Oregon NASA Space Grant Consortium

Affiliate Faculty Research Incubator Program (AFRIP), Year 2

Proposals Due: ***11:59 PM final day of each month***

Partner

Oregon NASA Space Grant Consortium
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Phone: 541.737.2414 Fax: 541.737.9946
http://www.spacegrant.oregonstate.edu

Funding Opportunity Description

1. Introduction

The Oregon NASA Space Grant Consortium (OSGC) is accepting proposals for the Affiliate Faculty Research Incubator Program (AFRIP), Year 2. OSGC is a participant of the *NASA National Space Grant College and Fellowship Program (Space Grant)* dedicated to building, sustaining, and deploying a skilled, high-performing, and diverse workforce meeting the current and emerging needs of NASA and the nation. A critical point in the student education pathway is access to faculty engaged with research and education efforts aligning with NASA's workforce needs. The traditional way faculty have engaged students with hands-on research experiences has been to serve as a Principal Investigator of a NASA research award and to provide limited-scope research projects to be conducted by undergraduate or graduate students. Over the past decade, fewer NASA awards have been granted to OSGC faculty and hence the pool of student research projects has dwindled. To compensate, OSGC has strategically expanded the number of OSGC students funded for summer NASA Center internships where they are mentored by a NASA researcher to work on a project relevant to that Center's mission. This OSGC NASA Internship effort has been an unqualified success. Attention is now needed to sustain and increase the involvement of OSGC affiliated faculty who recruit and educate STEM undergraduates. Such an effort will help build student academic work resumes and qualify students for NASA internships. OSGC is experiencing the same aging workforce problem facing much of the aerospace industry. Many of the OSGC faculty who have been highly successful mentors are approaching the end of their working careers and new faculty need to be recruited to fill the void. The first step in this process is to provide a limited funding base to entice faculty to work on NASA research questions, thereby giving an opportunity for undergraduate STEM majors to experience research and gain specific skillsets needed for NASA internships. This funding opportunity is structured to be fluid, enabling faculty to take advantage of windows of opportunity and become engaged with a NASA research focus at the earliest moment. The OSGC Affiliate Faculty Research Incubator Program goal is to act as a path to develop "internship ready" OSGC students for the NASA education pipeline and to prepare young faculty to leverage the experience into a potential full-scale NASA research award.

1.1 Goals and Objectives

The goal of the OSGC Affiliated Faculty Research Incubator Program is to recruit additional faculty to become involved with the Oregon NASA Space Grant Consortium and to provide basic resources needed to develop authentic hands-on student experiences in STEM disciplines. Such experiences include the incorporation of active participation by students in hands-on learning or practice with experiences rooted in NASA-related, STEM-focused questions and issues, and the incorporation of real-life problem-solving. The OSGC priority for NASA-related activities means focus on projects supporting the efforts of NASA Mission Directorates in the following order: Science Mission Directorate, (SMD), Space Technology Mission Directorate (STMD), Human Exploration and Operations Mission Directorate (HEOMD), and Aeronautics Research (AR).

1.2 Eligibility

Proposals will be accepted from OSGC affiliate member institutions. Beyond the normal approval of the institution's Authorized Organization Representative, each proposal must include an approval signature of the OSGC Affiliate Representative. For a list of eligible institutions and Affiliate Representatives, visit:
https://spacegrant.oregonstate.edu/members-oregon-nasa-space-grant-consortium

1.3 Availability of Funds and Period of Performance

Oregon Space Grant Consortium's ability to make awards is contingent upon the availability of awarded funds from the NASA Office of STEM Engagement. The period of performance for awards made under this announcement is May 1, 2021 through February 22, 2022. A total of $50,000 has been allocated to Year 2 of this program. OSGC anticipates making up to 4 -6 awards ranging between $5,000 to $15,000 each. Cost-share is not required; however, voluntary cost-share will be welcomed.

1.4 Schedule of Awards

Selection notifications will be communicated electronically from OSGC to the institution's Authorized Organization Representative (AOR), the Principal Investigator (PI) and the institution's OSGC Affiliate Representative.

2. Proposal Format Guidance

- Cover Pages *(Page limit: As needed)*
- Executive Abstract *(Page limit: 1)*
- Principal Investigator (PI) Curriculum Vitae *(Page limit: 2)*
- Body of Proposal (*Page limit: 5*)
- Appendices *(Page limit: As needed)*
  - Budget Table
  - Narrative and Details
  - Milestones

General Format: Proposals shall use standard size 8 ½" x 11" paper with at least a 12-point font with a minimum 1" margin on all sides of each page. Proposals shall use an easily readable font such as Times New Roman, Calibri, Arial, Helvetica, Georgia or Garamond. Illustrations, tables and charts shall not be smaller than an 8-point font.

2.1 Proposal Content (required information)

Cover Pages (Page limit: As needed)

Principal Investigator (PI)/Institution OSGC Affiliate Representative's information (address, phone, email), proposal title, total amount requested, period of performance, submitting institutional information, and appropriate signatures.

Executive Abstract* *(Page limit: 1)

Concisely describe the content and scope of the project and identify the objective(s), methodology, and intended results.

Body of Proposal **(*Page limit: 5*)**

a. Introduction
b. Goals and objectives
c. Demonstrate how the research project and activities provide:
   - Basic resources needed to develop authentic hands-on student experiences in STEM disciplines
   - Experiences rooted in NASA-related, STEM-focused questions and issues, and incorporation of real-life problem-solving skills
   - Experiences associated with one or more of NASA Mission Directorates

d. Diversity and inclusion are top priorities for NASA and the Office of STEM Engagement. Describe strategies and goals your project will encompass for supporting and enhancing diversity and inclusion. Provide specific plans for promoting this opportunity to eligible female and underrepresented students in the STEM fields, such as targeted advertisement and collaboration with on-campus organizations including Native American, African American, Latinx, Hispanic, and Pacific Islander student organizations.

e. Demonstrate alignment with one or more of NASA Mission Directorates:
   i. Science Mission Directorate (SMD) http://science.nasa.gov
   ii. Space Technology Mission Directorate (STMD) https://www.nasa.gov/directorates/spacetech/home/index.html
   iii. Human Exploration and Operations Mission Directorate (HEOMD) http://www.nasa.gov/directorates/heo/home/index.html
   iv. Aeronautics Research (AR) http://www.aeronautics.nasa.gov

   See *Appendix A. Strategic Framework for NASA* and *Appendix B. Research Priorities for NASA Mission Directorates* for more information.

2.1.1 Required Appendices

Budget: Narrative and Details *(Page limit: As needed)*

Provide a budget spreadsheet for the proposed work. A budget narrative/description is also required and shall accompany the spreadsheet. The proposed budget shall be adequate, appropriate, reasonable, realistic, and demonstrate the effective use of funds to align with the proposed projects.

- The budget shall reflect clear alignment with the content and text of the proposal.
- The budget shall contain sufficient cost detail and supporting information to facilitate a speedy evaluation and award. In order to expedite the evaluation of the proposal, it is highly recommended that the proposal text reference specific and consistent budget categories and vice-versa.
- Direct labor costs shall be separated by titles (e.g., director, program manager, program coordinator, graduate research assistant, clerk, etc.) with estimated hours, hourly rates, and total amounts of each.
- Cost-share is not required; however, voluntary cost-share must be demonstrated in the budget.
- Other costs (with each significant category detailed) shall be explained in reasonable detail and substantiated whenever possible.
- Domestic travel shall include the purpose, the number of trips and expected location, duration of each trip, airfare, and per diem. Domestic travel shall be appropriate and reasonable to conduct proposed activities and must adhere to host institution’s COVID-19 related travel restrictions. Foreign travel is not permitted under this or any OSGC program.

2.2 Proposal Evaluation Criteria

Proposals will be reviewed and evaluated by OSGC staff for compliance with this request for proposals and by a review panel appointed by the OSGC Director. Award decisions are made by the OSGC Director. All sections of the proposal will be individually evaluated. Proposals will not be considered unless all solicitation requirements are met. The review panel will consider the following:

1) Required elements are included in proposal (see Proposal Content section, Section 2.1)
2) Proposal provides the basic resources needed to develop authentic hands-on student

experiences in science and engineering disciplines
3) Experiences are rooted in NASA-related STEM-focused questions and issues
4) Demonstrates how problem-solving skills will be utilized in the proposed activities
5) Proposed activities incorporate diversity and inclusion of female, and underserved and underrepresented students in STEM fields
6) Alignment with NASA Mission Directorates and the agency's top research priorities
7) Alignment of budget with proposed activities

2.3 Deliverables if Awarded

Student Data

Students who are significantly involved with the AFRIP project (minimum of 160 hours participation) are longitudinally tracked to evaluate the effectiveness of NASA's higher education programs and are expected to present their research/experience at the mandatory OSGC Student Symposium held in November of the award year. OSGC staff will provide guidance to awardees on student data collection.

Progress Reports

The Principal Investigator shall provide an annual performance report to the OSGC Director. This report shall include student data information and expenditure summary. For awards of less than one-year duration, the annual report serves as the final project report. For multi-year awards, the final close-out report will contain a summary of overall program achievements, expenditure report, and shall by reference include all submitted annual reports.

Articles and Publications

OSGC must be cited as a source of funding in all publications resulting from the work using the phrase *"…supported in part through NASA and Oregon Space Grant Consortium, cooperative agreement 80NSSC20M0035"*. The PI must contact OSGC should peer-reviewed journal articles or papers from conferences be published as a result of the work, so that publications can be made 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 for download within one year of publication.

2.4 Proposal Submission Instructions

Proposals are due by **11:59pm Pacific Time, on the final day of each month**. Proposals are received and reviewed throughout the calendar year. Awards are made on a monthly basis. Submit complete proposal packages online: https://spacegrant.net/proposals/osgc/.

2.5 Inquiries

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

Catherine Lanier
Associate Director, Oregon Space Grant Consortium
catherine.lanier@oregonstate.edu
542-737-2414

Appendix A. Strategic Framework for NASA

I. NASA's Vision
To discover and expand knowledge for the benefit of humanity

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

III. Four strategic themes are the foundation for the 2018 Strategic Plan and NASA's goals:
DISCOVER – Expand human knowledge through new scientific discoveries
EXPLORE – Extend human presence deeper into space and to the Moon for sustainable long-term exploration and utilization
DEVELOP – Address national challenges and catalyze economic growth
ENABLE – Optimize capabilities and operations

NASA Strategic Plan 2018:
https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf

IV: NASA's vision and mission draw support from the organizational structure of the Mission Directorates, each with a specific responsibility
See *Appendix B. Research Priorities for NASA Mission Directorates* for detailed Mission Directorate descriptions

NASA's Mission Directorates

- Aeronautics Research Mission Directorate (ARMD): transforms aviation with research to dramatically reduce the environmental impact of flight, and improves aircraft and operations efficiency while maintaining safety in increasingly crowded skies. ARMD also generates innovative aviation concepts, tools, and technologies for development and maturation by the aviation community. https://www.nasa.gov/aeroresearch
- Human Exploration and Operations (HEOMD): leads human exploration in and beyond low Earth orbit by developing new transportation systems and performing scientific research to enable sustained and affordable human life outside of Earth. HEOMD also manages space communication and navigation services for the Agency and its international partners. http://www.nasa.gov/directorates/heo/home/
- Science Mission Directorate (SMD): expands the frontiers of Earth science, heliophysics, planetary science, and astrophysics. Using robotic observatories, explorer craft, ground-based instruments, and a peer-reviewed portfolio of sponsored research, SMD seeks knowledge about our solar system, the farthest reaches of space and time, and our changing Earth. http://science.nasa.gov/
- Space Technology Mission Directorate (STMD): pursues transformational technologies that have high potential for offsetting future mission risk, reducing cost, and advancing existing capabilities. STMD uses merit-based competition to conduct research and technology

development, demonstration, and infusion of these technologies into NASA's missions and American industry. This mission directorate is being refocused as a new Exploration Research & Technology (ER&T) organization to support exploration as a primary customer. http://www.nasa.gov/directorates/spacetech/home/index.html.

- The Mission Support Directorate (MSD): enables the Agency's missions by managing institutional services and capabilities. MSD is actively reducing institutional risk to NASA's current and future missions by improving processes, stimulating efficiency, and providing consistency and uniformity across institutional standards and practices. https://www.nasa.gov/msd.

Appendix B. Research Priorities for NASA Mission Directorates

Note: This information is current as of 6/28/2019.

I. Aeronautics Research Mission Directorate Research

Aeronautics Research Missions Directorate (ARMD) conducts high-quality, cutting-edge research that generates innovative concepts, tools, and technologies to enable revolutionary advances in our Nation's future aircraft, as well as in the airspace in which they will fly. ARMD programs will facilitate a safer, more environmentally friendly, and more efficient national air transportation system. Using a Strategic Implementation Plan, NASA 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 ARMD can be found at: http://www.aeronautics.nasa.gov.

II. Human Exploration and Operations Mission Directorate Research

Human Exploration and 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. HEOMD also oversees low-level requirements development, policy, and programmatic oversight. The International Space Station (ISS), 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 HEOMD can be found at: (http://www.nasa.gov/directorates/heo/home/index.html)

Areas of Interest

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:

- Using 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.
- Using 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.
- Using 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), the Jet Propulsion Laboratory (JPL) and the 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)

III. Science Mission Directorate Research

Science Mission Directorate (SMD) leads the Agency in four areas of research: Earth Science, Heliophysics, Planetary Science, and Astrophysics. SMD, using the vantage point of space to achieve with the science community and our partners a deep scientific understanding of our planet, other planets and solar system bodies, the interplanetary environment, the Sun and its effects on the solar system, and the universe beyond. In so doing, we lay the intellectual foundation for the robotic and human expeditions of the future while meeting today's needs for scientific information to address national concerns, such as climate change and space weather. 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 SMD can be found at: (http://nasascience.nasa.gov)

Areas of Interest

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 2018 Strategic Plan 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

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) and NASA's 2010 climate-centric architecture plan (https://smd-prod.s3.amazonaws.com/science-pink/s3fs-public/atoms/files/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.

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). 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.

IV. Space Technology Mission Directorate Research

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 take 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

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 take 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