National Aeronautics and Space Administration

EXPLORE

SCIENCE 2020-2024

A Vision for Science Excellence

www.nasa.gov

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

May 27, 2020

Exploration and scientific discovery are at the core of what we do in the National Aeronautics and Space Administration (NASA)'s Science Mission Directorate (SMD). We are guided by the recommendations of the National Academies of Sciences, Engineering, and Medicine (NASEM) and are responsive to national priorities. We rely on innovation and strategic partnerships to enable progress. Our work inspires all and we seek to create an inclusive environment where all can participate.

Science 2020-2024: A Vision for Scientific Excellence represents a departure from past Science Plans in that we present four cross-cutting priorities and accompanying strategies that reflect our shared values and are directly responsive to changes in the broader ecosystem in which we work. We have been intentional in setting these priorities and strategies to focus attention on those areas where we can have the greatest impact. This Vision document is designed to communicate with the entire science community – the SMD workforce and the diverse set of stakeholders and partners that enable us to achieve our mission – so that there is a shared sense of understanding of our values.

This document is arranged by priority area and provides a brief description of our intentions and high-level objectives associated with each. As new opportunities arise, we will evolve our strategies to respond to these evolving conditions. Through implementation of this strategic direction, we are and will continue to make progress answering key science questions in each of our disciplines. While implementation of the strategies may look different between our divisions, we acknowledge that there are core principles underlying our actions, and opportunities to leverage pioneering efforts in one division for the benefit of all. We provide examples throughout the document to show how our divisions are making progress.

We measure success by our ability to:

- Implement recommendations of Decadal Surveys in concert with national priorities and needs through creative partnership models that go beyond traditional ways of developing and executing missions
- Challenge assumptions about what is technically feasible and enable revolutionary scientific discovery through a deliberate focus on innovation, experimentation, and cross-disciplinary research
- Create a more collaborative culture within the Science Mission Directorate and across the science community, encouraging diversity of thought, sharing best practices, and informed risk-taking to improve operations
- Develop future leaders and inspire learners of all ages through new opportunities and hands-on experiences

Our priorities were developed in close collaboration with the entire Science Mission Directorate leadership team and NASA Center Directors, as well as advisory bodies at NASA and NASEM, and I would like to thank all participants for their contributions.

Sincerely,

Thomas H. Zurbuchen, Ph.D.
Associate Administrator,
Science Mission Directorate

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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 NASEM'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, the Moon, other worlds of our solar system, the stars, and the deep universe. As NASA's mission evolves, the Science Mission Directorate (SMD) continually strives to be innovative and drive discovery. SMD utilizes technological advances and new partnership opportunities, including public-private partnerships that leverage commercial investments to further NASA's science objectives. The 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, SMD incorporates the four NASA core values in all aspects of its work, as well 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.

SMD Core Values

LEADERSHIP

From studying the origin and evolution of the universe to seeking to understand the Earth as an interconnected system, SMD has advanced scientific knowledge and has had a direct positive impact on the quality of life on Earth. We know that scientific discovery is achieved through collaboration and therefore we seek to create space for people to come together to continue expanding our understanding of Earth and space for the benefit of all.

EXCELLENCE

The work of SMD 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.

INTEGRITY

SMD is committed to ensuring that all decisions are made with integrity and transparency, believing 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 timely, appropriate decisions to reduce unnecessary administrative burden.

TEAMWORK

SMD believes in the importance of diverse teams to most effectively and innovatively 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 and inspire 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 SMD's work. Not only are we concerned about protecting life and property, but we also recognize the importance of psychological health and safety. We strive to create an environment where everyone can contribute to our work. People must feel comfortable bringing up issues and concerns without fear of retribution or reprisal. This extends to all members of the science community who work with us.

Introduction

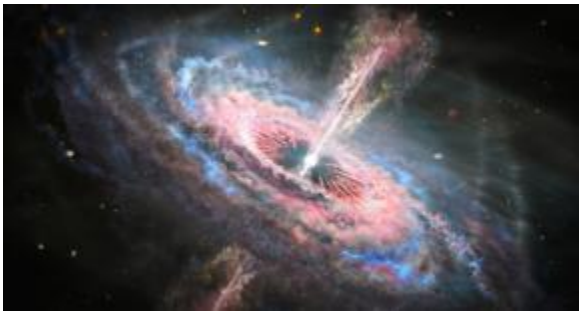

Photo Credit: *NASA/ESA/J. Olmsted (Space Telescope Science Institute)*
Using the unique capabilities of the Hubble Space Telescope, scientists have discovered a quasar emitting large amounts of energy generated by a supermassive black hole fueled by infalling matter. The blistering radiation pressure from the vicinity of the black hole pushes material away from the galaxy's center at a fraction of the speed of light.

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 has created public value. Our impact has been two-fold: *We discover the secrets of the universe*. Whether 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 fundamental research and preparing this knowledge for translation to our government and private sector partners.

We celebrated the 60th anniversary of NASA and its Science program in 2018. NASA's strategy for the future builds on this legacy, recognizing that 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. SMD has the responsibility to continue delivering the most compelling and highest impact science program to the American public while inspiring the next generation of explorers.

NASEM sets high-level science priorities through their decadal surveys. Not only does SMD support scientific discovery for the sake of new knowledge, but it also advances fundamental science that serves as the foundation for future exploration, and the technology innovations that will enable it.

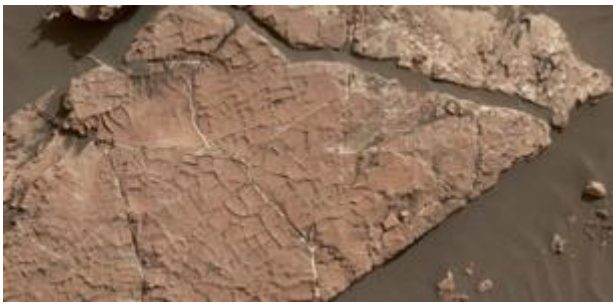

Photo Credit: *NASA/JPL-Caltech/MSSS*
NASA's Curiosity rover has found evidence of an ancient Martian oasis where streams of water may have once flowed. Mars missions, like the Curiosity rover, look to unravel the mystery of how the Martian climate changed and search for evidence of conditions that might have supported ancient Martian life.

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 (e.g., understanding how geologic processes on Mars and on ocean-bearing worlds in our solar system might give rise to habitable environments), in astrophysics (e.g., understanding how planets form and how to find them around other stars), in Earth science (e.g., understanding how measurements of atmospheric emissions can be used to search for signs of life on other worlds) and in heliophysics (e.g., understanding how stellar activity and stellar magnetospheres affects planetary atmospheres and climate).

SMD 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 enable us to build on past success. SMD therefore has the 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 other space agencies, universities, industry and others, we are able to generate diverse ideas, technology, research and processes, and support the development of a diverse workforce.

For example, SMD actively looks for opportunities to build on private sector investments and to utilize innovative public-private partnerships to advance SMD 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 also propels significant improvements in predictive capability that protects 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.

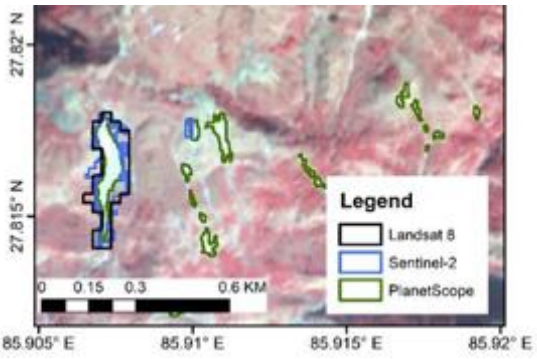

Photo Credit: *PlanetScope/RapidEye/NASA*
The Commercial Small Satellite Data Acquisition Program enables the purchase of Earth science observation data from commercial small satellite constellations (e.g., PlanetScope) to provide a cost-effective means to augment and complement NASA observations. For example, data purchased from the PlanetScope constellation was overlaid with NASA & ESA data to better map smaller landslides areas in Nepal during 2018.

The challenge to any successful enterprise like SMD is to continually test its own assumptions and unlock new opportunities. To answer the aspirational questions we ask, we push to make leaps of progress, and test new approaches. By applying such innovative approaches, we truly can realize our full potential.

Science Leadership Priorities

To achieve our goals, SMD relies on four cross-cutting priorities: Exploration and Scientific Discovery, Innovation, Interconnectivity and Partnerships, and Inspiration. Our core purpose 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 priority area and the high-level implementation approach. These strategies are designed to be ambitious new pursuits for SMD, going above and beyond the current program of record to drive action and make progress in specific directions over the next five years.

PRIORITY 1
EXPLORATION AND SCIENTIFIC DISCOVERY

STRATEGY 1.1: Execute a balanced science program based on discipline-specific guidance from the National Academies of Sciences, Engineering, and Medicine, Administration priorities, and direction from Congress.

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-user focused approach to applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness.

SMD seeks 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 flight missions, research and analysis, technology development, and applications as critical components of our work. The relative balance across these efforts is informed by NASEM through their Decadal Surveys and is responsive to Administration priorities and direction from Congress.

Photo Credit: *NASA*
NASA's Astrobiology Program combines the efforts of missions across astrophysics, heliophysics and planetary science to further the search for life beyond Earth.

We are undertaking new work that builds on our past success 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. That program is now being expanded to include heliophysics research on the impact of different stellar types on orbiting planets.

Closer to home, our Earth Science program pioneered the use of SMD 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. We recognize that this is an iterative process – as SMD data is used in support of such capabilities, new users and user needs will be identified, which will drive fundamental research that may yield even more models and tools.

Finding answers to these profound science questions requires continued progress on the scientific priorities identified by NASEM through their Decadal Surveys, as well as support for 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 of Sciences, Engineering, and Medicine, Administration priorities, and direction from Congress.

NASEM provides guidance that helps SMD 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 focusing 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 SMD is responsible for managing their own portfolio in accordance with this guidance and progress against the Decadal Surveys is assessed by NASEM as part of their mid-term reviews. Implementation of Decadal Survey recommendations is modified to reflect existing budgets, in particular when funding for new missions is different from that assumed in the Decadal Surveys.

Astrophysics

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 the combination of basic research and flight missions. In this quest, astrophysics is guided by NASEM's *Astro2020: Decadal Survey on Astronomy and Astrophysics*, which sets the science and technology priorities informing our investment decisions.

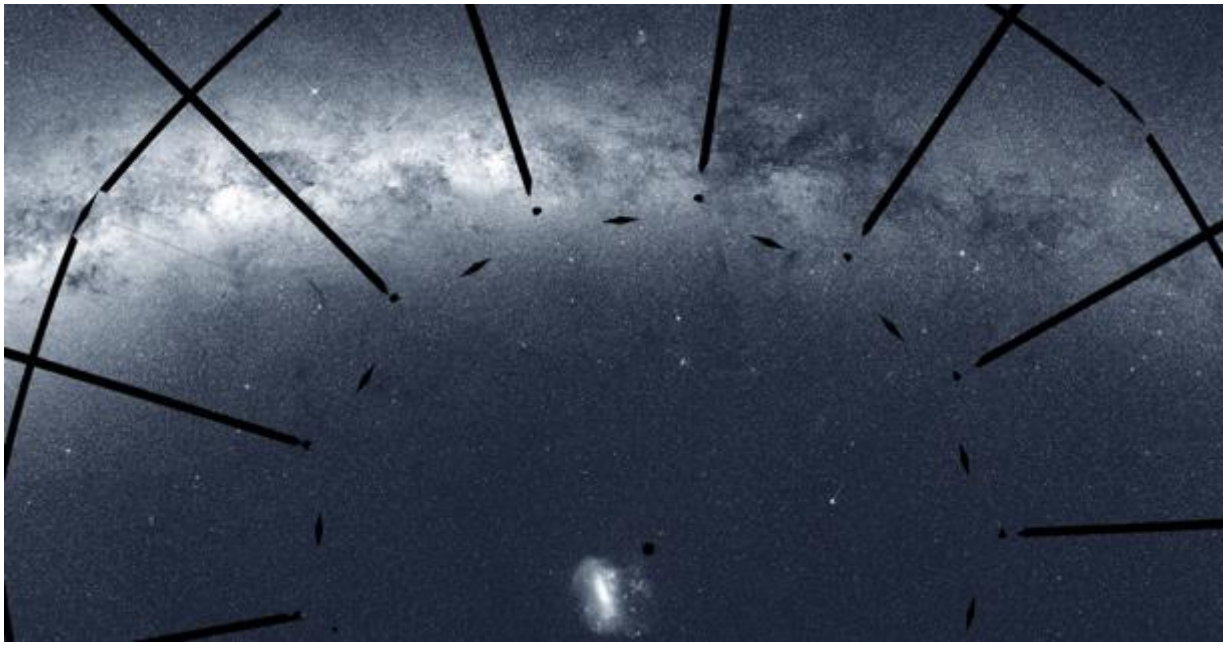

Photo Credit: *NASA/MIT/TESS*
NASA's Transiting Exoplanet Survey Satellite (TESS) created a mosaic of the southern sky from 208 images taken during its first year of science operations, completed in July 2019. The mission divided the southern sky into 13 sectors, each of which was imaged for nearly a month by the spacecraft's four cameras. Among the many notable celestial objects visible is the glowing band (left) of the Milky Way, our home galaxy seen edgewise, the Orion Nebula (top), a nursery for newborn stars, and the Large Magellanic Cloud (center), a nearby galaxy located about 163,000 light-years away. The prominent dark lines are gaps between the detectors in TESS's camera system.

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, Principal Investigator-led Explorers missions. Large and medium strategic missions are directed to NASA Centers for implementation and are managed within the Astrophysics Strategic Missions Program.

Earth Science

NASA Earth Science unlocks the mysteries of our planet, exploring, discovering, and responding to the need to understand our planet's interconnected systems, from a global scale to minute processes. This knowledge and understanding serves the fundamental need to improve our lives on Earth, advancing this frontier for all humanity. NASA pursues both curiosity-driven and practically focused Earth science because our ability to thrive on our home planet is undeniably tied to our scientific understanding and predictive capability of its dynamics and phenomena.

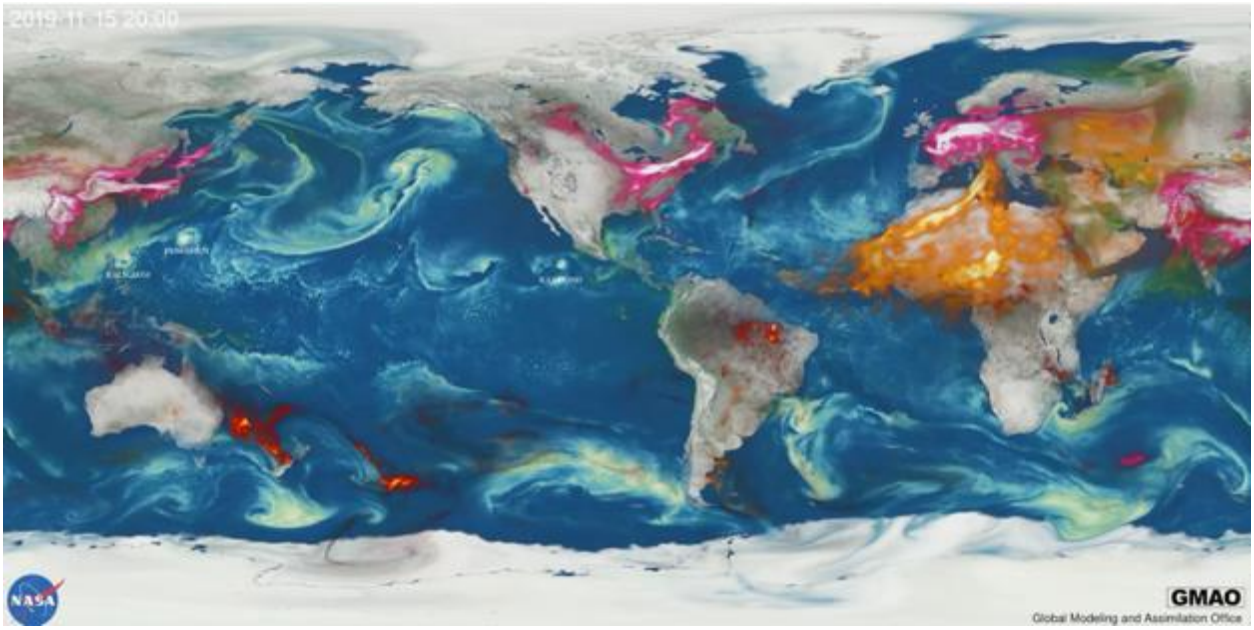

Photo Credit: *NASA's Goddard Space Flight Center*
NASA's Global Modeling and Assimilation Office used Earth science data gathered from multiple missions to visualize several high impact events across the globe between August 2019 and January 2020, including Hurricane Dorian (August to September 2019), major fire events in South America and Indonesia (August to September 2019), and extreme wildfires in Australia (December 2019 to January 2020). The model helps demonstrate how different events interact and the environmental impacts they can have around the globe.

NASA Earth Science explores our rapidly changing world, where natural and human factors interact, following an interdisciplinary, Earth systems approach that examines the interplay among the atmospheric, ocean, land, and ice systems. Using the recommendations of the 2017 NASA Earth Science Decadal Survey, *Thriving on Our Changing Planet a Decadal Strategy for Earth Observation from Space*, as a compass, NASA Earth Science is developing the observing systems that will answer the most important science and application questions of the next decade across the following focus areas:

- Coupling of the water and energy cycles
- Ecosystem change
- Extending and improving weather and air quality forecasts
- Reducing climate uncertainty and informing societal response
- Sea-level rise
- Surface dynamics, geological hazards and disasters

Heliophysics

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 and dynamic solar atmosphere impacting all the planets. This solar atmosphere extends 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.

Guided by 2013 Decadal Survey, *Solar and Space Physics: A Science for a Technological Society*, the strategic objective of heliophysics is to understand the Sun and its interactions with Earth, the solar system and the interstellar medium, including space weather. Heliophysics incorporates studies of the interconnected elements into a single system that produces dynamic space weather 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 helps protect our technology and astronauts in space from the impacts of space weather. 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.

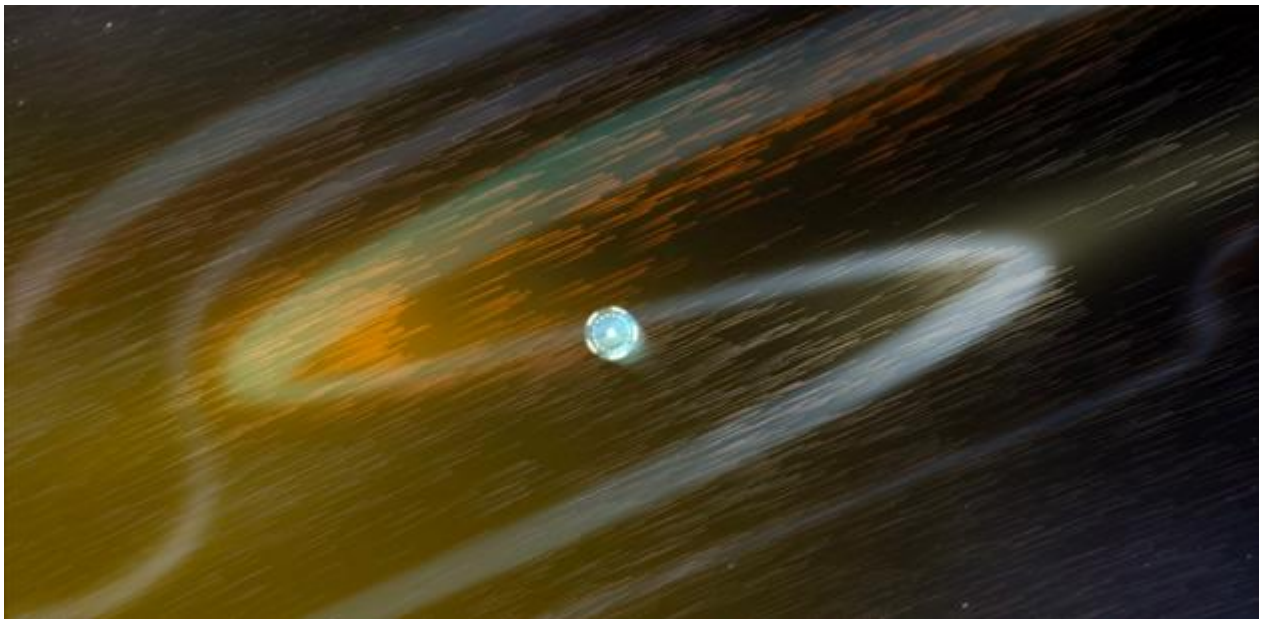

Photo Credit: *NASA/GSFC/CIL/Adriana Manrique Gutierrez*
NASA's Parker Solar Probe has observed switchbacks — traveling disturbances in the solar wind that caused the magnetic field to bend back on itself — an as-yet unexplained phenomenon that might help scientists uncover more information about how the solar wind is accelerated from the Sun. Space Weather, driven by the solar wind, directly affects the technology that we rely on in everyday life, from GPS systems to telecommunications satellites, all the way to the power transformers that provide electricity to residents all around the globe.

Planetary Science

Planetary science is a grand enterprise undertaken for the benefit of all humanity. Through the observation and discovery of complex planetary worlds and objects, we seek to understand our solar system and the distribution of life within it. The NASA Planetary Science strategic objective is to advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space. The scientific foundation of this endeavor is NASEM's 2011 planetary science decadal survey, *Vision and Voyages for Planetary Science in the Decade 2013-2022*. NASA pushes the limits of spacecraft as well as robotic engineering design and operations to implement this vision and manages a diverse portfolio of research and technology development that secures maximized science return for resources invested.

The excitement of venturing further with planetary science exploration is coupled with unique mission investigations. NASA's New Horizons spacecraft in 2019 completed the first in human history fly-by of a Kuiper Belt object, Arrokoth, and continues onward. NASA currently is operating spacecraft at Mars, Jupiter, the asteroid Bennu, and the Moon; and is undertaking a flagship mission to Jupiter's moon Europa, as its subsurface ocean has great potential to harbor extraterrestrial life. Our Moon holds important information about the formation of our planet, resources for living and working in space and traveling farther, and strategic and economic opportunities. Knowledge gained by future human missions to the Moon will be utilized to visit Mars and possibly other solar system bodies, in concert with continued robotic missions. Advances in planetary science, coupled with leading efforts to detect, track, and characterize near-Earth objects, will continue to improve planetary defense.

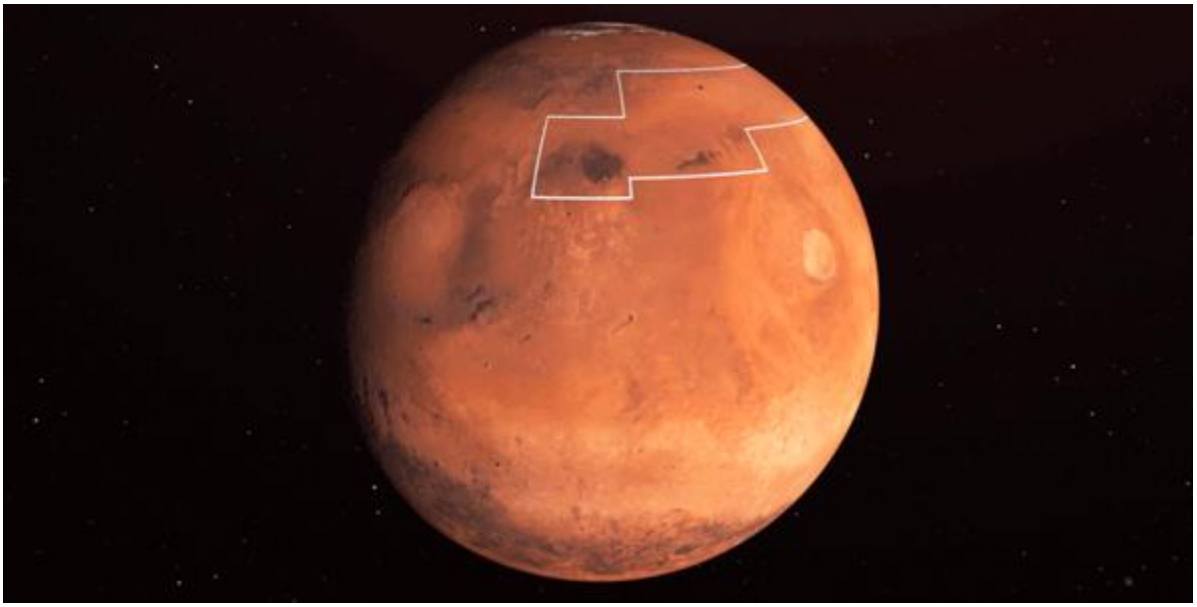

Photo Credit: *NASA/JPL-Caltech*
The annotated area of Mars in this illustration holds near-surface water ice that would be easily accessible for astronauts to dig up. Satellites orbiting Mars are essential in helping scientists determine the best places for building the first Martian research station. Data from two of those spacecrafts, NASA's Mars Reconnaissance Orbiter (MRO) and Mars Odyssey orbiter, have located water ice that could potentially be within reach of astronauts on the Red Planet.

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 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." As its next step in human space exploration, NASA is preparing to send the first woman and next man to the Moon by 2024 under the Artemis program, establish sustainable lunar exploration by 2028, and plans to send astronauts to Mars as early as the late 2030s. SMD is a direct contributor to this national priority through ongoing investments in fundamental research, 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 opportunities of scientific exploration of the Moon.

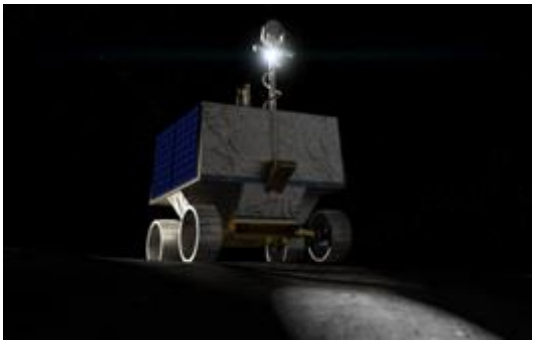

Photo Credit: *NASA Ames/Daniel Rutter*
NASA's VIPER will go to the South Pole of the Moon to get a close-up view of the location and concentration of water ice that could eventually be harvested to sustain human exploration on the Moon, Mars — and beyond.

In particular, SMD is leading NASA's Commercial Lunar Payload Services (CLPS) initiative to enable rapid acquisition of lunar delivery services from a growing number of American companies for payloads that advance capabilities for science, exploration or commercial development of the Moon. Early lunar missions will enable important technology demonstrations to inform the development of future landers and other exploration systems needed for humans to return to the lunar surface. Future payloads could include rovers, power sources, science experiments including NASA's Volatiles Investigating Polar Exploration Rover (VIPER), and technology demonstrations to be infused into the Artemis program. NASA has awarded initial surface task order awards to CLPS providers, with two companies on track to launch commercial landers to the Moon in July 2021. We have also identified NASA and external science payloads that will fly on future CLPS missions.

SMD will continue to seamlessly collaborate with the Human Exploration and Operations (HEOMD) and Space Technology (STMD) 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

SMD 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. SMD therefore seeks to provide opportunities for integrated, interdisciplinary research that encourages collaboration. To be successful, SMD must balance the ownership of these opportunities to ensure consistency and alignment to the program of record. For example, SMD has restructured its Exoplanet Research Program to better function as a cross-divisional program involving personnel and funding from all four science divisions. SMD has also adopted a new process to evaluate these proposals by topic, with panels that are agnostic to the common funding sources of the Principal Investigators (PI).

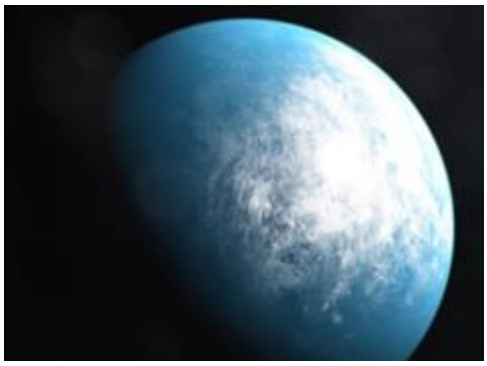

Photo Credit: *NASA's Goddard Space Flight Center*
NASA's TESS has found its first earth sized exoplanet in the habitable zone, TOI 700d. In the future, the James Webb Space Telescope may be able to identify whether the planet has an atmosphere, which could provide insight into if TOI 700 d is a life-bearing world.

The experience with the Exoplanet Research Program can serve as a model for how other disciplines might work together in the future. For example, emerging opportunities exist to use Earth as a laboratory in support of habitability and to answer questions from the heliophysics domain. SMD recently surveyed the scientific community asking for suggested research areas not currently solicited by the existing grants programs and received nearly 100 responses, demonstrating high potential for cross-divisional scientific discovery.

STRATEGY 1.4

Develop a broadly applicable, target-audience focused approach to SMD's applied programs, including Earth Science Applications, Space Weather, Planetary Defense, and Space Situational Awareness.

One of SMD's goals is to protect and improve life on Earth. To accomplish this, we will build on our long-standing work on 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, engaging directly and through our partnerships with operational agencies and user communities, to leverage best practices that meet the needs of the communities our data can positively affect. As these capabilities mature, there may be opportunities for commercialization that would increase the return on investment of NASA research and foster commercial innovation.

PRIORITY 2
INNOVATION

STRATEGY 2.1: Foster a culture that encourages innovation and entrepreneurship across all elements of the SMD 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.

SMD recognizes that innovation and measured risk-taking are the cornerstones of a forward-looking program of scientific discovery. This boldness in vision must be coupled with tailored management processes. To answer the science questions defined in Priority #1, we must rely on innovation. We currently 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 as they are developed. Therefore, we have identified four innovation strategies to enable both incremental steps and giant leaps in knowledge.

As research has shown, diversity is a key driver of innovation and more diverse organizations are more innovative. We will address this important aspect of innovation in Priority #4.

STRATEGY 2.1

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

Measured risk-taking is a necessary part of progress and SMD seeks to create an environment in which risk-taking is encouraged and transparently managed. To do this, SMD will develop a coherent and strategic Directorate-wide innovation ecosystem, including early stage technology identification, technology development and maturation, and ultimately transition to flight. We recognize that not all innovation will be successful, and that room for experimentation and failure should be allowed during the developmental process.

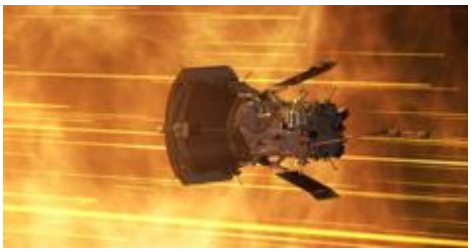

Photo Credit: *NASA's Goddard Space Flight Center*
NASA's Parker Solar Probe employs a revolutionary heatshield capable of withstanding temperatures of nearly 2,500° F. This innovation enables the probe to venture closer to our Sun than ever before, orbiting within the outer atmosphere as close as 3.8 million miles to the star's surface.

While the importance of innovation and experimentation is significant, proactive communication about the risks associated with a particular mission concept, early investments in technology development, and other risk reduction efforts are 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 SMD enterprise. In the future, SMD seeks grow innovation through both its competed and directed work by using a portfolio-level approach. Allowing SMD to take varying risk postures between missions, depending on their scale, and tailor management processes accordingly. For competitive opportunities, SMD must encourage and reward proposers for novel approaches towards scientific discovery, when they are accompanied by realistic risk maturation processes. In addition, clear lines of authority and accountability for risk-related activities are necessary for proper management.

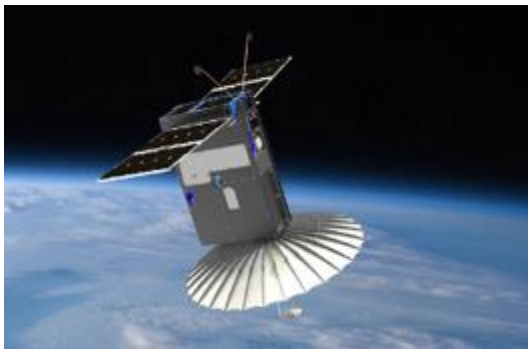

Photo Credit: *Tyvak/Jonathan Sauder/NASA/JPL-Caltech*
In-space technology demonstrations such as NASA's Radar in a CubeSat (RainCube) allow SMD to increase technology readiness and supports risk reduction for future missions.

Innovative management of an executable, compelling and exciting portfolio is accomplished by balancing both large and directed missions with medium to small-sized and competed missions. The selection of missions with a determined cadence and cost-cap engages the scientific community to present impactful and diverse ideas to meet emerging priorities. Sound planning prevails as missions exist in various stages of formulation - development, prime operations, and extended operations - wherein high return on investment has been proven. Finally, effort is leveraged between missions, research and analysis, technology and supporting infrastructure.

STRATEGY 2.2

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

SMD is a learning organization that 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, SMD 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.

SMD 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 as well as reassessing how the current peer review process evaluates 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. SMD must remain flexible in its mission design approach to enable enhanced collaborations with other government agencies and the commercial sector to best take advantage of these new modalities.

Photo Credit: *NASA's Scientific Visualization Studio*
NASA's Global-scale Observations of the Limb and Disk (GOLD) instrument is hosted by a commercial communications satellite, operated by SES Government Solutions. GOLD is examining the response of the upper atmosphere to interactions with the Sun, magnetosphere and the lower atmosphere.

SMD is actively pursuing opportunities to host science instruments on commercial satellites. These opportunities enable NASA to secure lower-cost access to space while leveraging existing commercial capacity, demand, and expertise. Similarly, SMD actively searches for opportunities where commercial entities enable different capabilities (new launches, research platforms, etc.) or new, service-based business models. In all cases, the criteria for collaboration include "enabling new science", or resulting in "more science per dollar". To find such novel partnership, experimentation is key.

PRIORITY 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 SMD's mission.

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

Scientific discovery does not occur in isolation and SMD directly supports the U.S. researchers in their pursuit of knowledge. SMD 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, SMD has an opportunity to partner with other U.S. agencies to help further national interests in a coordinated and efficient manner.

Photo Credit: *National Academies of Sciences, Engineering, and Medicine*
Implementation of the 2017 Earth Science Decadal Survey encouraged the development of interagency, commercial and international 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.

SMD seeks to strategically engage with NASA Centers to implement SMD programs and projects, requiring knowledge of the health and capabilities at each NASA Center. SMD and Center leadership will create a shared understanding of the important technical capability priorities for each center that are renowned within the community. These prioritized capabilities will guide focused investment decisions at the portfolio level. SMD will ensure that roles and responsibilities are assigned in alignment with each Center's

unique strengths and ability to manage work. SMD is also engaged in activities that develop both talent and technical capabilities at the Centers to ensure that future needs can be met. NASA Centers should be seen as “employers of choice” that attract recent graduates and mid-career scientists and engineers, and also provide exchange and career growth opportunities for employees.

SMD is actively working in concert with NASA Centers to build and manage directed missions and well as to ensure a robust research and analysis (R&A) program and maintain the competitiveness of the Centers to develop proposals for PI-led missions, with PIs originating in the entire community.

STRATEGY 3.2

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

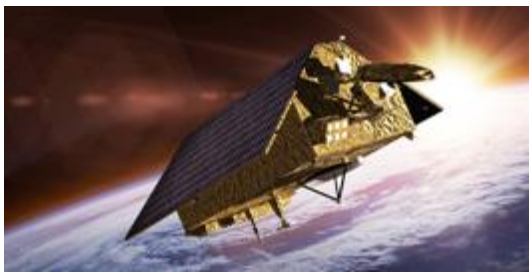

Photo Credit: *NASA/ESA*
As a testament to the strength of the partnership between the U.S. and Europe, the first of two identical Sentinel-6 satellites in ESA’s Sentinel mission, Sentinel 6-Michael Freilich, was named in honor of NASA’s former Earth Science Division director.

Scientific discovery is a global endeavor and SMD empowers the scientific community worldwide. With growing international interest in space exploration, the competition for partnerships among space agencies is increasing. In addition, we are aware of and informed by the context of economic competitiveness issues and national security concerns in the areas in which we work. We seek to be the partner of choice in Earth and space science and to contribute to the nation’s diplomacy goals. To that end, we will continue to actively seek strategic partnerships with traditional, new and emerging international partners and entities based on their unique capabilities and our shared goals for science excellence. While demonstrating U.S. leadership in Earth and space science is sine qua non for SMD, NASA should not always have the primary responsibility for a science mission; decisions on mission leadership should be based on each partners’ capabilities and resources to advance scientific discovery.

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.

SMD continually and strategically evolves partnerships with other organizations across the federal government in pursuit of common interests and priority. These partnerships can take several different forms, from enabling new missions, to improving our understanding of common areas of study. They also facilitate the transfer of knowledge between agencies to enhance our overall contribution to the Nation. In all cases, our interests may evolve over time

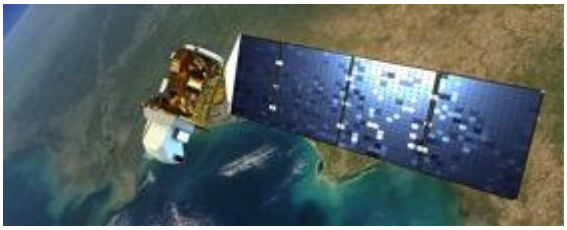

Photo Credit: *NASA*
The Landsat satellites, a partnership between NASA and the U.S. Geological Survey, have provided an uninterrupted space-based data record of the Earth’s land surface since 1972 to help advance scientific research towards understanding our changing planet.

to ensure continued alignment to national and Agency priorities, and to capitalize on each partner's unique strengths.

STRATEGY 3.4

Provide increasing opportunities for research institutions, including academia and non-profits, to contribute to SMD's mission

The vibrant research community across the United States is already making significant contributions to answer the science questions defined in Priority #1 through NASA's missions and grants. The research community is the major source of new science questions and innovative mission 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.

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 will increase that support by actively encouraging students and early career researchers to take a more hands-on engagement with our missions and research. We will also increase partnerships across institutions to provide additional opportunities for engagement and increasing diversity of thought. Together, these efforts align to support the development of a more diverse future workforce directly advancing SMD's mission.

STRATEGY 3.5

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

SMD 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. 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.

PRIORITY 4
INSPIRATION

STRATEGY 4.1: Increase the diversity of thought and backgrounds represented across the entire SMD 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.

SMD 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 Priority #3. We therefore build opportunities to encourage as wide an audience as possible to engage in our work. Research shows that diverse teams maximize an organization's potential for innovation. SMD therefore seeks to increase the diversity of talent contributing varied viewpoints and approaches across all elements of our work. Our goal is to reduce barriers to entry, in order to allow people of all ages and backgrounds to join us for the benefit of the entire scientific and engineering community, as well as the world. While we do not have complete answers to engaging people of diverse backgrounds, we are committed to the goal of intentionally including all by reducing barriers, increasing access, and treating everyone equitably across the entire science community ecosystem.

STRATEGY 4.1

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

Photo Credit: *NASA*
SMD interns tour the NASA Centers to learn more about the groundbreaking innovative programs taking place across the Agency.

SMD believes in the importance of diverse and inclusive teams to tackle strategic problems and maximize scientific return. SMD is therefore investing in its people to increase the diversity and inclusivity of its teams, both internal and external to NASA, to provide equitable opportunities for personal development and growth.

SMD is taking a strategic approach to managing its workforce, strengthening recruitment practices and identifying leadership development opportunities as ways to grow a more diverse and stronger organization. SMD is a strong supporter of programs that provide students and recent graduates with opportunities to work with, and learn from leaders in their chosen fields. Such programs not only benefit SMD, but strengthen the overall community in which we work.

SMD is also investing in students and early career faculty to help them grow into leaders of the future. SMD has been particularly focused on developing a new cadre of mission Principal Investigators through workshops and hands-on training as part of existing mission teams. Long-duration missions, such as Discovery and New Frontiers missions, provide a unique opportunity to develop future leaders from within the team, and are assessed on the robustness of teams over the lifetime of the mission.

SMD recognizes the importance of creating inclusive environments so that everyone can participate equitably. People must feel safe, valued, and included before they are comfortable contributing to the team. We have therefore initiated several efforts designed to address the problem of harassment within the scientific community. For example, we have introduced new tools that address systemic disparities by reducing unconscious and implicit bias.

STRATEGY 4.2

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

SMD creates value by transforming taxpayer investments into knowledge, about the many worlds around us and our place in them, that is used to solve problems and create a better future. But knowledge is only advanced when it is shared using the rigorous processes that science affords – replicability, peer-evaluation, publication, civil discourse, and the creation of new questions. The public should have confidence in NASA's findings, particularly when that information concerns them, their families, communities and the world at large.

SMD's achievements inspire learners of all ages. One of our goals is for learners across the U.S. to become architects of their own life-long learning pathways. Through collaborations with community-based partnerships and using transdisciplinary, digital tools and real-world experiences, we can enable learners to participate in the advancement of knowledge.

Photo Credit: *NASA/Aubrey Gemignani*
SMD coordinated space and ground observations of the August 21, 2017 total solar eclipse, allowing scientists to safely take advantage of a research opportunity. Eighty-eight percent of all U.S. adults shared in the experience of the first total solar eclipse to cross the continental United States in almost 100 years.

SMD reaches the American public and beyond by sharing its science and encouraging greater public understanding of its missions, research, and related activities. We disseminate science results to elevate awareness, excitement, and understanding. We do this using techniques such as storytelling to help connect the work that NASA does to people's everyday lives. We recognize that communication channels change and evolve with time, and thus our communication – just like our research – needs to be innovative and incorportate lessons learned into current practice and future plans.

SMD also encourages opportunities for new engagements, such as in citizen science projects. Through these programs, volunteers can directly participate in data analysis, observations, and problem solving, thereby contributing to NASA's science mission and the overall advancement of knowledge.

Implementation

SMD focuses on excellence as a deliberate activity, supported by governing processes and behaviors across the entire portfolio. As highlighted throughout the document, implementation efforts are ongoing and will continue to be evaluated for their success in advancing the priorities described earlier. 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. A dashboard of major milestones will be developed and posted publicly on the SMD website to share with the community both implementation details and our progress in meeting them. The dashboard is intended to evolve over time in response to changing opportunities and needs.

Appendix A: Acronym List

CLPS	Commercial Lunar Payload Services
COR	Cosmic Origins
ESA	European Space Agency
ESD	Earth Science Division
ExEP	Exoplanet Exploration
GOLD	Global-scale Observations of the Limb and Disk
GPS	Global Positioning System
HEOMD	Human Exploration and Operations Mission Directorate
MRO	Mars Reconnaissance Orbiter
NASA	National Aeronautics and Space Administration
NASEM	National Academies of Sciences, Engineering, and Medicine
NSF	National Science Foundation
PCOS	Physics of the Cosmos
PI	Principal Investigator
PSD	Planetary Science Division
R&A	Research and Analysis
RainCube	Radar in a CubeSat
ROSES	Research Opportunities in Space and Earth Science
SMD	Science Mission Directorate
STScI	Space Telescope Science Institute
STMD	Space Technology Mission Directorate
TESS	Transiting Exoplanet Survey Satellite
USGS	United States Geological Survey
VIPER	Volatiles Investigating Polar Exploration Rover


NASA
EXPLORE
with us