COMMITTEE ON
SCIENCE, SPACE AND TECHNOLOGY
CHAIRMAN FRANK LUCAS

SPACE AND AERONAUTICS SUBCOMMITTEE

HEARING CHARTER

"Advancing Scientific Discovery: Assessing the Status of NASA's Science Mission Directorate"

Thursday, March 21, 2024
10:00 AM
2318 Rayburn House Office Building

Purpose

The purpose of this hearing is to review the National Aeronautics and Space Administration's current and future activity across the Science Mission Directorate as well as to explore the Agency's management of these missions. The hearing also provides an opportunity to discuss ongoing challenges to addressing decadal survey priorities.

Witnesses

- **Dr. Nicola Fox,** Associate Administrator, Science Mission Directorate, National Aeronautics and Space Administration
- **Mr. George A. Scott,** Acting Inspector General, National Aeronautics and Space Administration
- **Dr. Jonathan I. Lunine,** The David C. Duncan Professor in the Physical Sciences, Cornell University
- **Mr. A. Thomas Young,** Former Director, Goddard Space Flight Center and Former President and COO, Martin Marietta Corp.

Overarching Questions

- What is the optimal "balance" for the Science Mission Directorate's portfolio of programs and projects, including balance between mission types and balance between different Science divisions?

- What lessons has NASA learned from executing major Science Mission Directorate missions in the past, particularly related to cost, schedule, and performance, and how is NASA applying these lessons learned to new and ongoing Directorate activities?

- How can the Science Mission Directorate leverage its diverse network of domestic and international partners to help mitigate the effects of resource constraints on NASA science activities?

Background

NASA's Science Mission Directorate (SMD) seeks to discover the secrets of the Universe, search for life in the Solar System and beyond, and protect and improve life on Earth and in space.[1] Scientific research has been a key tenet of NASA's mission since the Agency's founding. The National Aeronautics and Space Act of 1958 established "the expansion of human knowledge of phenomena in the atmosphere and space" as one of the Agency's eight objectives.[2] Through the NASA Transition Act of 2017, Congress expanded the scope of NASA's objectives to include "the search for life's origin, evolution, distribution, and future in the universe."[3] More recently, in 2023, the Agency stated that "science is the foundation of the agency's Moon to Mars exploration approach," highlighting the centrality of science to NASA's activity and missions.[4]

SMD supports a range of basic and applied research efforts to expand our understanding of naturally occurring space and Earth phenomena, as well as human-induced changes in the Earth system. The directorate also looks farther out into space, studying our galaxy and the universe beyond. SMD primarily focuses on fundamental questions and challenges, but its research also provides insight for other directorate activities and serves as the foundation for future exploration. Not only does SMD research advance space discovery, but it also leads to breakthroughs in fundamental science that have implications for research and technology back on Earth.

SMD strives to maintain a diverse, balanced mission portfolio that includes flight missions, research and analysis, and technology development and applications. Accordingly, SMD utilizes a measured risk-taking approach, allowing NASA to take varying risk postures between missions and foster innovation in a transparent manner. SMD also cultivates entrepreneurialism in its research community. For example, NASA opened the I-Corps program, which works to translate fundamental research into the commercial marketplace, to its research community.[5]

In addition to operating more than 80 spacecraft in locations from low-Earth orbit (LEO) to beyond our solar system, SMD utilizes high-altitude ballons, sounding rockets, and suborbital spacecraft for its research needs. SMD also frequently uses capabilities offered by the International Space Station (ISS), taking advantage of the micro-gravity environment to conduct continuous and interactive research similar to Earth-based laboratories. SMD also uses terrestrial science facilities across the country, including Ames Research Center (Moffett Field, CA);

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[1] NASA, *Science 2020-2024: A Vision for Scientific Excellence*, (September 1, 2023), https://smd-cms.nasa.gov/wp-content/uploads/2023/09/2020-2024-nasa-science-plan-yr-23-update-final.pdf
[2] P.L. 85-567
[3] P.L. 115-10
[4] *Id.* at 1
[5] *Id.* at 1

Armstrong Flight Research Center (Edwards, CA); Glenn Research Center (Cleveland, OH); Goddard Space Flight Center (Greenbelt, MD); and Langley Research Center (Hampton, VA).

Science Mission Directorate Funding

The Fiscal Year 2025 (FY25) President's Budget Request (PBR) proposes $7.56 billion for SMD, a decrease of 3 percent, or $229 million, from FY2024 enacted funding.[6] This funding enables missions and technology development along with grants which support approximately 10,000 U.S. scientists.[7] Notably, the PBR states that "SMD uses [the National Academies' decadal surveys] recommendations to prioritize future flight missions (including space observatories and probes), as well as technology development and proposals for theoretical and suborbital supporting research."[8] The NASA funding for SMD between FY20 and FY24 as well as the budget request for FY2025, including the out years, are detailed in appendix A.

Decadal Process

NASA's scientific priorities are informed by decadal surveys conducted by the National Academies of Science, Engineering, and Medicine (NASEM). Decadal surveys are independent assessments that consider Earth and space science discipline fields and aeronautics research and recommend priorities for research and programmatic areas over the next decade.[9] The decadal surveys consider inputs from the scientific community, life cycle costs, technical readiness of missions, and more. Appendix B provides a summary of the programs prioritized for each division by its most recent corresponding decadal.

NASEM published the first decadal survey on astronomy in 1964.[10] As of 2023, NASEM has issued decadal surveys relevant to each of the SMD divisions, including the first decadal survey for Biological and Physical Sciences.[11] NASA acts as the lead in this process, but NASEM considers inputs from a range of agencies, including the National Science Foundation, the Department of Energy, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey.

The most recent decadal survey for each SMD division is as follows:

- Earth Science – *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space* (2018).[12]
- Planetary Science – *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032* (2022).[13]

[6] NASA, Fiscal Year 2025 Budget Request, (March 11, 2024), https://www.nasa.gov/fy-2025-budget-request/
[7] NASA, About NASA Science, https://science.nasa.gov/about-us
[8] NASA, FY 2025 Agency Fact Sheet, (March 11, 2024), https://www.nasa.gov/fy-2025-budget-request/
[9] 51 USC § 20305
[10] National Academy of Sciences, *Ground-based Astronomy: A Ten-Year Program*, The National Academies Press, (1964), https://doi.org/10.17226/13212
[11] Joseph K. Alexander, *Science Advice to NASA: Conflict, Consensus, Partnership, Leadership*, NASA Office of Communications, NASA History Division, Monographs in Aerospace History, No. 57, (2017)
[12] National Research Council, *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space*, The National Academies Press, (2018), https://doi.org/10.17226/24938
[13] National Research Council, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*, The National Academies Press, (2023), https://doi.org/10.17226/26522

- Astrophysics – *Pathways to Discovery in Astronomy and Astrophysics for the 2020s* (2021).[14]
- Heliophysics – *Solar and Space Physics: A Science for a Technological Society* (2013).[15]
- Biological and Physical Sciences – *Thriving in Space: Ensuring the Future of Biological and Physical Sciences Research* (2023).[16]

Science Mission Directorate Divisions

SMD is comprised of five divisions, as follows: Earth Science; Planetary Science; Astrophysics; Heliophysics; and Biological and Physical Sciences.

Earth Science

The Earth Science Division exists "to advance knowledge of Earth as a system in order to meet the challenges of environmental change and to improve life on our planet."[17] The Division seeks to understand natural and human influences on the Earth and how they interact with one another. Earth Science studies a range of Earth cycles and processes, such as the water cycle and the movement of heat, to build a more comprehensive understanding of the processes that impact Earth as a system. Earth Science also translates these observations into data that can be used for terrestrial benefit, seeking "to deliver actionable Earth science to decisionmakers at every level."[18]

The Division operates more than 20 spacecraft on-orbit and 7 instruments on the ISS.[19] Earth Science also utilizes airborne and ground-based assets for its activities. Earth Science research falls into one of the following focus areas:

- *Atmospheric Composition* – research on Earth's atmosphere, including its chemical and physical properties, Earth's energy budget, and air quality.
- *Weather and Atmospheric Dynamics* – research on the dynamics of the atmosphere to improve our understanding of the fundamental processes that drive weather.
- *Climate Variability and Change* – measures and models Earth's dynamic systems and how they change over time.
- *Water and Energy Cycle* – research to improve our understanding of the global water cycle.
- *Carbon Cycle and Ecosystems* – detects, explains, and predicts changes in Earth's ecosystems, biogeochemical cycles, biodiversity, and land cover.
- *Earth Surface and Interior* – research and analysis of solid-Earth processes from crust to core.[20]

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[14] National Research Council, *Pathways to Discovery in Astronomy and Astrophysics for the 2020s*, The National Academies Press, (2023), https://doi.org/10.17226/26141
[15] National Research Council, *Solar and Space Physics: A Science for a Technological Society*, The National Academies Press, (2013), https://doi.org/10.17226/13060
[16] National Research Council, *Thriving in Space: Ensuring the Future of Biological and Physical Sciences Research*, The National Academies Press, (2023), https://doi.org/10.17226/26750
[17] NASA, NASA Earth Science, https://science.nasa.gov/earth-science/
[18] *Id.* at 1
[19] NASA, Earth Science Missions, https://science.nasa.gov/earth-science/missions/earth-missions/
[20] *Id.* at 14

Planetary Science

NASA's Planetary Science Division seeks to understand the solar system, and the distribution of life within the solar system, through observation and discovery of complex planetary worlds and objects. Planetary Science missions also support and inform human exploration efforts. More specifically, the Division's "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."[21] Beginning with the launch of Mariner 2 to Venus in 1962, a NASA instrument has visited every planet in our solar system, along with a variety of small space bodies.

Planetary Science divides missions into three categories (Flagship, New Frontiers, and Discovery) based on the mission size. Each mission category operates on a different cadence with distinct cost caps. The guidelines for each mission category are as follows.[22]

- *Flagship*: Large missions that address broad, high-priority science objectives. Unlike New Frontiers and Discovery class missions which are led by principal investigators, Flagship missions are managed by a NASA center or office.

- *New Frontiers*: Medium missions intended to bridge the gap between Discovery and Flagship missions. They're intended to launch every 60 months with a $850 million cost-cap per mission excluding launch vehicle, mission operations, data analysis or partner contributions.

- *Discovery*: Small, rapid cadence missions with limited scope. They're intended to launch every 36 months with a $450 million cost-cap per mission excluding launch vehicle mission operations, data analysis or partner contributions.

These missions often require complex technologies that regularly push the limits of spacecraft and robotic engineering. For example, in 2023, the Origins, Spectral Interpretation, Resource Identification, and Security – Regolith Explorer (OSIRIS-Rex) mission traveled to an asteroid passing near Earth, collected samples, and returned to Earth for the first time.[23] Presently, the Division operates spacecraft on Mars, Jupiter, and the Moon, as well as the Lucy mission heading for the Trojan asteroids.[24]

SMD also houses NASA's Planetary Defense Coordination Office,[25] which is tasked with providing a better understanding of near-Earth objects (NEOs) by tracking, cataloging, characterizing, and identifying potential hazards. In 2005, Congress directed NASA to evaluate methods for detecting and tracking NEOs, leading to the Near-Earth Object Surveyor Space Telescope (NEO Surveyor) mission.[26] Currently under development, the NEO Surveyor will support NASA's planetary defense effort by identifying asteroids, comets, and other objects that

[21] *Id.* at 1
[22] NASA, Unlocking the Mysteries of the Solar System, https://www.nasa.gov/planetarymissions/planetary-mission-program-overview/
[23] NASA, Origins, Spectral Interpretation, Resource Identification, and Security – Regolith Explorer (OSIRIS-Rex), https://science.nasa.gov/mission/osiris-rex/
[24] *Id.* at 1
[25] NASA, Planetary Defense Coordination Office, https://science.nasa.gov/planetary-science/programs/planetarydefense/
[26] NASA, Near-Earth Object Survey and Deflection Analysis of Alternatives, (March 2007), https://www.nasa.gov/wp-content/uploads/2015/01/171331main_NEO_report_march07.pdf

could present a threat to Earth.[27] The office also considers mitigations for any potential threat caused by NEOs. In 2022, NASA completed a Double Asteroid Redirection Test (DART) to demonstrate a method for deflecting an asteroid through kinetic impact.[28]

Astrophysics

Complementing the Planetary Science Division's research within the solar system, the Astrophysics Division concentrates on the universe beyond it. The Astrophysics Division expands humanity's understanding of how the universe began, how the universe works, and how the universe is evolving, as well as whether there are places in the universe which are capable of supporting life.[29] The Division contains three science themes: Physics of the Cosmos (PCOS), Cosmic Origins (COR), and Exoplanet Exploration (ExEP).[30] There are also two cross-cutting programs, Astrophysics Explorer Program and Astrophysics Research Program, which conduct activities across the three themes.

- *Physics of the Cosmos* – understanding the makeup of energy, space and time, and how they behave in extreme physical conditions through the study of cosmology, high-energy astrophysics, and fundamental physics projects that directly address questions regarding astrophysical phenomena.
- *Cosmic Origins* – understanding the origination and history of the universe, and how stars, galaxies, and planets are formed over time.
- *Exoplanet Exploration* – discovering and characterizing planetary systems and Earth-like planets around nearby stars with the ultimate goal of discovering habitable planets and evidence of life.
- *Astrophysics Explorers* – opportunities for principal-investigator led, small and medium class Astrophysics missions for focused scientific investigations and missions to address scientific gaps not filled by larger missions.
- *Astrophysics Research* – sponsored research programs for theoretical research and applied technology investigations.

SMD operates a fleet of space-based observatories that can look across billions of light years, including the Hubble Space Telescope, the James Webb Space Telescope, and the Fermi Gamma-ray Space Telescope. While these observatories require substantial investment in both time and resources, they provide researchers with cutting edge capabilities. During its first year of operations, James Webb Space Telescope observations challenged the existing ideas regarding the evolution of the universe during its infancy.[31] Several of these assets have continued to produce high-quality data well beyond their original missions.[32]This technological overperformance combined with a budget-constrained environment have created a dilemma for NASA, forcing hard decisions on whether to continue extending the lifespan of older, yet reasonably well-functioning instruments at the cost of new programs, or end the missions and

[27] NASA, NEO Surveyor, https://science.nasa.gov/mission/neo-surveyor/
[28] NASA, Double Asteroid Redirection Test (DART), https://science.nasa.gov/mission/dart
[29] *Id.* at 1
[30] *Id.* at 1
[31] Tereza Pultarova, *The James Webb Space Telescope discovers enormous distant galaxies that should not exist*, Space.com, (February 22, 2023), https://www.space.com/james-webb-space-telescope-giant-distant-galaxies-surprise
[32] NASA, NASA Response to the 2022 Astrophysics Senior Review of Operating Missions, (August 5, 2022), https://smd-cms.nasa.gov/wp-content/uploads/2023/04/NASAs_Response_SR2022_Final_Tagged.pdf

fund the next generation of technologies. Smaller Pioneer, Explorer, and Probe missions along with airborne and ground-based assets accompany the large strategic missions.

Heliophysics

NASA's Heliophysics Division studies the nature of the Sun and how it influences space, including the effect of the Sun on planets and technology. The Sun constantly releases particles and energy, resulting in a solar atmosphere that extends well beyond our solar system and on to interstellar space. The Heliophysics Division operates a fleet of spacecraft throughout the heliosphere to observe the near and far-reaching effects of the Sun. For example, the Parker Solar Probe became the first spacecraft to fly through the Sun's upper atmosphere in 2021. The probe progressively moves closer to the sun with each orbit, providing scientists with unprecedented observations and data on the behavior of solar wind.[33]

Along with improving our understanding of the Sun, heliophysics research helps protect technology on Earth, as well as astronauts and spacecraft in space. Extreme space weather can damage electronics and interfere with communications, satellites, and power grids.[34] Efforts to properly plan for and mitigate the negative effects of space weather rely on research performed by the Heliophysics Division.

Biological and Physical Sciences

SMD's fifth division, Biological and Physical Sciences, was added in 2020 and took over activities previously managed by the Human Exploration Organization Directorate's Space Life and Physical Sciences Research and Applications Division.[35] The mission of the new division is "to lead the world in fundamental space-based research, pioneer transformational discoveries, enable sustained human space exploration, and improve life on Earth and in space."[36]

The Biological and Physical Sciences Division studies phenomena in the spaceflight environment in a way that is not possible on Earth. Division activities include:

- *Space Biology Program* – research using the space environment to understand the impacts of gravity on living organisms and how biological systems react to spaceflight environments.
- *Physical Sciences Program* – research using the space environment to improve understanding of physics and engineering science, and to understand how physical systems respond to space conditions, such as weightlessness and partial gravity.
- *Commercially Enabled Rapid Space Science Project* – collaborative effort with the commercial space industry to develop transformative research capabilities.

The Division uses a range of instruments, including ground-based facilities, and assets in both suborbital and low-Earth orbit locations. The most critical asset is the ISS, which provides the Division with access to a micro-gravity facility that is similar to terrestrial laboratories. For

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[33] NASA, Parker Solar Probe, https://science.nasa.gov/mission/parker-solar-probe/
[34] NASA, NASA Heliophysics, https://science.nasa.gov/heliophysics
[35] NASA, *A New Home for NASA's Biological and Physical Sciences Research*, (October 15, 2020), https://science.nasa.gov/science-research/biological-physical-sciences/a-new-home-for-nasa-s-biological-and-physical-sciences-research/
[36] NASA, Biological and Physical Sciences Division Overview, (2023), https://science.nasa.gov/wp-content/uploads/2020/08/bps-overview-handout-2023-11.pdf?emrc=65e8d384d934d

example, ISS research addresses human disease and aging, informs the development of quantum technologies, and contributes to the development of novel materials.[37] Biological and Physical Division research is critical to enabling the safety and productivity of future long duration human space exploration.

SMD Partnerships

SMD often works in tandem with other departments within NASA, other federal agencies, nongovernmental partners, and international partners to accomplish its many objectives. NASA has taken steps to expand interdisciplinary research opportunities, including between the divisions of SMD. For example, NASA's research coordination network to study planetary habitability, Nexus for Exoplanet System Science (NExSS), has "created a framework for an unprecedented collaboration among the […] science communities supported by [SMD]."[38] Since discoveries in one field often have nexus to the work of other divisions, this collaboration amplifies the impact of any individual research effort.

SMD also engages with other NASA mission directorates. Often, there is overlap between the science objectives SMD seeks to address and the underlying research that must be completed to facilitate objectives in other directorates, and the two directorates are able to collaborate. For example, SMD signed a Memorandum of Understanding (MOU) with NASA's Space Technology Mission Directorate (STMD) to formalize a process for increasing collaboration and avoiding duplication of the directorate's technology programs that are mutually beneficial for both STMD and SMD.[39]

Outside of NASA, SMD forms partnerships with other federal agencies, foreign governments, and non-governmental entities. Partnerships with other government agencies are critical to avoid duplicative efforts, ensure effective use of limited resources, and support the transfer of knowledge and technology between Federal agencies with different applications. NASA collaborates closely with NSF, NOAA, USGS, FAA and other agencies on a number of projects. Reimbursable agreements facilitate these inter-agency partnerships. For example, NASA's Joint Agency Satellite Division (JASD), located under SMD, facilitates NASA's partnership with NOAA to develop, launch, and operate satellite programs on a reimbursable basis.[40]

Beyond the federal government, international partnerships are involved in two-thirds of SMD missions.[41] SMD is partner to approximately 350 active international agreements across 140 countries and regions. For example, in 2021, SMD issued a Request for Information (RFI) seeking programs that both advanced science while also promoting NASA best practices and values to emerging international partners.[42] The benefits of these international partnerships are both scientific and diplomatic. International partnerships allow for cost-sharing on mutually beneficial projects and demonstrate the benefits of the American model of space exploration. But notably, they require SMD to accept greater risk owing to the partner's performance.

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[37] *Id.* at 1
[38] NExSS, About NExSS, https://nexss.info/about/about-nexss/
[39] *Id.* at 1
[40] NASA, Joint Agency Satellite Division, https://science.nasa.gov/about-us/smd-programs/joint-agency-satellite-division
[41] *Id.* at 1
[42] NASA, *Implementation and Changes to Science Policy Document (SPD)-41: Science Information Policy*, (November 19, 2021), SPD-41 RFI

Collaboration with the private sector takes on several forms. SMD utilizes traditional contractor relationships and public-private partnerships to advance NASA's science objectives and build on private sector investments. For example, through Venture-Class Acquisition of Dedicated and Rideshare (VADR) missions, SMD "is actively pursuing opportunities to host science instruments on commercial satellites."[43] These partnerships also facilitate cooperation on shared challenges, such as orbital debris mitigation.

<u>Mars Sample Return Program</u>

As part of NASA's Mars Sample Return Campaign, the Mars Sample Return (MSR) program plans to retrieve samples collected by the agency's Mars Perseverance rover from the Martian surface and return them to Earth between 2030 and 2031.

The MSR program continues to receive growing attention, particularly as it approaches its Key Decision Point-C (KDP-C) review, planned for March 2024. In 2023, an Independent Review Board (IRB) assessment of the MSR program raised concerns about the program's affordability and schedule.[44] The IRB report assigned an unofficial cost estimate of $7.4 billion for the program, over double the cost estimate attached to the program at the time of the review. The NASA Office of Inspector General (OIG) issued its own audit report on the program in February 2024 that highlighted MSR's cost and schedule estimation challenges and warned that the program's actual cost may grow to between $8 and $11 billion.[45]

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[43] *Id.* at 1

[44] NASA, Mars Sample Return Independent Review Board-2 Final Report, (September 1, 2023), https://www.nasa.gov/wp-content/uploads/2023/09/msr-irb-report-final-copy-v3.pdf?emrc=65e19c1cd16af

[45] NASA OIG, Audit of the Mars Sample Return Program, IG-24-008, (February 28, 2024), https://oig.nasa.gov/docs/IG-24-008.pdf

Appendix A

NASA SMD funding for FY20 to FY24

Table 1. NASA Budget Authority, FY2019-FY2024
(in $ millions)

	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024
Science	**$6,887**	**$7,143[a]**	**$7,291**	**$7,611**	**$7,792**	**$7,334**
Earth Science	1,931	1,972	1,997	2,061	2,175	2,195
Planetary Science	2,747	2,713	2,693	3,120	3,217	2,717
Astrophysics	1,191	1,306	1,356	1,394	1,510	1,530
James Webb Space Telescope	305	423	415	175	—[b]	—[b]
Heliophysics	713	725	751	778	805	805
Biological and Physical Sciences[c]	—	5	79	83	85	88

NASA SMD funding request for FY25 to FY29

	Fiscal Year						
Budget Authority ($ in millions)	**Op Plan 2023**	**CR 2024**	**Request 2025**	**2026**	**2027**	**2028**	**2029**
Science	**7,791.5**	**7,795.0**	**7,565.7**	**7,717.0**	**7,871.3**	**8,028.7**	**8,189.3**
Earth Science	**2,175.0**	--	**2,378.7**	**2,396.3**	**2,446.1**	**2,489.7**	**2,543.4**
Planetary Science	**3,216.5**	--	**2,731.5**	**2,850.5**	**2,911.6**	**2,976.8**	**3,042.5**
Astrophysics	**1,510.0**	--	**1,578.1**	**1,587.0**	**1,613.6**	**1,647.1**	**1,673.4**
Heliophysics	**805.0**	--	**786.7**	**791.9**	**807.0**	**820.3**	**833.4**
Biological and Physical Sciences	**85.0**	--	**90.8**	**91.3**	**93.0**	**94.8**	**96.6**

Appendix B

Earth Science Division Decadal Priorities

Program	Notes
Designated Observables	A program element for cost-capped, competed or directed, medium- and large-size missions to address observables essential to the overall program: aerosols; clouds, convection, and precipitation; mass change; surface biology and geology; and surface deformation and change.
Earth System Explorer	A new program element for competitive, cost-capped medium-size instruments and missions targeting: Greenhouse gases, Ice elevation, Ocean surface winds and currents, ozone and trace gases, snow depth and snow water equivalent; and terrestrial ecosystem structure.
Incubation	A new program element focused on investment for capabilities for priority observations: atmospheric winds, planetary boundary layer, and surface topography and vegetation, with an innovation fund to respond to emerging needs
Earth Venture	Add a new "Venture-continuity" component to the existing Earth Venture program element.

Planetary Science Division Decadal Priorities

Large (Flagship) Mission Priorities	
Program	**Notes**
Uranus Orbiter and Probe (UOP)	Highest-priority new Flagship mission. Optimal launch and cruise times could be achieved with a FY 2024 start of the UOP mission.
Enceladus Orbilander	Viable launch opportunities on existing heavy-lift launch vehicles occur in 2037, 2038, and during the 2040s; these lead to Enceladus landing during favorable south pole illumination and Earth-communication conditions that begin in the early 2050s.
Mars Sample Return (MSR)	The highest scientific priority of NASA's robotic exploration efforts this decade should be completion of Mars Sample Return as soon as is practicably possible with no increase or decrease in its current scope.
Medium (New Frontiers) Mission Priorities	
New Frontiers-6 (NF-6)	NF-6 candidate missions: Centaur Orbiter and Lander; Ceres Sample Return; Comet Surface Sample Return; Enceladus Multiple Flyby; Lunar Geophysical Network; Saturn Probe; Titan Orbiter; and Venus In-Situ Explorer.
New Frontiers-7 (NF-7)	NF-7 candidate missions: All of the above not selected in NF-6 and Triton Ocean World Surveyor.
Planetary Defense	
Rapid Response, Flyby Reconnaissance Mission	The highest priority planetary defense demonstration mission to follow Double Asteroid Redirection Test (DART) and the Near-Earth Object Surveyor should be a rapid-response, flyby reconnaissance mission targeted to a challenging near-Earth object (NEO) population of objects posing the highest probability of a destructive Earth impact.

Astrophysics Division Decadal Priorities

Program	Notes
Space Based	
Time-Domain Program	A program of competed missions and missions of opportunity to realize and sustain the suite of capabilities required to study transient phenomena and follow up multi-messenger events
Infrared/optical/ultraviolet (IR/O/UV) Large Strategic Mission	IR/O/UV telescope for exoplanet characterization and general astronomy. Mission-specific funding to begin mid to late decade, after mission and technology maturation program.
Ground Based	
Extremely Large Telescope (ELT) Program	Federal investment in the U.S. ELT program for the U.S. community. $1.7 billion NSF share of $5.1 billion project.
The Next Generation Very Large Array (ngVLA)	Design, cost trade studies, and prototyping to prepare for construction, which could begin by the end of the decade.

Heliophysics Division Decadal Priorities

Program	Notes
Implement the Diversify, Realize, Integrate, Venture, Educate (DRIVE) Initiative	Includes small satellites, science centers and grant programs, and instrument development.
Accelerate and expand the Heliophysics Explorer Program	Enable Medium Explorer and Mission of Opportunity lines resulting in an increased cadence of one launch every 2-3 years.
Restructure Solar Terrestrial Probes as a moderate-scale, PI-led line	Implement three mid-scale missions meeting the science targets of the following reference missions (priority order): 1. Interstellar Mapping and Acceleration Probe (IMAP) 2. Dynamical Neutral Atmosphere-Ionosphere Coupling (DYNAMIC) 3. Magnetosphere Energetics, Dynamics, and Ionospheric Coupling Investigation (MEDICI)
Implement a large Living with a Star (LWS) Geospace Dynamics Constellation (GDC)-like mission	

Biological and Physical Sciences Division Decadal Priorities

Program	Notes
Bioregenerative Life Support Systems (BLiSS)	To build and understand the systems that would provide high-quality food, refresh air and water, process waste, and enable the creation of space environments sustainable for long periods of time independent of Earth.
Manufacturing Materials and Processes for Sustainability in Space (MATRICES)	To understand and harness the physical processes by which materials and complex fluids can be repeatably utilized in space, to enable sustainable exploration and circular lifecycles for the built environment on Earth and in space.
Biological and Physical Science Free Flyer (BiPS-Free) vehicle	Addresses current constraints of crew-tended, LEO-limited BPS research, including months-long access by non-human living organisms and engineered materials to the gravitational forces and cosmic ray radiation exposure beyond LEO.