Proposal Guidelines
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1. Maine Space Grant Consortium

The Maine Space Grant Consortium (MSGC) is an Affiliate-based 501(c)(3) corporation and governed by a Board of Directors. Our mission is to:

- Improve our Affiliates research infrastructure in areas of mutual interest to NASA and the state of Maine;
- Encourage more students to consider careers in STEM; and
- Enhance NASA’s presence throughout the State of Maine.

Our Affiliates are higher education institutions, not-for-profit research laboratories, state agencies, technology-based businesses and science and education organizations, all of whom help further NASA’s goals while benefiting Maine in many different areas of science and technology. Through our Affiliates we achieve our mission by competitively funding projects that support four national objectives: Research Infrastructure, Higher Education, Pre-College and Informal Science. Specifically, we:

- Provide scholarships and fellowships for undergraduate and graduate students studying science and engineering at Maine colleges and universities.
- Provide seed research grants and travel grants to stimulate collaborative endeavors between Maine researchers and researchers at NASA’s field centers.
- Provide undergraduate students with internship opportunities at NASA and in the State of Maine.
- Support higher education STEM course development
- Support K-12 STEM-focused professional development.
- Provide summer internships for Maine High School students with Maine businesses conducting STEM related research and education.
- Support informal science education activities designed to inspire future scientists and engineers and enhance public awareness of the impact of STEM and NASA on everyday life.

2. National Space Grant College and Fellowship Program

The National Space Grant College and Fellowship Program (Space Grant) is administered through NASA’s Office of Education. Space Grant is a national network of 52 consortia in all 50 states, the District of Columbia and the Commonwealth of Puerto Rico. The network includes over 850 affiliates from universities, colleges, industry, museums, science centers, and state and local agencies. Collectively, these institutions are working to expand opportunities for Americans to understand and participate in NASA’s aeronautics and space projects by supporting and enhancing STEM education, research and public outreach efforts.

The goal of the Space Grant Program is to contribute to the nation’s science enterprise by funding education, research, and informal education projects through a national network of Space Grant consortia. The objectives of the Space Grant Program are to:

1. Promote a strong STEM education base from elementary through secondary levels while preparing teachers in these grade levels to become more effective at improving student academic outcomes.
2. Establish and maintain a national network of universities with interests and capabilities in aeronautics, space and related fields.
3. Encourage cooperative programs among universities, aerospace industry, and Federal, state and local governments.
4. Encourage interdisciplinary training, research and public service programs related to aerospace.
5. Recruit and train U.S. citizens, especially women, underrepresented minorities, and persons with disabilities, for careers in aerospace science and technology.

The Space Grant Program follows the requirements of NASA’s Education Portfolio. This portfolio is guided by three Outcomes:

- **Outcome 1:** Contribute to the development of the STEM workforce in disciplines needed to achieve NASA’s strategic goal through a portfolio of investments.
- **Outcome 2:** Attract and retain students in STEM disciplines through a progression of educational opportunities for students, teachers, and faculty.
- **Outcome 3:** Build strategic partnerships and linkages between STEM formal and informal education providers that promote STEM literacy and awareness of NASA’s mission.

### 3. NASA Strategic Plan and Relevance to Education

The Mission of NASA, as stated in the NASA 2018 Strategic Plan is to: “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 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 America leadership.”

NASA contributes to national efforts for achieving excellence in STEM education through a comprehensive education portfolio implemented by the Office of Education, the Mission Directorates, and the NASA Centers. NASA will continue the Agency’s tradition of investing in the Nation’s education programs and supporting the country’s educators who play a key role in preparing, inspiring, exciting, encouraging, and nurturing the young minds of today that will manage and lead the Nation’s laboratories and research centers of tomorrow.

### 4. Diversity

It is a national priority to increase diversity in the Science, Technology, Engineering and Mathematics (STEM) marketplace from university students to employees. Traditionally, minority groups, women, and the handicapped have been underrepresented in the STEM disciplines as students and faculty as well as in the workplace after graduation. MSGC is committed to addressing this concern and utilizing its programs, to the degree possible, to increase the diversity among its awardees. All proposers are encouraged to help address the diversity objective.
5. **Indirect Costs**

MSGC caps indirect cost rate on proposals submitted to MSGC programs to 10%, unless otherwise specified in MSGC’s individual program request for proposals/program announcement.

6. **Cancellation of Awards**

MSGC reserves the right not to make any awards under this announcement and/or to cancel at any time prior to award. MSGC assumes no liability (including bid and proposal costs in case of cancellation) for cancelling this announcement or for any entity’s failure to receive an actual notice of cancellation.

7. **Federal STEM Priorities**

The February 2012: [Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education Investments: Progress Report](http://www.whitehouse.gov/sites/default/files/microsites/ostp/ncstc_federal_stem_education_coordination_report.pdf) (Co-STEM Report¹), which established a set of federal-wide objectives to increase the coordination of STEM education efforts, identified the following four federal STEM education priority areas to focus federal investments:

1. **Effective K-12 STEM Teacher Education** – Increase the number and proportion of individuals, particularly from groups that are traditionally underrepresented in STEM fields, who complete teacher pre-service and in-service programs with an ability to increase students’ understanding of STEM.

2. **Engagement in STEM** – Expand the availability and coherence of investments that increase interest in, involvement in, or value placed on STEM by PreK-12 aged individuals (especially those from traditionally underrepresented groups).

3. **Undergraduate STEM Education** – Improve retention rates, including among groups traditionally underrepresented, in STEM majors during the first two years of undergraduate education.

4. **Serving Groups Traditionally Underrepresented in STEM Fields** – Increase the number of individuals from underrepresented groups that graduate with STEM degrees.

The importance of Priority Areas 1 and 3 can be found in two President’s Council of Advisors on Science and Technology (PCAST) reports:

(a) **Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math for America’s Future**². One of the first steps in supporting the retention of students in STEM and producing STEM professionals lies with the educators involved in students’ educational pursuits. To this end, among other recommendations in the *Prepare and Inspire* report, is a push to support over the next decade at least 100,000 new STEM educators.

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² Report to the President, *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math for America’s Future*, President’s Council of Advisors on Science and Technology, September 2010. [http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf)
middle and high school teachers who have strong grounding in STEM fields and strong content-specific pedagogical preparation so that they will achieve mastery of instruction skills and practices needed to confidently teach STEM topics.

*Engage to Excel: Producing one million additional college graduates with degrees in Science, Technology, Engineering, and Mathematics*. According to the *Engage to Excel* report, fewer than 40% of students who begin their undergraduate experience with the intent of majoring in a STEM field will complete a STEM degree. Reasons for this may include, but are not limited to: uninspiring introductory courses, difficulty with the mathematics requirements and/or content in STEM curricula, or even an unwelcoming atmosphere from faculty. Among the undergraduate students most at risk for this attrition are first-year and sophomore students. A strong component of this report focuses on improving STEM education reach and retention during the first two years of college through supporting the development and identification of practices that increase the number of STEM graduates and further seeks to increase the quality of these learners’ preparation.

8. NASA Research Areas of Interest

NASA research priorities are defined by the Mission Directorates (Aeronautics Research, Human Exploration & Operations, Science, and Space Technology), and NASA’s ten Centers. Each Mission Directorate and Center covers a major area of the Agency’s research and technology development efforts.

Research priorities for each of the Mission Directorates (includes Centers) are summarized below; please note the NASA Point of Contact (POC) for each Mission Directorate and Center.

8.1  **MISSION DIRECTORATES**

**AERONAUTICS RESEARCH MISSION DIRECTORATE (ARMD)**

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 programs will facilitate a safer, more environmentally friendly, and more efficient national air transportation system. Using a Strategic Implementation Plan NASA Aeronautics Research Mission Directorate (ARMD) sets forth the vision for aeronautical research aimed at the next 25 years and beyond. It encompasses a broad range of technologies to meet future needs of the aviation community, the nation, and the world for safe, efficient, flexible, and environmentally sustainable air transportation. Additional information on the Aeronautics Research Mission Directorate (ARMD) can be found at: [http://www.aeronautics.nasa.gov](http://www.aeronautics.nasa.gov).

**Areas of Interest** - POC: Tony Springer, [tony.springer@nasa.gov](mailto:tony.springer@nasa.gov)

Researchers responding to the ARMD should propose research that is aligned with one or more of the ARMD programs. Proposers are directed to the following:

- ARMD Programs: [http://www.aeronautics.nasa.gov/programs.htm](http://www.aeronautics.nasa.gov/programs.htm)
- The National Aeronautics and Space Administration (NASA), Headquarters, Aeronautics Research Mission Directorate (ARMD) Current Year version of the NASA Research Announcement (NRA) entitled, "Research Opportunities in Aeronautics (ROA)" has been posted

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1 Report to the President, *Engage to Excel: Producing one million additional college graduates with degrees in Science, Technology, Engineering, and Mathematics*, President’s Council of Advisors on Science and Technology, February 2012. [http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel_final_feb.pdf](http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel_final_feb.pdf)
on the NSPIRES web site at http://nspires.nasaprs.com (select “Solicitations” and then “Open Solicitations”).

Detailed requirements, including proposal due dates are stated in appendices that address individual thrust areas. These appendices will be posted as amendments to the ROA NRA and will be published as requirements materialize throughout the year.

**HUMAN EXPLORATION & OPERATIONS MISSION DIRECTORATE (HEOMD)**

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 Biology**
The Space Biology research has three primary goals:

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

These goals are achieved by sponsoring research studies in five program elements to contribute basic knowledge of biological adaptation to spaceflight to accelerate solutions to biomedical problems affecting human exploration of space as well as human health on Earth: Microbiology; Cell and Molecular Biology; Plant Biology; Animal Biology; and Developmental Biology

Current Space Biology emphases include:

- Use ground-based facilities to characterize the effects of space-like radiation on biological systems. NASA is interested in projects that will characterize how radiation exposure impacts living organisms during a single lifecycle, or over multiple generations.
- Use ground-based simulations to study how spaceflight conditions might impact plant and microbial interactions and growth. Questions of interest to NASA include, but are not limited to, whether spaceflight induces changes in the virulence of plant pathogens and/or whether spaceflight might change benign or commensal microbes on plants into pathogenic ones.
- Use ground-based facilities to simulate a range of gravitational levels on biological specimens to understand and characterize the dose-response curve between 0 and 2 G for various biological systems to determine A) if there are G-level thresholds required to trigger gravity-specific
responses in living organisms, and B) the effect that exposure to levels of gravity similar to those encountered on Mars (.38 G) or the moon (0.16 G), and/or hypergravity has on living organisms.

Further details about Space Biology goals, objectives and progress can be found at the Space Biology 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 and in new ways to improve the quality of life on Earth.

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

- Biophysics: biological macromolecules, biomaterials.
- Combustion science: spacecraft fire safety, droplets, gaseous (premixed and non-premixed), solid fuels, supercritical reacting fluids.
- Complex fluids: colloidal systems, liquid crystals, foams, gels, granular flows.
- Fluid physics: adiabatic two-phase flow, boiling and condensation, capillary flow, interfacial phenomena, cryogenics storage and handling.
- Fundamental physics: space optical/atomic clocks, quantum test of equivalence principle, cold atom physics, critical point phenomena, dusty plasmas.
- Materials science: glasses and ceramics, granular materials, metals, polymers and organics, semiconductors.

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 (Johnson Space Center (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))

**SCIENCE MISSION DIRECTORATE (SMD)**

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. At every step we share the journey of scientific exploration with the public and partner with others to substantially improve science, technology, engineering and mathematics (STEM) education.
nationwide. Additional information on the Science Mission Directorate (SMD) can be found at: (http://nasascience.nasa.gov)

Areas of Interest - POC: Kristen Erickson kristen.erickson@nasa.gov

The Science Mission Directorate (SMD) has developed science objectives and programs to answer fundamental questions in Earth and space sciences in the context of our national science agenda. The knowledge gained by researchers supporting NASA’s Earth and space science program helps to unravel mysteries that intrigue us all.

- What drives variations in the Sun, and how do these changes impact the solar system and drive space weather?
- How and why are Earth’s climate and environment changing?
- How did our solar system originate and change over time?
- How did the universe begin and evolve, and what will be its destiny?
- How did life originate, and are we alone?

Each of the SMD’s four science divisions – Heliophysics, Earth Science, Planetary Science, and Astrophysics – makes important contributions to address national and Agency goals. The NASA 2014 Science Plan (http://science.nasa.gov/media/medialibrary/2015/06/29/2014_Science_Plan_PDF_Update_508_TAGGED.pdf) reflects the direction NASA has received from our government’s executive branch and Congress, advice received from the nation’s scientific community, the principles and strategies guiding the conduct of our activities, and the challenges SMD faces. Specifically,

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
See Section 4.1 of the NASA 2014 Science Plan for specifics, including missions currently in operation, in formulation or development, and planned for the future.

**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 climate change and other global environmental concerns. The purpose of NASA’s Earth science program is to advance our scientific understanding of Earth as a system and its response to natural and human-induced changes and to improve our ability to predict climate, weather, and natural hazards.

NASA’s ability to observe global change on regional scales and conduct research on the causes and consequences of change position it to address the Agency strategic objective for Earth science, which is to advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet. NASA addresses the issues and opportunities of climate change and environmental sensitivity by answering the following key science questions through our Earth science program:

- 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

Two foundational documents guide the overall approach to the Earth science program: the NRC 2007 Earth science decadal survey ([http://www.nap.edu/catalog/11820/earth-science-and-applications-from-space-national-imperatives-for-the](http://www.nap.edu/catalog/11820/earth-science-and-applications-from-space-national-imperatives-for-the)) and NASA’s 2010 climate-centric architecture plan ([http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf](http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf)). The former articulates the following vision for Earth science research and applications in support of society:

> Understanding the complex, changing planet on which we live, how it supports life and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most challenges for society as it seeks to achieve prosperity, health, and sustainability.

The latter addresses the need for continuity of a comprehensive set of key climate monitoring measurements, which are critical to informing policy and action, and which other agencies and international partners had not planned to continue. 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.

See Section 4.2 of the NASA 2014 Science Plan for specifics, including missions currently in operation, in formulation or development, and planned for the future.

Planetary Science Division

Planetary science is a grand human enterprise that seeks to understand the history of our solar system and the distribution of life within it. The scientific foundation for this enterprise is described in the NRC planetary science decadal survey, Vision and Voyages for Planetary Science in the Decade 2013-2022 (http://www.nap.edu/catalog/13117/vision-and-voyages-for-planetary-science-in-the-decade-2013-2022). Planetary science missions inform us about our neighborhood and our own origin and evolution; they are necessary precursors to the expansion of humanity beyond Earth. Through five decades of planetary exploration, NASA has developed the capacity to explore all of the objects in our solar system. Future missions will bring back samples from some of these destinations, allowing iterative detailed study and analysis back on Earth. In the future, humans will return to the Moon, go to asteroids, Mars, and ultimately other solar system bodies to explore them, but only after they have been explored and understood using robotic missions.

NASA’s strategic objective in planetary science is to ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere. We pursue this goal by seeking answers to fundamental science questions that guide NASA’s exploration of the solar system:

- How did our solar system form and evolve?
- Is there life beyond Earth?
- What are the hazards to life on Earth?

The Planetary Science Division has translated these important questions into science goals that guide the focus of the division’s science and research activities:

- 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 our 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 selecting new missions for development, NASA’s Planetary Science Division strives for balance across mission destinations, using different mission types and sizes. Achievement of steady scientific progress requires a steady cadence of missions to multiple locations, coupled with a program that allows for a consistent progression of mission types and capabilities, from small and focused, to large and complex, as our investigations progress. The division also pursues partnerships with international partners to increase mission capabilities and cadence and to accomplish like-minded objectives.

See Section 4.3 of the NASA 2014 Science Plan for specifics, including missions currently in operation, in formulation or development, and planned for the future.

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.

Through its Astrophysics Division, NASA leads the nation on a continuing journey of transformation. From the development of innovative technologies, which benefit other areas of research (e.g., medical, navigation, homeland security, etc.), to inspiring the public worldwide to pursue STEM careers through its stunning images of the cosmos taken with its Great Observatories, NASA’s astrophysics programs are vital to the nation.

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](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.

NASA’s Astrophysics Division has developed several strategies to advance these scientific objectives and respond to the recommendations outlined in the decadal survey on a time horizon of 5-10 years. The successful development of JWST is an Agency priority. Since its re-baseline in 2011, the project has remained on schedule and within budget for an October 2018 launch. JWST and the science it will produce are foundational for many of the astronomical community’s goals outlined in the 2010 decadal survey. NASA’s highest priority for a new strategic astrophysics mission is the Wide Field Infrared Survey Telescope (WFIRST), the number one priority for large-scale missions of the decadal survey. NASA plans to be prepared to start a new strategic astrophysics mission when funding becomes available. NASA also plans to identify opportunities for international partnerships, to reduce the Agency’s cost of the mission concepts identified, and to advance the science objectives of the decadal survey. NASA will also augment the Astrophysics Explorer Program to the extent that the budget allows. Furthermore, NASA will continue to invest in the Astrophysics Research Program to develop the science cases and technologies for new missions and to maximize the scientific return from operating missions.

See Section 4.4 of the NASA 2014 Science Plan for specifics, including missions currently in operation, in formulation or development, and planned for the future.
SPACE TECHNOLOGY MISSION DIRECTORATE (STMD)
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, 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 the Space Technology Mission Directorate (STMD) can be found at: (http://www.nasa.gov/directorates/spacetech/about_us/index.html)

Areas of Interest - POC: Joseph Grant joseph.grant-1@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 executes its mission according to the following tenets:

- Advancing transformative and crosscutting technologies that can be directly infused into future missions;
- Investing in a comprehensive portfolio covering low to high technology readiness levels;
- Competitively selecting research by academia, industry, and NASA Centers based on technical merit;
- Executing with lean structured projects with clear start and end dates, defined budgets and schedules, established milestones, and project level authority and accountability;
- Operating with a sense of urgency and informed risk tolerance to infuse quickly or terminate judiciously;
- Partnering with other NASA Mission Directorates, other government agencies, and the private sector to leverage resources, establish customer advocacy, and support US commercial aerospace interests;
- Delivering new inventions, enabling new capabilities and creating a pipeline of NASA and national innovators

Current space technology topics of particular interest include:

- Advanced manufacturing methods for space and in space
- Autonomous in-space assembly of structures and spacecraft
- Ultra-lightweight materials for space applications
- Materials and structures for extreme environments (high temperature, pressure)
- Extreme environment (including cryogenic) electronics for planetary exploration
- Advanced robotics for extreme environment sensing, mobility, and manipulation
- Deep space optical communication
- Extremely High Frequency microwave technologies for communication, remote sensing, and
navigation
- Advanced power generation, storage, and transfer for deep space missions
- Advanced entry, decent, and landing systems for planetary exploration
- 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
- Radiation mitigation for deep space crewed missions
- Biological approaches to environmental control and life support systems
- Autonomous systems for deep space missions
- Advanced telescope technologies for exoplanet imaging
- 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, robotic assembly/manufacturing, and in-space propulsion
- Enabling technologies for low-cost small spacecraft launch vehicles
- Advancements in engineering tools and models supporting Space Technology focus areas

Applicants are strongly encouraged to familiarize themselves with the roadmap document most closely aligned with their space technology interests. The individual roadmap documents may be downloaded at the following link: [http://www.nasa.gov/offices/oct/home/roadmaps/index.html](http://www.nasa.gov/offices/oct/home/roadmaps/index.html)

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](http://nspires.nasaprs.com) (select “Solicitations” and then “Open Solicitations”). The NRA provides detailed information on specific proposals being sought across STMD programs.

### 8.2 NASA CENTERS AREAS OF INTEREST

Examples of Center research interest areas include these specific areas from the following Centers. If no POC is listed or contact information is needed, please contact the POC using contact information listed in Appendix E.

**GODDARD SPACE FLIGHT CENTER (GSFC)**

POC: Mablelene S Burrell, mablelene.s.burrell@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](http://www.nasmotech.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).

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.

Education efforts in all science divisions seek to develop interest in and understanding of the science at GSFC by K-12 educators and students and the development of future scientist and computer scientists at the undergraduate and graduate level.

Outreach efforts in all four science divisions raise public awareness of the projects and missions in which we are involved, the research we conduct, and the associated benefits to society.

• Quantum computing
• Artificial intelligence and machine learning
• (Big) data analytics

**AMES RESEARCH CENTER (ARC)**

POC: Danielle Carmichael (danielle.n.carmichael@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 factory**: 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

**GLENN RESEARCH CENTER (GRC)**
POC: Mark David Kankam, Ph.D.  mark.d.kankam@nasa.gov

Research and technology, and engineering engagements comprise including:

- Acoustics
- Advanced Energy (Renewable Wind and Solar, Coal Energy and Alternative Energy)
- Advanced Microwave Communications
- Aeronautical and Space Systems Analysis
- Computer Systems and Networks
- Electric (Ion) Propulsion
- Icing and Cryogenic Systems
- 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
- Systems Engineering

The above engagement areas relate to the following key GRC competencies:

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

**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)

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 Test beds and Demonstrators (Pressure Systems)
• Combustion Physics
• Cryogenic Fluid Management
• 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
• 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

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 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)

Science
- Replicated Optics
- Large Optics (IR, visible, UV, X-Ray)
- High Energy Astrophysics (X-Ray, Gamma Ray, Cosmic Ray)
- Solar, Magnetospheric and Ionospheric Physics
- Radiation Mitigation/Shielding
- Earth Science Applications
- Convective and Severe Storms Research
- Climate Dynamics
- Lightning Research
- Geochronology, Geochemistry, Atmospheres and Interiors of Planetary Bodies
- Physical Science Informatics
- Biophysics (Protein Crystals)

KENNEDY SPACE CENTER (KSC)
Roadmap Technical Area (TA), POC Michael Lester, gregory.m.lester@nasa.gov
- TA 4.0 Robotics and Autonomous Systems
  Barbara Brown, barbara.l.brown@nasa.gov, Ph: 321-867-1720
  - 4.1 Sensing and Perception
  - 4.1.4 Natural, Man-Made Object, and Event Recognition
  - 4.3 Manipulation
  - 4.3.6 Sample Acquisition and Handling
  - 4.5 System-Level Autonomy
  - 4.5.3 Autonomous Guidance and Control
- TA 6.0 Human Health, Life Support, and Habitation Systems
  Charlie Quincy, charles.d.quincy@nasa.gov, Ph: 321-867-8383
  - 6.1 Environmental Control and Life Support Systems and Habitation Systems
    - 6.1.1 Air Revitalization
    - 6.1.2 Water Recovery and Management
    - 6.1.3 Waste Management
- TA 7.0 Human Exploration Destination Systems
  Stanley Starr, stanley.o.starr@nasa.gov, Ph: 321-861-2262
  - 7.1 In-Situ Resource Utilization
  - 7.1.1 Destination Reconnaissance, Prospecting, and Mapping
- 7.1.2 Resource Acquisition
- 7.1.3 Processing and Production
- 7.1.4 Manufacturing Products and Infrastructure Emplacement
- 7.2 Sustainability and Supportability
- 7.2.4 Food Production, Processing, and Preservation

- TA 13.0 Ground and Launch Systems
  Robert Johnson, robert.g.johnson@nasa.gov, Ph: 321-867-7373
  - 13.2 Environmental Protection and Green Technologies
  - 13.2.5 Curatorial Facilities, Planetary Protection, and Clean Rooms
  - 13.3 Reliability and Maintainability
  - 13.3.3 On-Site Inspection and Anomaly Detection and Identification
  - 13.3.6 Repair, Mitigation, and Recovery Technologies

- KSC SBIR, Mike Vinje, michael.e.vinje@nasa.gov, Ph: 321-861-3874
  - Standardized Interfaces (a USB port for space)
  - A substantial portion of pre-launch processing involves the integration of spacecraft assemblies to each other or to the ground systems that supply the commodities, power or data. Each stage or payload requires an interface that connects it to the adjacent hardware which includes flight critical seals or connectors and other components. Development and adoption of simplified, standardized interfaces holds the potential of reducing the cost and complexity of future space systems, which increases the funding available for flight hardware and drives down the cost of access to space for everyone.

**JET PROPULSION LABORATORY (JPL)**
POC: Linda Rodgers, linda.l.rogers@jpl.nasa.gov

- **Solar System Science**
  Planetary Atmospheres and Geology; Solar System characteristics and origin of life; Primitive solar systems bodies; Lunar science; Preparing for returned sample investigations

- **Earth Science**
  Atmospheric composition and dynamics; Land and solid earth processes; Water and carbon cycles; Ocean and ice; Earth analogs to planets; Climate Science

- **Astronomy and Fundamental Physics**
  Origin, evolution, and structure of the universe; Gravitational astrophysics and fundamental physics; Extra-solar planets and star and planetary formation; Solar and Space Physics; Formation and evolution of galaxies

- **In-Space Propulsion Technologies**
  Chemical propulsion; Non-chemical propulsion; Advanced propulsion technologies; Supporting technologies

- **Space Power and Energy Storage**
  Power generation; Energy storage; Power management & distribution; Cross-cutting technologies

- **Robotics, Tele-Robotics and Autonomous Systems**
  Sensing; Mobility; Manipulation technology; Human-systems interfaces; Autonomy; Autonomous rendezvous & docking; Systems engineering

- **Communication and Navigation**
  Optical communications & navigation technology; Radio frequency communications; Internetworking; Position, navigation and timing; Integrated technologies; Revolutionary concepts

- **Human Exploration Destination Systems**
  In-situ resource utilization and Cross-cutting systems
• **Science Instruments, Observatories and Sensor Systems**
  Science Mission Directorate Technology Needs; Remote Sensing instruments/sensors; Observatory technology; In-situ instruments/sensor technologies

• **Entry, Descent and Landing Systems**
  Aerobraking, aerocapture and entry systems; Descent; Landing; Vehicle system technology

• **Nanotechnology**
  Engineered materials; Energy generation and storage; Propulsion; Electronics, devices and sensors

• **Modeling, Simulation, Information Technology and Processing**
  Flight and ground computing; Modeling; Simulation; Information processing

• **Materials, Structures, Mechanical Systems and Manufacturing**
  Materials; Structures; Mechanical systems; Cross cutting

• **Thermal Management Systems**
  Cryogenic systems; Thermal control systems (near room temperature); Thermal protection systems

**JOHNSON SPACE CENTER (JSC)**
POC: Kamlesh Lulla, kamlesh.p.lulla@nasa.gov

• **In-space propulsion technologies**
• **Energy Storage technologies-Batteries, Regenerative 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**
    - 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 system 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 Hardened Graphics Processing
  – Human Computer Interaction design methods (Multi-modal and Intelligent Interaction) and apparatuses
  – 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 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
  - Methane/Oxygen liquefaction and storage

STENNIS SPACE CENTER (SSC)
POC: Nathan Sovik, nathan.a.sovik@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 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.

LANGLEY RESEARCH CENTER (LARC)
POC: Gamaliel (Dan) Cherry, Gamaliel.R.Cherry@nasa.gov
- Intelligent Flight Systems – Revolutionary Air Vehicles (POC: Guy Kemmerly 757-864-5070)
- Atmospheric Characterization – Active Remote Sensing (POC: Malcolm Ko 757-864-8892)
- Advanced Materials & Structural System – Advanced Manufacturing (POC: David Dress 757-864-5126)
- Aerosciences - Trusted Autonomy (POC: Sharon Graves 757-864-5018)
- Entry, Decent & Landing - Robotic Mission Entry Vehicles (POC: Keith Woodman 757-864-7692)

Measurement Systems - Advanced Sensors and Optical Measurement (POC: Tom Jones 757-864-4903)
Appendix A – NASA Center Contacts

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

**NASA Mission Directorate and Office of Chief Technologist Contacts**

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<thead>
<tr>
<th>Aeronautics Research Mission Directorate</th>
<th>Science Mission Directorate</th>
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<tr>
<td>Aeronautics Research Mission Directorate</td>
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<td>Lead, Communications and Education NASA Headquarters</td>
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<th>Space Technology Mission Directorate</th>
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<td>Human Exploration &amp; Operations Mission Directorate</td>
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**NASA Center Contacts**

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<th>Armstrong Flight Research Center</th>
<th>Langley Research Center</th>
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<th>Goddard Space Flight Center</th>
<th>Glenn Research Center</th>
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<th>Jet Propulsion Laboratory</th>
<th>Marshall Space Flight Center</th>
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<tr>
<td>Linda Rodgers</td>
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<td>University Programs Administrator</td>
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<tr>
<th>Johnson Space Center</th>
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<td>Kamlesh Lulla</td>
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<td>Education Program Specialist</td>
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Appendix B: Useful Reference Web Sites

NASA http://www.nasa.gov

NASA Office of Education http://education.nasa.gov

NASA Education Strategic Coordination Framework http://education.nasa.gov/about/strategy
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Strategic_Coordination_Framework.html

Vision for Space Exploration http://www.nasa.gov/missions/solarsystem/explore_main.html

NASA Grant and Cooperative Agreement Handbook
http://prod.nais.nasa.gov/pub/pub_library/grcover.htm

NASA Centers & Facilities: http://www.nasa.gov/offices/education/centers/index.html

Guidebook for Proposers Responding to a NASA Research Announcement
http://www.hq.nasa.gov/office/procurement/nraguidebook

NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES)
http://nspires.nasaprs.com

Office of the Chief Technologist Overview
http://www.nasa.gov/pdf/485335main_OCT_Overview_slides_TAGGED.pdf

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Appendix C: Definitions

- **Center** – The ten NASA Centers including the Jet Propulsion Laboratory (JPL). For purposes of collaboration in NASA EPSCoR, JPL is considered a NASA Center.

- **Directorate** – Aeronautics Research Mission Directorate (ARMD), Human Exploration & Operations Mission Directorate (HEOMD), and Science Mission Directorate (SMD),

- **NASA Research Contact** – The NASA Research Contact is the primary NASA point of contact during the proposal writing stage for the proposed research area. If the proposer has contacted and received permission from a NASA scientific or technical person, that individual may be listed in the proposal as the NASA Research Contact. Otherwise the NASA Research Contact is the University Affairs Officer at the Center, or the NASA MD/OCT contact at NASA Headquarters. (See Appendix B.)

- **Partnership** – A reciprocal and voluntary relationship between the project personnel and NASA, industry or other partners, to cooperatively achieve the goals of the proposed research.

- **Research area** – One of the areas of research interest for the NASA Mission Directorate(s) and the Office of the Chief Technologist.

- **Research Student** – A student (undergraduate, graduate, or postdoctoral) who receives a research appointment in direct support of the NASA EPSCoR research in the research proposals.

- **Underrepresented Minority** – Refers to persons from racial and ethnic groups whose enrollment in STEM education or participation in STEM professions is much smaller than that group's representation in the general population. African Americans, Hispanics/Latinos, and Native Americans and Pacific Islanders currently fit this definition.