



# Request for Proposals

## Kansas NASA EPSCoR Program Partnership Development Grant (PDG)



Proposal Due: **Noon, March 12, 2021**  
Anticipated Grant End Date: **April 30, 2022**

With support from NASA and the Kansas Board of Regents - the Kansas NASA EPSCoR Program (KNEP) is preparing to award Partnership Development Grants (PDG) to Kansas investigators, under the KNEP Research Infrastructure Development (RID) program.

These grants are intended to facilitate the development of beneficial and promising NASA collaborations.

The PDG recipient is expected to initiate, develop, and formalize a meaningful professional relationship with a NASA researcher. Given this expectation, it is vital investigators and students travel to a NASA center if selected for an award.

Ideally the faculty member, student, and research host become co-participants in a promising research effort. Indeed, the PDG award should lead to sustained collaborations, joint publications, and, most importantly, future grant proposals.

### Award Criteria

PDG awards are competitive, with a strong emphasis on:

- Addressing NASA Mission Directorate and Kansas interests (required)
- Developing new, sustained, and meaningful NASA contacts (required)
- Involving US-students, especially underrepresented and underserved Kansas undergraduate and graduate students, in the research (required)
- Strengthening collaboration among academia, government agencies, business, and industry
- Exploring new and unique R&D opportunities
- Shared publications and future EPSCoR and non-EPSCoR grant submissions

It's important to note that NASA EPSCoR program is seeking to more directly align efforts with Mission Directorate (MD) objectives. Additional information on NASA, and Kansas, objectives and other resources can be found in this document's appendices. Proposers should clearly align their work with KS and NASA MD interests!

Additionally, proposals must detail other important infrastructure development related components, including:

- Investigator experience and long-term research plans
- Investigator specific goals, objectives, and priorities
- Measurable, award related, deliverables or metrics
- Detailed budget information; including all costs, matching funds, and any indirect cost waivers

The KNEP PDG program cannot support proposals augmenting existing funded or well-established research projects. NASA specifically states: "*NASA EPSCoR RID elements should not augment existing funded research projects. RID activities should target unique activities that increase jurisdiction competitiveness.*" Clearly, new and unique activities increasing Kansas' research infrastructure and competitiveness are essential and required.

### Funding, Required Match, and Restrictions

KNEP expects to award three (3) PDG grants, of \$18,456 each.

The following KNEP PDG program restrictions apply:

- Proposers are required to provide at least \$3,238 in matching funds (cash or in-kind) from non-federal sources
- Funds cannot be used for equipment (items under \$5,000 are “supplies”)
- Funds cannot be used for foreign travel
- Funds cannot be used for civil-service personnel labor or travel
- Proposals augmenting existing funded or well-established research projects cannot be supported - new and unique activities are essential and required (as noted in a previous section)
- All NASA funds must be expended within the award period (no-cost extensions are extremely unlikely)

### Grant Reporting

Grant recipients must submit a final report (and potentially a progress report), addressing KNEP Research Infrastructure Development (RID) program objectives, including:

- Grant related publications, presentations, and theses and dissertations
- Additional proposals, submitted or accepted, owing directly to the KNEP award
- Additional funding secured from industry or other sources
- Detailed information on the faculty and students supported (e.g., number of people involved, demographics, funding amounts, activities, performance, student future plans, etc.)
- New collaborations formed with NASA and industry
- Impact on Kansas’ economic development
- Other quantifiable items, as defined by individual investigators (in their original proposals)
- An update on short- and long-term research plans
- Patent applications or awards or technical transfer activities
- Other products (courses developed, websites, software and hardware, models, etc.)

PDG target outcomes, per award, include:

- One or more publications, with NASA or relevant industry co-authors
- One or more EPSCoR or non-EPSCoR grant proposals, as a product of the PDG award
- Significant project involvement by one or more students

### Increasing Access to the Results of Scientific Research

In keeping with the NASA Plan for Increasing Access to Results of Scientific Research, new terms and conditions consistent with the Rights in Data clause in the award which make manuscripts and data publicly accessible may be attached to NASA EPSCoR Research awards. All proposals will be required to provide a Data Management Plan (DMP) or an explanation of why one is not necessary given the nature of the work proposed. See Appendix E for additional information.

Additionally, researchers submitting NASA-funded articles in peer-reviewed journals or papers from conferences now shall make their work accessible to the public through NASA's PubSpace at <https://www.nihms.nih.gov/db/sub.cgi>.

PubSpace provides free access to NASA funded and archived scientific publications. Research papers will be available within one year of publication to download and read. <sup>[1]</sup><sub>SEP</sub>

### Special Note:

It is critical that investigators assure the proposed work is accurately planned and completed by the noted KNEP grant end date. NASA is under notable budget pressure. Indeed, they recently indicated, *“requests for no-cost extensions (NCEs) will be reviewed with increased scrutiny. It is possible that future NCE requests will be denied, and remaining funds will be returned to the Federal Government.”*

Proposal Submission:

There is an 8-page limit for all PDG proposal content (no exceptions). Use one-inch margins, a 12-pt times new roman font, and single-spaced text. A specific proposal format or style (e.g., NSF) is not expected or required. Proposers simply need to effectively address expectations outlined in this RFP.

The proposal budget must clearly identify the distribution of available KNEP and university matching funds.

Proposals must include a signature of the submitting Organization's Authorizing Official.

Submit a single proposal document in PDF-format (less than 2-MB in size) to the KNEP director, [scott.miller@wichita.edu](mailto:scott.miller@wichita.edu), by noon on the noted date (see the page-one header).

Contact the KNEP Director ([scott.miller@wichita.edu](mailto:scott.miller@wichita.edu) or 316-978-6334) with any RFP related questions.

Availability of Funds and Period of Performance:

KNEP's ability to make awards is obviously contingent upon the availability of NASA and Kansas Board of Regents appropriated funds from which payment can be made. The award period of performance is for approximately 6-months.

## Appendices

PDG awards are designed to help researchers develop relationships with NASA Mission Directorates and Field Centers, and possibly industry, as appropriate. The efforts must, obviously, also address areas of Kansas and NASA interest.

The following material outlines Kansas and NASA strategic interests. Additional NASA specific resources and contact information is also included.

## Appendix I

### Kansas Strategic Interests

State science and technology strategic interests are outlined in a strategic planning document entitled *Kansas Building an Environment for Science and Technology for Innovation* or “*Kansas B.E.S.T. for Innovation.*”

An approach to meeting Kansas’ strategic objectives is outlined in this document using four goals, listed as follows:

- *“Stimulate discovery and innovation through partnerships by building on current areas of strength in agriculture, transportation, health, and education, and nurturing emerging areas of opportunity in bioscience, energy, and the environment”*
- *“Translate the results of research into meaningful solutions to societal challenges by fabricating new and patentable devices and methodologies, and providing invaluable in-formation for better-informed policies and partnerships with stakeholders”*
- *“Grow the economy by applying new technologies and expanding access to information technology, resulting in vibrant and diverse economic development that brings tangible benefits to the citizens of Kansas and attracts new business to the state”*
- *“Educate a diverse workforce and the next generation of science, technology, and business leaders”*

Kansas’ relevant areas of strength and focus include:

- Health and well-being
- Aviation and transportation
- Bioscience
- Materials
- Energy and environment

The creation of new multidisciplinary groups, industrial collaborations, partnerships, and an appropriately educated workforce leading to new products, jobs, and industry in Kansas is highly desirable.

## Appendix II

### NASA Strategic Goals

KNEP focuses its program and project elements on NASA's interests. From the Kansas perspective, as outlined in previous sections, the following specific "NASA Strategic Plan 2014" goals and objectives are significant:

- Strategic Goal 1 - *"Expand the frontiers of knowledge, capability, and opportunity in space."*
  - Objective 1.2: *"Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity."*
  - Objective 1.4: *"Understand the Sun and its interactions with Earth and the solar system, including space weather."*
- Strategic Goal 2 - *"Advance understanding of Earth and develop technologies to improve the quality of life on our home planet."*
  - Objective 2.1: *"Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research."*
  - Objective 2.2: *"Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet."*
  - Objective 2.3: *"Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, ensuring the greatest national benefit."*
  - Objective 2.4: *"Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets."*

The underlined portions of NASA's strategic objectives are particularly important to Kansas. Specific state interests intersect strongly with NASA's in the science and aeronautics related areas. Kansas has notable expertise in aviation, advanced materials, biotechnology, energy, and earth sciences. Logically, it's within these common areas Kansas is positioned to do well. KNEP is eager to grow and diversify related research infrastructure to assist NASA and Kansas in meeting its goals.

The 2014 NASA Strategic Plan is accessible at:

[http://www.nasa.gov/sites/default/files/files/FY2014\\_NASA\\_SP\\_508c.pdf](http://www.nasa.gov/sites/default/files/files/FY2014_NASA_SP_508c.pdf).

## Appendix III

### NASA Mission Directorates and Center Alignment

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

#### A.1 Aeronautics Research Mission Directorate (ARMD)

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

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

Additional information on the Aeronautics Research Mission Directorate (ARMD) can be found at: <https://www.nasa.gov/aeroresearch> and in ARMD's Strategic Implementation plan that can be found at: <https://www.nasa.gov/aeroresearch/strategy>.

**Areas of Interest** - POC: Karen Rugg, [karen.l.rugg@nasa.gov](mailto:karen.l.rugg@nasa.gov)

Proposers are directed to the following:

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

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

**Human Exploration & Operations Mission Directorate (HEOMD)** provides the Agency with leadership and management of NASA space operations related to human exploration in and beyond low-Earth orbit. HEO also oversees low-level requirements development, policy, and programmatic oversight. The International Space Station, currently orbiting the Earth with a crew of six, represents the NASA exploration activities in low-Earth orbit. Exploration activities beyond low Earth orbit include the management of Commercial Space Transportation, Exploration Systems Development, Human Space Flight Capabilities, 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](mailto: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.

##### *Engineering Research*

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



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

### **A.3 Science Mission Directorate (SMD)**

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

[Astrophysics Research Program Overview](#)

[Earth Science Research Overview](#)

[Heliophysics Research Program Overview](#)

[Planetary Science Research Program Overview](#)

<https://solicitation.nasaprs.com/ROSES2020table3>

<https://solicitation.nasaprs.com/ROSES2020table2>

Please note, even if 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](mailto:kristen.erickson@nasa.gov)

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

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

The mission of BPS is two-pronged:

- Pioneer scientific discovery in and beyond low Earth orbit to drive advances in science, technology, and space exploration to enhance knowledge, education, innovation, and economic vitality

- Enable human spaceflight exploration to expand the frontiers of knowledge, capability, and opportunity in space

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

BPS administers NASA's:

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

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

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

### **Space Biology Program**

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

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

Research proposals are being solicited on the following topic:

- Organismal Biology – responses of whole organisms and their systems to ionizing radiation and/or altered gravity simulators.
  - These will be ground-based studies.
  - Ionizing radiation and altered gravity regimes (partial gravity and microgravity) are a hallmark of the deep space environment. Studies should effectively delineate the biological effects of these factors, radiation and altered gravity, separately and/or in combination.
  - Understand the mechanistic bases of the changes induced in these unique environments, preferably from a systems biology perspective, including genetic, cellular, or molecular biological effects.

Further information for the Space Biology program are available at:

<https://science.nasa.gov/biological-physical/programs/space-biology>

<https://science.nasa.gov/biological-physical/documents>

### **Physical Science Program**

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

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

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

### Heliophysics Division

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

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

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

The overarching goal of NASA's Earth Science program is to develop a scientific understanding of Earth as a system. 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

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

The Earth Science Division (ESD) places particular emphasis on the investigators' ability to promote and increase the use of space-based remote sensing through the proposed research. Proposals with objectives connected to needs identified in most recent Decadal Survey (2017-2027) from the National Academies of Science, Engineering, and Medicine, *Thriving on our Changing Planet: A Decadal Strategy for Earth Observation from Space* are welcomed. (see

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<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](http://www.nasa.gov/directorates/spacetech/about_us/index.html)).

**Areas of Interest** – POC: [Damian.Taylor@nasa.gov](mailto: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: Kristina Wilmoth ([kristina.wilmoth@nasa.gov](mailto:kristina.wilmoth@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*
- Autonomy & robotics: *Enabling complex air and space missions, and complementing humans in space*
- Low-cost missions: *Enabling high value science to low Earth orbit, the moon and the solar system*
- Biology & astrobiology: *Understanding life on Earth and in space*
- Exoplanets: *Finding worlds beyond our own*
- Autonomy & robotics: *Complementing humans in space*
- Lunar science: *Rediscovering our moon, searching for water*
- Human factors: *Advancing human-technology interaction for NASA missions*
- Wind tunnels: *Testing on the ground before you take to the sky*

Additional Center core competencies include:

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

### A.5.2 Armstrong Flight Research Center (AFRC)

POC: Dave Berger, [dave.e.berger@nasa.gov](mailto: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](mailto: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
- Networks, Architectures and Systems Integration
- Intelligent Systems-Smart Sensors and Electronic Systems Technologies
- Aeronautical and Space Systems Analysis
- Electrified Aircraft
- Computer Systems and Networks
- Electric (Ion) Propulsion
- Fluid and Cryogenic Systems / Thermal Systems
- Growth of Ice on Aircraft
- Aviation Safety Improvements
- Instrumentation, Controls and Electronics
- Fluids, Computational Fluid Dynamics (CFD) and Turbomachinery
- Materials and Structures, including Mechanical Components and Lubrication
- Mechanical and Drive Systems (Shape Memory Alloys-Base Actuation)
- Computational Modeling
- Microgravity Fluid Physics, Combustion Phenomena and Bioengineering
- Nanotechnology
- Photovoltaics, Electrochemistry-Physics, and Thermal Energy Conversion
- Propulsion System Aerodynamics
- Power Architecture, Generation, Storage, Distribution and Management
- Urban Air Mobility (UAM)
- Systems Engineering

The above engagement areas relate to the following key 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 L. Harrington, [james.l.harrington@nasa.gov](mailto:james.l.harrington@nasa.gov)

**Applied Engineering and Technology Directorate:** POC: Danielle Margiotta, [Danielle.V.Margiotta@nasa.gov](mailto:Danielle.V.Margiotta@nasa.gov)

- **Advanced Manufacturing** - facilitates the development, evaluation, and deployment of efficient and flexible additive manufacturing technologies. (ref: [NAMII.org](http://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](mailto: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](mailto:Alan.p.cudmore@nasa.gov)).
- **Integrated Photonic components and systems** - Integrated photonic components and systems for Sensors, Spectrometers, Chemical/biological sensors, Microwave, Sub-millimeter and Long-Wave Infra-Red photonics, Telecom- inter and intra satellite communications.
- **Quantum computing**
- **Artificial intelligence and machine learning**
- **(Big) data analytics**
- **Radiation Effects and Analysis**
  - Flight validation of advanced event rate prediction techniques
  - New approaches for testing and evaluating 3-D integrated microcircuits and other advanced microelectronic devices
  - End-to-end system (e.g., integrated component level or higher) modeling of radiation effects
  - Statistical approaches to tackle radiation hardness assurance (i.e., total dose, displacement damage, and/or single-event effects) for high-risk, low-cost missions.

**Sciences and Exploration Directorate** POC: Blanche Meeson, [Blanche.W.Meeson@nasa.gov](mailto: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](mailto:eric.c.browndecolsto@nasa.gov)).
- The **Astrophysics Science Division** conducts a broad program of research in astronomy, astrophysics, and fundamental physics. Individual investigations address issues such as the nature of dark matter and dark energy, which planets outside our solar system may harbor life, and the nature of space, time, and matter at the edges of black holes. Observing photons, particles, and gravitational waves enables researchers to probe astrophysical objects and processes. Researchers develop theoretical models, design experiments and hardware to test theories, and interpret and evaluate observational data. POC: Rita Samburna ([Rita.m.Sambruna@nasa.gov](mailto:Rita.m.Sambruna@nasa.gov)).
- The **Heliophysics Science Division** conducts research on the Sun, its extended solar-system environment (the heliosphere), and interactions of Earth, other planets, small bodies, and interstellar gas with the heliosphere. Division research also encompasses Geospace, Earth's magnetosphere and its outer atmosphere, and Space Weather—the important effects that heliospheric disturbances have on spacecraft and terrestrial systems. Division scientists develop spacecraft missions and instruments, systems to manage and disseminate heliophysical data, and theoretical and computational models to interpret the data. Possible heliophysics-related research include: advanced software environments and data-mining strategies to collect, collate and analyze data relevant to the Sun and its effects on the solar system and the Earth (“space weather”); and advanced computational techniques, including but not limited to parallel architectures and the effective use of graphics processing units, for the simulation of magnetized and highly dynamic plasmas and neutral gases in the heliosphere. POC: Doug Rabin ([Douglas.Rabin@nasa.gov](mailto:Douglas.Rabin@nasa.gov)).
- The **Solar System Exploration Division** builds science instruments and conducts theoretical and experimental research to explore the solar system and understand the formation and evolution of planetary systems. Laboratories within the division investigate areas as diverse as astrochemistry, planetary atmospheres, extrasolar planetary systems, earth science, planetary geodynamics, space geodesy, and comparative planetary studies. To study how planetary systems form and evolve, division scientists develop theoretical models and experimental research programs, as well as mission investigations and space instruments to test them. The researchers participate in planetary and Earth science missions, and collect, interpret, and evaluate measurements. POC: Brook Lakew ([Brook.Lakew@nasa.gov](mailto:Brook.Lakew@nasa.gov))
- **Quantum computing:** Quantum computing is based on quantum bits or qubits. Unlike traditional computers, in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values simultaneously. Representing information in qubits allows the information to be processed in ways that have no equivalent in classical computing, taking advantage of phenomena such as quantum tunneling and quantum entanglement. As such, quantum computers may theoretically be able to solve certain problems in a few days that would take millions of years on a classical computer. POC: Mike Little ([m.m.little@nasa.gov](mailto:m.m.little@nasa.gov))
- **Artificial intelligence and machine learning:** Artificial Intelligence (AI) is a collection of advanced technologies that allows machines to think and act, both humanly and rationally, through sensing, comprehending, acting and learning. AI's foundations lie at the intersection of several traditional fields - Philosophy, Mathematics, Economics, Neuroscience, Psychology and Computer Science. Current AI applications include big data analytics, robotics, intelligent sensing, assisted decision making, and speech recognition just to name a few. POCs: Mark Carroll ([mark.carroll@nasa.gov](mailto:mark.carroll@nasa.gov)) across the entire organization and in Heliophysics Barbara Thompson ([Barbara.j.thompson@nasa.gov](mailto:Barbara.j.thompson@nasa.gov))
- **(Big) data analytics:** Data Analytics, including Data Mining and Pattern Recognition for Science applications and with special emphasis on:

- Quantification of uncertainty in inference from big data
- Experiment design to create data that is AI/ML ready and robust against misleading correlations
- Methods for prediction of new discovery spaces
- Strength of evidence and reproducibility in inference from big data

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

Scientists in all four divisions publish research results in the peer-reviewed literature, participate in the archiving and public 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](mailto:linda.l.rodgers@jpl.nasa.gov)

- [Solar System Science](#)  
Planetary Atmospheres and Geology  
Solar System characteristics and origin of life  
Primitive (1) solar systems bodies  
Lunar (9) science  
Preparing for returned sample investigations
- [Earth Science](#)  
Atmospheric composition and dynamics (Atmospheric Dynamics)  
Land and solid earth processes (Solid Earth Processes)  
Water and carbon cycles, Carbon Cycles, Water Cycles  
Ocean and ice  
Earth analogs to planets, Earth Analog  
Climate Science
- [Astronomy and Fundamental Physics](#)  
Origin, evolution, and structure of the universe, Origin Universe, Evolution Universe, Structure Universe  
Gravitational astrophysics and fundamental physics  
Extra-solar planets: Exoplanets; Star formation; Planetary formation  
Solar and Space Physics  
Formation and evolution of galaxies; Formation Galaxies; Evolution Galaxies
- [In-Space Propulsion Technologies](#)  
Chemical propulsion  
Non-chemical propulsion  
Advanced propulsion technologies  
Supporting technologies  
Thermal Electric Propulsion  
Electric Propulsion
- [Space Power and Energy Storage](#)  
Power generation  
Energy storage  
Power management & distribution  
Cross-cutting technologies  
Solar power, Photovoltaic  
Tethers  
Radioisotope  
Thermoelectric

- [Robotics, Tele-Robotics, and Autonomous Systems](#)  
Sensing (Robotic Sensing)  
Mobility  
Manipulation technology  
Human-systems interfaces  
Autonomy  
Autonomous rendezvous & docking  
Systems engineering  
Vision  
Virtual reality  
Telepresence  
Computer Aided
- [Communication and Navigation](#)  
Optical communications & navigation technology  
Radio frequency communications, Radio Technologies  
Internetworking  
Position navigation and timing  
Integrated technologies  
Revolutionary concepts  
Communication technology  
Antennas  
Radar  
Remote Sensing  
Optoelectronics
- [Human Exploration Destination Systems](#)  
In situ resource utilization and Cross-cutting systems

### [Science Instruments, Observatories and Sensor Systems](#)

#### Science Mission Directorate Technology Needs

Remote Sensing instruments/Remote Sensing Sensors  
Observatory technologies  
In-situ instruments, Sensor technologies  
Sensors  
In situ technologies  
Instrument technologies  
Precision frequency  
Precision timing

- [Entry, Descent and Landing Systems](#)  
Aerobraking, Aerocapture and entry system; Descent; Engineered materials; Energy generation and storage;  
Propulsion; Electronics, devices and sensors
- Nanotechnology
- Microtechnology
- Microelectronics
- Microdevice
- Orbital Mechanics



Spectroscopy

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

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## **Other Research Areas**

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

### **A.5.6 Johnson Space Center (JSC)**

POC: Kamlesh Lulla, [kamlesh.p.lulla@nasa.gov](mailto:kamlesh.p.lulla@nasa.gov)

#### **Active Thermal Control**

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

#### **ECLSS**

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

## **EVA**

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

## **Entry, Descent, and Landing**

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

## **Energy Storage technologies**

- Batteries, Regenerative Fuel cells

## **In-Situ Resource Utilization**

- Lunar/Mars regolith processing (Regolith collection and drying; Water collection and processing, water electrolysis)
- Mars atmosphere processing (CO<sub>2</sub> collection; Dust filtering; Solid Oxide CO<sub>2</sub> electrolysis; Sabatier; Reverse water gas shift)
- Methane/Oxygen liquefaction and storage

## **In-space propulsion technologies**

### **Autonomy and Robotics**

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

### **Autonomous Rendezvous and Docking**

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

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

## **Computer Human Interfaces (CHI)**

### **CHI - Human System Integration**

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

### **CHI - Informatics**

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

### **CHI - Audio**

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

### **CHI - Imaging and Display**

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

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

#### Wearable Technology

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

#### Wireless and Communications Systems

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

#### Radiation and EEE Parts

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

### A.5.7 Kennedy Space Center (KSC)

POC Jose Nunez, [jose.l.nunez@nasa.gov](mailto: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
- Launch technologies including propellant management, range & communications
- Vehicle, payload and flight science experiment integration and testing
- Landing & recovery operations
- Biological sciences (Plant research & production)
- Destination systems including ISRU, surface construction & dust mitigation
- Autonomous/robotic (unmanned) surface systems and operations
- Water resource utilization technologies
- Logistics reduction technologies

**NOTE:**

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

### **A.5.8 Langley Research Center (LaRC)**

**Langley Research Center (LaRC)**, POC: Dr. Garnise Dennis, [garnise.a.dennis@nasa.gov](mailto:garnise.a.dennis@nasa.gov)

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

### **A.5.9 Marshall Space Flight Center (MSFC)**

POC: Frank Six, [frank.six@nasa.gov](mailto: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.5.10 Stennis Space Center (SSC),**

POC: Dr. Mitch Krell, [mitch.krell@nasa.gov](mailto: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**

ISHM 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 cryogenics 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 maneuvering 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.