

National Aeronautics and Space Administration



DRAFT

# EXPLORE

## SCIENCE 2019-2024

A Vision for Scientific Excellence

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## Welcome Message

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# Who We Are

## **NASA VISION**

*To discover and expand knowledge for the benefit of humanity.*

## **NASA MISSION**

*Pioneer advances in aeronautics, space exploration, science, and technology to transform our understanding of the universe, unlock new opportunities, and inspire the world.*

## **SMD VISION**

*To lead a globally interconnected program of scientific discovery that encourages innovation, positively impacts people's lives, and is a source of inspiration.*

## **SMD MISSION**

*Discover the secrets of the universe. Search for life elsewhere. Protect and improve life on Earth.*

Since 1958, NASA has led the way in Earth and space science research with a team of world-class scientists and engineers dedicated to its mission. Success in the harsh, unforgiving environment of space requires an unwavering commitment to excellence in order to build and operate our missions and to develop cutting-edge technologies to further our fundamental research. In turn, investments in fundamental research enable new mission concepts and transform data into knowledge. Prioritization of these activities is guided by the National Academies of Science, Engineering, and Medicine's Decadal Surveys and other national priorities, which provide effective focus to the programs.

From decades of experience we have learned the importance of taking small steps to accomplish big goals. We seek to reach beyond our current knowledge by investigating our home the Earth, the sun, moon, other worlds of our solar system, the stars, and the deep universe. As NASA's mission evolves, the NASA Science Mission Directorate (NASA Science) continually strives to be innovative and drive discovery. NASA Science utilizes technological advances and new partnership opportunities, including public-private partnerships that leverage commercial investments to further NASA's science objectives. Key to our success is fulfilling our commitment to improve people's lives today and to inspire and engage the workforce of tomorrow.

As an organization, NASA Science incorporates the four NASA core values (Safety, Integrity, Teamwork, Excellence) in all aspects of its work and also has as a fifth value of leadership. Through these values, we are able to drive towards a future in which we continue to expand the frontiers of human knowledge and our understanding of Earth and space.

## EXCELLENCE

The work of NASA Science is at the forefront of scientific discovery and innovation. The questions we seek to answer affect humanity on a global scale and focus on our place in the universe – Where did we come from? Are we alone? Tackling such difficult questions requires courage and a dedication to excellence. It requires a culture where there is a willingness to learn and change and to take risks in the interest of science. We do not identify these opportunities in a vacuum; rather, the science community guides our prioritization and investment choices through decadal surveys, competitive processes, and peer review. Our commitment to challenge ourselves means that we must learn from both our successes and our failures. We must dig deep for lessons, be willing to make adjustments, and continually expand our knowledge.

## LEADERSHIP

From studying the origin and evolution of the universe to seeking to understand the Earth as an interconnected system, NASA Science has advanced scientific knowledge and has had a direct positive impact on the quality of life on Earth. We demonstrate leadership in these fields by steering humanity towards a future in which our scientists continue to expand the frontiers of human knowledge and our understanding of Earth and space.

## INTEGRITY

NASA Science is committed to ensuring all decisions are made with integrity and transparency, and believes in the importance of living up to our commitments. To be successful, we must establish clear guidelines and criteria for decision-making processes and communicate these expectations in a timely manner to all stakeholders so that there is a common understanding. Such processes should allow us to make decisions in a timely manner and should also be tailorable to reduce unnecessary administrative burden.

## TEAMWORK

NASA Science believes in the importance of diverse teams to most effectively tackle strategic problems and maximize scientific return. Internally, we seek to grow our workforce by providing opportunities for personal and professional development and cross-divisional collaboration. Externally, we are working to promote opportunities for collaboration across and between disciplines, as well as to develop of the next generation of science and engineering leaders to carry our work into the future.

## SAFETY

NASA has a strong safety culture which extends to all aspects of NASA Science's work. Not only are we concerned about protecting life and property, but we also recognize the importance of psychological safety and creating an environment where everyone can contribute to our work. People must feel comfortable bringing forth issues and concerns without fear of retribution or reprisal. This extends to all members of the science community who work with us.

## Introduction

With the successful launch of Explorer 1 in January 1958, research in and from space has broadened our view of the world we live in and also has created public value. Our impact has been two-fold: *We discover the secrets of the universe.* Whether it is near our home in space or all the way to the deepest reaches of the universe, we explore the world around us, constantly questioning what we know. We have learned how to make missions successful both at Earth and traveling into deep space. Through our research, we *protect and improve life on Earth* by conducting application-motivated fundamental research, and preparing this knowledge for translation to government and our private sector partners.



2018 marked the 60<sup>th</sup> anniversary of both NASA and NASA's Science program. NASA's strategy for the future builds on this legacy, recognizing we can and must continually modernize and improve how we operate, while still being good stewards of the resources made available by the United States of America and its taxpaying citizens. This vision outlines the major drivers of our program over the next five years. As leaders, we continuously compare our achievements against our potential and our opportunities, and it is in that sense that this strategy is looking towards the future. NASA Science has the responsibility to continue delivering the most compelling and highest impact science program for the American public, while inspiring the next generation of explorers.

The National Academies of Sciences, Engineering, and Medicine (National Academies) set high-level science priorities through their decadal surveys, and there are additional strategic considerations addressed in this report that relate to NASA Science's overarching driving priorities. For example, some of the most important questions we address cut across the traditional boundaries of the decadal surveys. The fundamental science quest

to search for life elsewhere is one that requires advances in planetary sciences (research at Mars, Ocean Worlds, etc.), in astrophysics (exoplanets, planet formation), and increasingly also in Earth science (measurements of atmospheric emissions from space) and heliophysics (stellar variability and mass ejections) to be addressed.

NASA Science does not perform its research in isolation and it is important to assess the meaning of leadership in this context. Partnerships enable new approaches to do research and are the innovative ingredients critical to continue building upon the successes of the past. NASA Science therefore has opportunity to enter into strategic partnerships that leverage the unique strengths of each contributor to drive scientific progress on behalf of the greater good. By partnering with universities, industry and others, we are able to generate diverse ideas, technology, research and processes. For example, NASA Science actively looks for opportunities to build on private sector investments and to utilize innovative public-private partnerships to advance NASA science objectives. Building an entrepreneurial ventures-based perspective not only enables us to achieve a fundamentally new understanding of our home planet and the star that sustains us, but compels significant improvements in predictive capability that serves to protect life, health, and property. Working closely with partners around the world, our strategy drives both innovative technology and science to synergistically address global challenges that no one nation or organization can address on their own. Additional opportunities are unlocked through the engagement of our cross-agency partners, as well as other government and private sector partners within the United States on behalf of the Nation.



The challenge of any successful enterprise like NASA Science is to continually test its own assumptions and unlock new opportunities. Aspirational questions such as the ones we seek to answer require us to make leaps of progress and test new approaches. Through the advancement of our science, we inspire the public to become active participants through Citizen Science in the quest for knowledge. As a result of this engagement and through its awe-inspiring endeavors, NASA Science inspires the next generation on explorers and attracts

a highly skilled future workforce, not just within NASA, but across the scientific and engineering community .



## Science Leadership Priorities

To achieve our goals, NASA Science relies on four cross-cutting foci: Exploration and Scientific Discovery, Innovation, Interconnectivity and Partnerships, and Inspiration. Our core reason for being is to explore and make scientific discoveries on behalf of the world. To be successful in this pursuit requires innovation and collaboration. Our work is inspirational and encourages future leaders to contribute their ideas in pursuit of new science questions and means of discovery.



The following sections detail the strategies associated with each focus area and the high-level implementation approach. These strategies are designed to be ambitious new pursuits for NASA Science, going above and beyond the current program of record to drive action and make progress in specific directions over the next five years.

Underlying these strategies are the management processes documented in the SMD Handbook, a tool that enables us to make timely decisions with integrity and transparency.





## FOCUS 1 EXPLORATION AND SCIENTIFIC DISCOVERY

**STRATEGY 1.1:** Execute a balanced science program based on discipline-specific guidance from the National Academies.

**STRATEGY 1.2:** Participate as a key partner and enabler in the agency's exploration initiative, focusing on scientific research of and from the Moon, lunar orbit, Mars, and beyond.

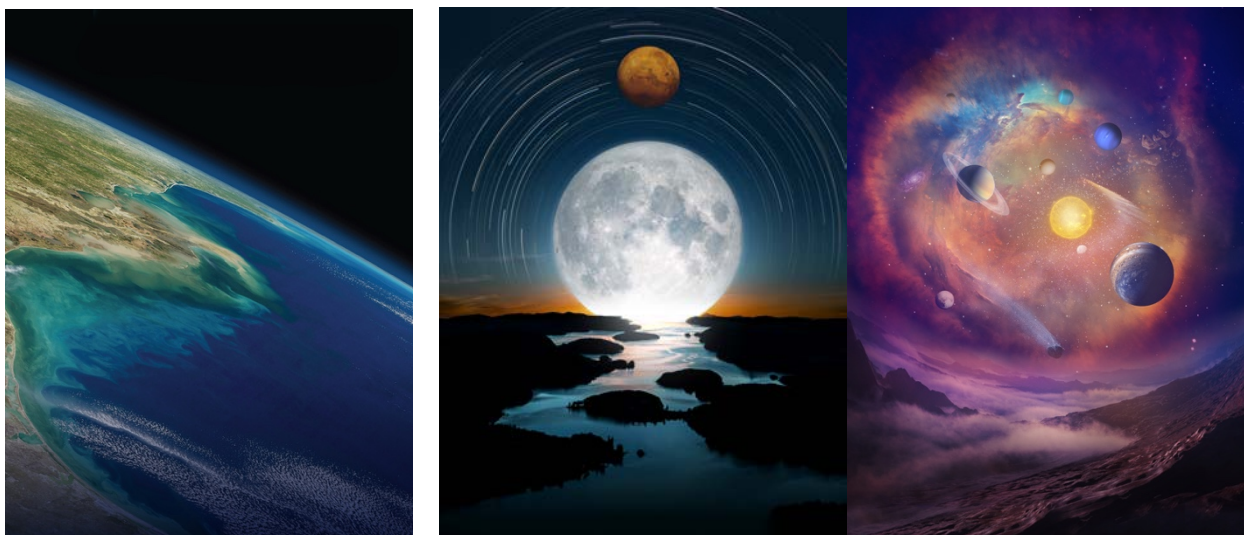
**STRATEGY 1.3:** Advance discovery in emerging fields by identifying and exploiting cross-disciplinary opportunities between traditional science disciplines

**STRATEGY 1.4:** Develop a Directorate-wide, target-audience focused approach to applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness.

NASA Science seeks to answer profound questions to discover the secrets of the universe, to search for life, and to protect and improve life on Earth. To be successful, we have a balanced portfolio approach that includes flights missions, research and analysis, technology development, and applications as critical components of our work. The relative balance across these efforts is informed by the National Academies through their Decadal Surveys and is responsive to direction from the Administration and Congress.

We are undertaking new work that builds on our past successes in individual science disciplines to enable a more collaborative environment at the forefront of science and science applications. For example, we have established new interdivisional grant programs that enable researchers in Astrophysics and Planetary Science to study the formation and characterization of extrasolar planets, which is now being expanded to include Heliophysics research on the impact of different stellar types conditions on orbiting planets. The Astrobiology Program is another example of interdisciplinary science where we are creating new collaborative models to connect researchers. Closer to home, our Earth Science program pioneered the use of NASA science data to inform decision-makers. We are applying those lessons learned and best practices in support of other National needs, including space weather prediction and planetary defense.

Finding answers to these profound science questions requires a focus not only on continuing to make progress on the scientific priorities identified by the National Academies through their Decadal Surveys, but also by supporting national priorities in science and exploration and enhancing new opportunities for cross-disciplinary science. In addition to responding to guidance provided by the scientific community, national priorities may also be defined by the Administration through space policy directives and executive orders, and by Congress via legislation.



## STRATEGY 1.1

Execute a balanced science program based on discipline-specific guidance from the National Academies.

The National Academies of Science, Engineering, and Medicine (NASEM) provide guidance that helps NASA Science execute a balanced portfolio built on the pillars of scientific and technical excellence. Through the Decadal Survey process, the scientific community provides input on key science drivers and the recommended balance between strategic-scale missions, competitively-selected small and mid-scale missions, technology programs, and research and analysis programs. This guidance is designed to enable lasting leadership by providing focus on the highest priority science questions the Nation should be addressing and highlighting areas of opportunity to grow the scientific community's capabilities. Each Division Director within NASA Science is responsible for managing their portfolio in accordance with this guidance and, progress against the Decadal Surveys is assessed by NASEM as part of their mid-term reviews.

## STRATEGY 1.2

Participate as a key partner and enabler in the agency's exploration initiative, focusing on scientific research of and from the Moon, lunar orbit, Mars, and beyond.

Exploration unites and is at the heart of what NASA does. Space Policy Directive-1 calls on NASA to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations." NASA Science is a direct contributor to this national priority through its lunar samples, investments in science and technology payloads, and support for commercial

landers and payloads. Our active collaboration with commercial and international partners opens up new means of scientific exploration of the Moon.

NASA Science will continue to seamlessly collaborate with the Human Exploration and Operations and Space Technology Mission Directorates, as well as their partners, to further these mutual national objectives:

- Robotically assess environmental constraints that could impact crew safety and resource availability at the Moon, Mars, and beyond
- Develop opportunities across all science disciplines that leverage investments in Human Exploration towards performing high-priority science, using novel platforms, and robotic and human-assisted research paradigms
- Engage across the Agency to ensure that its technological approaches are aligned with Agency investments in platform technologies, and feed forward towards human exploration goals, where appropriate

### STRATEGY 1.3

Advance discovery in emerging fields by identifying and exploiting interdisciplinary opportunities between traditional science disciplines

NASA Science has traditionally operated within the disciplines identified in Strategy 1.1. We recognize that there is tremendous potential to make revolutionary scientific advances not just within these disciplines, but also at the interfaces between and among disciplines. NASA Science therefore seeks to provide opportunities for integrated, interdisciplinary research that encourage collaboration. To be successful, NASA Science must balance the ownership of these opportunities to ensure consistency and alignment to the program of record. For example, the on-going collaboration between planetary science and astrophysics has enabled significant progress in the field of exoplanets, and serves as a model for how other disciplines might work together in the future. Emerging opportunities exist to use the Earth as a laboratory in support of habitability and Heliophysics scientific questions.

### STRATEGY 1.4

Develop a Directorate-wide, target-audience focused approach to applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness.

One of NASA Science's goals is to protect and improve life on Earth. To accomplish this, we will build on our long-standing work in the area of Earth Science Applications and expand our approach to providing applied information in the areas of Space Weather, Planetary Defense, and Space Situational Awareness. It is our intent to develop a Directorate-wide strategy across these different research areas in order to leverage best practices to meet the needs of the communities and customers we serve. As these capabilities are matured, there may be opportunities for commercialization that would increase our ability to be customer-driven.





## FOCUS 2 Innovation

**STRATEGY 2.1:** Foster a culture that encourages innovation and entrepreneurship across all elements of the NASA Science portfolio.

**STRATEGY 2.2:** Foster a culture that encourages collaboration in pursuit of common goals.

**STRATEGY 2.3:** Enhance our focus on high intellectual risk/high impact research investments.

**STRATEGY 2.4:** Drive innovation in focused technology areas to capitalize on the rapid evolution of commercial capabilities.



Excellence is achieved through continuous innovation and learning.

NASA Science recognizes that innovation and risk-taking are the cornerstones of a forward-looking program of scientific discovery. This boldness in vision must be coupled with tailored management processes. In order to answer the science questions defined in Focus #1, we must rely on innovation to achieve our scientific

goals. We already have programs in place to identify and mature technologies in support of future missions, but we must also be ready to take advantage of revolutionary new capabilities when they present themselves. Therefore, we have identified four innovation goals that will enable both incremental steps and giant leaps in knowledge.

### STRATEGY 2.1

Foster a culture that encourages innovation and entrepreneurship across all elements of the NASA Science portfolio.

Risk-taking is a necessary part of progress and NASA Science seeks to create an environment in which risk-taking is encouraged and transparently managed. To do this, NASA Science will develop a coherent and strategic Directorate-wide innovation ecosystem that includes early stage technology identification, technology development and

maturation, and ultimately transition to flight. We recognize that not all innovation will ultimately be successful, and that room for experimentation and failure should be allowed during the developmental process. The importance of innovation and experimentation is significant, even when those efforts may not ultimately succeed. Proactive communication about risks associated with a particular mission concept, early investments in technology development, and other risk reduction efforts, are also key components of this strategy.

Too often, we think about risk-management in the context of a single project rather than the overall risk posture of the entire NASA Science enterprise. Instead, NASA Science seeks to incentivize innovation through both its competed and directed work by using a portfolio-level approach to risk management. This approach allows NASA Science to take varying risk postures between missions, depending on their scale, and also tailor its management processes accordingly. For competitive opportunities, NASA Science must encourage and reward proposers for their novel approaches towards scientific discovery when they are accompanied by realistic risk maturation processes. Clear lines of authority and accountability for risk-related activities are also necessary for proper management.

## **STRATEGY 2.2**

Foster a culture that encourages collaboration in pursuit of common goals.

NASA Science is a learning organization and encourages best practices learned in one area to be rapidly shared and implemented across the entire organization and Agency. While each division within the organization has been established to align with the needs of the communities they serve, areas of mutual interest that overlap between divisions do exist. This creates opportunities for one division to pilot new ways of doing business and for the other divisions to adopt them. To the extent possible, NASA Science uses cross-divisional teams to respond to strategic opportunities or issues that impact the entire organization and uphold its mission toward excellence.

## **STRATEGY 2.3**

Enhance our focus on high intellectual risk/high impact research investments.

NASA Science invests in research that can have transformational impacts on our understanding of the world around us. Our research programs provide opportunities for the science community to offer new ideas and new approaches towards scientific discovery. We recognize that the peer review process used to make investment decisions may inadvertently discourage innovative concepts, and therefore we seek to be more proactive in encouraging high intellectual risk/high impact research proposals. This may include establishing new research elements dedicated to these types of proposals and also reassessing how the current peer review process assesses the risk and impact of proposals.

## STRATEGY 2.4

Drive innovation in focused technology areas to capitalize on the rapid evolution of commercial capabilities.



While NASA invests heavily in new technologies to meet its needs, there are also opportunities to translate technologies from outside entities into NASA concepts. In some cases, these technologies present opportunities for NASA to capitalize on the investments of others to reduce mission costs and yield more advanced science capabilities. NASA Science must remain flexible in its mission design approach to enable enhanced

collaborations with other government agencies and the commercial sector in order to best take advantage of these new modalities.





## FOCUS 3

### Interconnectivity and Partnerships

**STRATEGY 3.1:** Actively engage with the NASA Centers to make more informed strategic decisions that further NASA's scientific goals and are aligned with each Center's unique capabilities.

**STRATEGY 3.2:** Actively seek collaborations with international partners based on their unique capabilities and mutual scientific goals.

**STRATEGY 3.3:** Actively engage with other Federal agencies to make more informed decisions, cooperate in scientific research, and pursue partnerships that further national interests.

**STRATEGY 3.4:** Provide increasing opportunities for research institutions, including academia and non-profits, to contribute to NASA Science's mission.

**STRATEGY 3.5:** Pursue public-private partnerships in support of shared interests with industry.

Scientific discovery does not occur in isolation and NASA Science directly supports the Nation's researchers in their pursuit of knowledge. NASA Science recognizes the important role that NASA Centers, other Federal agencies, private industry, academia, non-profits, community-based organizations, and international partners play in helping make our scientific vision a reality. Strategic partnerships that leverage each contributor's strengths and interests can be an effective means of yielding advances in science and understanding for mutual benefit. Similarly, NASA Science has an opportunity to partner with other agencies within the United States to help further national interests in a coordinated and efficient manner.

#### STRATEGY 3.1

Actively engage with the NASA Centers to make more informed strategic decisions that further NASA's scientific goals and are aligned with each Center's unique capabilities.

NASA Science seeks to strategically engage with NASA Centers to implement NASA Science programs and projects. This requires NASA Science to be knowledgeable of the health and capabilities at each NASA Center, both now and in the future. This information will guide investment decisions at the portfolio level to ensure that roles and responsibilities are delegated in alignment with each Center's unique strengths and ability to manage work. NASA Science is also engaged in activities that develop both talent and

technical capabilities at the NASA Centers to ensure that future needs can be met. The NASA Centers should be seen as “employers of choice” that attract recent graduates and mid-career scientists, and also provide exchange and career growth opportunities for employees.

### **STRATEGY 3.2**

Actively seek collaborations with international partners based on their unique capabilities and mutual scientific goals.

Scientific discovery is a global endeavor and NASA Science empowers the scientific community worldwide. With growing international interest in space exploration, the competition for partnerships among space agencies is increasing. We therefore seek to be the premier global partner in Earth and Space Science within the context of global challenges to competitiveness and security and to contribute to the Nation’s diplomacy goals. To that end, we will continue to strategically seek excellent partnerships with traditional partners, and actively engage with new and emerging international partners and entities. These partnerships help further our mutual scientific goals and demonstrates United States leadership and collaboration goals. This is not to suggest that NASA should always have primary responsibility for a mission; such strategic decisions should be made based on each partners’ strengths and interests in order to further drive global scientific goals and such relationships may vary between science divisions.

### **STRATEGY 3.3**

Actively engage with other Federal agencies to make more informed decisions, cooperate in scientific research, and pursue partnerships that further national interests.

NASA Science continually and strategically evolves partnerships with other organizations across the Federal government in pursuit of common interests. These partnerships can take several different forms, from enabling new missions, to improving our understanding of common areas of study and in facilitating the transfer of knowledge between agencies to enhance our overall contribution to the Nation. In all cases, our interests evolve over time to ensure continued alignment to national and Agency priorities, and to capitalize on each partners’ unique strengths.

### **STRATEGY 3.4**

Provide increasing opportunities for research institutions, including academia and non-profits, to contribute to NASA Science’s mission

The vibrant research community across the United States is already making significant contributions to answer the science questions defined in Focus #1 through NASA’s missions and research and technology grants. The research community is the major source of new science questions and innovative missions concepts. For example, we will adjust our calls for proposals in response to the science community’s feedback on alternative ways to make scientific measurements.

If we want to continue making scientific progress in the future, we must recognize the important role that research institutions play in developing new talent and be supportive of these efforts. We therefore seek to increase such opportunities by actively encouraging the development of students and early career researchers by providing multiple pathways for them to have hands-on engagement with our missions and research. We also seek to increase partnerships across institutions as a method of providing additional opportunities for engagement and increasing diversity of thought.

### **STRATEGY 3.5**

Pursue public-private partnerships in support of shared interests with industry.

NASA Science recognizes its buying power and seeks to foster an environment that allows for more cost-effective approaches to enable new scientific discovery and innovation. We are committed to partnering with the United States aerospace industry and will continually assess partnership models, including traditional contractor relationships and emerging public-private partnerships, to advance important science objectives as well as to engage the public in our efforts. For example, we have recently undertaken several initiatives to leverage new commercial capabilities, such as expanded use of SmallSats and CubeSats in all science disciplines via focused mission and constellations, commercial Earth Science data buys, rideshare opportunities, and commercial lunar payload transport services. We have also pursued innovative agreements with the Breakthrough Foundation to support initial studies of a future mission to Saturn's moon, Enceladus and an international agreement with the Israel Space Agency and the nonprofit, Spacell, to collaborate on a commercially built lunar mission. Such new partnership models may require opportunities for commercial providers to demonstrate their capabilities through targeted experiments that provide a more in-depth understanding of alternative mission architectures, data acquisition approaches, and data licensing agreements.





## FOCUS 4 Inspiration

**STRATEGY 4.1:** Increase the diversity of thought and backgrounds represented across the entire NASA Science portfolio through a more inclusive environment.

**STRATEGY 4.2:** Purposefully and actively engage with audiences and learners of all ages to share the story of NASA's integrated science program.

NASA Science inspires the learners of today and develops the leaders of tomorrow. The success of these efforts not only benefits NASA, but also strengthens our partners identified in Focus Area #3.

### STRATEGY 4.1

Increase the diversity of thought and backgrounds represented across the entire NASA Science portfolio through a more inclusive environment.



NASA Science believes in the importance of diverse and inclusive teams to most effectively tackle strategic problems and maximize scientific return. Such teams have been demonstrated to maximize an organization's potential for innovation. NASA Science therefore seeks to increase the diversity of talent contributing varied viewpoints and approaches across all elements of our work. These efforts include the best and brightest from a variety of the diverse fabric of the Nation's cultural, geographical, ethnic, racial, and

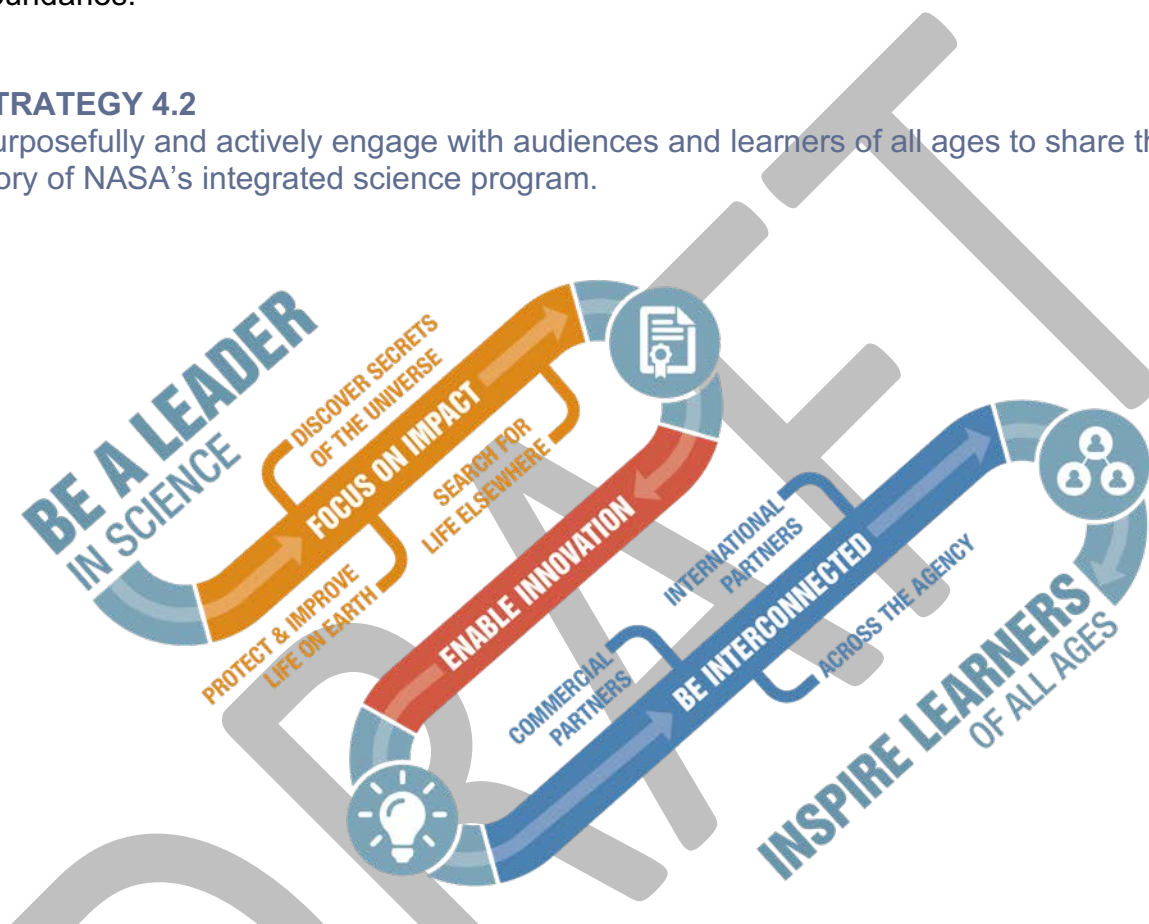
educational backgrounds, life experiences, and perspectives.

In order to encourage this diversity, NASA Science recognizes the importance of creating inclusive environments so that everyone can participate. People must feel safe, valued, and included before they are comfortable contributing to the team. We are therefore initiating several efforts designed to address the problem of harassment within the scientific community. Many of these efforts are being led or requested by NASA Science, and have broad implications for the rest of NASA and the communities with which we work.

NASA Science is also investing in its people to increase the diversity and inclusivity of its teams, both internal and external to NASA, in order to provide opportunities for personal development and growth. This includes investing in students and early career faculty to help them grow into leaders of the future and rethinking our organizational structure. We are intentional about providing meaningful opportunities for collaboration across traditional boundaries.

#### STRATEGY 4.2

Purposefully and actively engage with audiences and learners of all ages to share the story of NASA's integrated science program.



NASA Science's achievements inspire learners of all ages. Our collaborations enable learners through community-based partnerships, transdisciplinary and digital tools, and real-world experiences. One of our goals is for learners across the Nation to become architects of their own life-long learning pathways.

NASA Science reaches the American people by sharing its science and encouraging greater public understanding of its missions and activities. We disseminate science results through multiple mechanisms designed to elevate awareness, excitement, and understanding. One aspect of this work is storytelling to help connect the work that NASA does to people's everyday lives.

NASA Science also encourages opportunities for new engagements, such as Citizen Science, through which volunteers can directly contribute to NASA's Science mission and thereby increase the overall scientific literacy of the Nation.

## Implementation

A focus on excellence is a deliberate activity, supported by governing processes and behaviors across the entire NASA Science portfolio. It is our intention to identify owners and implementation timelines for each of the strategies detailed in this vision to provide accountability and transparency. We will use our internal processes to help prioritize the strategies for implementation.

Underlying all of the work enabled by NASA Science are the management processes documented in the SMD Handbook that enable timely decision-making that is done with integrity and transparency. The SMD Handbook provides tactical guidance on the policies and procedures NASA Science personnel use to conduct business on a day-to-day basis. The SMD Handbook outlines roles and responsibilities for all aspects of the NASA Science portfolio and documents interfaces between organizations. It is our intention to evaluate whether the SMD Handbook should be updated to enable for effective implementation of the strategies detailed in this vision.

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## Astrophysics Division

**STRATEGIC OBJECTIVE:** Discover how the Universe works, explore how it began and evolved, and search for life on planets around other stars

**SCIENCE QUESTIONS:**

How does the universe work?

How did we get here?

Are we alone?

### DIVISION OVERVIEW

Astrophysics is humanity's scientific quest to discover the origin of the Universe and of life itself. How does the Universe work? How did we get here? Are we alone? These three questions form the basis of the three Astrophysics science themes: Physics of the Cosmos (PCOS), Cosmic Origins (COR), and Exoplanet Exploration (ExEP). Progress is advanced through basic research and flight missions. In this quest, Astrophysics is guided by the [Decadal Survey of the National Academies](#), which sets the science and technology priorities informing our investment decisions.

Basic research synthesizes the data from our missions to create new knowledge and advance our understanding of the universe. This inevitably leads to new questions, which motivates new measurements and new missions. The Astrophysics Research Program includes competed programs in data analysis, theory, technology development, and suborbital projects. Small missions are undertaken as competitively selected, PI-led Explorers missions. Large and medium strategic missions are directed to NASA Centers for implementation and are managed within the Astrophysics Strategic Missions Program.

### STRATEGY AND MANAGEMENT PHILOSOPHY

Priorities in Astrophysics are provided by the community through the Decadal Survey. Ad hoc National Academies studies, including the [Midterm Assessment](#), provide tactical advice. The Astrophysics Division keeps the community informed on its progress implementing the Decadal Survey recommendation through its biannual [Astrophysics Implementation Plan](#). The long-term vision for Astrophysics is spelled out in community roadmaps; this decades' community roadmap is [Enduring Quests, Daring Visions: NASA Astrophysics in the Next Three Decades](#) (2013). NASA Astrophysics strategic documents are available at <https://science.nasa.gov/astrophysics/documents>.

The core principles that inspire our management process are collaboration, communication, and transparency. The tight collaboration and open communication



between NASA, academia, and industry are at the heart of our success for every Program and Project. Transparency ensures that we are accountable to the community. We embrace and hold dear the diversity of our staff and community; our multi-cultural backgrounds ensure a variety of perspectives and problem-solving skills, leading to innovation and progress.

## SUMMARY OF PORTFOLIO BY PROGRAM

**Physics of the Cosmos:** Understanding how the universe works is the main theme of the [Physics of the Cosmos \(PCOS\) Program](#), which encompasses science ranging from the conditions of matter near compact objects and black holes to the epoch of inflation to space tests of General Relativity. The PCOS Program develops technology for future missions that address the science through both competed and directed investigations. Operating missions in the PCOS Program are the Chandra X-ray Observatory, the ESA-led XMM-Newton Mission, and the Fermi Gamma-ray Space Telescope, while missions in pre-formulation are the Athena X-ray observatory and the Laser Interferometer Space Antenna (LISA), both ESA-led missions with NASA participation.

**Cosmic Origins:** The [Cosmic Origins \(COR\) Program](#) seeks to understand the many phenomena and processes associated with galaxy, stellar, and planetary system formation and evolution from the earliest epochs of the universe to today. The COR Program supports a vibrant program in theoretical, observational, and technology development for future missions. The COR flight missions include telescopes—both present and future—that together operate across a wide swath of the electromagnetic spectrum, from the far-ultraviolet through the far-infrared and sub-millimeter. Currently operating facilities are the Hubble Space Telescope, the Spitzer Space Telescope, and the SOFIA airborne observatory.

**Exoplanet Exploration:** The [Exoplanet Exploration \(ExEP\) Program](#) encompasses a portfolio of science and technology research tasks that advance the search for planets around other stars, the characterization of those planets, and ultimately the identification of planets that could harbor life. The ExEP Program provides access to a wide range of data products and the observational tools and facilities needed to interpret of exoplanet observations. The Program also provides critical infrastructure and support for the development of the advanced technologies that will be needed to enable a future mission capable of directly imaging Earth-sized, rocky worlds in the habitable zones of nearby stars and searching for the signatures of life.

**James Webb Space Telescope:** The [James Webb Space Telescope Program](#) is responsible for the development, launch, and commissioning of the James Webb Space Telescope, NASA's next flagship mission in astrophysics. Webb, the highest priority of the 2000 Decadal Survey, is an international mission designed to seek first light of stars and galaxies in the early universe and explore distant planets. Webb's 6.5m diameter segmented mirror, four near- and mid-infrared instruments, and cryogenic operating temperature enables humankind to seek light from the first stars and galaxies and to explore distant worlds including exoplanets and the outer solar system. Led by NASA, in partnership with ESA and CSA, the Webb telescope will launch by 2021.

**Astrophysics Strategic Missions:** The Astrophysics Strategic Missions Program is responsible for the development of NASA's large and medium strategic missions, developed in response to recommendations from the Decadal Survey. The Wide Field Infrared Survey Telescope (WFIRST), the highest priority of the 2010 Decadal Survey, is a near infrared space telescope with the sensitivity and image quality of Hubble, but 100 times the field-of-view. WFIRST key science goals include the nature of dark energy, completing the demographic survey of exoplanetary systems, and surveys of the Milky Way galaxy. WFIRST also includes a coronagraph technology demonstration instrument that will demonstrate as a system the technologies needed to image and characterize habitable-zone planets around nearby stars.

**Astrophysics Explorers:** The [Astrophysics Explorers Program](#) oversees an agile fleet of small, PI-led missions that address focused topics in astrophysics and can be developed quickly under a strict cost-cap. A sustained cadence of Explorers missions was the second highest priority of the 2010 Astrophysics Decadal Survey. The currently operating Astrophysics Explorers missions are NuSTAR, Swift, and ISS-NICER. Astrophysics Explorers' missions under development include GUSTO, IXPE, and SPHEREx. The Astrophysics Explorers program also includes contributions to partner-led missions, including the JAXA-led XRISM and the ESA-led Euclid.

**Astrophysics Research:** Research is the quest for knowledge that starts with the analysis and interpretation of data taken with NASA's operating missions. In turn, knowledge generates new questions, which lead to new missions. The Astrophysics Research Program supports this cycle, starting with the Astrophysics Data Archive program (ADAP), which funds analysis of data from NASA missions, and the Astrophysics Theory program (ATP), which funds theory for interpreting the data. Technology for new missions is funded through the Astrophysics Research and Analysis (APRA) and Strategic Astrophysics Technology (SAT) programs, including suborbital-class missions on sounding rockets, balloons, and cubesats. The Astrophysics Research Program also includes the NASA Astrophysics Archives, for curation and dissemination of astrophysics mission data, and the Balloon Project, which provides balloon launch and mission services for the Agency.



## Earth Science Division

**STRATEGIC OBJECTIVE:** Advance knowledge of Earth as a system to meet the challenges of environmental change and to improve life on our planet

**SCIENCE QUESTIONS:**

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

### DIVISION OVERVIEW

Our home planet is changing on all spatial and temporal scales and studying the Earth as a complex system is essential to understanding the causes and consequences of global to local environmental variability and change. NASA addresses the issues and opportunities of global environmental changes and climate risks by answering the following key science questions through our Earth science program:

- How is the global Earth system changing?
- What are the natural and anthropogenic drivers of these changes in the Earth system?
- How will the Earth system change in the future?
- What are the societal benefits of the Earth system?

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 ecological and chemical 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

## STRATEGY AND MANAGEMENT PHILOSOPHY

NASA's Earth Science Division (ESD) helps us to understand our planet's interconnected systems, from a global scale down to local processes. ESD activities address the Earth system and seek to characterize its properties on a broad range of spatial and temporal scales, to understand the naturally occurring and human-induced processes that drive them, and to improve our capability for predicting its future evolution. ESD uses space-based measurements to provide information not available by other means. NASA's ESD program is end-to-end: it starts with the development of observational techniques and the instrument technology needed to implement them; tests the techniques in the laboratory and from an appropriate set of observational platforms; uses the subsequent results to increase basic process knowledge; and incorporates the results into complex computational models that can be used to more fully characterize the present state and future evolution of the Earth system. ESD works in concert with a network of interagency and international partners, measuring sea level, atmospheric composition, ice distributions, vegetation, and precipitation, among other quantities globally, and it can employ its own constellation of small satellites to look into the eye of a hurricane. ESD technology can track dust storms across continents and mosquito habitats across cities. ESD delivers the technology, expertise and global observations that help us to map the myriad connections between our planet's vital processes and the effects of ongoing natural and human-caused changes, but also allowing NASA to consider the extensive and evolving studies of our home planet in its exploration of other planets and our solar system.

Using observations from satellites, instruments on the International Space Station, airplanes, balloons, ships, and other in situ platforms, ESD researchers collect data about the science of our planet's atmospheric motion and composition; land cover, land use and vegetation; deep Earth processes; ocean currents, temperatures and upper-ocean life; and ice on land and sea. These data sets, which cover even the most remote areas of Earth, are freely and openly available to the public. ESD works with government and commercial partners in the U.S. and internationally to put that unique information to work as we explore our home planet, discover Earth's secrets, and improve lives and safeguard the future for people all over the world. Earth science research also helps advance space exploration by helping scientists recognize the basic markers for life across the universe. NASA's ESD embraces interdivisional work by considering the environments on other worlds, from coupling of upper and middle atmosphere, comparative oceans and cryospheres on other planetary bodies, and supporting common approaches that support multiple divisions (e.g., laboratory spectroscopy, radiative transfer modeling, multi-dimensional modeling), and the search and investigation of ecosystems that may both reflect non-Earth analogues.

## SUMMARY OF PORTFOLIO BY PROGRAM

**Earth Systematic Missions Program:** The Earth Systematic Missions (ESM) program portfolio consists of a collection of polar-orbiting and low-inclination satellites, as well as instruments/payloads hosted on the International Space Station (ISS) or other platforms



for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans; a comprehensive data and information system to receive, process, archive, and distribute data and information from all of NASA's Earth science programs and activities; and a broad range of multi-disciplinary, mission-focused science investigations. The ESM program type addresses Earth science objectives through multiple independent flight projects along with associated mission operations, science data processing systems, and dedicated mission science teams. Each project within the ESM program has an assigned set of mission objectives that benefits the program as a whole.

**Earth System Science Pathfinder Program:** The [Earth System Science Pathfinder](#) (ESSP) program is a science-driven program designed to provide an innovative approach to Earth science research by providing periodic opportunities to solicit and competitively select missions, instruments, and suborbital investigations. These projects are PI-led. To ensure a robust portfolio with a regular cadence of selections, projects are cost-capped. To this end, the ESSP objective is to ensure the success of each project within its programmatic and schedule constraints. The program has the flexibility to take advantage of opportunities presented by domestic and international cooperative efforts and technical innovation. ESSP addresses specific Earth science objectives through multiple spaceflight projects of varied scope. The ESSP program supports missions that complement those of the larger, generally non-competitively selected, ESM program, which is designed to facilitate ongoing or longer term measurement sets. While there is no required interdependence between the ESSP constituent projects, there is no prohibition to leveraging scientific information from other missions.

**Earth Science Research Program:** The Earth Science Research Program aims to advance understanding of the components of the Earth system, their interactions, and the consequences of changes in the Earth system for life, by researching Atmospheric Composition, Weather, Carbon Cycle and Ecosystems, Water and Energy Cycle, Climate Variability and Change, and the Earth Surface and Interior. Earth system interactions occur on a continuum of spatial and temporal scales: Earth scientists investigate phenomena that range from short-term weather, to long-term climate and motions of the solid Earth that have local, regional, and global effects. These Earth system components involve multiple, complex, and coupled processes that affect climate, air quality, water resources, biodiversity, and other features that allow our Earth to sustain life and society. A major challenge is to predict changes that occur on time scales from the next month to next century, both naturally and in response to human activities. To do so requires a comprehensive scientific understanding of the entire Earth system—how its component parts and their interactions have evolved, how they function, and how they may be expected to further evolve on all time scales.

The research program is designed to leverage NASA's unique capabilities in space observation, modelling, airborne science, surface-based measurements, data and information systems, and High-End and Scientific Computing in relation to research carried out by, and in collaboration with, other federal agencies and international partners.

Similarly, using the observations from ESD flight programs, the research program both advances the interdisciplinary field of Earth system science and provides much of the scientific basis for major periodic assessments of environmental change such as the World Meteorological Organization's and United Nations (UN) Environment Programme's quadrennial ozone assessment, the Assessment Reports of the Intergovernmental Panel on Climate Change, and the National Climate Assessment of the Global Change Research Program.

**Applied Sciences Program:** The [Applied Sciences Program](#) leverages NASA Earth science satellite measurements and new scientific knowledge to foster innovative and practical uses by public and private sector organizations. The program enables near-term uses of Earth observations data and information products, discovers and demonstrates new applications, and facilitates adoption of applications by non-NASA stakeholder organizations that have connections to users and decision makers. The Applied Sciences Program has three primary goals:

- Advance applications;
- Build capacity with Earth observations by improving the ability of individuals and institutions in the United States and abroad;
- Enhance satellite missions by encouraging potential users to envision and anticipate possible applications from upcoming satellite missions and to provide input to mission development teams.

**Earth Science Technology Program:** The Earth Science Technology Program, operated through the [Earth Science Technology Office](#) (ESTO), demonstrates and provides technology research and development projects that advance Earth observing instrumentation, mission components, and information systems to make future missions feasible and affordable. This program is based on a science-driven strategy that employs open peer-reviewed solicitations to produce the best appropriate technologies. ESTO holds a broad, continually growing portfolio of more than 800 past and active investments at over 200 institutions nationwide.



## Heliophysics Division

**STRATEGIC OBJECTIVE:** Understand the Sun and its interactions with Earth, the Solar System and the interstellar medium, including space weather

**SCIENCE QUESTIONS:**

What drives the constant change we observe on our sun?

What drives the changes in near-Earth space, the planetary space environments and the heliosphere?

What are the impacts of this dynamic space system on humanity?

### DIVISION OVERVIEW

[NASA's Heliophysics program](#) embraces arguably the original “first light” of scientific wonder - the Sun, and how it influences the very nature of space. Our nearest star sends out a steady outpouring of particles and energy, the solar wind, which forms an extensive, dynamic solar atmosphere impacting all the planets, and extending far out to the edge of the heliosphere, shaping the protective bubble in which our solar system travels around the Milky Way.

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. Studying this system allows us to discover the fundamental physics governing how the universe works, and also helps protect our technology and astronauts in space. The study of the coupled Solar-Terrestrial system can also teach us more about the habitability of planets in other stellar systems throughout the universe.

### STRATEGY AND MANAGEMENT PHILOSOPHY

NASA's Heliophysics program pursues 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. Understanding this interconnected system requires a holistic study of the Sun's influence on space, Earth and other planets. The [Heliophysics System Observatory](#) is a fleet of spacecraft strategically placed throughout our heliosphere -- from Parker Solar Probe at the Sun observing the very start of the solar wind, to satellites around Earth, to the farthest human-made object, Voyager, which is sending back observations on interstellar space. Each mission is positioned at a critical, well-

thought out vantage point to observe and understand the flow of energy and particles throughout the solar system.

The Heliophysics Division strives for balance across the Sun-Earth-Heliosphere system, using different mission types and sizes. Priorities for missions are provided by the community through the [Decadal Survey](#). Heliophysics missions include directed and competed missions and range from large, complex endeavors, to more focused missions that can be accomplished with small spacecraft and missions of opportunity. Increased investment in new technologies allows for a consistent progression of mission and instrument capabilities. In addition, the division pursues partnerships with international, interagency, academia and commercial partners where appropriate to maximize mission capabilities and scientific research.

## SUMMARY OF PORTFOLIO BY PROGRAM

**Living With a Star (LWS):** The [Living With a Star \(LWS\) Program](#) emphasizes the science necessary to understand the aspects of the Sun and Earth's space environment that affect life and society. The ultimate goal of the LWS Program is to provide a scientific understanding of the system that leads to predictive capability of the space environment conditions at Earth, other planetary systems, and in the interplanetary medium. The LWS Program is a loosely coupled program wherein each mission has unique science, but the science from one mission can support supplemental investigations in other LWS missions.

**Solar Terrestrial Probes (STP):** The [STP program](#) develops missions and technology to address fundamental science questions about the physics of space plasmas and the flow of mass and energy through the solar system. Successive missions target the “weakest links” in the chain of understanding. The missions use a creative blend of in situ and remote sensing observations, often from multiple platforms, to understand the causes and effects of solar variability over the vast spatial scales involved in planetary and heliospheric responses. Following a recommendation from the 2013 Decadal Survey, the STP Program was reconfigured from directed, large scale missions, to focus on competed PI-led missions with targets specified in the report.

**Heliophysics Explorers:** The objective of the Heliophysics Explorers Program is to provide frequent flight opportunities for world-class scientific investigations from space, accomplished within NASA Heliophysics Space Science goals using efficient management approaches. The Heliophysics Explorers address focused and timely science problems that are investigated with smaller, fully competed missions that complement the science of strategic missions of Living With a Star (LWS) and Solar Terrestrial Probes (STP) Programs. Because they are smaller missions that can be conceived and executed in a relatively short development cycle, Explorers are highly responsive to new knowledge, new technology, and updated scientific priorities. The program emphasizes missions that can be accomplished under the control of the scientific community and seeks to constrain total mission life-cycle costs. Following recommendations from the 2013 Decadal Survey, the Heliophysics Division has increased the Explorer cadence to compete missions through the AO process every 2-3 years.



**Space Weather Science and Applications (SWxSA):** Understanding space weather is the domain of heliophysics. Space weather is a naturally occurring phenomenon with the potential to substantially disrupt or damage technological systems, including communication and navigation systems, the electric power grid, and space launch and satellite operations, as well as adversely impact the health of humans in space and passengers and crew in high altitude aircraft. Space Weather Science and Applications (SWxSA) is an HPD program established in response to the need to understand space weather, and called for by the 2019 National Space Weather Strategy and Action Plan. Reducing the Nation's vulnerability to space weather has been identified as a national priority and necessitates the development of improved capabilities to understand and mitigate the associated hazards. SWxSA is comprised of competed, directed, and partnership elements. The program's elements advance understanding and enable improved characterization and prediction of the complex space environment of the coupled Sun-Earth-Interplanetary system, in order to enhance capabilities that protect and mitigate space weather impacts on life, society, infrastructure, and space exploration.

**Heliophysics Research:** The [Heliophysics Research Program](#) supports technology development and scientific investigation to achieve a program of excellence and operates through open scientific competition. The research program highlights the newest mission data, utilizes the latest advances in modeling and machine learning, and develops the most innovative technological solutions. Theory and numerical simulations, artificial intelligence, data analysis techniques, and data modeling are key areas supported to ensure scientific progress. Innovative instrument development feeds into the next generation of space hardware first launched through our Heliophysics Flight Opportunities for Research and Technology (H-FORT) program graduating to mature instrumentation for our dedicated missions. The Heliophysics Division is committed to creating a robust research program and implementing growth as recommended by the [2013 Decadal Survey](#), including the implementation of the Diversify, Realize, Integrate, Venture, Educate (DRIVE) initiative. DRIVE was designed to more fully develop and effectively implement the entire Heliophysics Division portfolio of missions, experiments, simulations, theoretical models, and data analysis.

**Groundbreaking science results lay the foundation for the formulation of a next generation of unanswered, more specific questions to be addressed by future missions.** The research program uniquely fosters the system science of the Heliophysics System Observatory (HSO), enabling research that crosses mission boundaries. Competed programs allow for a cost-effective, diversified way to develop the next generation of space hardware, train scientists and engineers, and make breakthrough science observations.

Heliophysics also partners with other SMD divisions to maximize science return from overlapping areas of science interest, including the recent addition of heliophysics participating scientists to the Juno mission within Planetary Science. The Heliophysics Research Program also consists of the Sounding Rocket Program Office and the Wallops Research Range. Heliophysics manages these shared assets for the benefit of all SMD science divisions.



## Planetary Science Division

**STRATEGIC OBJECTIVE:** Ascertain the content, origin, and evolution of the Solar System and the potential for life elsewhere

**SCIENCE QUESTIONS:**

How did our solar system form and evolve?

Is there life beyond Earth?

What are the hazards to life on Earth?

### DIVISION OVERVIEW

NASA's planetary science program is engaged in one of the oldest scientific pursuits: the observation and discovery of our solar system's planetary objects. We undertake this enterprise in order to better understand the history of our solar system and the distribution of life within it.

For decades, NASA's planetary science program has advanced the scientific understanding of the solar system in extraordinary ways, while pushing the limits of spacecraft and robotic engineering design and operations. To date, NASA spacecraft have visited every planet as well as a variety of small bodies; and some of our current missions will bring back new samples from exciting destinations, allowing iterative detailed study and analysis back on Earth. 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\*](#) (NRC, 2011). Using the decadal recommendations as our guide, planetary science missions and research inform us about our neighborhood and our own origin and evolution, and they are necessary precursors to the expansion of humanity beyond Earth. In the future, humans will return to the Moon, and visit Mars, and possibly other solar system bodies to explore them, in concert with continued robotic missions to further extend our scientific understanding.

### STRATEGY AND MANAGEMENT PHILOSOPHY

NASA's planetary science program pursues a strategy of surveying the planetary bodies of our solar system and targeting repeated visits to those bodies likely to enable the greatest progress toward answering fundamental science questions. The Planetary Science Division strives for balance across mission destinations, using different mission types and sizes. For selected planetary bodies, science drivers require successive visits to progressively answer ever more challenging questions. This involves a steady cadence of missions to multiple locations, coupled with a strong research program that articulates the questions that drive new missions, analyzes mission data to answer those questions, and

develop new questions for the next generation of missions. Steady investment in new technologies allows for a consistent progression of mission capabilities and a solid, continual research component as our investigations advance.

Planetary Science missions include directed, strategic missions of national importance and competed missions soliciting the best ideas from the community. Our flight programs range from large and complex undertakings to more focused missions that can be accomplished with small spacecraft utilized as secondary payloads. In addition, the division pursues partnerships with international, interagency, academia and commercial partners where appropriate to increase mission capabilities and cadence, develop new technologies, enhance scientific research and overall, to accomplish like-minded objectives.

## SUMMARY OF PORTFOLIO BY PROGRAM

### Discovery Program

[Discovery](#) is an ongoing program that offers the scientific community the opportunity to conduct focused investigations that complement NASA's larger planetary science missions. The goal is to achieve outstanding results by launching more, smaller-class missions using fewer resources and shorter development times. In addition, Discovery advocates infusion of new technologies and applications. Each mission works with industry to transfer technologies used in the mission, especially those that enhance science acquisition and reduce cost. Discovery missions have achieved ground-breaking science, each taking a unique approach to space exploration, and driving technology innovations that may also improve life on Earth.

### New Frontiers Program

Missions in the [New Frontiers Program](#) tackle specific solar system exploration goals identified as priorities of the planetary science community and defined in the Decadal Survey. The strategy is to explore the solar system with medium-class spacecraft missions that conduct high-science-return investigations that add to our understanding of the solar system. New Frontiers builds on the innovative approaches used in NASA's Discovery and Explorer Programs, but provides a mechanism for identifying and selecting strategic missions that cannot be accomplished within the cost and time constraints of Discovery.

### Solar System Exploration Program

The [Solar System Exploration Program](#) consists of large, strategic missions that seek to advance high priority science objectives set forth in the planetary decadal survey. Due to their complexity, NASA typically assigns these efforts directly to a NASA center or other implementing organization. Missions within the program investigate a synergistic array of science objectives with more depth and breadth than is possible for smaller, tightly focused missions in the Discovery and New Frontiers programs. One current area of emphasis within the program is the study of ocean worlds. Using knowledge gained through NASA's Earth Science programs regarding our own oceans and water cycle, we discovered that water exists in diverse forms on moons, planets, and even comets. As we explore these bodies with future missions, the ice, water vapor in the atmosphere, and oceans on other worlds offer clues in the quest to discover life beyond our home planet.

## **Mars Exploration Program**

The [Mars Exploration Program](#) is a science-driven program that seeks to understand whether Mars was, is, or can be, a habitable world. The goal of the Mars Exploration Program is to explore Mars and to provide a continuous flow of scientific information and discovery through a carefully selected series of robotic orbiters, landers and mobile laboratories interconnected by a high-bandwidth Mars/Earth communications network. To achieve this, the program supports the implementation of large and small directed missions as well as those that are competitively selected and led by a principal investigator. From studying the Martian solar environment with the Heliophysics Division to investigating resources for future human explorers, the Mars Exploration Program provides insight and knowledge into areas of interest across the Science Mission Directorate and invaluable support to agency-wide initiatives.

## **Planetary Research**

The Research and Analysis (R&A) Program enables utilization of the data returned by planetary science missions and provides the crucial context within which those data are interpreted. Discoveries and concepts generated by the R&A Program help inform scientific priorities, new mission concepts and develop cutting-edge science instrumentation from concept to flight hardware. The program is inherently crosscutting; spanning theoretical work, laboratory studies, fieldwork and the continuing analysis and modeling of data and returned samples from past missions. As such, the program provides unique mission support capabilities to enable and facilitate this research:

- Creation of research program elements as new fields of research emerge, such as the Exoplanets Research Program coordinated primarily with the Astrophysics Division but extending to Heliophysics and Earth Science Divisions as well;
- Sample return curation facilities to store, disseminate and support the analysis of extraterrestrial samples, including those returned from other planetary bodies;
- The Planetary Data System (PDS) to archive and disseminate data from planetary science missions; and,
- Virtual institutes such as the Solar System Exploration Research Virtual Institute (SSERVI) to promote broad collaboration on key scientific foci.

## **Planetary Defense Program**

NASA's [Planetary Defense Program](#) supports the ground and space-based observatories that are responsible for the discovery and characterization of Near-Earth Objects (NEOs) as well as to study strategies and technologies for increasing the discovery rate and mitigating potential impacts. To accomplish this, the program funds research activities to better understand the motions and compositions of these objects, including the use of optical and radar techniques to determine orbits, shapes, sizes and rotation states. These activities enable the science community to sufficiently understand the nature of the objects should mitigation of a possible impact to Earth be required. The program also supports flight missions to near-Earth asteroids and ground-based efforts to study asteroids and comets. However, asteroids are not just important when they cross the Earth's orbit: studying asteroids can inform future exploration and resource utilization as well as provide insights into the origins of the material – and possibly life – in our solar system.



**Technology:**

Planetary Science missions span the solar system and encompass the harshest known environments. From the scorching, caustic surface of Venus to the frigid cold-traps on the Moon, advanced technologies and new capabilities are required to enable exciting missions across a broad set of destinations. While not a formal program, the Planetary Science Division invests 6-8 percent of its budget each year to develop technologies needed for future missions per the recommendation of the Decadal Survey. These investments encompass advanced energy production and conversion technologies, scientific instruments, ground support technologies, and spacecraft technologies that are enabling for unique planetary science missions. Our current emphasis is on instruments for life detection and habitability characterization, advanced power systems to enable long-duration missions far from the Sun, and spacecraft technologies to enable the scientific exploration of European ice and the Venus surface. However, we continuously study emerging mission requirements to identify needs for new technology investment, and work to infuse technologies onto missions to enable better science.

**Outer Planets and Ocean Worlds Program:****Lunar Discovery and Exploration Program:**

The Lunar Discovery and Exploration Program (LDEP) is a key component of the Agency's Exploration Campaign. On-going LDEP activities include the establishment of commercial contracts for lunar landing transportation services and the development of exploration, science, and technology payloads to support this investment. LDEP is also responsible for operating the Lunar Reconnaissance Orbiter (LRO) and developing future lunar missions, including SmallSats and long-duration rovers.

## Appendix A: Science Performance Goals

To advance scientific discovery through exploration, we have identified nine broad, cross-cutting science areas and seeks to answer questions in each area through the breadth of our diverse portfolio of programs and the scientific community's expertise. Nine specific scientific research areas, as shown in Table 1, are evaluated on an annual basis to determine whether NASA Science is making progress implementing its programs.

Table 1: NASA Science Performance Goals as defined in the NASA's Annual Performance Plan.

PERFORMANCE GOALS	APD	ESD	HPD	PSD
<b>1.1.1</b> NASA shall demonstrate progress in exploring and advancing understanding of the physical processes and connections of the Sun, space, and planetary environments throughout the Solar System.		●	●	●
<b>1.1.2</b> NASA shall demonstrate progress in exploring and probing the origin, evolution, and destiny of the galaxies, stars, and planets that make up the Universe.	●		●	●
<b>1.1.3</b> NASA shall demonstrate progress in exploring, observing, and understanding objects in the Solar System in order to understand how they formed, operate, interact, and evolve.			●	●
<b>1.1.4</b> NASA shall demonstrate progress in discovering and studying planets around other stars.	●		●	
<b>1.1.5</b> NASA shall demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere, exploring and finding locations where life could have existed or could exist today, and exploring whether planets around other stars could harbor life.	●		●	●
<b>1.1.6</b> NASA shall demonstrate progress in developing the capability to detect and knowledge to predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.			●	
<b>1.1.7</b> NASA shall demonstrate progress in identifying, characterizing, and predicting objects in the Solar System that pose threats to Earth or offer resources for human exploration.				●
<b>1.1.8</b> NASA shall demonstrate progress in detecting, predicting, characterizing, and understanding changes and evolution of the Earth system, including Earth's interior, and the resulting impacts to inform decisions and provide benefits to society.		●		
<b>1.1.9</b> NASA shall demonstrate progress in improving the capability to characterize climate and to predict weather, extreme weather events, and natural hazards.		●		

Legend: ● Primary Contributor ● Supporting Contributor

## Appendix B: Acronym List

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NASA



EXPLORE  
with us