & Management Support from the
Louisiana NASA EPSCoR Team at LSU

La NASA EPSCoR Management Office
364 Nicholson Hall, Department of Physics and Astronomy
Louisiana State University, Baton Rouge, LA -70803
225.578.8697 | http://lanasaepscor.lsu.edu/ -| laspace@lsu.edu

Revised, September 2020

All previous versions of this program's guidelines are null and void.

RAP Program Summary Page

About the RAP

The RAP sub-program is designed for those researchers who have made a NASA contact and are ready to take the next step of initiating a small project. This could involve almost any type of NASA relevant work, such as utilizing a specific NASA facility, employing NASA expertise, or building upon previous NASA work (akin to technology/knowledge transfer) or working with a NASA group on problems of common interest. In all cases, the Louisiana researcher must have the support of a NASA researcher and include a plan for developing a research partnership, and the proposal must clearly state which Mission Directorate this project aligns with. The goal here is to develop larger, longer-lasting collaborative projects that can transition to the next level. There are two components to the proposed RAP subprogram.

Single Institution Projects (SIP) are designed to provide seed grants for R&D that have a demonstrated tie-in to a NASA priority. Projects are open to any area relevant to NASA's mission. Each project proposal must include a NASA Collaboration Development Plan that describes what effort has already been, and will be, undertaken to establish a partnership with one or more NASA researchers.

Partnership Projects (PP) involve two or more institutions, one of which should be a non-research-intensive institution and preferably an HBCU. In addition to the SIP requirements, a Partnership Project must demonstrate significant contributions from each institution, an equitable distribution of resources, and a management plan that details how the institutions will work together on the project.

An NOI is required in advance of proposal submission. Institutional sign-off is not required for the NOI. RAP awards will be issued for a 12-month period of performance. RAP-SIP awards are anticipated to be in the $30K-$40K range; RAP-PP awards are anticipated to range from $60K-$75K. Proposing institutions are expected to provide a 50% total cost-match. The project PI must be a faculty member at one of Louisiana's institutions of higher education.

Proposal Submissions

- Submit a compliant RAP NOI to laspace@lsu.edu by 11:59 pm on Thursday, October 22, 2020.
- Submit fully compliant, signed proposal via email as a <u>fully searchable pdf</u> document to laspace@lsu.edu by 11:59 pm on Thursday, November 12, 2020.
- **Important Dates:**
  - **Proposal Release Date: Thursday, September 3, 2020**
  - NOI Due Date: Thursday, October 22, 2020
  - Proposal Due Date: Thursday, November 12, 2020
  - **Anticipated Award Announcements: late December 2020**
  - **Anticipated Period of Performance: February 1, 2021 – January 31, 2022**

RAP Program Guidelines

Introduction to the NASA EPSCoR RID Program

The NASA Established Program to Stimulate Competitive Research (EPSCoR) is administered through NASA's Office of STEM Engagement. The purpose of NASA EPSCoR is to strengthen the research capability of jurisdictions that have not in the past participated equitably in competitive federal research and development activities.

The NASA EPSCoR Research Infrastructure Development (RID) program for 2019-2022 focuses on building the core strength needed to develop competitive research and technology development methods and activities for the solution of scientific and technical problems of importance to NASA as defined by one or more of the four Mission Directorates and one or more of the ten NASA Centers (including JPL). RID programs will also contribute to the overall research infrastructure, science and technology capabilities, higher education, and/or economic development of the EPSCoR jurisdiction. An emphasis should be placed on developing a core expertise and robust research program capable of successfully competing for funds offered by NASA, industry, other federal agencies, and additional external sources beyond the EPSCoR program.

NASA 2018 Strategic Plan

NASA's 2018 strategic plan aligns the Agency's future activities along three strategic themes of Discover, Explore, and Develop, as well as a fourth theme focused on the activities that will Enable the Agency's mission.

- **DISCOVER references NASA's enduring purpose of scientific discovery.**
- **EXPLORE references NASA's push to expand the boundaries of human presence in space.**
- **DEVELOP references NASA's broad mandate to promote the technologies of tomorrow.**
- **ENABLE references the capabilities, workforce, and facilities that allow NASA to achieve its Mission.**

The complete plan can be downloaded here.

NASA Vision

To discover and expand knowledge for the benefit of humanity.

NASA Mission

Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and bring new knowledge and opportunities back to Earth. Support the growth of the Nation's economy in space and aeronautics, increase understanding of the universe and our place in it, work with industry to improve America's aerospace technologies, and advance American leadership.

NASA Office of STEM Engagement *(formerly Office of Education)*

NASA's journeys have propelled technological breakthroughs, pushed the frontiers of scientific research, and expanded our understanding of the universe. These accomplishments, and those to come, share a common genesis: education in science, technology, engineering, and math. NASA's Office of STEM Engagement (OSTEM) delivers tools for young Americans and educators to learn and succeed. OSTEM seeks to:

- **Create unique opportunities for students and the public to contribute to NASA's work in exploration and discovery.**
- **Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA people, content, and facilities.**
- **Strengthen public understanding by enabling powerful connections to NASA's mission and work.**

To achieve these goals, NASA's Office of STEM Engagement strives to increase K-12 involvement in NASA projects, enhance higher education, support underrepresented communities, strengthen online education, and boost NASA's contribution to informal education. The intended outcome is a generation prepared to code, calculate, design, and discover its way to a new era of American innovation.

The Aerospace Research and Career Development (ARCD) EPSCoR program strengthens the research capabilities of the nation's colleges and universities. The EPSCoR research conducted contributes to the research needs of NASA's mission directorates and advances the nation's scientific and technology innovation agenda as well as the jurisdiction's aerospace research and development priorities.

NASA Mission Directorates

Research and technology priorities are aligned with one or more of NASA's Mission Directorates:

The **Science Mission Directorate (SMD)** expands the frontiers of Earth science, heliophysics, planetary science, and astrophysics. Using robotic observatories, explorer craft, ground-based instruments, and a peer-reviewed portfolio of sponsored research, SMD seeks knowledge about our solar system, the farthest reaches of space and time, and our changing Earth.

The **Aeronautics Research Mission Directorate (ARMD)** transforms aviation with research to dramatically reduce the environmental impact of flight, and improves aircraft and operations efficiency while maintaining safety in increasingly crowded skies. ARMD also generates innovative aviation concepts, tools, and technologies for development and maturation by the aviation community.

The **Space Technology Mission Directorate (STMD)** pursues transformational technologies that have high potential for offsetting future mission risk, reducing cost, and advancing existing capabilities. STMD uses merit-based competition to conduct research and technology development, demonstration, and infusion of these technologies into NASA's missions and American industry. This mission directorate is being refocused as a new Exploration Research & Technology (ER&T) organization to support exploration as a primary customer.

The **Human Exploration and Operations Mission Directorate (HEOMD)** leads human exploration in and beyond low Earth orbit by developing new transportation systems and performing scientific research to enable sustained and affordable human life outside of Earth. HEOMD also manages space communication and navigation services for the Agency and its international partners.

Programs supported by La NASA EPSCoR must support the NASA organization, align with the NASA Strategic Plan, and support the goals of one or more directorates, NASA centers, and the Office of STEM Engagement. See Appendix A for a current list of areas of interest listed by MD and Center.

NASA EPSCoR Research Liaisons

There is a NASA EPSCoR Research Liaison within each Mission Directorate and at each Center. These liaisons can assist with activities ranging from site visits for establishing collaborations to resolving issues after the award. Technical and scientific questions about research opportunities in this announcement may be directed to the appropriate contact below. Discussions of research with the appropriate NASA EPSCoR Research Liaison (MD, Center, or JPL) personnel are strongly encouraged.

NASA Mission Directorate Contacts

The Aeronautics Research Mission Directorate (ARMD), POC: Karen Rugg, Lead, Communications & Education, Phone: (202) 358-2197 karen.l.rugg@nasa.gov

Human Exploration and Operations Mission Directorate (HEOMD), POC: Bradley Carpenter, Space Life and Physical Sciences Research & Applications Division, Phone: (202) 358-0826, BCarpenter@nasa.gov

Science Mission Directorate (SMD), POC: Kristen Erickson, Director, Science Engagement & Partnerships, Phone: (202) 358-1017, kristen.erickson@nasa.gov

Space Technology Mission Directorate (STMD), POC: Damian Taylor, Directorate Liaison, SBIR and STTIR Mission, Phone: (202) 358-1432, damian.taylor@nasa.gov

NASA EPSCoR Center Liaisons

Ames Research Center, *Brenda Collins* Chief, Education and Public Outreach Phone: (650) 604-3540 brenda.j.collins@nasa.gov	Kennedy Space Center, *Jeffrey A. Kohler* Technology Transfer Office Phone: (321) 867-2462 jeffrey.a.kohler@nasa.gov
Armstrong Flight Research Center, *Dave Berger* University Affairs Officer Phone: (661) 276-5712 dave.e.berger@nasa.gov	Langley Research Center, *Kim Brush* LaRC OSTEM Integration Manager Phone: (757) 864-6454 kimberly.m.brush@nasa.gov
Goddard Space Flight Center, *James Harrington* STEM Engagement Specialist Phone: (301) 286-4063 james.l.harrington@nasa.gov	Glenn Research Center, *Mark David Kankam, Ph.D.* University Affairs Officer Dir. of NASA Space & Aeronautics Academy at Glenn, Phone: (216) 433-6143 Mark.D.Kankam@nasa.gov
Jet Propulsion Laboratory, *Linda Rodgers or Petra Kneissl* University Programs Administrators Linda - Phone: (818) 354-3274 Linda.L.Rodgers@jpl.nasa.gov Petra – Phone: (818) 201-8805 Petra.A.Kneissl-milanian@jpl.nasa.gov	Marshall Space Flight Center, *Frank Six* University Affairs Officer Office of Academic Affairs (HS30) Phone: (256) 961-0678 Norman.F.Six@nasa.gov
Johnson Space Center, *Kamlesh Lulla* Director, University Research Collaborations and Partnership Office Phone: (281) 483-3065 Kamlesh.P.Lulla@nasa.gov	Stennis Space Center, *Mitch Krell* University Affairs Officer Phone: (228) 688-1821 Mitch.Krell@nasa.gov

NASA EPSCoR RID Program in Louisiana

The Louisiana Board of Regents (BoR) has received an EPSCoR Research Infrastructure Development (RID) award, “New Development for Louisiana Aerospace Research,” from the NASA EPSCoR program. Moving a jurisdiction forward in competitiveness is the foundational goal of all EPSCoR programs and is measured by a jurisdiction’s rank in its percentage of federal R&D funds received over a three-year period. Louisiana’s success with EPSCoR can be seen by looking at the state’s rankings over time – moving from the bottom to the mid-point on the EPSCoR list. Aerospace has accounted for much of our growth with expertise developed in areas ranging from smart materials to air traffic management, from additive manufacturing to astrophysics. But the work is far from completed. We need to build upon what has been accomplished and move forward into increased competitiveness.

Achieving this goal requires a number of plans and actions: (a) expanding university educational opportunities, (b) enhancing research infrastructure, (c) fostering R & D capabilities, and (d) capitalizing upon the resultant intellectual property. NASA EPSCoR provides university students and faculty exposure to and involvement in the Aerospace research enterprise, improves faculty research capabilities (both at a given institution and between institutions), enhances research facilities and infrastructure, and opens opportunities for faculty (particularly junior faculty), post-doctoral researchers, and students to engage in meaningful Aerospace R&D all with the goal of graduating from the EPSCoR program designation. The Research Infrastructure Development (RID) component of NASA EPSCoR is of critical importance to prepare Louisiana’s researchers to become involved in larger projects which can be proposed as NASA EPSCoR Research Implementation Projects or proposed to NASA opportunities issued by the directorates. Thus, the overall Goal for the NASA EPSCoR RID is to Elevate the Competitiveness of the State's researchers in Aerospace Science and Technology Development.

Research Award Program (RAP)

The RAP sub-program provides seed funding for Louisiana researchers working on a NASA-related research project with the explicit support of a NASA researcher. This could involve almost any type of NASA relevant project, such as utilizing a specific NASA facility, employing NASA expertise, building upon previous NASA work (akin to technology/knowledge transfer), or working with a NASA group on problems of common interest. **In all cases, the Louisiana researcher must 1) have the support of a NASA researcher and include a plan for developing a research partnership and 2) provide evidence of direct alignment with at least one NASA Mission Directorate.** The goal here is to develop larger, longer-lasting collaborative projects that can transition to the next level. There are two variations within the RAP subprogram.

Single Institution Projects (SIP) are designed to provide seed grants for R&D projects to be conducted at a single Louisiana institution that have a demonstrated tie-in to a NASA priority. Projects are open to any area relevant to NASA's mission. Each project proposal must include a NASA Collaboration

Development Plan that describes what effort has already been, and what will be, undertaken to establish a partnership with one or more NASA researchers. Proposal evaluation criteria will include whether the PI has already established a NASA link as evidenced by a letter or e-mail from one or more NASA supporters indicating their interest in the project and willingness to host a visit by the PI or the PI team. During the period of the award (nominally 12 months), the research team should plan to make one or more trips to the NASA facility to interact with the NASA researcher who supports the project. The project PI must be a faculty member at one of Louisiana's institutions of higher education. Post-doctoral associates, graduate students, and undergraduate student researchers should be involved as needed. Single Institution Projects may involve more than one faculty researcher, but only one faculty member can serve as the PI.

Partnership Projects (PP) involve two or more institutions, one of which should be a non-research-intensive institution and preferably one of Louisiana's HBCU campuses. A Partnership Project is much like a SIP except involving multiple institutions. In addition to the SIP requirements, a Partnership Project must demonstrate significant contributions from each institution, an equitable distribution of resources, and a management plan that details how the institutions will work together on the project. Like a SIP, a PP must be focused upon evolving the team toward more significant research involvement. Since they involve significant work at multiple institutions, we anticipate that PP awards will be approximately double the value of a SIP award. For PP awards, there will be only one PI at the lead institution and a single Co-I for any partner institution.

These seed grants from NASA EPSCoR are not just research grants. Excellent research must be performed, but the project should also be designed to (a) increase research capacity and competitiveness and (b) be scalable to a team approach for a larger future endeavor. Evidence of the probability of (a) and (b) must be presented in the proposal and addressed in the project report.

Eligibility

The project PI must be a faculty member at one of Louisiana's institutions of higher education. Post-doctoral associates, graduate students, and undergraduates should be involved as needed.

The RAP sub-program is designed to provide seed grants to LA researchers for R & D that has a demonstrated tie-in to a NASA center. Projects must involve Research or Technology and are open to any area relevant to NASA. Proposals must explicitly link the proposed project to a research priority within one of NASA's four Mission Directorates. A letter/email of interest from a NASA researcher which shows support for the project, a willingness to host a visit from the PI/team and recognizes potential for future collaborations must be included. During the period of the award (nominally 12 months), the researcher must make one, or more, trips to the NASA center to interact and/or work with the NASA researcher who has shown interest in the project. *Contact info for Mission Directorate Leads and University Affairs Officers at the various NASA centers are included earlier in these guidelines.*

NASA Collaboration Development Plan

Each project proposal must include a NASA Collaboration Development Plan that describes what effort has already been, and will be, undertaken to establish a partnership with one or more NASA researchers. Proposal evaluation criteria will include whether the PI has already established a NASA link as evidenced by a letter or e-mail from one or more NASA supporters indicating their interest in the project and willingness to host a visit by the PI or the PI team. See Appendix A for a current list of areas of interest listed by NASA MD and Center.

Period of Performance

RAP awards will be issued for a 12-month period of performance. No cost extensions (NCEs) for ongoing projects may be considered if submitted to the La Board of Regents Sponsored Programs office no later than 60 days before the initial project end-date. All NCE requests must include a multi-page status report (similar to a final technical report) which addresses all accomplishments made to-date on the project (including all publications, proposals, presentations, patents, etc), where the project is in relation to the originally proposed end date, reasons why the project has been delayed, and a proposed plan for completing the project. This status report must also identify all participants on the project and include demographics for each (students, post-docs, faculty, and staff).

Award Funding Amounts

RAP-SIP awards are anticipated to be in the $30K-$40K range; RAP-PP awards are anticipated to range from $60K-$75K. We anticipate funding 2 to 5 SIPs and 1 to 2 PPs this cycle.

Proposed Costs

This program is intended to improve research capability in Louisiana and, consequently, costs should primarily support effort within the state. Direct labor costs will be allowed *exclusively* for faculty, staff, students, and visiting researchers at Louisiana institutions. Funding allocated outside of the state is not recommended. If proposed, it should be minimal, must be well justified with compelling evidence that such an investment would still offer substantial permanent improvement to Louisiana's research infrastructure. A statement that funding to external sites would improve the probability of proposal selection would not be sufficient justification. Project costs should be documented in the proposal as necessary to meet the project goals and objectives. Reasonable costs include salary and wages for faculty, research associates, and student researchers, travel to NASA centers for collaboration development meetings, and basic materials and supplies to conduct the research. This program is not designed to fully support a graduate student, and <u>student tuition is not an allowable expense</u>. Any rebudgeting in excess of 20% requires advanced approval from the Board of Regents. Rebudget requests must be submitted in writing with a complete explanation as to why the funds could not be spent as proposed, why a rebudget is necessary, and how the newly structured budget will still meet the spirit of the award. Rebudget requests must include the original budget and budget justifications along with the proposed revised budget and budget justification.

Cost-Share

Proposing institutions are expected to provide at least a 50% cost-match. This is taken by the reviewers as evidence of commitment on the part of the proposing institution(s). Such an institutional commitment in the form of re-assigned responsibilities is most significant since it allows the faculty member(s) sufficient time to participate in and manage the proposed research. Lack of such time calls into question the ability of the proposers to actually carry the project to a successful conclusion. All cost sharing must be certified in the project final financial report.

Indirect (F&A) Costs

RAP awards are typically funded with BoR cost-share funds and as such indirect (F&A) cost recovery will be allowed at the BoR rate, i.e. 25% of salaries, wages, and fringe benefits. Unrecovered indirect is allowable (and recommended) cost sharing. The LaSPACE/La NASA EPSCoR program management team may choose to use any available NASA funds to support a RAP project, and in such instances the proposing institution agrees to retain the BoR indirect rate charges and cost restrictions, as originally proposed.

Award Subcontract

Award funds will be provided by subcontract from the Board of Regents to the lead applicants' college or university, which will assume responsibility for administering the funds according to standard procedures. For PP awards, one institution must be the lead institution to which the award will be given. This lead institution will subcontract with the partner institution.

Diversity

It is a national priority to increase diversity in Science, Technology, Engineering, and Mathematics (STEM), from university students, faculty, and staff to industry employees. Traditionally, minority groups and women have been under-represented in the STEM disciplines as students and faculty as well as in the workplace after graduation. All proposers are encouraged to help recruit diverse participants to their proposed projects.

Animal Use

Any project proposing the use of an animal model for validation <u>must include a local IACUC approval letter, fully signed, which specifies a validity period longer than the proposed project period</u>. Failure to obtain the Institutional Animal Care and Use Committee's approval in advance, is grounds for returning the proposal unreviewed. Attach the IACUC material as an additional appendix.

Human Subjects

Projects that involve human subjects are <u>not acceptable</u> for this program.

Certifications

When preparing a proposal that requires institutional certification, waiver, or approval the proposers will need to address applicable compliance issues in advance. **All necessary internal approvals from**

the lead and collaborator institutions must be secured and documented in writing. A letter (see sample in the attachments section of these guidelines) signed by the authorized organization representative certifying that all reviews and waivers relevant to the proposal have been completed must be submitted to laspace@lsu.edu no later than 30 calendar days after the proposal due date. Even through extra time is allowed to submit the commitment document, the letter is considered to be part of the proposal and will be included as an appendix in the subaward contract from the Board of Regents. Failure to provide this commitment in the approved time frame may result in disqualification and selection of alternate proposals.

Public Nature of Applications

Once an application is received, it becomes public record. Although the staff will not disseminate applications to individuals other than to reviewers, applicants should be aware that, if a request for information is made by the public (e.g., the news media), a copy of the application, by law, must be provided.

Disclosure of Information

All La NASA EPSCoR programs must conform to applicable Federal, State, and NASA Agency regulations and stipulations. This includes annual reporting of award participant information to both the Louisiana Board of Regents and NASA. Part of this information will include both directory information such as name, address, telephone number, date of birth, and demographic information such as gender, ethnicity, and race for all award participants including faculty, staff, and students. Further, outreach includes public dissemination of its supported programs through *The Spaceporter Newsletter*, the La NASA EPSCoR website (http://laNASAepscor.lsu.edu/), as well as papers and/or presentations at Space Grant or related Education & Public Outreach conferences. The contents of award reports, including participant names, titles, institution, project summaries, results or conclusions and images, might be included in such public outreach articles. It is not intended that these public articles will disclose directory or demographic information except as aggregated statistical data.

Final Deliverables

At the end of the project, two final reports are required: the Final Technical Report and the Final Financial Report. These reports are due within 30 days after the subcontract expiration date.

The Final Technical Report will be a multi-page write-up that is suitable for transmission to NASA and BoR. This report should describe the activities undertaken, the participants, and your assessment, as Principal Investigator, of the success of the venture, the impact that it had (or will have), any follow-on proposals in preparation/submitted and any further plans for a continuation of this or similar projects. Please also include a full bibliography. Copies of reports, presentations, publications, follow-on proposals, patent related material, technology transfer, or publicity may be submitted as required in the report narrative. These items should contain citations acknowledging NASA EPSCoR/BoR support. This report shall be submitted to the Board of Regents (jessica.patton@laregents.edu) and the LA NASA EPSCoR/ LaSPACE office (laspace@lsu.edu) via email.

The Final Financial Report is an official report that shows the final expenditure of the funds and certifies the cost sharing. This report is to be submitted to the Board of Regents by your university's financial office using the BoR electronic reporting system.

Additional instructions for reporting are given in the sub-award document.

Evaluation Criteria

A panel of external reviewers will rate all of the proposals on the following criteria.

- **(25%) Scientific & Technical Merit**
- **(15%) Relevance to space/aerospace fields**
- **(10%) Relevance to on-going research project/priority at a NASA Mission Directorate/Center**
- **(15%) Potential for additional funding at more competitive/higher levels**
- **(10%) Evidence of NASA enthusiasm based on the letter of interest**
- **(15%) Demonstrated competency of the proposed team to complete the scope of work**
- **(10%) Appropriateness of the budget to complete the work; sufficient university investment**

RAP Proposal Format & Submittal

RAP proposals should be submitted as fully searchable pdf documents via email to laspace@lsu.edu.
A RAP proposal must include the following completed sections in the order presented:

- **RAP Cover Page**
- **Proposed Project Summary Page**
- **Current & Pending Support Form**
- **Proposal Narrative (*not to exceed 10 pages, including figures and tables, no smaller than 11 point font & one inch margins*)**
    1) Introduction (overview of the scope of work for this proposal, include mention of the NASA mission directorate and any major ongoing NASA research projects this work is relevant to).
    2) Background (provide a bigger picture of how the proposed work fits into your overall research plans and the field of study at large).
    3) Research Objectives (clearly identify all science and technical objectives for this proposal).
    4) Relevance to NASA and NASA Mission Directorates/Centers (identify all the current and potential applications/relevance to NASA, including future scalability of this project and where a larger scale project would fit in. Explicitly identify the mission directorate to which this project aligns with details on the related research priorities of said MDs). See Appendix A for a current list of areas of interest listed by MD and Center.
    5) Implementation Strategy and Milestone Schedule (detail exactly what deliverables are expected, when, and by whom; clearly reference any partner institutions if this is a PP).
    6) NASA Collaboration Development Plan (map out any contact you have had thus far with a reasonable plan for development over the course of this project, including number of meetings in person or via phone/web technology; be sure to identify what you will get from NASA and what NASA will get from you over the period of the award).
    7) Management Plan (lay out a hierarchy of individuals/institutions working on the project, a recruitment plan for team members not yet identified, and methods for tracking and reporting progress throughout the project; partnership proposals must clearly divide tasks and lay out a clear plan for managing work at multiple institutions).
    8) Anticipated Outcomes/Plans for Future Endeavors/Future Collaborations with NASA (include plans for publications, conferences, funding opportunities, and full-scale collaborations).
- **References Cited within the proposal**
- **Budget Section: Each participating institution must have its own completed Budget Form followed by a narrative explanation of all costs listed on its form. Explanations are required for both requested funds and proposed cost-shares.**
- **Letter of Interest from a NASA Researcher**
- **Short Vita for Principal Investigator (and for Co-I on PP proposals)**
- **Letter Certifying all Institutional Reviews are complete (can be submitted 30 days after proposal due date. See section on Certifications.)**
- **Letter of Commitment from the Co-I on PP proposals**

Attachments
Required Proposal Forms

Required Forms for Proposal

All proposals submitted must use the forms included following this page. Proposals not using these forms may be rejected without review.

- **NOI (due October 22, 2020)**
- **Cover Sheet**
- **Proposed Project Summary**
- **Current & Pending Support Form**
- **Proposal Budget Form**
- **Sample Letter for Certifying all Institutional Reviews are complete**
- **Sample Letter of Commitment for PPs**

La NASA EPSCoR RAP Program Notice of Intent (NOI) to Propose

This NOI must be submitted by the PI to LaSPACE on, or before, Thursday, October 22, 2020 via email to laspace@lsu.edu. No institutional signature is required for the NOI.

<table>
<tr><td>NAME OF PRINCIPAL INVESTIGATOR (PI):</td><td>NAME INSTITUTION:</td></tr>
<tr><td>PI DEPARTMENT/ MAILING ADDRESS</td><td>PI PHONE NUMBER and EMAIL ADDRESS</td></tr>
<tr><td colspan="2">TITLE OF PROPOSED PROJECT:</td></tr>
<tr><td colspan="2">LIST PROJECT DISCIPLINES:</td></tr>
<tr><td colspan="2">ADDITIONAL INSTITUTIONS IF SUBMITTING A PARTNERSHIP PROPOSAL</td></tr>
<tr><td colspan="2">THE PROPOSED WORK WILL SUPPORT THE RESEARCH PRIORITIES OF THE FOLLOWING NASA DIRECTORATES:

☐ Aeronautics Mission Directorate ☐ Human Exploration and Operations Mission Directorate ☐ Science Mission Directorate ☐ Space Technology Mission Directorate

LIST ASSOCIATED NASA FIELD CENTERS HERE: ____________________

NAME & TITLE OF NASA CONTACT:____________________

Check here to confirm you have already requested a letter of support from this contact ☐</td></tr>
<tr><td colspan="2">PROJECT ABSTRACT (maximum 250 words):</td></tr>
</table>

A NASA EPSCoR – La BoR RID Project

Research Awards Program (RAP) Cover Sheet

1. Title of Proposed Project:____

____ Is this a ____ SIP or ____ PP project?

2. Principal Investigator: ____
(Name)

____
(Department)

3. Institution of Higher Education:____

4. PI Address:____
(Street Address/P.O. Box Number)

____
(City, State) (Zip Code)

5. Telephone:_____________________________ FAX:__________________________________

PI E-mail:____

6. NASA Sponsor: ____
(Name) (Position)

____
(Center) (e-mail)

7. Total Funds Requested:$____________________ Institutional Commitment:$_____________

****

Certification of Compliance with Applicable Executive Orders and U.S. Code: By signing and submitting this proposal, the signatories certify that the statements made in this proposal are true and complete to the best of their knowledge; they agree to comply with LaSPACE award terms and conditions if an award is made as a result of this proposal; and the institution and proposed project are in compliance with all applicable Federal and State laws and regulations including, but not limited to, Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participant's responsibilities; Non-Discrimination; Certification against Lobbying imposed by section 1352, title 31, U.S. Code; Compliance with China Funding Restriction as detailed in Public Laws 112-10 Section 1340(a) and 112-55, Section 539; ACORN Compliance in accordance with 534 of the Consolidated and Further Continuing Appropriations Act of 2012 (Pub. L.112-55); and does not have a federal tax liability or federal felony conviction (sections 544 and 543 of Public Law 112-55).

8. Signature of Principal Investigator:____

9. Name of Authorized Institutional Rep:____

10. Signature of Authorized Institutional Rep:_______________________________________

11. Date Signed: ____

Proposed RAP Project Summary

NAME OF INSTITUTION (INCLUDE BRANCH/CAMPUS AND SCHOOL OR DIVISION)
ADDRESS (INCLUDE DEPARTMENT)
PRINCIPAL INVESTIGATOR
PP PROPOSALS: Co-INVESTIGATOR NAME, INSTITUTION
THE PROPOSED WORK WILL SUPPORT THE RESEARCH PRIORITIES OF THE FOLLOWING NASA DIRECTORATES: ☐ Aeronautics Mission Directorate ☐ Human Exploration and Operations Mission Directorate ☐ Science Mission Directorate ☐ Space Technology Mission Directorate LIST ASSOCIATED NASA FIELD CENTERS HERE: ____
NASA CONTACT
PROJECT TITLE
ABSTRACT (DO NOT EXCEED 250 WORDS, suitable for general distribution)

Current and Pending Support Form

This Form is to be filled out for the Principal Investigator and the Co-I for PP proposals. For each Project provide the following information: Funding Agency, Title, Funding Amount, Starting and Ending Dates, and Personnel Effort Committed to the Project (person-months or % of effort). Please add additional pages as needed.

1. Current Support

Agency/Grant No.:
Title:
Amount
Period:
Effort:
Location:

Agency/Grant No.:
Title:
Amount
Period:
Effort:
Location:

2. Pending Support

Agency:
Title:
Amount
Period:
Effort:
Location:

Agency:
Title:
Amount
Period:
Effort:
Location:

A NASA EPSCoR – La BoR RID Project

Research Awards Program (RAP) Budget Request Sheet

Include a budget narrative page with explanations and justifications for all costs following each budget form submitted.

Proposal Title: ____

Principal Investigator: ____

Institution: ____

		NASA/BORSF Funds Requested	Institutional Contribution*
A. Direct Labor			
	1. Researchers	$	$
	2. Graduate Student(s)	$	$
	3. Undergraduate Student(s)	$	$
	4. Fringe Benefits	$	$
	5. Subtotal A	$	$
B. Supportive Expenses			
	1. Travel	$	$
	2. Supplies & Materials	$	$
	3. Communications	$	$
	4. Equipment	$	$
	5. Other Expenses (Identify)	$	$
	6. Subcontracts	$	$
	7. Subtotal B	$	$
	8. F&A (Indirect) **	$	$
C. Total Project Cost			
		$	**$**

**Must be certified on all financial billings/reports. ** BoR rate (25% of Subtotal A) allowed. Revised 6/2015*

Sample Letter Certifying Completion of Institutional Reviews

Please use university letterhead.

Month, Day, Year

LaSPACE / LA NASA EPSCoR Program Office
Dr. T. Gregory Guzik, Director
LSU Department of Physics
Baton Rouge, LA 70803

Dear Dr. Guzik:

"Insert Institution" agrees to participate as a subrecipient in Louisiana Board of Regents' and NASA EPSCoR RID program, RAP project entitled "Insert Proposal Title." The "Insert Institution" portion of the work as described in the attached proposed scope of work will be under the primary direction of "Insert Name of PI."

This letter acknowledges that the institution has conducted all reviews, and signed all waivers, and certifications associated with the proposed effort so that the project can be immediately implemented following award by the Board of Regents.

We look forward to a rewarding and productive research effort.

Sincerely,

Authorized Institutional Rep Printed: Full Name

Authorized Institutional Rep Signature: ____

Enclosures: *<Any necessary attachments>*

Sample Letter of Commitment for Partnership Proposals

Please use university letterhead.

Month, Day, Year

This letter of commitment acknowledges that "Insert Co-I name" of "Insert Institution" is identified by name as a Co-Investigator to the proposal, "Insert Proposal Title" that is submitted by "Insert Name of PI" from "Insert Name of Lead Institution" in response to the **Louisiana NASA/BoR EPSCoR RID call for proposals for the Research Awards Program (RAP)**. The Co-I confirms his/her intent to carry out all responsibilities identified in this proposal. We understand that the extent and justification of our institution's participation as stated in this proposal will be considered during peer review in determining in part the merits of this proposal. We have read the entire proposal, including the management plan and budget, and agree that the proposal correctly describes our institution's commitment to the proposed project under review.

Co-I Printed: Full Name

Co-I Signature: ____

Authorized Institutional Rep Printed: Full Name

Authorized Institutional Rep Signature: ____

Appendix A: NASA Mission Directorates and Center Alignment

**Provided by Jeppie Compton, NASA EPSCoR Program Manager, NASA Office of STEM Engagement, included in the FY20 NASA EPSCoR CAN Solicitation*

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

A.1 Aeronautics Research Mission Directorate (ARMD) conducts high-quality, cutting-edge research that generates innovative concepts, tools, and technologies to enable revolutionary advances in our Nation's future aircraft, as well as in the airspace in which they will fly. ARMD's four research programs develop advanced technologies to reduce aviation's environmental impact & transform the way we fly.

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

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

Areas of Interest - POC: Karen Rugg, karen.l.rugg@nasa.gov

Proposers are directed to the following:

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

A.2 Human Exploration & Operations Mission Directorate (HEOMD) provides the Agency with leadership and management of NASA space operations related to human exploration in and beyond low-Earth orbit. HEO also oversees low-level requirements development, policy, and programmatic oversight. The International Space Station, currently orbiting the Earth with a crew of six, represents the NASA exploration activities in low-Earth orbit. Exploration activities beyond low Earth orbit include the management of Commercial Space Transportation, Exploration Systems Development, Human Space Flight Capabilities, Advanced Exploration Systems, and Space Life Sciences Research & Applications. The directorate is similarly responsible for Agency leadership and management of NASA space operations related to Launch Services, Space Transportation, and Space Communications in support of both human and robotic exploration programs. Additional information on the Human Exploration & Operations Mission Directorate (HEOMD) can be found at: (http://www.nasa.gov/directorates/heo/home/index.html)

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

Human Research Program

The Human Research Program (HRP) is focused on investigating and mitigating the highest risks to human health and performance in order to enable safe, reliable, and productive human space exploration. The HRP budget enables NASA to resolve health risks in order for humans to safely live and work on missions in the inner solar system. HRP conducts research, develops countermeasures, and undertakes technology development to address human health risks in space and ensure compliance with NASA's health, medical, human performance, and environmental standards.

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

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

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

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

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

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

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

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

Engineering Research

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

- Miniaturized Digital EVA Radio (JSC)
- Transformational Communications Technology (GRC)
- Long Range Optical Telecommunications (Jet Propulsion Laboratory (JPL))
- Long Range Space RF Telecommunications (JPL)
- Surface Networks and Orbit Access Links (GRC)
- Software for Space Communications Infrastructure Operations (JPL)
- TDRS transponders for launch vehicle applications that support space communication and launch services (GRC)

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

A.3 Science Mission Directorate (SMD) leads the Agency in four areas of research: Earth Science, Heliophysics, Planetary Science, and Astrophysics. SMD, using the vantage point of space to achieve with the science community and our partners a deep scientific understanding of our planet, other planets and solar system bodies, the interplanetary environment, the Sun and its effects on the solar system, and the universe beyond. In so doing, we lay the intellectual foundation for the robotic and human expeditions of the future while meeting today's needs for scientific information to address national concerns, such as climate change and space weather. SMD's high-level strategic objectives are presented in the 2018 NASA Strategic Plan. Detailed plans by science area corresponding to the science divisions of SMD: Heliophysics, Earth Science, Planetary Science, and Astrophysics appear in Chapter 4 of the 2014 NASA Science Plan. The best expression of specific research topics of interest to each Division within SMD are represented in by the topics listed in SMD's "ROSES" research solicitation, see Table 3 of ROSES-2019 and the text in the Division research overviews of ROSES, i.e., the Earth Science Research Overview, the Heliophysics Division Overview, the Planetary Science Research Program Overview and the Astrophysics Research Program Overview. Please note, even if particular topic is not solicited in ROSES this year it is still a topic of interest and eligible for this solicitation. Additional information about the Science Mission Directorate may be found at: http://nasascience.nasa.gov.

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

Heliophysics Division

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

The Agency's strategic objective for heliophysics is to **understand the Sun and its interactions with Earth and the solar system, including space weather.** The heliophysics decadal survey conducted by the National Research

Council (NRC), *Solar and Space Physics: A Science for a Technological Society* (*http://www.nap.edu/catalog/13060/solar-and-space-physics-a-science-for-a-technological-society*), articulates the scientific challenges for this field of study and recommends a slate of design reference missions to meet them, to culminate in the achievement of a predictive capability to aid human endeavors on Earth and in space. The fundamental science questions are:

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

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

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

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

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

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

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

Earth Science Division

Our planet is changing on all spatial and temporal scales and studying the Earth as a complex system is essential to understanding the causes and consequences of global change. The Earth Science Division of the Science Mission Directorate (https://science.nasa.gov/earth-science) contributes to NASA's mission, in particular, Strategic Objective 1.1: Understanding The Sun, Earth, Solar System, And Universe. This strategic objective is motivated by the following key questions:

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

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

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

The most recent decadal survey (2017-2027) from the National Academies of Science, Engineering, and Medicine, *Thriving on our Changing Planet: A Decadal Strategy for Earth Observation from Space*, serves as a foundational document to guide the overall approach to the Earth science program (see https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth).

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

Planetary Science Division

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

- Explore and observe the objects in the Solar System to understand how they formed and evolve.
- Advance the understanding of how the chemical and physical processes in the Solar System operate, interact and evolve.
- Explore and find locations where life could have existed or could exist today.

- Improve our understanding of the origin and evolution of life on Earth to guide our search for life elsewhere.
- Identify and characterize objects in the Solar System that pose threats to Earth or offer resources for human exploration.

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

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

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

Astrophysics Division

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

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

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

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

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

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

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

The broad themes of the Astrophysics Research Program are:

(i) Physics of the Cosmos:

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

(ii) Cosmic Origins:

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

(iii) Exoplanet Exploration:

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

(iv) Research Analysis and Technology Development:

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

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

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

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

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

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

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

Areas of Interest – POC: Damian.Taylor@nasa.gov

Space Technology Mission Directorate (STMD) expands the boundaries of the aerospace enterprise by rapidly developing, demonstrating, and infusing revolutionary, high-payoff technologies through collaborative partnerships. STMD employs a merit-based competition model with a portfolio approach, spanning a wide range of space technology discipline areas and technology readiness levels. Research and technology development takes place at NASA Centers, academia, and industry, and leverages partnerships with other government agencies and international partners.

STMD plans future investments to support the following strategic thrusts:

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

Current space technology topics of particular interest include:

- Methods for space and in space manufacturing
- Autonomous in-space assembly of structures and spacecraft
- Ultra-lightweight materials for space applications
- Materials, structures and mechanisms for extreme environments (low and high temperatures, radiation, etc.).
- Resource prospecting, mining, excavation, and extraction of in situ resources. Efficient in situ resource utilization to produce items required for long-duration deep space missions including fuels, water, oxygen, food, nutritional supplements, pharmaceuticals, building materials, polymers (plastics), and various other chemicals
- High performance space computing
- Smart habitats
- Extreme environment (including cryogenic) electronics for planetary exploration
- Advanced robotics for extreme environment sensing, mobility, manipulation and repair
- Advanced power generation, storage, and distribution for deep space missions and surface operations
- Advanced entry, decent, and landing systems for planetary exploration including materials response models and parachute models
- Radiation modeling, detection and mitigation for deep space crewed missions
- Biological approaches to environmental control, life support systems and manufacturing
- Autonomous systems for deep space missions

- Low size, weight, and power components for small spacecraft including high-bandwidth communication from space to ground, inter-satellite communication, relative navigation and control for swarms and constellations, precise pointing systems, power generation and energy storage, thermal management, system autonomy, miniaturized instruments and sensors, and in-space propulsion
- Technologies that take advantage of small launch vehicles and small spacecraft to conduct more rapid and lower-cost missions
- Advancements in engineering tools and models that support Space Technology advancement and development

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

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

A.5 NASA Centers Areas of Interest

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

A.5.1 Ames Research Center (ARC), POC: Brenda Collins (brenda.j.collins@nasa.gov)

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

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

Additional Center core competencies include:

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

A.5.2 Armstrong Flight Research Center (AFRC), POC: Dave Berger, dave.e.berger@nasa.gov

Autonomy (Collision Avoidance, Separation assurance, formation flight, peak seeking control)

(POC: Jack Ryan, AFRC-RC)

- Adaptive Control
  (POC: Curt Hanson, AFRC-RC)

- Hybrid Electric Propulsion
  (POC: Starr Ginn, AFRC-R)

- Control of Flexible Structures using distributed sensor feedback
  (POC: Marty Brenner, AFRC-RS; Peter Suh, AFRC-RC)

- Supersonic Research (Boom mitigation and measurement)
  (POC: Ed Haering, AFRC-RA)

- Supersonic Research (Laminar Flow)
  (POC: Dan Banks, AFRC-RA)

- Environmental Responsive Aviation
  (POC: Mark Mangelsdorf, AFRC-RS)

- Hypersonic Structures & Sensors
  (POC: Larry Hudson, AFRC-RS)

- Large Scale Technology Flight Demonstrations (Towed Glider)
  (POC: Steve Jacobson, AFRC-RC)

- Aerodynamics and Lift Distribution Optimization to Reduce Induced Drag
  (POC: Al Bowers, AFRC-R)

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

Research and technology, and engineering engagements comprise including:

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

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

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

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

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

- Advanced Manufacturing - facilitates the development, evaluation, and deployment of efficient and flexible additive manufacturing technologies. (ref: NAMII.org)
- Advanced Multi-functional Systems and Structures - novel approaches to increase spacecraft systems resource utilization
- Micro - and Nanotechnology - Based Detector Systems - research and application of these technologies to increase the efficiency of detector and optical systems
- Ultra-miniature Spaceflight Systems and Instruments - miniaturization approaches from multiple disciplines - materials, mechanical, electrical, software, and optical - to achieve substantial resource reductions
- Systems Robust to Extreme Environments - materials and design approaches that will preserve designed system properties and operational parameters (e.g. mechanical, electrical, thermal), and enable reliable systems operations in hostile space environments.

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

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

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

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

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

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

- The **Earth Sciences Division** plans, organizes, evaluates, and implements a broad program of research on our planet's natural systems and processes. Major focus areas include climate change, severe weather, the atmosphere, the oceans, sea ice and glaciers, and the land surface. To study the planet from the unique perspective of space, the Earth Science Division develops and operates remote-sensing satellites and instruments. We analyze observational data from these spacecraft and make it available to the world's scientists and policy makers. The Division conducts extensive field campaigns to gather data from the surface and airborne platforms. The Division also develops, uses, and assimilates observations into models that simulate planetary processes involving the water, energy, and carbon cycles at multiple scales up to global. POC: Eric Brown de Colstoun (eric.c.browndecolsto@nasa.gov).

- The **Astrophysics Science Division** conducts a broad program of research in astronomy, astrophysics, and fundamental physics. Individual investigations address issues such as the nature of dark matter and dark energy, which planets outside our solar system may harbor life, and the nature of space, time, and matter at the edges of black holes. Observing photons, particles, and gravitational waves enables researchers to probe astrophysical objects and processes. Researchers develop theoretical models, design experiments and hardware to test theories, and interpret and evaluate observational data. POC: Amber Straughn (Amber.n.Straughn@nasa.gov).

- The **Heliophysics Science Division** conducts research on the Sun, its extended solar-system environment (the heliosphere), and interactions of Earth, other planets, small bodies, and interstellar gas with the heliosphere. Division research also encompasses Geospace, Earth's magnetosphere and its outer atmosphere, and Space Weather—the important effects that heliospheric disturbances have on spacecraft and terrestrial systems. Division scientists develop spacecraft missions and instruments, systems to manage and disseminate heliophysical data, and theoretical and computational models to interpret the data. Possible heliophysics-related research include: advanced software environments and data-mining strategies to collect, collate and analyze data relevant to the Sun and its effects on the solar system and the Earth ("space weather"); and advanced computational techniques, including but not limited to parallel architectures and the effective use of graphics processing units, for the simulation of magnetized and highly dynamic plasmas and neutral gases in the heliosphere. POC: Doug Rabin (Douglas.Rabin@nasa.gov).

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

- **Quantum computing:** Quantum computing is based on quantum bits or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. As such, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer..
- **Artificial intelligence and machine learning**: Artificial Intelligence (AI) is a collection of advanced technologies that allows machines to think and act, both humanly and rationally, through sensing, comprehending, acting and learning. AI's foundations lie at the intersection of several traditional fields - Philosophy, Mathematics, Economics, Neuroscience, Psychology and Computer Science. Current AI applications include big data analytics, robotics, intelligent sensing, assisted decision making, and speech recognition just to name a few
- **(Big) data analytics:** Data Analytics, including Data Mining and Pattern Recognition for Science applications and with special emphasis on:
  - Quantification of uncertainty in inference from big data
  - Experiment design to create data that is AI/ML ready and robust against misleading correlations
  - Methods for prediction of new discovery spaces
  - Strength of evidence and reproducibility in inference from big data

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

A.5.5 Jet Propulsion Laboratory (JPL)

POC: Linda Rodgers, linda.l.rodgers@jpl.nasa.gov

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

- **Solar System Science**
  Planetary Atmospheres and Geology
  Solar System characteristics and origin of life
  Primitive solar systems bodies
  Lunar science
  Preparing for returned sample investigations
- **Earth Science**
  Atmospheric composition and dynamics
  Land and solid earth processes
  Water and carbon cycles
  Ocean and ice

Earth analogs to planets
Climate Science

- **<u>Astronomy and Fundamental Physics</u>**
  Origin, evolution, and structure of the universe
  Gravitational astrophysics and fundamental physics
  Extra-solar planets and star and planetary formation
  Solar and Space Physics
  Formation and evolution of galaxies
- **<u>In-Space Propulsion Technologies</u>**
  Chemical propulsion
  Non-chemical propulsion
  Advanced propulsion technologies
  Supporting technologies
- **<u>Space Power and Energy Storage</u>**
  Power generation
  Energy storage
  Power management & distribution
  Cross-cutting technologies
- **<u>Robotics, Tele-Robotics and Autonomous Systems</u>**
  Sensing
  Mobility
  Manipulation technology
  Human-systems interfaces
  Autonomy
  Autonomous rendezvous & docking
  Systems engineering
- **<u>Communication and Navigation</u>**
  Optical communications & navigation technology
  Radio frequency communications
  Internetworking
  Position, navigation and timing
  Integrated technologies
  Revolutionary concepts
- **<u>Human Exploration Destination Systems</u>**
  In-situ resource utilization and Cross-cutting systems
- **<u>Science Instruments, Observatories and Sensor Systems</u>**
  Science Mission Directorate Technology Needs
  Remote Sensing instruments/sensors
  Observatory technology
  In-situ instruments/sensor technologies
- **<u>Entry, Descent and Landing Systems</u>**
  Aerobraking, aerocapture, and entry systems
  Descent
  Landing
  Vehicle system technology
- **<u>Nanotechnology</u>**
  Engineered materials

Energy generation and storage
Propulsion
Electronics, devices and sensors

- **Modeling, Simulation, Information Technology and Processing**
  Flight and ground computing
  Modeling
  Simulation
  Information processing
- **Materials, Structures, Mechanical Systems and Manufacturing**
  Materials
  Structures
  Mechanical systems
  Cross cutting
- **Thermal Management Systems**
  Cryogenic systems
  Thermal control systems (near room temperature)
  Thermal protection systems

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

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

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

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

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

- Advanced habitat systems
  - GN&C for descent systems
  - Large body GN&C

- Human-in-the-loop system data acquisition and performance modeling
  - Imaging and information processing

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

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

- Human System Interfaces
  - OLED Technology Evaluation for Space Applications
  - Far-Field Speech Recognition in Noisy Environments
  - Radiation-Tolerant/ Hardened Graphics Processing
  - Machine-Learning human interfaces and methods
  - Human Computer Interaction design methods (Multi-modal and Intelligent Interaction) and apparatuses
  - Human Systems Integration, Human Factors Engineering: state of the art in Usability and performance assessment methods and apparatus.
  - Humans Systems Integration Inclusion in Systems Engineering

- ECLSS
  - Air Revitalization
  - Advanced water, O2 and CO2 monitoring and sensors
  - Advance thermally regenerated ionic fluids for CO2 and Humidity Control
  - Water Recovery and Management
  - Brine water recovery systems and wastewater treatment chemical recover for reuse or repurpose
  - Waste Management
  - Advance wastewater treatment systems (lower toxicity, recoverable)
  - Advanced trace contaminant monitoring and control technology
  - Quiet fan technologies

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

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

- Autonomous Rendezvous and Docking
  - Crew Exercise

- Small form Equipment

- Biomechanics

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

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

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

- In-Situ Resource Utilization
  - Mars atmosphere processing
  - CO2 collection, dust filtering, Solid Oxide CO2 electrolysis, Sabatier
  - Reverse water gas shift
  - Lunar/Mars regolith processing
  - Regolith collection and drying
  - Water collection and processing, water electrolysis (PEM and Solid Oxide)
  - Carbothermal reduction of regolith
  - Solar concentrator heat collection
  - Methane/Oxygen liquefaction and storage

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

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

- Food production and waste management
- Robotic, automated and autonomous food production
- Robotic, automated and autonomous food production
- Damage-resistant and self-healing materials
- Automated and autonomous detection and repair
- Propulsion: Chemical Propulsion flight integration (human transportation)
- Space Environments Test: Right/West Altitude Chamber

NOTE:

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

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

- Intelligent Flight Systems – Revolutionary Air Vehicles
  (POC: Guy Kemmerly 757-864-5070) – retired, awaiting new POC
- Atmospheric Characterization – Active Remote Sensing
  (POC: Allen Larar 757.864.5328)
- Systems Analysis and Concepts - Air Transportation System Architectures & Vehicle Concepts (POC: Phil Arcara 757.864.5978)
- Advanced Materials & Structural System – Advanced Manufacturing
  (POC: David Dress 757-864-5126)
- Aerosciences - Trusted Autonomy
  (POC: Sharon Graves 757-864-5018) –retired, awaiting new POC
- Entry, Decent & Landing - Robotic Mission Entry Vehicles
  (POC: Jeff Herath or Ron Merski)
- Measurement Systems - Advanced Sensors and Optical Measurement
  (POC: Tom Jones 757-864-4903)

A.5.9 Marshall Space Flight Center (MSFC), POC: Frank Six, frank.six@nasa.gov

Propulsion Systems

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

- Materials Compatibility
- Computational Fluid Dynamics
- Unsteady Flow Environments
- Acoustics and Stability
- Low Leakage Valves

Space Systems

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

Space Transportation

- Mission and Architecture Analysis
- Advanced Manufacturing
- Space Environmental Effects and Space Weather
- Lander Systems and Technologies
- Small Spacecraft and Enabling Technologies (Nanolaunch Systems)
- 3D Printing/Additive Manufacturing/Rapid Prototyping
- Meteoroid Environment
- Friction Stir and Ultrasonic Welding
- Advanced Closed-Loop Life Support Systems
- Composites and Composites Manufacturing
- Wireless Data & Comm. Systems
- Ionic Liquids
- Guidance, Navigation and Control (Autonomous, Small Launch Vehicle)
- Systems Health Management
- Martian Navigation Architecture/Systems
- Planetary Environment Modeling
- Autonomous Systems (reconfiguration, Mission Planning)

- Digital Thread / Product Lifecycle Management (for AM and/or Composites)
- Material Failure Diagnostics

Science

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

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

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

Propulsion Testing

Active and Passive Nonintrusive Remote Sensing of Propulsion Test Parameters

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

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

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

Advanced Non-Destructive Technologies

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

Advanced Propulsion Systems Testing

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

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

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

Ground Test Facilities Technology

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

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

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

Vehicle Health Management/Rocket Exhaust Plume Diagnostics

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