Strategic Goals and Strategic Objectives

Theme	Goal Statement	Objective Statement
Discover	Expand human knowledge through new scientific discoveries	1.1: Understand the Earth system and its climate
		1.2: Understand the Sun, solar system, and universe
		1.3: Ensure NASA's science data are accessible to all and produce practical benefits to society
Explore	Extend human presence to the Moon and on towards Mars for sustainable long-term exploration, development, and utilization	2.1: Explore the surface of the Moon and deep space
		2.2: Develop a human spaceflight economy enabled by a commercial market
		2.3: Develop capabilities and perform research to safeguard explorers
		2.4: Enhance space access and services
Innovate	Catalyze economic growth and drive innovation to address national challenges	3.1: Innovate and advance transformational space technologies
		3.2: Drive efficient and sustainable aviation
Advance	Enhance capabilities and operations to catalyze current and future mission success	4.1: Attract and develop a talented and diverse workforce
		4.2: Transform mission support capabilities for the next era of aerospace
		4.3: Build the next generation of explorers

NASA's Aqua satellite captured this true-color image in September 2020, showing the fires in the West, the smoke from those fires drifting over the country, several hurricanes converging from different angles, and Hurricane Sally making landfall. Image Credit: NASA Worldview, Earth Observing System Data and Information System.

STRATEGIC GOAL 1

EXPAND HUMAN KNOWLEDGE THROUGH NEW SCIENTIFIC DISCOVERIES.

Goal Statement

NASA's enduring purpose is scientific discovery and exploration for the benefit of the United States and all of humanity. NASA seeks to discover the secrets of the universe, search for life elsewhere, and protect and improve life on Earth and in space. Finding answers to these profound science questions requires support for national priorities in science and exploration, enhancing new opportunities for cross-disciplinary science, and expanding the societal benefits of our science programs. It also requires continued progress on the scientific priorities, including those identified by the National Academies of Scien ces, Engineering, and Medicine through their decadal surveys.

We will extend our 60-year history of scientific achievements, make groundbreaking discoveries, and transform knowledge of humanity, our home planet, the solar system, and the universe. NASA's missions have not only changed what we know, but also how we think as a society—truly civilization-scale science. NASA's missions and sponsored research provide access to the farthest reaches of space and time and deliver essential information about our home planet, directly improving life here on Earth.

We are undertaking new work that builds on our past successes in individual disciplines to enable a more collaborative environment at the forefront of science and science applications. We are applying those lessons learned and best practices in support of other national needs, including climate change, space weather prediction, and planetary defense. We embrace and thrive on this iterative process that is supportive of evolving national and user needs.

NASA has an open data policy that makes its science data available to all. Current data systems are focused on disseminating data to the science community to support research in five science disciplines: Earth Science, Astrophysics , Planetary Science, Heliophysics, and Biological and Physical Sciences. We plan to undertake investments and initiatives that will make our data more accessible and accelerate its use by the science community. In Earth Science, we are exploring new ways to work with the social science community to integrate NASA data and information with socioeconomic and other kinds of data to provide insights on environmental challenges that disproportionately impact communities of color.

Finally, NASA acts as a global champion of free and open access to scientific data. We collaborate with our partners in a spirit of global engagement and science diplomacy. As more nations seek to use space for scientific investigation, the body of knowledge grows for the benefit of all.

Maintaining America's Global Standing

The activities undertaken within Strategic Goal 1 directly leverage existing and emerging international and domestic partnerships to maintain and expand U.S. leadership in Earth and space science, advancing America's global standing in science and innovation. With over 400 active international partnerships, NASA Science missions are a valuable tool for projecting soft power and for global engagement. In addition to those mission-related agreements, NASA's Global Learning and Observations to benefit the Environment (GLOBE) program and Aerosol Robotic Network programs have a presence in over 100 countries.

These existing NASA partnerships offer an excellent foundation for strengthening and expanding alliances across the world, continuing to model the importance of open and transparent science that benefits all. Further, NASA's continuing leadership in open data and open science serves to champion free and open access to scientific data so that the body of knowledge grows for the benefit of all humankind. NASA also supports and leads international diplomatic efforts in developing global norms of behavior to ensure a safe, secure, and sustainable space environment.

Driving Economic Growth

NASA-funded research, contracts, and Small Business Innovative Research initiatives provide economic benefits across the United States. Likewise, addressing climate change and enabling climate forecasting will contribute to economic growth across the United States.[1]

Addressing Climate Change

NASA's Earth science activities are focused on increasing our understanding of the Earth and its changing climate. NASA's ability to view Earth from the unique vantage point of space provides a broad and integrated set of uniformly high-quality data covering all parts of the planet. These data help inform decision makers across all levels of Government—as well as industry, disaster prevention and response, and agriculture—to make policy and operational decisions to address climate change.

1 https://openknowledge.worldbank.org/handle/10986/35178

Strategic Objective 1.1

Understand the Earth system and its climate.

Integrate and advance knowledge of Earth as a system to meet the challenges of environmental change, strengthen our Nation, and improve life for all people.

Lead Office

Science Mission Directorate (SMD)

Objective Overview

Earth's changing environment impacts every aspect of life on our planet and has profound implications on society and our Nation's well-being. Studying Earth as an integrated, complex system is essential to understanding the causes and consequences of climate change and other global environmental concerns. Based on the increasing body of Earth observation data and corresponding research, we know now that our planet and its climate are profoundly changing. While much remains to be understood about the natural and human-induced processes and the complex coupling at the heart of these changes, one thing is clear: NASA's measurements are critical to their understanding.

Climate adaptation and mitigation efforts cannot succeed without these robust climate observations and research. As the impacts of global climate change become more numerous and acute, the demand for accurate, timely, and actionable knowledge about the Earth system is more pressing than ever. NASA is a world leader in the production of data necessary to understand, model, monitor, and ultimately predict climate and environmental change. NASA is the only organization in the world with an integrated end-to-end program in Earth-observing mission development, launch, operations, technology, research, data systems, and applications.

NASA's measurements and predictive models provide information for decision makers and organizations that work with communities affected by the impacts of changing climate, including information regarding the efficacy of policies and decisions that help the United States and others adapt and thrive on our changing planet. NASA also works with international partner satellites; data from airborne, ship-based, and ground network instrumentation; and outputs from operational weather models from National Oceanic and Atmospheric Administration (NOAA) and other meteorological agencies. NASA integrates and harnesses these disparate data sources, enabling scientists to investigate and solve large questions

Below: Inside the Integrated Processing Facility at Vandenberg Space Force Base in California, United Launch Alliance (ULA) technicians prepare to remove the contamination barrier and access door from the two ULA Atlas V rocket payload fairings for the joint NASA-U.S. Geological Survey Landsat 9 satellite on June 24, 2021. Image credit: NASA/Randy Beaudoin

that cannot be addressed using data from only a single mission or spaceborne instrument.

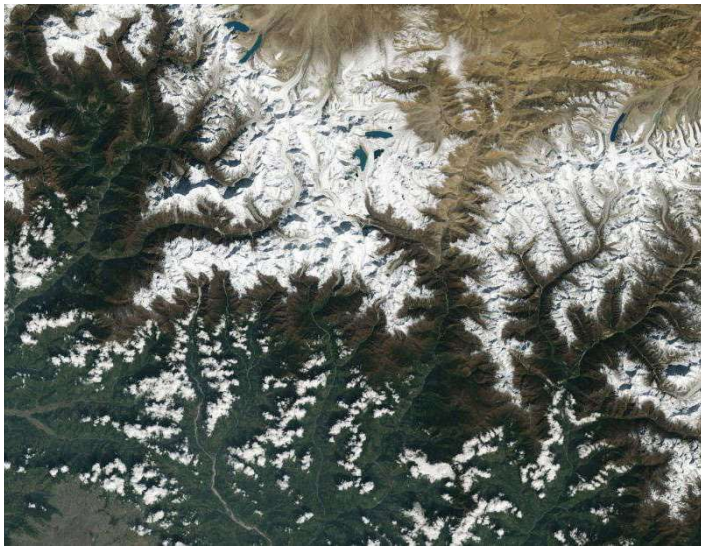
NASA Earth Science projects explore our rapidly changing world, where natural and human factors interact, following an interdisciplinary, Earth systems approach that examines the interplay among the atmospheric, ocean, land, and ice systems. Using the recommendations of the National Academies' 2017-2027 decadal survey for Earth science and applications from Space[1] as a compass, and informed by Government-wide priorities, 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:

- Atmospheric Composition
- Weather and Atmospheric Dynamics
- Climate Variability and Change
- Water and Energy Cycle
- Carbon Cycle and Ecosystems
- Earth Surface and interior

Implementation is achieved through a balanced portfolio of programs as articulated in the SMD's Science Strategy[2], and engages various commercial, interagency, and international partnerships.

Objective Strategy

NASA's Earth science activities utilize observations from the vantage points of space, air, and in-situ to advance our scientific understanding of the Earth in service to the United States and the world. We lead the world in the production of data necessary to understand, model, monitor, and ultimately predict climate change, and we are expanding our efforts in the years ahead. In May 2021, NASA announced the implementation of the Earth System Observatory in response to the 2017-2027 Decadal Survey, consisting of a new set of Earth-focused missions to provide key information to understand the Earth's systems and processes, as well as interactions between the processes on the land, ocean, and in the atmosphere. We use our understanding of natural processes and their interactions to provide objective information on changes happening now, as well as estimates of how our environment might evolve in the future.



Recently received Landsat 9 photos provide a preview of how the mission will help people manage vital natural resources and understand the impacts of climate change on the Earth's landscapes and coastlines, adding to Landsat's unparalleled data record that spans nearly 50 years of space-based Earth observation.

Our pursuit of answers to fundamental science questions about the Earth system benefits humanity in many ways. NASA's unique ability to view Earth from the perspective of space allows for the collection of broad, high-quality data from all parts of the planet. Only from space can we make the observations of the complex Earth system that can illuminate connections between short and long time scales, fine and global spatial scales, and chemical, physical, and biological processes. NASA shares this unique knowledge and data freely and openly with the global community, including members of the Government, commercial, and academic communities. For example, in the agriculture sector alone, NASA's Earth science observations have proven helpful with crop area estimates, productivity assessments, and yield models across a range of time scales, water planning, and irrigation management. Likewise, NASA observations and models serve many other economic sectors and industries, disaster management, and community planning.

To complete innovative Earth science missions, NASA will effectively manage a diverse portfolio while balancing innovation with successful program execution. Specifically, NASA will:

- Measure mission success against clearly written top-level measurement requirements;
- Develop objective criteria to enable

1 *Thriving on Our Changing Planet: A Decadal Survey for Earth Observation from Space*, National Academies of Science, Engineering, and Medicine, Space Studies Board (2018)

2 Science 2020-2024: A Vision for Scientific Excellence, NASA Science Mission Directorate (2020)

unequivocal measurement of success or failure in meeting each requirement;
- Establish a budget for each new mission that funds the mission's complete lifecycle cost, based on detailed engineering studies and independent cost estimates;
- Obtain tactical-level community advice on portfolio adjustments via the NASA Advisory Council, Science Committee, and the science advisory committees; and
- Implement effective partnerships—commercial, international, interagency, academic, and others—that leverage NASA resources and extend scientific results.

As an example, NASA's Commercial Smallsat Data Acquisition (CSDA) program evaluates and procures data from commercial vendors that complement NASA's measurements and help advance NASA's Earth science research and applications activities.

NASA's commitment to equity is based on the understanding that the use of NASA data, products, and personnel can and should inform the just treatment and meaningful involvement of all people—regardless of race, color, national origin, income, or ability—with respect to development, implementation, and evaluation of programs, practices, and activities that affect human health and the environment.

How NASA Engages and Works with Partners

NASA improves national capabilities to predict climate, weather, and natural hazards, to manage resources, and to develop environmental policy by leveraging our partnerships with other agencies that maintain forecast and decision support systems, such as NOAA, USGS and EPA. Most notably, NASA develops, builds, tests, and launches weather satellites that are operated by NOAA, as well as Earth observation satellites operated by USGS.

NASA also works with our international partners to jointly develop or coordinate our Earth observation activities. NASA and the European Space Agency (ESA) have a long and successful history working together to understand our changing planet. For example, in 2020, NASA, NOAA, and our European partners, launched the Sentinel-6 Michael Freilich satellite, which is collecting the most accurate data yet on global sea level rise. The mission also measures atmospheric temperature and humidity that will help improve climate models and weather forecasts.

Most recently, NASA and ESA have formed a first-of-its-kind strategic partnership to observe Earth and its changing environment. Recognizing that climate change is an urgent global challenge, the timing is right for NASA and ESA, as partners in space, to join forces to lead and support a global response to climate change. The partnership is an effort to help address and mitigate climate change through monitoring Earth with combined efforts of both agencies in Earth science observations, research, and applications. This partnership was formalized through a joint statement of intent, signed in July 2021, which outlines how the agencies will collaborate to ensure continuity of Earth observations; advance understanding of the Earth system, climate change and application of that knowledge; and collaborate on an open data policy that promotes open sharing of data, information, and knowledge within the scientific community and the wider public.

Contributing Programs and/or Program Activities for Strategic Objectives

Earth Science Research; Earth Science Technology; Earth System Explorers; Earth System Science Pathfinder; Earth Systematic Missions.

Strategic Objective 1.2

Understand the Sun, solar system, and universe.

Conduct scientific studies of the Sun and solar system, use space as a laboratory, peer out into the vast reaches of the universe, and play a catalyzing role in lunar robotic exploration. These efforts are guided by National priorities and recommendations from the National Academies' decadal surveys and implemented through a balanced portfolio of programs.

Lead Office
Science Mission Directorate (SMD)

Objective Overview
The success criteria for SMD are progress in answering fundamental science questions, implementing the decadal survey priorities, and responding to direction from the Executive Branch and Congress. Four of NASA's science areas contribute directly to this Strategic Objective.

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? Progress is advanced through the combination of basic research and flight missions. Astrophysics is guided by the *Pathways to Discovery in Astronomy and Astrophysics for the 2020s* (Astro2020) Decadal Survey, which identifies science goals and recommendations for astrophysics planning and investment for the next decade. Basic research uses the data from our missions to create new knowledge and advance our understanding of the universe. The 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 Strategic Missions Program.

Heliophysics 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 to the edge of the heliosphere, shaping the protective bubble in which our solar system travels

Below: Using its Wide Angle Topographic Sensor for Operations and eNgineering (WATSON) camera, NASA's Perseverance Mars rover took this selfie over a rock nicknamed "Rochette," on September 10, 2021, the 198th Martian day, or sol, of the mission. Two holes can be seen where the rover used its robotic arm to drill rock core samples for potential return to Earth as part of a future mission. Image Credit: NASA/JPL-Caltech/MSSS

around the Milky Way. Guided by the 2013 *Solar and Space Physics: A Science for a Technological Society* decadal survey, the goal 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. Studying this system allows us to discover the fundamental physics governing how the universe works and helps protect our technology and people 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.

Space weather directly affects the safety of humans in space and on Earth by influencing the operation of electrical power grids, communications and navigation systems, gas and oil pipelines, and spacecraft electronics and orbital dynamics. NASA develops instrumentation, technology, models, and research tools to understand space weather. NASA also collaborates with agencies such as the National Science Foundation and NOAA to improve space weather predictive capabilities.

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 focus of Planetary Science 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 the 2011 Vision and Voyage for planetary science in the Decade 2013-2022 decadal survey. NASA manages a diverse portfolio of research and technology development and unique mission investigations. NASA is operating spacecraft at Mars, Jupiter, and the Moon, and preparing to launch two missions to asteroids. NASA is also undertaking flagship missions to Jupiter's moon Europa and to return samples from Mars, and selected two missions to explore Venus. 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. NASA's Near-Earth Objects Observations Program funds research activities to increase our understanding of the motions, compositions, and nature of near-Earth objects. This includes using optical and radar techniques to better understand objects' orbits, shapes, sizes, and other relevant characteristics. These planetary defense activities enable the science community to understand the nature of near-Earth objects, information that could be leveraged to mitigate a possible Earth impact.

Tomato plants growing under LED lights in a growth chamber inside a laboratory at the Kennedy Space Center. These plants are growing in units equipped with features designed to mitigate the effects of microgravity on water distribution, oxygen exchange, and root growth when aboard the International Space Station. Image credit: NASA

Biological and physical sciences pioneers scientific discovery and enables space exploration by using the spaceflight environment, in and beyond low Earth orbit, to conduct experiments that cannot be done on Earth. This work focuses on transformative science to contribute to advances in science, technology, and space exploration. This research also enables human spaceflight exploration to expand the frontiers of knowledge, capability, and opportunity in space. Implementation requires both scientific research and technology development. Strategic priorities in this area are informed by the National Academies of Sciences' decadal survey and research is currently guided by the first decadal survey (2011). Recommendations for the second, the decadal survey on biological and physical sciences research in space 2023-2032, are expected to be delivered during the summer of 2023. NASA partners with the research community and a wide range of organizations (e.g., academic, commercial, and Government laboratories) to do this work. Partnerships with other NASA organizations, other Government agencies, industry and international partners also provide access to a broad range of experimental platforms (e.g., ISS, un-crewed space-

craft, ground-based analogs for spaceflight, drop towers, aircraft) and a diverse set of experts. NASA strives for broad involvement of the research and technology development communities in the formulation and dissemination of its work.

Objective Strategy

NASA's success in science discovery across these core contexts is based on a balanced program that involves a number of critical and enabling elements: laying the scientific and technical foundation for space-based missions through Research and Development; inventing and using new space-based observing and sampling capabilities; creating the context and capabilities to interpret the resulting data; and maximizing the return on investment in the acquisition of data. SMD's suborbital and ground-based programs are conducted to enable or complement space-based observations and train future mission scientists and engineers.

To complete innovative space missions NASA will effectively manage a diverse portfolio while balancing innovation with successful program execution. Like our approach in Strategic Objective 1.1, NASA will:

- Measure mission success against clearly written top-level measurement requirements
- Develop objective criteria to enable unequivocal measurement of success or failure in meeting each requirement
- Establish a budget for each new mission that funds the mission's complete life-cycle cost, based on detailed engineering studies and independent cost estimates
- Obtain tactical-level community advice on portfolio adjustments via the NASA Advisory Council, Science Committee, and the science advisory committees
- Implement effective partnerships—commercial, international, interagency, academic, and others—that leverage NASA resources and extend scientific results

NASA will implement missions only after focused development has matured required technologies. A balanced science program proactively identifies potential technologies required to meet future mission requirements, conduct trade studies, assess development risks, and invest in new technologies well in advance of mission implementation. NASA is also expanding the use of lower-cost CubeSats and SmallSats to accomplish our science goals.

NASA engages the science advisory committees annually to rate scientific progress. In addition, the National Aeronautics and Space Administration Authorization Act of 2005 directed that the performance of each science division shall be reviewed and assessed by the National Academy of Sciences at five-year intervals.

Searching for Life Elsewhere

The search for life in the solar system and beyond is guided by the ability to understand how life originated on Earth and by the quest to find habitable environments outside of Earth. To improve the knowledge of environmental requirements for habitability, NASA will develop tools for detecting life, develop tools for determining the relative habitability of present or ancient environments, and explore analog environments on Earth. This will facilitate target selection for further robotic, and ultimately human, exploration. Observations from SMD's astrophysics missions have made it clear that habitable planets exist around stars other than the Sun and that such planets are plentiful. Improving techniques and ideas for discovering and characterizing habitable and/or inhabited environments on these planets, coupled with an understanding of the potential false positives for habitability or life, will enable prioritization of exoplanets for targeted follow-up observations. In the coming decades, this will help to push frontiers of discovery and enable the search for signs of life on worlds that may be capable of harboring life, both within our own solar system and within the galaxy.

NASA's strategy relies on applying the lessons learned about the origin, evolution, and distribution of life on Earth to other bodies in our solar system and beyond. There is no single measurement or experiment that will definitively reveal the presence of extant or past life on a body in our solar system or a planet around another star. NASA will utilize many measurement results in a "Ladder of Life Detection" that will inform any certainty of the discovery of past or present life elsewhere.

How NASA Engages and Works with Partners

NASA will extend partnerships domestically and internationally. Science is a broad national and international enterprise and SMD partners with U.S. Federal agencies and more than 60 nations and international research organizations to leverage ideas, capabilities, and resources. NASA's constellation of Sun, Earth, solar system, and distant universe spacecraft and observatories are models of international and interagency cooperation and serve to further common scientific interests; about

two-thirds of all of NASA's science missions have at least one international partner, and many missions have multiple interagency or international partners.

NASA's science is uniquely positioned among Federal agencies to transfer content and expertise to an informative environment to support learning across all age groups. Data are accessible through multiple channels, which allows NASA to benefit from partners actively engaged in learning communities and emerging citizen-based science.

Contributing Programs and/or Program Activities for Strategic Objectives

Astrophysics Explorer; Astrophysics Research; Cosmic Origins; Exoplanet Exploration; Physics of the Cosmos; Biological and Physical Sciences ; Heliophysics Explorer Program; Heliophysics Research; Heliophysics Technology; Living with a Star; Solar Terrestrial Probes; Discovery; Lunar Discovery and Exploration; Mars Exploration; Mars Sample Return; New Frontiers; Outer Planets and Ocean Worlds; Planetary Defense; Planetary Science Research; Radioisotope Power; Space Weather.

Strategic Objective 1.3

Ensure NASA's science data are accessible to all and produce practical benefits to society.

In order to ensure NASA's science data are accessible to all and produce practical benefits to society, SMD plans to undertake investments and initiatives that will accelerate the accessibility and use of SMD data by its user community by investing in the following: 1) capabilities to enable open-source science; 2) continuous evolution of data and computing systems; and 3) community and strategic partnerships for innovation.

Lead Office

Science Mission Directorate (SMD)

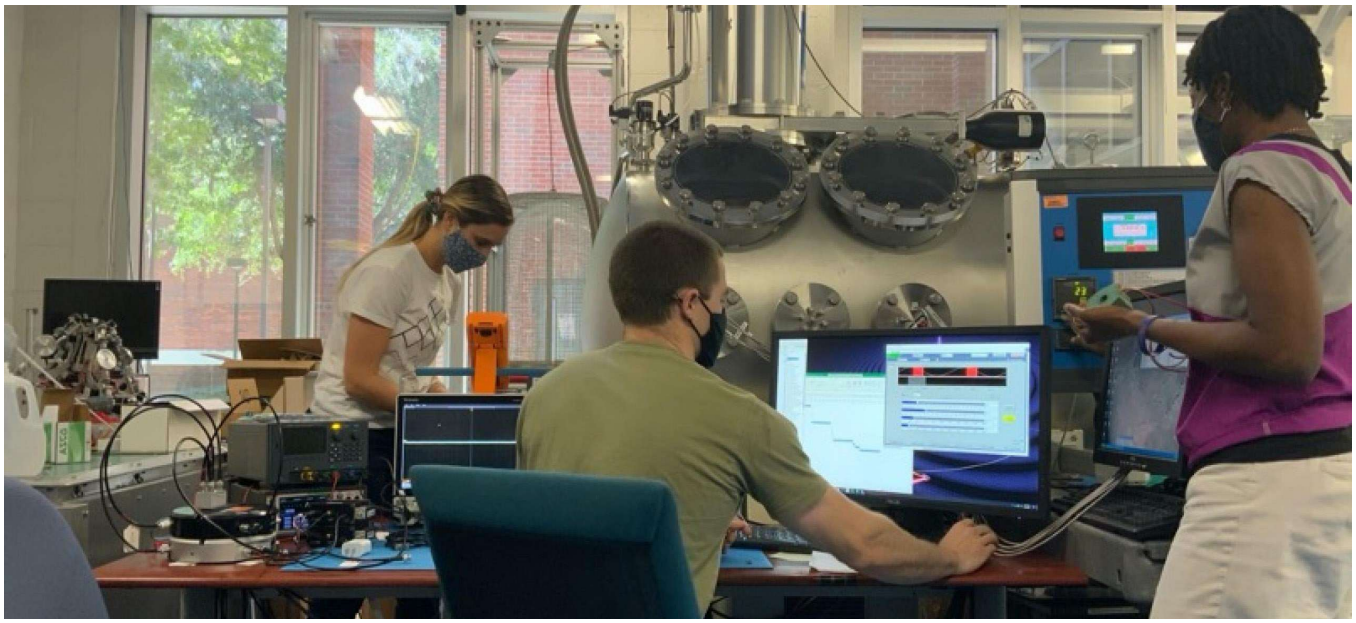
Objective Overview

SMD's missions and research activities inspire curiosity and increase the understanding of our planet, the solar system, and the universe. One of our core capabilities is the ability to collect, store, manage, analyze, and distribute data and information for scientists, international partners, learners of all ages, decision-makers, and industry to further science, improve modeling, increase knowledge, and spur economic innovation.

The science divisions within SMD generate, analyze, activate, and archive large amounts of data to support science objectives and deliver data and scientific results to users around the world. Over the next 5 years, SMD divisions will substantially increase the size of data archives as the volume of data generated by new missions increases from approximately 10 petabytes per year today to over 100 petabytes per year in 2026. This growth of NASA's science archives presents unique opportunities for new scientific discovery and partnerships, as well as significant challenges for data management, curation, access, analysis, computing, and computational modeling.

As part of this effort, we plan to undertake investments and initiatives that will accelerate the accessibility and use of SMD data by its existing and new user communities. NASA's data initiatives are focused on making actionable data accessible to other Federal agencies, relevant decision-makers, stakeholders, and the public.

Below: University of Florida team members conduct thermal-vacuum testing of the European Space Agency (ESA)-NASA Laser Interferometer Space Antenna observatory's Charge Management Device. From left to right: Ph.D. students Samantha Parry Kenyon and Benjamin Letson, and Postdoc, Dr. Taiwo Olatunde. Image Credit: NASA



This will be done by investments in three key areas: 1) capabilities to enable open-source science; 2) continuous evolution of data and computing systems; and 3) community and strategic partnerships for innovation.

Objective Strategy

NASA is working on several initiatives to invest in the three key areas identified above. Open-source science is the collaborative culture enabled by technology that empowers the open sharing of data, information, and knowledge within the scientific community and with the wider public to accelerate scientific research and understanding. Open-source science builds on concepts from open-source software that expanded participation in the developing code and applies these to the scientific process to accelerate discovery by openly conducting science from project initiation through implementation. Data and computing programs play a critical role in enabling open-source science through thoughtfully-designed software systems that are initiated as open-source software projects, are easy to use, and support the wide variety and high volume of data generated by NASA's scientific missions. Specifically, this initiative will allow open development of software and models, and better enable researchers to perform computational experiments that are constrained or verified by observations.

Community and strategic partnerships will accelerate the modernization of various modeling efforts. The adoption of machine learning and artificial intelligence technologies will greatly speed up the data analysis and computational performance of the models. Our commercial partners will access our science data and integrate it into models and service offerings, while our interagency partners benefit from improved data system services through easier access to data and the software used to generate the products.

NASA is also leveraging strategic and commercial partnerships to drive technological innovation. For example, NASA has piloted programs that use unsupervised learning and anomaly detection to explore the extreme conditions associated with superstorms. The more we understand what causes such space weather, the more we can improve our ability to forecast and mitigate the effects. Finally, expansion of citizen science initiatives through the use of volunteers in the pursuit of knowledge, consistent with the 2017 America INNOVATES Act,[1] continues beyond the current 23 projects to countless more with the open-source science approach.

Open-source science requires a culture shift to a more inclusive, transparent, and collaborative scientific process, which will increase the pace and quality of scientific progress. To help build a culture of open science, NASA is championing the Open-Source Science Initiative, focused on data transparency, accessibility, inclusivity, and reproducibility.

NASA recognizes that Earth's changing climate disproportionately influences environmental exposures and vulnerabilities of the world's poorest and marginalized communities, and that NASA data, products, and personnel can and should inform the just treatment and meaningful involvement of all people. Through collaboration with the Office of Diversity and Equal Opportunity, SMD will identify current barriers to and opportunities for advancing equity for underserved communities and expand partnerships with organizations currently working

1 America Implementing New National Opportunities To Vigorously Accelerate Technology, Energy, and Science Act (America INNOVATES Act), S.1187, 2017.

directly with such communities. Likewise, NASA with our grantees to make data more accessible to organizations and explore across science disciplines (e.g., with social scientists) to ensure the more effective use of NASA data for furthering environmental justice.

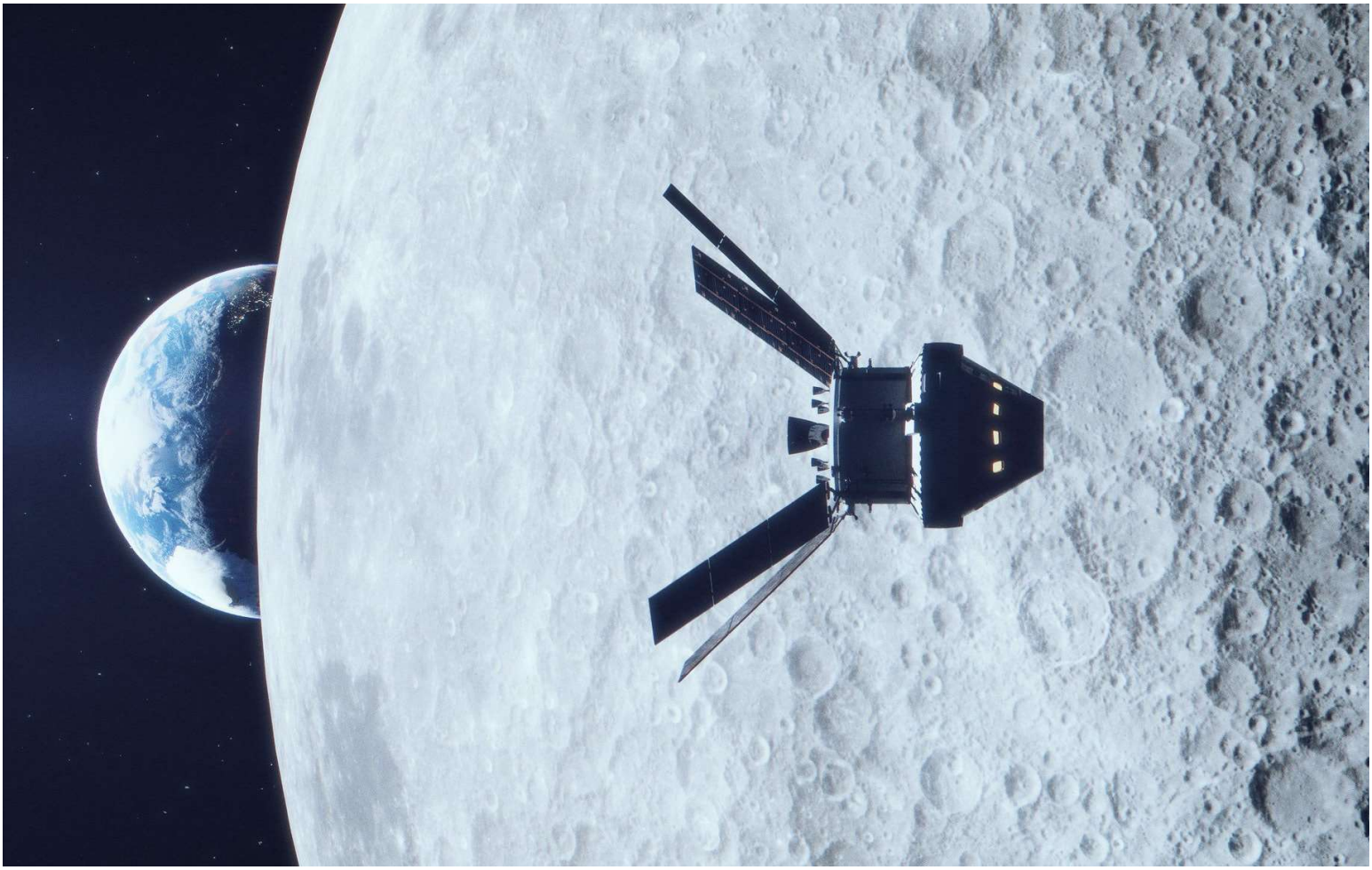
How NASA Engages and Works with Partners

NASA works with a broad range of users and stakeholders in furthering our understanding of climate and its impacts through the collected data, analysis, and modeling; these communities include all levels of government (Federal, state, and local), international governments, domestic and international consortia, think tanks and philanthropies, academia, and industry. Using Earth observation data, we work with a number of state and local agencies in responses to disasters from wildfires to hurricanes. NASA has also partnered with local government entities to help plan for climate change and sea level rise in urban environments.

NASA also partners with members of the interagency community, through agreements with specific agencies, as well as interagency working groups, to further the use of relevant data. Internationally, NASA partners with space agencies across the world to develop, build, launch, and maintain platforms and instruments for long-term climate data, including satellite altimetry. Likewise, NASA partners with organizations around the world to provide data to support sustainable, climate-resilient decision-making.

Contributing Programs and/or Program Activities for Strategic Objectives

Earth Science Data Systems; Applied Sciences.



A strong commitment to maintain U.S. leadership in space is required to establish a lasting human presence at the Moon. NASA will continue to lead a bold coalition into deep space, uniting international exploration goals with private-sector ambitions for a peaceful human endeavor beyond Earth. (Artist Illustration) Image Credit: NASA

STRATEGIC GOAL 2

EXTEND HUMAN PRESENCE TO THE MOON AND ON TOWARDS MARS FOR SUSTAINABLE LONG-TERM EXPLORATION, DEVELOPMENT, AND UTILIZATION.

Goal Statement

NASA's rich history of human spaceflight provides the foundation for today's exploration vision: to maintain U.S. leadership in space, establish a lasting presence on and around the Moon, and pave the way forward to Mars and beyond. This strategy begins with the Artemis, a series of missions that will land the first woman and the first person of color on the lunar surface, marking the first time in nearly 50 years that humans have landed on the Moon. Along the way, we will develop and inspire a diverse national science, technology, engineering, and mathematics (STEM) workforce, and inspire new generations to join our ranks.

The Moon is the ideal location to revive human activities in deep space and develop the orbital and surface infrastructure needed to support repeated missions in a campaign that will evolve in complexity and duration as we prepare for Mars. Building on more than two decades of operations in low Earth orbit aboard the International Space Station, and leveraging our wealth of experience with groundbreaking exploration, we will explore farther to ensure U.S. leadership in global space exploration, build back better through innovation and collaboration with industry, strengthen our global partnerships, and empower NASA to develop technologies to solve challenges here on Earth.

Establishing a long-term human presence at the Moon and conducting the first human mission to the surface of Mars will be among the most challenging technical enterprises in human history. This era of human exploration will require innovative technologies and systems—some of which have not yet been demonstrated—to explore new and more challenging locations, like the lunar South Pole. Developing these capabilities will spur advancements in critical fields like medicine, energy, materials science, manufacturing, and climate science.

Artemis mission success will require the continuation of existing partnerships and the development of new ones. Working with commercial partners enables NASA to focus its attention forward, while creating jobs and stimulating the economy . An emerging space economy will create new jobs and industries and empower countless future generations while benefitting life on Earth.

Our Nation is not alone in making plans to explore the Moon. Pursuing human exploration missions to the Moon and Mars ensures continued American preeminence in science, technology, and exploration, and encourages others to join us. Our existing international partners have expressed great interest in collaboration on Artemis. NASA is pursuing opportunities for collaboration with several emerging space nations interested in joining us on the Moon via the Artemis Accords. NASA also contributes to other nations' science missions, leveraging their skills and interests to conduct scientific research, develop and demonstrate technology, and train international crews to operate farther from Earth for longer periods of time than ever before.

Over the next several decades, NASA will establish long-term footholds in cislunar space and on the lunar surface and deploy complex crew-rated transportation and habitation systems to the Moon and Mars. All of these elements are necessary to establish the surface infrastructure that will enable humans to live at and explore new, scientifically rich locations.

Throughout this century, NASA has focused on increasing private-sector involvement in space, laying a foundation for long-term exploration where Government agencies are one of several customers in a vibrant space economy. NASA has successfully implemented programs where the Government funds and supports key technologies such as advanced space communication technologies to enable higher data volume and reliability for communications between spacecraft and Earth as well as between astronauts on the lunar surface. NASA's investments in the global space economy and in the next-generation STEM workforce will ensure that people around the world can participate in a great vision of long-term human life in cislunar space. By making this vision a reality, we will improve life on Earth and extend U.S. leadership farther than ever before.

Maintaining America's Global Standing

NASA is focused on addressing the challenges of taking humanity toward the Moon and deeper into space, enabling future discoveries, and providing knowledge to improve life on Earth. We remain the partner of choice for human exploration missions, and through Artemis and exploration of Mars, NASA and America will maintain leadership among spacefaring nations, building on decades of successful multinational partnerships.

Building on successful multinational partnerships in low Earth orbit, NASA will extend its leadership role into deep space, continuing many of its partnerships at the Moon, while growing new partnerships with emerging spacefaring nations. Through the Artemis Accords, NASA has established a practical set of principles to guide cooperation among nations participating in the Agency's 21st century lunar exploration plans. The Accords implement the principles of the 1967 Outer Space Treaty and reinforce commitment by the United States and partner nations to the Registration Convention, the Agreement on the Rescue of Astronauts, and other norms of behavior, including the public release of scientific data, that NASA and our partners have supported. As of March 2022, the following countries have announced their signing of the Accords: Australia, Bahrain, Brazil, Canada, Israel, Italy, Japan, Luxembourg, Mexico, New Zealand, Poland, Romania, South Korea, Ukraine, the United Arab Emirates, the United Kingdom, and the United

States. Discussions with many other nations that wish to join the Artemis program and sign the Artemis Accords are ongoing.

Developing a lasting and effective exploration campaign requires the energy, expertise, and innovation of the world's top minds. Under NASA's leadership, Artemis is designed to leverage and maximize the ambitions and expertise of our international partners. These efforts will ensure U.S. international leadership while inspiring and benefitting the global public and strengthening our global partnerships while also easing the cost burden to the American taxpayer.

Driving Economic Growth

NASA supports the development of a robust low Earth orbit economy in which many stakeholders on Earth can participate. The new space economy benefits U.S. industry, promotes technological discovery, improves life on Earth, and allows NASA to focus on the challenges of exploring the Moon and Mars. NASA's activities follow the direction of Congress and the White House, recognizing that it is in the national security and economic interests of the United States to encourage the development of a healthy and robust commercial sector in low Earth orbit, in which the Government is one of many customers.

In the last decade, NASA has proven that a service-based model for access to space can successfully spur new, non-Government, space-based revenue streams for American companies. Following success with the Commercial Crew Program in low Earth orbit, NASA is acquiring human landing systems, logistics deliveries to the Moon, and advanced spacesuits for ISS and Artemis as services.

Public-private partnerships, like those formed under NASA's Next Space Technologies for Exploration Partnerships model (NextSTEP), provide the impetus for industry to invest in the space economy. Competition spurs innovation, reduces cost, and ensures NASA's economic impact is spread across a range of business types and sizes.

NASA understands the importance of promoting economic growth through tangible and measurable goals and activities. NASA initiatives and programs—along with the development of technologies required to make NASA missions possible—represent a significant investment in our Nation's industrial base and manufacturing capabilities, research and education endeavors, and advanced technology sectors. NASA's keen interest in promoting economic growth focuses on fostering competition and innovation for society's benefit. We will continue to partner with the U.S. private sector to push the economic frontier deeper into space and build on what we've already established in low Earth orbit.

Strategic Objective 2.1

Explore the surface of the moon and deep space.

Extend human presence into cis-lunar space to allow for sustained operations on the lunar surface and then on towards Mars to unlock mysteries of the universe.

Lead Office

Exploration Systems Development Mission Directorate (ESDMD)

Objective Overview

Artemis missions, and future human exploration of Mars, will expand opportunities for Americans, increase our global standing, and inspire the next generation of leaders in STEM. Long-term exploration and scientific utilization present unique opportunities for major discoveries impacting critical fields like medicine, energy, and manufacturing that will benefit society worldwide.

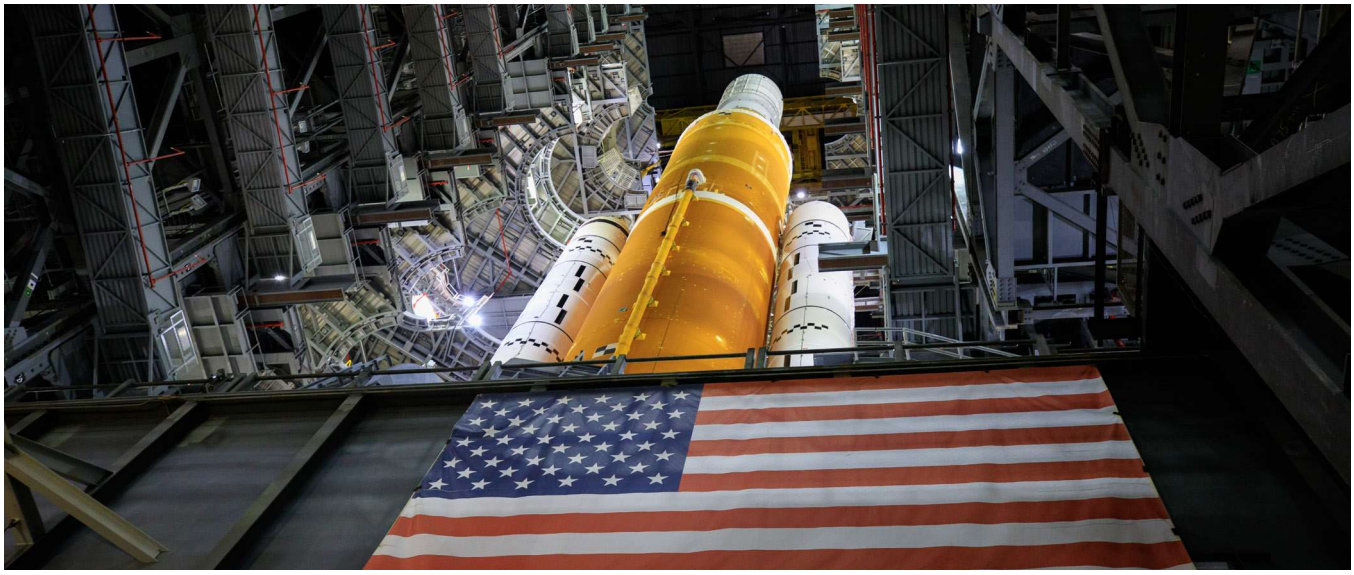
The Orion spacecraft will carry humans beyond low Earth orbit, provide emergency capability, sustain the crew in transit, and provide safe re-entry from deep space. The Space Launch System will send crew via Orion, as well as supplies to the Gateway space station around the Moon . NASA's Exploration Ground Systems team develops and operates the systems and facilities needed to process and launch rockets and spacecraft during assembly transport and launch.

The Human Landing System (HLS) will be the first commercially developed vehicle to transport humans to and from the surface of the Moon. NASA is encouraging innovation through competition to find the best possible systems for taking astronauts to the Moon on increasingly frequent and longer duration missions.

NASA will develop an Artemis Base Camp near the Moon's South Pole. The base camp is envisioned to include an unpressurized rover, a pressurized rover, a fixed surface habitat and a surface power system to keep the elements powered during the lunar night and dormant periods.

NASA will work closely with international partners to achieve Artemis objectives and grow the global space economy. These relationships will reinforce

Below: In this view looking up inside High Bay 3 of the Vehicle Assembly Building at NASA's Kennedy Space Center in Florida, the work platforms have been retracted from around the Artemis I Space Launch System on September 20, 2021. All 10 levels of platforms were extended and retracted as part of an umbilical test. Artemis I will be the first integrated test of the Space Launch System (SLS) and Orion spacecraft. In later missions, NASA will land the first woman and the first person of color on the surface of the Moon, paving the way for a long-term lunar presence and serving as a steppingstone on the way to Mars. Image credit: NASA/Frank Michaux



America's position as the global leader in space exploration and provide new avenues for partnership with nations around the world. NASA's deep space exploration efforts will continue to act as a beacon of peace and scientific partnership around the globe.

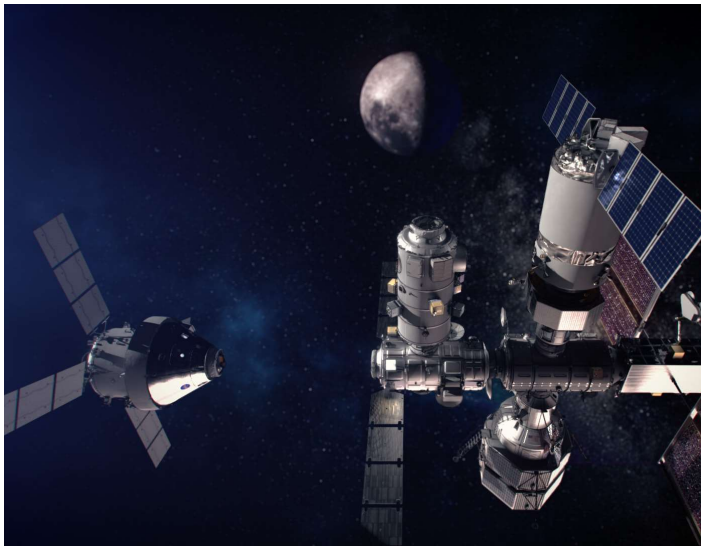
Artemis missions will be driven by scientific objectives like collecting new information on planetary processes and the character and origin of volatiles. NASA will uncover the history of our Earth-Moon system and new information about our Sun. The human data collected as mission durations increase will make future work in deep space safer and more efficient. What we learn will also help us protect our home planet and improve daily life for people around the world.

Objective Strategy

Exploring beyond low Earth orbit requires a space transportation system that can safely transport crew and cargo to deep space. Artemis includes a crew vehicle, heavy-lift launch vehicle, the Gateway in lunar orbit with logistics resupply, Human Landing Systems, and lunar surface systems to support astronaut expeditions, as well as supporting Earth-based ground facilities and systems.

As NASA establishes infrastructure at the Moon, a long-term orbiting platform will be necessary to support increasingly lengthy surface expeditions. The Gateway will also host some science experiments and provide additional data on the impacts of deep space flights on humans and systems.

NASA and its partners are preparing for a robust human return to the Moon, with an incremental buildup of capabilities in orbit and on the surface that will help prepare for the first human missions to Mars. Viewed as a deep space planetary laboratory, the Moon offers many opportunities to unlock new discoveries about the Earth-Moon system origins and the deep history of our solar system. Artemis systems have dual purposes, to explore the Moon and to demonstrate key capabilities for Mars. The rovers and power systems on the surface, HLS hazard avoidance and navigation systems, and even ascent capabilities could have direct applications to human missions to Mars. The orbit-to-surface operations involving astronauts ferrying between gravity fields will explore new challenges and techniques to mitigate them. Increasing surface duration stays and extravehicular activities on a planetary surface will provide crucial data in making surface exploration safer and more effective.



Artist's illustration of the Gateway at the Moon. Built and outfitted by NASA, commercial, and international partners, the Gateway will be humanity's first deep space exploration and research outpost. Image Credit: NASA/Alberto Bertolin

How NASA Engages and Works with Partners

Establishing a sustained human presence on the Moon and conducting the first human mission to the surface of Mars will be among the most challenging endeavors in human history. NASA will engage with other Government agencies for collaborative efforts (e.g., Department of Energy, Department of Commerce, National Science Foundation, United States Geological Survey), and to ensure compliance with national and international policies and obligations (e.g., Federal Aviation Administration, Department of State).

International partners are critical to Artemis and the Moon towards Mars plan. The Artemis Accords established in 2020 set common principles for the peaceful exploration and use of outer space. The Accords are grounded in the Outer Space Treaty of 1967. To date, more than a dozen countries have signed the Artemis Accords, including both established and new partners, and NASA anticipates many more to join in the months and years ahead.

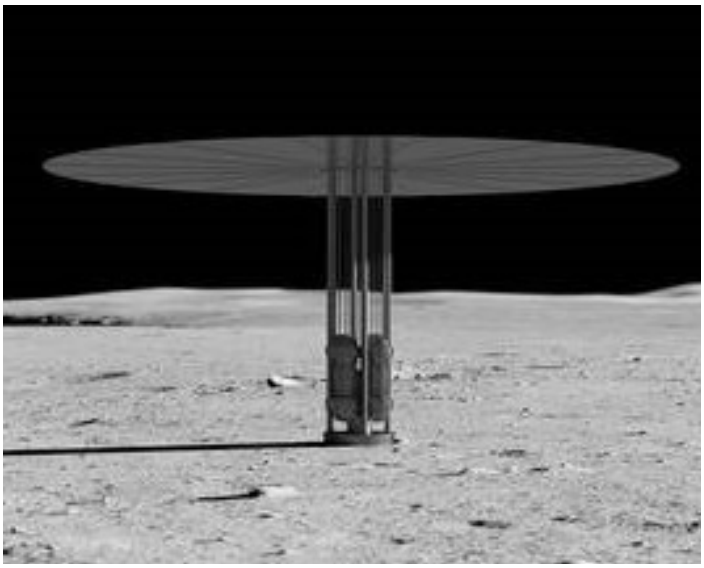
The NASA-led Gateway, that will be located in lunar orbit, is a multinational collaboration with many of our established partners in low Earth orbit. We have already signed agreements with three partners to provide modules and critical capabilities: the Canadian Space Agency (CSA), European Space

Agency (ESA), and Japan Aerospace Exploration Agency (JAXA). ESA and JAXA will also contribute early Gateway science instrument suites that will study the deep space radiation environment.

Following success with NASA's Commercial Crew Program in low Earth orbit, NASA is acquiring HLS, logistics deliveries to the Moon, and advanced spacesuits for ISS and Artemis as services. A services approach allows companies to engage other customers in addition to NASA and introduce new revenue streams into their business models. Competition leads to innovation, and these partnerships will ease the financial burden on NASA so our highly skilled workforce can focus on advanced technology development and research while solving the future challenges of exploration.

Contributing Programs and/or Program Activities

Exploration Capabilities; Exploration Operations; Space Launch System (SLS); Orion; Orion Production & Sustainment; Exploration Ground Systems (EGS); Advanced Cislunar and Surface Capabilities (ACSC); Gateway; Human Landing System (HLS); xEVA and Human Surface Mobility Program; Moon & Mars Architecture.



Fission Surface Power - To keep Artemis surface elements continuously powered, regardless of environmental conditions, NASA is developing a small, lightweight fission surface power system to demonstrate on the Moon. Expanding on the agency's former Kilopower project, NASA's Space Technology Mission Directorate has partnered with the Department of Energy and industry to make this concept a reality. In the coming years, NASA will design, fabricate, and test a system that provides up to 40 kilowatts of electrical power – enough to run 30 average households – continuously for at least 10 years.

Strategic Objective 2.2

Develop a human spaceflight economy enabled by a commercial market.

Expand the space economy by leveraging the ISS and stimulating the growth of human spaceflight commercial activities.

Lead Office
Space Operations Mission Directorate (SOMD)

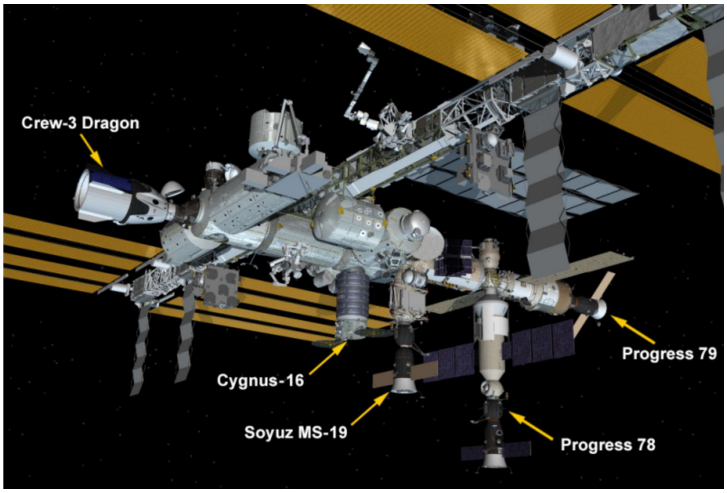
Objective Overview
A robust human spaceflight economy ensures national interests for research and development in space are fulfilled while allowing NASA to focus Government resources on the challenges of deep space exploration through Artemis.

NASA will maintain access to a human-rated platform in low Earth orbit (LEO) to continue U.S. human presence and expand the American foothold in space. The continuous operation of a research and technology demonstration platform in space is critical to achieving NASA's and the Nation's goals in science, technology, and human space flight. As such, we are investing resources to foster a robust human spaceflight economy.

Since its inception, industry, academia, and our international partners have used the International Space Station (ISS) as a testbed for research and the development and maturation of state-of-the-art systems that increase access to space. NASA is supporting new space stations from which we and other customers can purchase services and stimulate the growth of commercial human spaceflight activities. As commercial LEO destinations become available, we intend to implement an orderly transition from current ISS operations to these new commercial destinations.

Below: Two U.S. cargo ships are pictured attached to the International Space Station, as the orbital complex flew 260 miles above the Laccadive Sea south of India in 2019. In the right foreground, the Northrop Grumman Cygnus space freighter, with one of its prominent cymbal-shaped UltraFlex solar arrays is attached to the Unity module. At top rear, the SpaceX Dragon commercial resupply ship is attached to the Harmony module. Image Credit: NASA

The ISS is the prime example of American leadership in global space exploration, enabling a U.S.-led multinational partnership to advance shared goals in space. The ISS supports a robust commercial marketplace, with more than 20 commercial facilities operating and generating revenue, including in-space manufacturing facilities and a commercial airlock. As NASA increases the opportunities for business on the ISS, the number and types of companies taking advantage of those opportunities will likely increase, which will in turn create more demand.



On November 11, 2021, five spaceships were parked at the space station including Northrop Grumman's Cygnus space freighter; the SpaceX Crew Dragon vehicle; and Russia's Soyuz MS-19 crew ship and Progress 78 and 79 resupply ships. (Artist Illustration) Image Credit: NASA

Objective Strategy

NASA is committed to the development of both the supply side of the future human spaceflight economy (i.e., future platforms providing services for a fee) and the demand side (i.e., need for on-orbit services for Government requirements or to produce products of commercial value).

NASA pursues several avenues to enable the supply side of the human spaceflight economy. The ISS has entered an era of robust commercial use, taking advantage of our capacity to develop the technologies that industry needs to move from being dependent on NASA for access to space to providing the access we need to continue our mission in LEO after the lifetime of the ISS. These avenues include offering the use of an ISS port to a private company to deploy a new commercial element on the ISS; supporting the development and use of free-flying commercial LEO destinations; and offering the use of the ISS for private astronaut missions. NASA's expectation is that one or more of these development and demonstration efforts will prove commercially viable, allowing U.S. and international customers to purchase human spaceflight services in LEO while also providing us with the platforms and capabilities we require in LEO.

Creating a robust human spaceflight economy depends on bringing many new businesses and people into space and requires the development of not only the supply of services, but also the demand for those capabilities. NASA will soon see the first private astronaut mission to the ISS. Private astronaut missions are dedicated missions that are privately funded, fully commercial spaceflights on commercial launch vehicles for a variety of potential commercial purposes utilizing ISS.

Simultaneously, NASA's Commercial LEO Development and ISS programs are developing and maturing the demand side of the human spaceflight economy. NASA issued a preliminary "LEO Demand Forecast," which describes NASA's long-term needs for microgravity services. NASA also provides support for sustained demand focus areas, such as industrial biomedicine and manufacturing. NASA also offers marketing and advertising opportunities aboard ISS on a fully reimbursable basis.

Through the successful implementation of similar commercialization strategies, such as the Commercial Resupply Services and Commercial Crew Program, NASA demonstrates that companies can develop and operate the next generation of spacecraft and launch systems to serve the ISS. This success brought the commercial launch industry back to the United States, demonstrating that U.S. industry is more than capable of competing on the global stage. This commercial capability also fuels the growing U.S. share of the global launch market and provides expanded utility, additional research time, and broader opportunities for discovery and space exploration. An important goal of this commercialization strategy is to encourage the development of new industry capabilities, enabling these companies to sell future services to all customers, not just NASA.

Today, commercial crew and cargo transportation services provide a vital lifeline from Earth to the ISS for technology demonstrations. There are 21 commercial facilities operating onboard ISS today, including a 3-D printer, a bioprinter, and an airlock,

which are available for use by both NASA and other paying customers.

NASA is committed to using the ISS and its capabilities to aid in the development of the U.S. industry's ability to provide the necessary platforms and services in LEO. NASA is also committed to continued Government utilization of LEO beyond the ISS for basic research and development, Earth and deep space observations, and astronaut training. Our commitment includes providing Government funding to private industry via contracts and partnerships to ensure that future capabilities fulfill Government requirements.

These partnerships will enable private industry to assume roles that have been traditionally Government-only by creating new opportunities for economic growth through new markets and industries in LEO. They will potentially yield long-term cost savings to the Government by leveraging industry innovation and commercial market incentives. These activities will create a market environment in which commercial LEO destination services are available to both Government and private-sector customers. Commercial LEO destinations, along with commercial launch services, will provide the backbone of that the human spaceflight economy after the life of ISS.

How NASA Engages and Works with Partners

When NASA returns to the Moon, we will go in a way that reflects the world today, with Government, industry, and international partners working together in a global effort to build and test the sustainable systems needed for successfully executing challenging missions on towards Mars . The advent of a robust commercial space economy has introduced new partners to the world of human space exploration and shifted the way we do business. To remain the world leader in human space exploration, we will continue to evolve.

The emphasis on public-private partnerships as the preferred program acquisition approach to extend human presence deeper into space will continue to change, with a new focus on embedded teams with mutually agreed upon support and outcomes. We continue to engage industry and academia early to build trusted relationships during the program definition and solution creation process, providing NASA competencies through people, processes, tools, and facilities to help in the management of risks encountered during the execution of our partner's proposed approach.

NASA relies on partnerships with academia and industry where we are developing American-led space infrastructure enabled by a commercial market, enhancing space access for both Government and commercial entities. These activities are catalysts for economic development, including those related to space tourism. Together, NASA and our partners will help ensure the well-being of future space explorers and support existing and future space operations for both NASA and non-NASA missions.

Contributing Programs and/or Program Activities

Commercial LEO Development Program; International Space Station; Commercial Crew Program; Crew and Cargo Program.

Strategic Objective 2.3

Develop capabilities and perform research to safeguard explorers.

Provide enhanced capabilities, maintain crew health and performance, and conduct research to ensure safe space exploration.

Lead Office
Space Operations Mission Directorate (SOMD)

Objective Overview
Humans worked briefly on the Moon 50 years ago and have pioneered technological advances in low Earth orbit for the past 40 years. The activities that NASA leads that will return humans to the Moon, and from there on towards Mars, are focused on "buying down" risk through research and the development of tools and techniques to protect humans during deep space exploration. NASA is working to overcome radiation, crew isolation, and deep space communications delays, as well as food, medicines, and shelf-life constraints. Each of these challenges must be solved to ensure crew members are safe and healthy as we move beyond low Earth orbit.

NASA is pursuing new technologies that will help manage the effects of extended stays in space on human health and performance. Each advance in our knowledge can provide basic human needs, including oxygen and water, along with the ability to maintain and repair critical systems. NASA will demonstrate the performance of emergent technologies in an environment where the risk to the safety of human or vehicle operations can validate the performance of the technology without risking the crew or mission, and prior to their use in an operational environment.

Below: NASA astronaut Kate Rubins works inside the Life Sciences Glovebox in late 2020, conducting research for the Cardinal Heart study. Biomedical research seeks to help scientists understand the aging and weakening of heart muscles to provide new treatments for humans on Earth and astronauts in space. Image Credit: NASA

NASA emphasizes partnering with industry and academia to develop new technologies that will enable future space travel that is less reliant on resupply and communications from Earth. The resultant reduction in logistics costs and increase in system capabilities and reliability are designed to safeguard humans on missions beyond low Earth orbit. The knowledge gained though research on the effects of reduced gravity on the systems in the body—including studying research areas that are unique to the Moon, Mars, and other destinations—will help quantify the best methods and technologies to support safe and productive human missions in deep space.

Objective Strategy

NASA is developing capabilities, necessary countermeasures, and technologies in support of human space exploration, focusing on those capabilities that will mitigate the highest risks to crew health and performance. Some of these technologies will reduce medical and environmental risks and ensure effective human-system integration with the exploration mission systems necessary to safely explore in deep space.

New approaches are necessary to rapidly develop prototype systems, demonstrate key capabilities, and validate operational concepts to safeguard explorers during future human missions beyond low Earth orbit. NASA will continue to invest in exploration research and development and testing in both terrestrial and space environments. Most significantly, we will continue to use the ISS as a steppingstone to expand human presence farther into the solar system. The International Space Station (ISS) continues to expand our knowledge and experience in long-duration spacecraft operations and serves as an irreplaceable testbed for technology demonstrations of new capabilities and upgraded vehicle systems.

NASA enables space exploration by reducing the risks to astronaut health and performance using ground research facilities, the ISS, and analog environments. The performance of research in this combination of settings facilitates the development of procedures and furthers research areas that are unique to the Moon, Mars, and other destinations. Our portfolio is built around an architecture that uses evidence to identify a risk to the human system, gaps in our knowledge about characterizing or mitigating the risk, and the activities necessary to produce the knowledge necessary to close the gaps and reduce the risk.

NASA astronaut and Expedition 66 flight engineer Megan McArthur is seen with a taco made using fajita beef, rehydrated tomatoes and artichokes, and chile peppers. The chile peppers were grown as part of the Plant Habitat-04 investigation aboard the International Space Station. Image Credits: NASA/Megan McArthur

NASA supports the astronaut corps, space flight readiness training, and the health of crew members before, during, and after each spaceflight mission to the ISS. From Apollo through the Space Shuttle and to the ISS, crew members undergo rigorous preparation, which is critical to mission success. To pave the way to the Moon and onto Mars, NASA will partner with academia and commercial industry to prepare crewmembers for living and working for extended periods in space. Key activities include the identification of new training regimes to prepare crews for extended periods of space travel, including the identification of protocols for medical or technical problems that might arise when returning to Earth will take days, not hours.

How NASA Engages and Works with Partners

For decades, NASA has demonstrated world-wide leadership across a broad spectrum of life sciences research communities, where we work with our international partners, other Federal agencies, and the academic and private sector to develop the knowledge that supports safe and healthy space travel. Formal agreements between NASA, other Federal agencies, academia, and our international partners form the basis of decades-long joint research activities on quantifying and mitigating the effects of space travel on humans. The knowledge gained with our partners will continue to inform our design for safer deep-space exploration systems.

NASA will continue to focus on preparing humans for the stresses of living and working for extended periods in the hostile environment of space. As humans explore further from Earth, many different issues will arise and require investigation. NASA will continue to study multiple human system challenges, including bone and muscle loss, vision, health, and wellness monitoring, and physical and mental function maintenance. These activities have led us to develop an exploration biomedical program focused on several goals: informing human health, performance, and habitability standards; developing countermeasures and risk-mitigation solutions; and advancing habitability and medical-support technologies. The 2021 report by the National Academies of Science, Engineering, and Medicine for managing cancer risks associated with radiation exposure during crewed space missions[1] will help inform future crew health and safety.

Contributing Programs and/or Program Activities

Human Research Program; Human Space Flight Operations.

1 Space Radiation and Astronaut Health: Managing and Communicating Cancer Risks, National Academies of Science, Engineering, and Medicine, 2021.

Strategic Objective 2.4

Enhance space access and services.

Meet the communication, launch service, and strategic capabilities needs of NASA's programs.

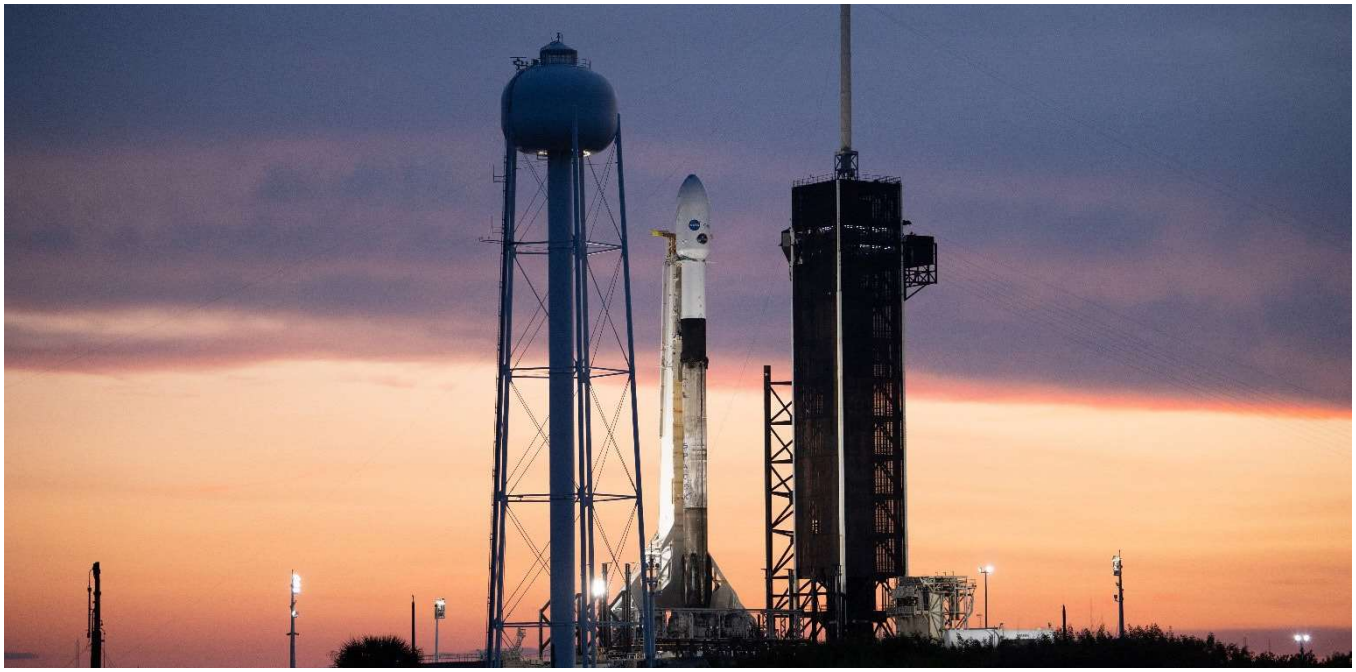
Lead Office
Space Operations Mission Directorate (SOMD)

Objective Overview
The ability to provide cost-effective, mission-essential services provides a stable foundation for America's human and robotic missions. These capabilities range from acquiring launch vehicles for U.S. Government civil sector and robotic missions, to communicating with both crewed missions such as the International Space Station (ISS) in low Earth orbit, the Artemis lunar missions, and uncrewed, scientific missions such as planetary rovers on the surface of Mars.

NASA provides safe, reliable, and cost-effective launch services for NASA and NASA-sponsored payloads seeking access to space on U.S. commercial launch vehicles. As the launch agent of the U.S civil space sector, NASA relies on the Launch Services Program (LSP) to certify new commercial launch vehicles for readiness to fly high-value spacecraft, and direct vital launch mission assurance efforts to ensure the greatest probability of launch mission success. LSP's primary responsibility is to meet the needs of a diverse customer base spanning our Mission Directorates, a wide range of educational organizations, and other customers. LSP is the Agency's recognized expert in all aspects of commercial launch services, including acquisition, certification, and mission management.

NASA provides the critical communications and navigation services to our operational missions, and we will continue to invest in critical technologies that will increase reliable communications capabilities. NASA engages with the satellite communications industry to develop communications capabilities that supports U.S. needs, are globally competitive, and advance U.S. leadership in the generation of new markets. Today, commercially provided satellite communications continues to mature, and NASA envisions a commercial communications market where near-Earth customers will have access to suitable commercial services and where NASA is one of many customers.

Below: A SpaceX Falcon 9 rocket carrying NASA's Imaging X-ray Polarimetry Explorer (IXPE) spacecraft is seen at sunset on the launch pad at Launch Complex 39A, December 8, 2021, at NASA's Kennedy Space Center in Florida. The IXPE spacecraft is the first satellite dedicated to measuring the polarization of X-rays from a variety of cosmic sources, such as black holes and neutron stars. Image Credit: NASA/Joel Kowsky



Developing and testing rocket propulsion systems is foundational to spaceflight. Whether the payload is a robotic science experiment or a crewed mission, the propulsion system used to launch it must be safe and reliable. Utilizing unique test facilities, NASA ensures the safe and effective execution of a rigorous engine test program, critical to any rocket propulsion development activity.

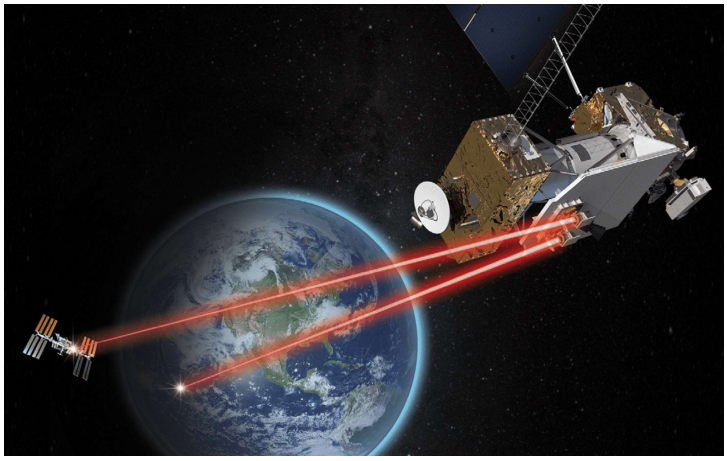
Objective Strategy

NASA has an important role as a valued partner and advisor to the U.S. commercial launch industry. To ensure the U.S. launch industry continues to grow and maintain a completive posture, NASA certifies new commercial launch vehicles for readiness to fly high value spacecraft, performs key mission design and launch integration activities, and directs launch mission assurance efforts to ensure the greatest probability of launch mission success.

The National Space Policy directs that we make use of, rather than duplicate, commercially provided services. NASA has a diverse set of users and communications needs against which commercial capabilities will be evaluated, such as launch vehicle support, visiting vehicles to ISS, human space flight, and science missions in Earth orbit, which range from flagship observatories to SmallSats and CubeSats. NASA will systematically migrate near-Earth missions from communications and navigation services provided by Government-owned networks to commercial networks. NASA will continue to provide support to our users and envisions transitioning future space-relay users to commercial providers over the next decade.

NASA is investing in critical technologies that will increase reliable communications capabilities and transform NASA mission technology. Our strategy is guided by the ability to acquire and utilize advanced space capabilities to the maximum extent possible. NASA's efforts in the continued development of communications technologies will enable, improve, and mature available communication and navigation technologies for both ground and space-based use. NASA will continue to leverage investments, experience, and accomplishments in many areas, including optical communications, building the initial technologies and capabilities required for future space-based communications networks.

NASA manages testing facilities across the Nation, where both our programs and U.S. industry conduct rocket engine and component tests under controlled conditions. Our decades of experience in rocket propulsion testing ensures the delivery of



Launched in December 2021, the Laser Communications Relay Demonstration will demonstrate optical communications capabilities for future missions. Most spacecraft use radio frequency technology to communicate with Earth. Optical communications could increase bandwidth 10-100 times more than radio frequency. (Artist Illustration) Image Credit: NASA

desired outcomes while minimizing test time and costs. NASA has a keen focus on streamlining facility usage and eliminating redundant capabilities that keep this national asset available, as required, by multiple customers and users.

How NASA Engages and Works with Partners

NASA continues to work with industry and academia through a variety of partnerships, including numerous Space Act Agreements, focusing on rocket propulsion testing, space-based communications, launch system risk reduction, and other strategic capabilities. For example, executing a robust and proven strategy, NASA achieves assured access to space through a competitive "mixed fleet" approach that utilizes the breadth of U.S. industry's capabilities. LSP provides expertise to NASA payload missions who are using launch services through other Government agencies, the launch industry, or contributed by a foreign partner. NASA collaborates extensively with the U.S. Space Force and other agencies in the areas of mission assurance, fleet surveillance, and acquisition strategy, and is an invaluable source of technical expertise and insights across the U.S. commercial space industry.

NASA's Rocket and Propulsion Test (RPT) program is responsible for managing and sustaining the Agency's expertise and facilities for ground testing of rocket engines. RPT provides vital propulsion data to validate initial designs, increase confidence

in technical performance, reduce risks, and ensure launch readiness in preparation for Artemis I and Artemis II, as well as supporting the Commercial Crew Program's milestones.

Contributing Programs and/or Program Activities

Communications Services Program; Launch Services; Rocket Propulsion Test; Space Communications and Navigation.

NASA astronaut and Expedition 63 Commander Chris Cassidy poses with two Astrobee robotic assistants during visual and navigation tests inside the Kibo laboratory module from Japan Aerospace Exploration Agency (JAXA) Image Credit: NASA

STRATEGIC GOAL 3

CATALYZE ECONOMIC GROWTH AND DRIVE INNOVATION TO ADDRESS NATIONAL CHALLENGES.

Goal Statement

NASA drives economic development and growth through technological innovation. The National Aeronautics and Space Act of 1958 specifically calls out this important theme, and since its inception NASA's investments have driven innovation, benefitting the U.S. economy and the American people. It was Apollo and other U.S. space programs, with their need for large quantities of integrated circuit components, that led to lower-cost production and provided a critical early boost to the growth of the American semiconductor industry. Similarly, NASA's early role in the development of satellite communications and remote sensing

eventually led to the emergence of the robust space-based market, spanning a broad range of commercial communication and data services.

Originally tied to keeping the Nation secure and advancing U.S. leadership in aeronautics, communications satellites, and Earth remote sensing, NASA's mandate is broader today. The challenges NASA addresses relate to gathering climate change data; driving American innovation through aerospace research and development; developing commercial and human space launch, transportation, and exploration capabilities; understanding cosmic phenomena as wide-ranging as space weather, asteroids, and exoplanets; supplying technological solutions that could also apply to terrestrial problems; and improving the Nation's innovation capacity.

Today, NASA invests in a broad portfolio of both space technology and aeronautics research, development, and demonstration. We invest more than 80 percent of our funds in U.S. industry and academia. Where possible, the Agency leverages public-private partnerships, reducing development costs, accelerating infusion of new technologies, meeting national needs, and potentially enabling new markets. Each year, NASA creates over 1,000 new technologies, and the Agency works diligently to ensure that the American people receive maximum benefit from those advancements through patent licenses, software usage agreements, and other commercialization efforts.

Maintaining America's Global Standing

In solving some of the most difficult technological challenges our Nation faces in space and flight, NASA serves as an innovation leader, sourcing ideas from a broad, diverse base of organizations and transferring technology into the aerospace economy. NASA's technology investments help grow the U.S. industrial and academic base, continuing the Nation's economic leadership and strengthening our national security.

In the coming years, NASA will advance space technologies that enable rapid, safe, and efficient transportation, as well as expanded access to diverse surface destinations. We seek to enable a vibrant space economy with technological advancements that foster U.S. innovation and competitiveness, drive economic growth and the creation of high-paying U.S. jobs, and ensure national leadership in space. Similarly, NASA is making significant contributions to keep U.S. aviation the global leader in safety, efficiency, and innovation. We explore early-stage concepts, develop new technologies and air traffic operational procedures, and demonstrate their potential to transform aviation into an economic engine at all altitudes. The Agency is committed to cutting-edge research and technology to assure U.S. competitiveness in space and in flight.

NASA embraces competition and external partnerships to spur innovation and entrepreneurship. We partner with universities, small businesses, industry, emerging commercial entities, individual innovators, and other Government agencies. With a focus on reducing technology risks through research, transitioning promising concepts, and infusing NASA technologies into commercially viable products and services, NASA furthers American technological leadership through active engagement with a diverse U.S. innovation community.

Driving Economic Growth

Technology drives the aerospace economy. Through its space technology and aeronautics portfolios, NASA proactively works to drive U.S. economic growth and job creation in the U.S. space industry by reducing research and development risks for U.S. companies; stimulating new business creation and maturation; removing barriers to entry for new businesses to enter the market; supplying small businesses with training and expertise to grow in the marketplace; providing opportunities for businesses to test and mature technologies in relevant environments; and building bridges for industry to access technologies through licensing technology and serving as an early customer to help jumpstart new markets.

Addressing Climate Change

NASA research is directly contributing to the long-term sustainability of aviation, including reduction of greenhouse gas emissions and noise by developing and testing new green technologies for next-generation aircraft, new automation tools for greener and safer airspace operations, and sustainable energy options for aircraft propulsion. We partner with industry, academia, and other Government agencies through the Sustainable Flight National Partnership to accomplish the aviation community's aggressive international carbon reduction goals. For example, through our work in advanced vehicle technologies, efficient airline operations, and sustainable aviation fuels, we aim to potentially achieve net-zero aviation carbon emissions by 2050. We also invest in technologies that can reduce greenhouse gases, provide new clean energy alternatives, and improve climate observations and climate adaptation decision support.

Strategic Objective 3.1

Innovate and advance transformational space technologies.

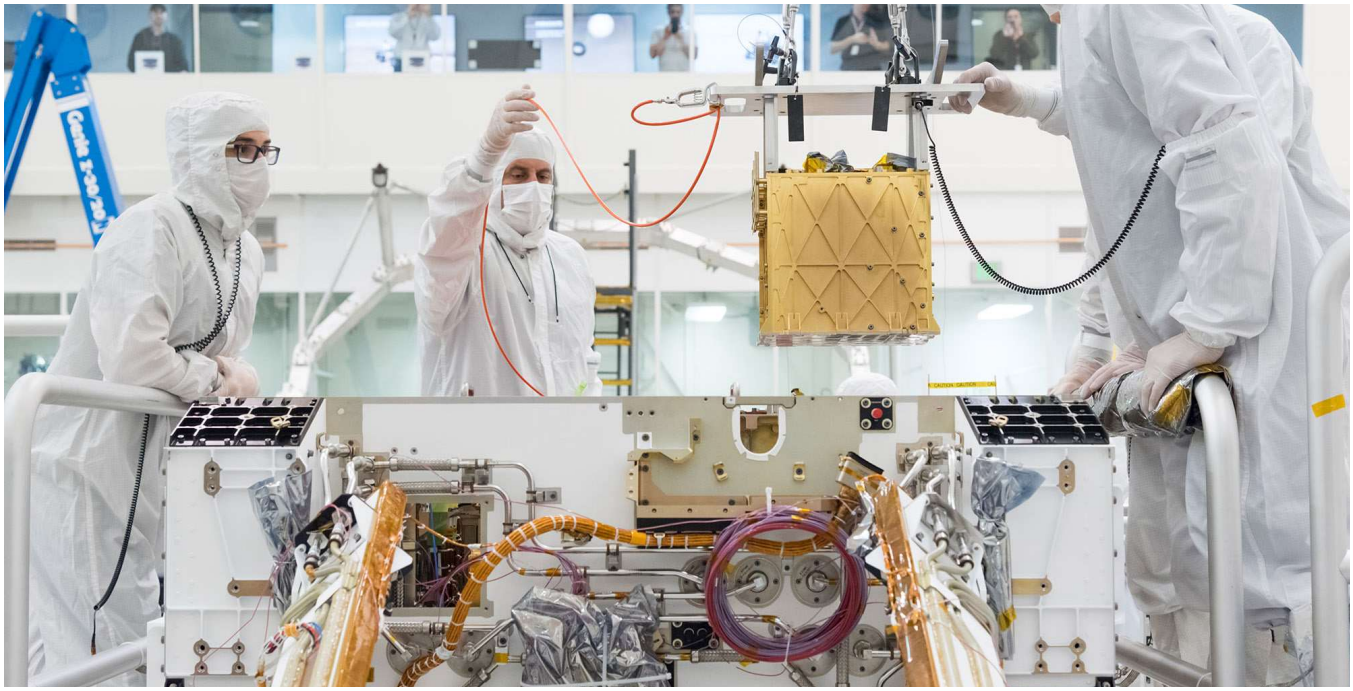
Develop revolutionary, high-payoff space technologies driven by diverse ideas to transform NASA missions and ensure American leadership in the space economy.

Lead Office
Space Technology Mission Directorate (STMD)

Objective Overview
Technological leadership remains vital to our national security, economic prosperity, and global competitiveness. The Nation's continued economic leadership is due in part to the technological investments made over time that enabled our country to emerge as a global technological leader. That commitment accelerated the economy with the creation of new industries, products, and services that yielded lasting benefits. Moving forward, a technology-driven NASA will continue to help fuel our Nation's economic engine and support the creation of jobs for decades to come, while also providing valuable breakthroughs for NASA's missions and the commercial space industry. In short, technology drives the space economy.

As NASA embarks on its next era of discovery and exploration, the advancement of transformational space technologies help guide the journey ahead. We invest in crosscutting and transformational technologies that have high potential for offsetting mission risk, reducing cost, and advancing existing or creating new capabilities. Our technology investments enable NASA's science and human exploration missions and foster growth and job creation in domestic industries. We harness innovation and entrepreneurship through partnerships with universities, small businesses, and other Government agencies, while also engaging the broader public. Through leadership in space technology, NASA will contribute to growing the U.S. industrial and academic base by transferring space technology into the space economy, continuing the Nation's global economic leadership, and strengthening our national security.

Below: Members of NASA's Mars 2020 project install the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) into the chassis of NASA's next Mars rover. MOXIE will demonstrate a way that future explorers might produce oxygen from the Martian atmosphere for propellant and for breathing. The car-battery-sized instrument does this by collecting carbon dioxide from the Martian atmosphere and electrochemically splitting the carbon dioxide molecules into oxygen and carbon monoxide molecules. The oxygen is then analyzed for purity before being vented back out to the Martian atmosphere along with the carbon monoxide and other exhaust products. Image credit: NASA/JPL-Caltech



In the coming years, NASA will advance technologies that enable rapid, safe, and efficient transportation as well as expanded access to diverse surface destinations. We seek to enable a vibrant space economy with supporting utilities and commodities through investments in in-situ resource utilization, sustainable power systems, and autonomous construction. NASA will invest in technologies to enable long duration human exploration missions and those that transform our missions and discoveries by investing in high performance computing, advanced robotics, satellite servicing and assembly, in-space manufacturing, and new vehicle platform technologies that are more rapid, affordable, and capable. These technological advancements will foster U.S. innovation and competitiveness, drive economic growth and the creation of good-paying jobs, and ensure national leadership in space.

NASA also continues to advance climate and clean energy technology innovations. We emphasize reducing greenhouse gas emissions (including carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons); production of clean energy; sustainable aviation; climate science observations; and harnessing data for climate research. We will formulate new prizes, topics within the Small Business Innovation Research and Small Business Technology Transfer programs, and grant opportunities to address climate challenges and the clean energy economy. In addition, NASA will be supporting Earth-observing capabilities for Small Spacecraft platforms to support breakthrough science and National efforts to address climate change.

In addition, NASA will be supporting Earth-observing capabilities for small spacecraft platforms to support breakthrough science and national efforts to address climate change.

Objective Strategy

Working closely with stakeholders, enlisting partnerships, utilizing evidence-based decision making, and promoting diversity, equity, inclusion, and accessibility are all key to our strategy.

To balance near-, mid-, and long-term technology requirements we employ a merit-based competition model, with a portfolio approach spanning a range of discipline areas and technology readiness levels. Integration across programs is key to identifying and successfully transitioning and transferring new capabilities. By working with potential stakeholders up front and continuously engaging through conception, maturation, and demonstration, we are more effective in transferring new transformative technologies and capabilities within NASA, the U.S. Government, and throughout industry and academia.

A NASA technology that could one day help land humans on Mars is under development and will be tested in 2022. The Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)will demonstrate entry of an aeroshell from low-Earth orbit. This technology enables a variety of proposed NASA missions to destinations such as Mars, Venus, Titan as well as return to Earth.

NASA's technology portfolio has grown significantly in recent years, and enhancements in portfolio management processes and functions are required to continue effective and efficient operations. We focus on evidence-based decision making as part of our success strategy. Continuous improvement of data management enables us to have a more complete understanding of the vast array of projects within our portfolio, allowing for the investigation of technology development history to inform future investment decisions. Strategic implementation planning remains an integral component of meeting our objectives. Moving forward, focused, outcome-based requirements and documentation will inform quantitative analysis of technology gaps and provide guidance for future investments.

NASA promotes diversity, equity, inclusion, and accessibility, guided by Executive Orders 13985 and 14041, through supporting participation by underserved communities in its technology programs. A key element of our strategy is inspiring and

developing a diverse and powerful U.S. aerospace technology workforce. We remain focused on increasing the diversity of our innovation community. Accordingly, our space technology programs participate in the NASA Science, Technology, Engineering, and Mathematics (STEM) Engagement Minority University Research and Education Project (MUREP) to engage and support Minority Serving Institutions (MSIs), including Historically Black Colleges and Universities (HBCUs). Through MUREP, NASA reaches scientists, engineers, and students from underserved and underrepresented communities. For example, in 2021, NASA awarded grants, up to $50,000 each, to 11 MSIs to foster partnerships between those institutions and U.S. small businesses while also potentially lowering the barriers of entry to participation in NASA's Small Business Technology Transfer program. We also recently launched a pilot initiative with the MSI STEM Research and Development Consortium aimed at increasing MSI participation in Federal research. Additionally, our annual "Technology Infusion Road Tour" reached representatives from MSIs to share insight and strategies on how to pursue procurement and technical opportunities with the Agency. Moving forward, our Early-Stage Innovation and Partnerships, Technology Maturation, and Technology Demonstration portfolios will continue to explore new approaches to increase participation by underserved communities.

How NASA Engages and Works with Partners

To ensure American leadership in the space economy, NASA aggressively pursues critical technology gaps and global space technology leadership. We embrace competition and external partnerships that spur innovation and entrepreneurship. We create partnerships with universities, small businesses, industry, emerging commercial entities, individual innovators, and other Government agencies to meet NASA mission needs and support commercial expansion in space. We also welcome opportunities to work with our international partners on shared priorities. With a focus on infusing NASA technologies into commercial products and services, we actively engage our stakeholders to help define investment content and identify opportunities where technological advances can enable a commercially viable product or service. We utilize multiple mechanisms to partner with industry, including public-private partnerships through contracts and Space Act Agreements. By sharing the risk and financial stakes with the private sector, other Government agencies and internal stakeholders, NASA encourages future commercial markets in the process of developing new capabilities. NASA invests in high-risk, high-reward activities across the technology development spectrum through our partnerships.

NASA understands the future of American leadership in space depends on a national aerospace technology workforce comprised of inventors and innovators across a wide spectrum of disciplines in addition to technologists and engineers that tackle the hard problems that space presents, and our partnerships spur growth in these disciplines. We also recognize that diversity of thought and background, and cross-disciplinary perspectives are critical to the Nation's success and that working to attain equity must include building better bridges to underserved and underrepresented communities, so no talent is missed in achieving our national space technology objectives.

Contributing Programs and/or Program Activities

Early-Stage Innovation and Partnerships; Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program ; Technology Demonstration; Technology Maturation.

Strategic Objective 3.2

Drive efficient and sustainable aviation.

Lead aviation innovation to enable safe and sustainable air transportation through revolutionary vehicle advances and efficient flight operations.

Lead Office

Aeronautics Research Mission Directorate (ARMD)

Objective Overview

Air transportation is an integral part of modern life, providing safe, affordable, and convenient travel to the public. Consequently, it has become an integral part of the U.S. and global economy. In a 2020 economic impact report[1] published by the Federal Aviation Administration, air transportation[2] provided $78 billion of positive trade balance for the U.S. manufacturing sector, 10.9 million direct and indirect jobs and 21.3 billion tons of freight by the U.S. airlines culminating in $1.8 trillion of total U.S. economic activity (8.6 percent of the 2018 U.S. Gross Domestic Product). Of the 10.9 million jobs, over one million were high-quality manufacturing jobs. Nearly every product created and purchased today (from toys to groceries) is touched by aviation in some way. Speed, convenience, and economic benefits from air transportation are the primary factors in its rapid growth; benefits that have been even more important during the COVID-19 pandemic.

NASA's research contributes significantly to the aviation sector in improving its safety, efficiency, and resulting economic well-being of the Nation. Our role is to reduce the risk inherent in innovative concepts. We explore early-stage concepts and ideas, develop new aviation technologies and air traffic operational procedures, and demonstrate their potential in a relevant environment. The Agency is steadfast in its commitment to cutting-edge research and technology development and demonstration to assure U.S. competitiveness in the aviation sector.

1 2020 Economic Impact Report
2 Pre-Covid-19

Below: An ultra-efficient aircraft shape called the "transonic truss-braced wing" undergoes testing in NASA's 14'x22' wind tunnel at Langley Research Center in Virginia. The unique design of its wing reduces drag during flight, which in turn reduces fuel consumption by up to 10 percent. Further development and testing of this concept are taking place under NASA's Sustainable Flight National Partnership, which is expanding research to enable more sustainable aviation. Image credit NASA

Objective Strategy

To continue NASA's leadership in aviation innovation and enable a revolutionary transformation of the aviation system, NASA is focused on six major research areas, or Thrusts, for the long-term future of aviation. These research Thrusts utilize the full capability of our in-house aeronautics expertise. Through high-risk, high-reward research and technology development, NASA seeks to enable:

- Safe and efficient growth in global operations;
- Innovation in commercial supersonic aircraft;
- Ultra-efficient subsonic transports;
- Safe, quiet, and affordable vertical lift air vehicles;
- In-time system-wide safety assurance; and
- Assured autonomy for aviation transformation.

Each Thrust is designed to address an important area of research and technology development that will further U.S. leadership in the aviation industry and enhance global mobility. This research is performed with an emphasis on multi-disciplinary collaboration focused on the critical, integrated challenges aligned to the six research Thrusts—what NASA refers to as convergent research. Together, these research Thrusts combine to enable safe, sustainable growth in the overall global aviation system, while pioneering transformative capabilities that will create revolutionary opportunities.

NASA works with partners in other Government agencies, industry, and academia to support innovative concepts and technologies, and with international counterparts to leverage complementary investments.

How NASA Engages and Works with Partners

NASA is committed to increasing diversity and broadening representation in the Nation's aeronautics research and development enterprise, both internal and external to NASA. We engage with the private sector and academia in research activities through solicitations such as the NASA Research Announcements. We encourage participation by academic institutions that serve underrepresented and minority groups through active outreach to professional organizations for women and to Minority Serving Institutions (MSIs) and Historically Black Colleges and Universities (HBCUs) informing them about NASA's portfolio and upcoming opportunities. ARMD's University Leadership Initiative (ULI) is one notable example of our efforts in this regard. ULI represents a new type of interaction with the university community, where universities take the lead, build their own teams, and set their own research path. Under this initiative, we explicitly require proposing university teams to include MSIs and HBCUs and continue to encourage women faculty members to apply. We also leverage Minority University Research and Education Project (MUREP) funded by NASA Office of Science, Technology, Engineering and Mathematics.

The X-59 QueSST (Quiet SuperSonic Technology) aircraft will fly at supersonic speeds above communities during the Low-Boom Flight Demonstration mission, generating sonic "thumps" instead of booms. Image credit: NASA/Lockheed Martin

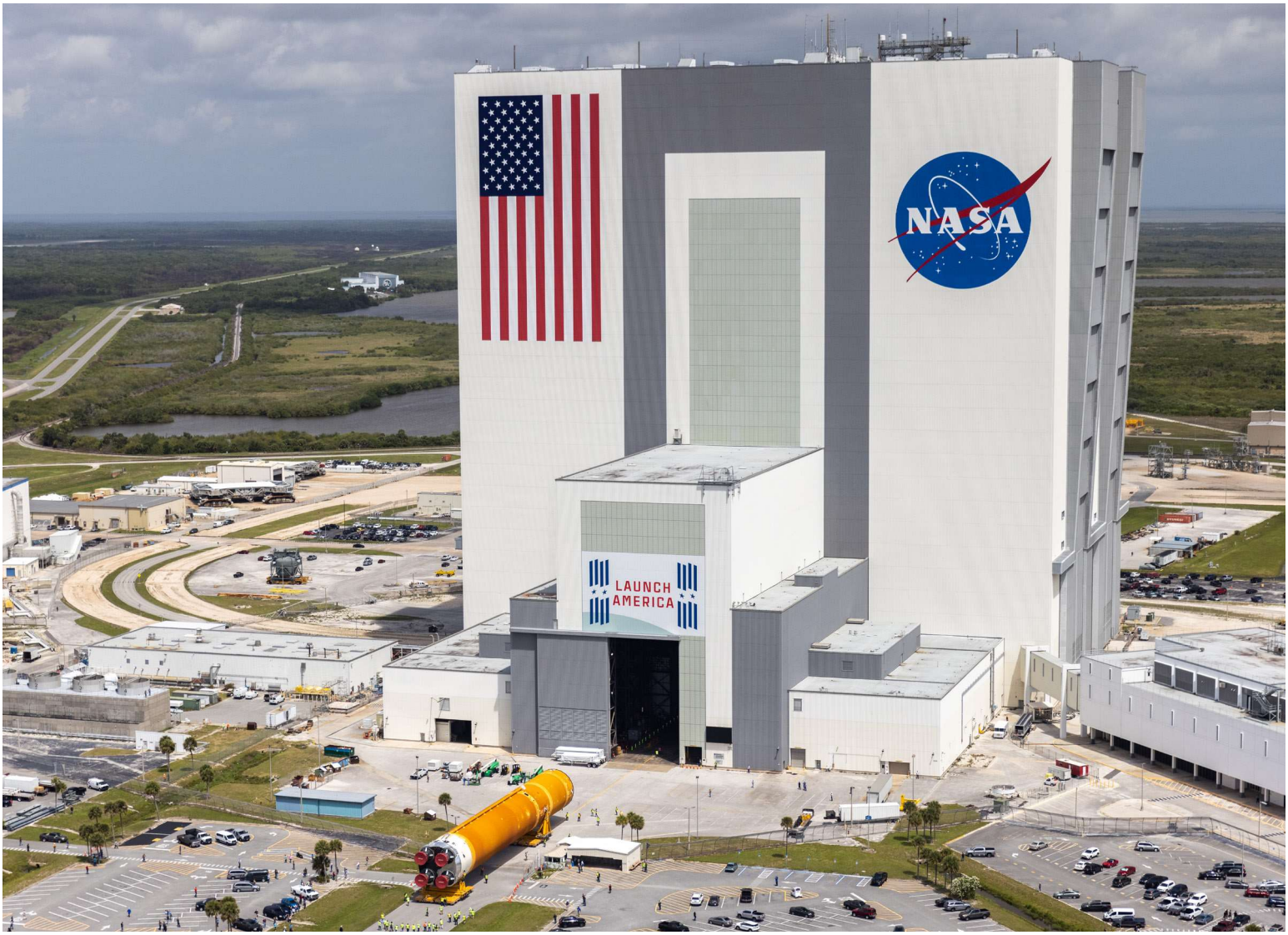
Partnerships with other Government, industry, academia, and foreign aeronautics agencies leverage ARMD's investments through joint efforts that complement NASA's internal capabilities, provide access to a wide range of technologies beyond the traditional aeronautics portfolio, and facilitate technology transfer to more mature states of development and eventual implementation. Integrated technology demonstrations typically include selected industry or Government partners who contribute their

own funding or knowledge. These partnerships also give ARMD deep insight into the goals and needs of the aviation community, as well as providing user feedback and facilitating industry engagement early in the technology development cycle.

ARMD collaborates closely with the Federal Aviation Administration to support their decision making and to improve the performance of the National Airspace System (NAS), as well as with the Department of Defense and other Government agencies to leverage technology investments. Industry partnerships allow rapid insertion of NASA aeronautics research results into air vehicles and subsystems, and NAS operations, tools, and processes. Partnerships with domestic academic institutions support cutting-edge research on emerging aviation technologies and on the education of new researchers in various fields of study. To help address the global nature of air transportation, ARMD also forges partnerships with a wide range of international Government entities, such as the International Forum for Aviation Research.

Contributing Programs and/or Program Activities

Advanced Air Vehicles Program; Transformative Aero Concepts Program; Integrated Aviation Systems Program; Airspace Operations and Safety Program; and Aerosciences Evaluation and Test Capabilities.



The Kennedy Space Center's Vehicle Assembly Building (VAB) is one of the largest buildings in the world. The high bay is big enough to hold the massive Space Launch System rocket boosters stacked on top of the mobile launcher. The high bay doors are 456 feet high. Image credit: NASA/Kim Shiflett

STRATEGIC GOAL 4

ENHANCE CAPABILITIES AND OPERATIONS TO CATALYZE CURRENT AND FUTURE MISSION SUCCESS.

Goal Statement

NASA's complex and bold missions require modern, adaptable technical and professional support capabilities to enable mission readiness, resilience, and our continued leadership in science, exploration, discovery, and innovation. The pace of change and innovation in aerospace is increasing, and NASA must deliver critical support capabilities for mission success. We will pursue the goal of enhancing capabilities and operations to ensure that NASA has the right people, infrastructure, technology, and technical excellence and oversight needed to advance the Agency into the Artemis era and beyond.

A diverse workforce, empowered in an equitable, inclusive, and accessible environment, is a key requirement for ensuring Agency success in the era of commercialized space. Diversity encourages new thought, inclusion ensures engagement, and accessibility creates a platform where all can participate. Together, these are key elements that spark innovation and ensure the Agency's ability to generate the best ideas and solutions to novel and unprecedented challenges. To support our Core Value of Inclusion, we will implement a robust and systematic strategy to ensure diversity, equity, inclusion, and accessibility (DEIA) for the benefit of all, internal and external to NASA. In addition to fulfilling presidential directives and executive orders, NASA will continuously promote the incorporation and transformation of DEIA into our culture and business practices at all levels of the Agency.

NASA and the Nation need a diverse and skilled science, technology, engineering, and mathematics (STEM) workforce today and in the future. We are committed to engaging, inspiring, and attracting future generations of explorers and building a diverse future STEM workforce through a broad set of programs, projects, internship opportunities, activities, and products that connect students to NASA's mission, work, and people, whether in-person or virtually.

Competition for top STEM talent, along with other business and professional skillsets needed at NASA, is increasing, and an ever-increasing portion of our current civil service workforce is retirement eligible. Meanwhile, top talent expects hybrid work experiences that allow flexibility around where, when, and how they work best. To address these factors, we will equip our people for the growing exploration, science, and aerospace economy through a focus on innovation, digital skill set development, and increased team agility (through hybrid collaboration tools and other innovations). We will also implement modern human capital solutions and policies to attract, hire, and retain our talented workforce.

NASA also recognizes that a modern physical infrastructure that will foster innovation is key in attracting, retaining, and supporting top talent to meet mission needs and be an employer of choice for years to come. NASA's physical infrastructure and technology support our missions. However, much of NASA's physical infrastructure dates back to the Apollo era and is well beyond design life. We will utilize a mission-driven, technology-enabled approach to ensure critical capabilities and assets are mission-ready, reliable, and affordable. NASA will also rebuild and right-size our infrastructure and technical capabilities to support hybrid work environments, accessibility, environmental stewardship, and sustainability.

NASA will transform and modernize our mission support capabilities to address rapidly changing information technology (IT), tools, expanding data collection, analysis and dissemination, and evolving cybersecurity threats. Digital technologies will improve the way that we work and collaborate internally and with our partners, increasing the effectiveness of our business processes and delivering better experiences and more value to our customers. NASA will continue pursuit of robotic process automation, data-driven decision lenses, enhanced cloud offerings and artificial intelligence at scale where possible while ensuring security, credentialing, and privacy standards are maintained. Improvements to NASA's cybersecurity measures, including new applications, encryption, and IT infrastructure, will protect vital assets against threats from malicious actors. As technology's role in the workplace continues to expand with a hybrid workforce, NASA's IT services are vital to enabling and protecting the Agency's work.

NASA already published tens of thousands of datasets, numerous open-sourced code projects, and data in other forms, including imagery, that is readily accessible for application developers. NASA will work to provide equitable access to datasets and other NASA-developed information, including addressing barriers and biases that may make access difficult for people from underserved groups and users that have not traditionally used NASA data . Democratizing data enables teachers, students, researchers, and other Government agencies to promote data literacy, data driven decision making, and the sharing of best practices.

In alignment with our Core Values, assuring safety, security, and mission success remains an Agency priority, especially as mission complexity and integration with industry increases, and as the aerospace environment in which we operate rapidly changes. We will focus on evolving our safety, health and medical, and engineering oversight policies and practices to protect the Agency, public, and orbital and planetary environments from potential harm, while reaching mission success through innovative technical excellence.

NASA will maintain and enhance our mission support capabilities that enable us to engage in mu-

tually beneficial partnerships with other Federal agencies, U.S. industry, academia, nonprofit organizations, state and local Governments, and international entities that contribute to and support the Agency's Strategic Objectives and Mission.

Finally, NASA is committed to inspiring an informed society by engaging the broadest audience possible, connecting with audiences outside of our traditional space community to expand the awareness of space, and effectively tell the stories that bring focus to our work, people, and value in everyday life.

Maintaining America's Global Standing

NASA's contributions to the Nation's leadership in science, exploration, discovery, and innovation have been enabled by the foundation of mission support services and infrastructure created by NASA.

Addressing Climate Change

NASA will continue to implement and improve sustainable best practices and outcomes in the management of our facilities, fleet, and cross-cutting operations, as well as our compliance with environmental laws. The NASA Mission Support Directorate and Office of Strategic Infrastructure will play key roles in the implementation of the NASA Climate Action Plan. NASA is developing an Agency Resilience Framework that will include adaptation to climate change. The framework will be integrated into the Agency Master Plan and Center Master Plans. The Agency Resilience Framework will provide guidance for development of Center Resilience Plans that will include a process for identifying threats, vulnerabilities, and risks; developing adaptation strategies; and prioritizing adaptation actions.

NASA will continue to invest in data management and collaboration capabilities to support collection, storage, processing, and appropriate sharing of information internally and externally to enable climate change analysis. We are dedicated to minimizing our mission and operational impacts on the environment and our use of natural resources. To ensure we uphold these high standards, share best practices, and promote transparency, we will continue to publish and implement NASA's annual Sustainability Report and Implementation Plan and other climate data.

Promoting Racial and Economic Equity

The NASA Office of Diversity and Equal Opportunity will work with all NASA Mission Directorates to help identify current barriers to and opportunities for advancing environmental justice, as well as potential partnership opportunities with organizations currently working on environmental issues. Through these efforts, we seek the fair treatment and meaningful involvement of all people regardless of race, color, ethnicity, gender, national origin, or income with respect to the development, implementation, and advancement of policies, knowledge, solutions, collaborations, partnerships, and the mitigation where possible of the effects of climate change on all people to which people are entitled under Title VI of the Civil Rights Act of 1964.

Through our STEM Engagement strategy, NASA will support student learning experiences and dedicated competitive opportunities for climate research capacity building at minority-serving institutions. Additionally, the STEM Engagement Internship program will support NASA climate change researchers through mentor-guided student intern experiences.

Strategic Objective 4.1

Attract and develop a talented and diverse workforce.

Cultivate a diverse, motivated, and highly qualified workforce through modernizing our Human Capital processes and systems, increasing our workforce agility and flexibilities, and implementing a robust Diversity, Equity, Inclusion, and Accessibility (DEIA) approach to ensure systematic and sustainable fairness, impartiality, and equity in our business practices.

Lead Office

Mission Support Directorate (MSD) and the Office of Diversity and Equal Opportunity

Objective Overview

NASA will modernize how we attract, hire, support, lead, and retain the quality, diversity, and depth of talent necessary for mission success. Recent experiences and lessons from the pandemic, as well as nationwide workforce and workplace trends, will inform and help NASA institutionalize and improve our hybrid work practices. NASA's modernization strategy will also address other factors such as an increasing number of retirement-eligible civil servants over the next five years and increasing competition for highly qualified science, technology, engineering, and mathematics (STEM) talent, especially as more commercial entities enter the field.

While NASA has long enjoyed a reputation of attracting top talent; we recognize the value of recruiting and employing a diverse workforce cannot be understated. The Agency is better positioned to fulfill its current and future missions when we intentionally invite people with different backgrounds, who show promise and potential, into spaces to inspire and challenge us to think and work differently.

Below: Diana Trujillo, an aerospace engineer, is Technical Group Supervisor for Sequence Planning and Execution and a Tactical Mission Lead for the Mars Perseverance rover. Born and raised in Colombia, Trujillo immigrated to the United States at the age of 17 to pursue her dream of working for NASA. In this photograph, Trujillo celebrates the completion of a successful shift as flight director. She is pointing at an image taken by the Perseverance Rover on the surface of Mars of the successful deployment of Ingenuity, the first helicopter ever delivered to the surface of another planet. Image Credit: NASA

In 2020, NASA added Inclusion to our Core Values, recognizing that inclusion is intrinsic to our work, our relationships, and our achievements. Inclusion increases collaboration and productivity. Additionally, it encourages employees to go above-and-beyond to achieve our goals. Also, all people want to feel a sense of inclusion and belonging. Inclusion happens when people can have psychological safety in being their authentic selves, sharing their ideas, knowledge, creativity, and innovation. The combination of all our values and the emphasis on Inclusion lets NASA strive to have a healthy culture and be an employer of choice.

Objective Strategy

NASA will continue to instill DEIA and other human capital best practices to modernize how we hire, retain, and develop our distributed and digitally enabled workforce. NASA will continuously improve our hiring and onboarding processes to enable our managers and human capital professionals to employ the right people, when and where they are needed to meet mission needs today and in the future. We will develop our people to meet evolving mission needs through increasing partnership opportunities with academia, and others, as well as through experiential rotations and meaningful leadership development assignments.

NASA will cultivate a workforce that is more agile and responsive to changing skill demands and requirements. Through effective and strategic workforce planning we will align workforce requirements directly to the Agency's Strategic Plan. In addition, we will identify gaps between competencies the workforce currently possesses and future requirements. Lastly, we will identify and implement gap reduction strategies such as: continuing to use contractors and term-limited appointments, leveraging NASA Excepted Employment appointments or temporary workers to meet current specific mission requirements, and ensuring we maintain a stable workforce to meet future demands. We will use Agency-specific direct hiring and term appointment authorities for the civil servant workforce to provide us the flexibility to optimally align competency and skill requirements to future mission needs.

We will transform our culture, policies, and tools to foster productive hybrid work environments that help NASA attract and retain a diverse, motivated, and highly qualified workforce. Informed by lessons learned from the pandemic and nationwide workforce and workplace trends, our remote work and telework options will be balanced now and in the future, to promote inclusive teams that incorporate multiple gender and racial identities, include diverse professional and education experiences, and lead to a greater diversity of thought which enables our workforce to provide premier support to our aerospace, science, technology, and exploration missions.

In support of the Administration's Executive Orders concerning DEIA, NASA will enhance our capabilities to identify barriers and mitigate their negative impacts on increasing diversity and inclusion, engaging underserved populations, and advancing environmental justice.

NASA enthusiastically supports the Administration's emphasis on DEIA to address social and political issues that need national and local attention and solutions. NASA is committed to inspiring and facilitating an environment in which DEIA standards are expected in our operations. To that end, our multi-prong strategy includes:

- Committing the Agency to action that fulfills Presidential directives (e.g., Executive Orders (see Appendix E), memoranda, etc.) and other Federal guidance and/or policies;
- Sustaining creative engagement to inspire and promote incorporation and transformation of DEIA in our culture and customary business practices at the Agency, Center, organization, and individual levels;
- Continuing our cross-collaborations with other agencies, such as the Equal Employment Opportunity Commission, Department of Justice, and the Office of Personnel Management for DEIA policy guidance, and reaching out to the

Department of Homeland Security and the Department of Defense to benchmark best practices in DEIA, and;
- Updating performance goals beginning in FY 2022 to align with this Strategic Objective.

Alignment with Federal Workforce and DEIA Priorities, and Related Executive Orders

NASA will align human capital practices to support the strategies outlined in the President's Management Agenda, place DEIA as a central norm of the workplace, and support Executive Orders concerning DEIA. Our programs seek to address under-representation based on race, ethnicity, gender identity, sexual orientation, tribal affiliation, and socioeconomics.

The Agency has already begun revising and updating its internal policies and guidelines, including a NASA Policy Statement on DEIA will enable NASA to achieve several objectives, including:

- Reinforcing NASA's historical commitment to improve DEIA;
- Providing notification to NASA employees of their DEIA rights and responsibilities;
- Taking proactive steps to prevent discrimination, retaliation, and harassment in order to avoid and mitigate legal liability; and
- Complying with the U.S. Equal Employment Opportunity Commission's Management Directive 715 requirement for the annual issuance of an equal employment opportunity policy statement by the head of each agency.

NASA will evaluate the current state of DEIA across the Agency and the workforce, and subsequently prepare an Agency DEIA Plan. This will also be followed by annual reports on the status of Agency efforts as required in Executive Order 14035 and includes efforts to incorporate guidance set forth by OMB. Working in concert with OMB, other Government agencies, and councils organized by the Administration, we seek to be a leading partner with other Government counterparts. A cornerstone of this planning will be collecting and analyzing comprehensive data, or leveraging existing data, related to diversity in overall workforce composition, senior workforce composition, employment applications, hiring decisions and applicant flow, promotions, pay and compensation, professional development programs, and attrition.

NASA believes that focusing a portion of recruitment efforts on early careerists and offering more remote and telework options will attract new, diverse applicant markets. We will also seek to understand the expectations and needs across our five generations of workers to maximize the use of programs such as term-limited employment that can tap part time, job-sharing options for those not seeking full-time employment, and our phased retirement and Emeritus programs to maximize knowledge transfer and mentoring from our senior careerists more fully. In addition, we are expanding internal job rotation and detail assignments by creating more "virtual/remote" opportunities that do not require physical relocation to provide broader career development opportunities across all Centers. Finally, we will expand our ability to understand workforce perspectives in real time by implementing ongoing pulse surveys, analyzing data from new-hire, Federal Employee Viewpoint Survey, and exit surveys, and piloting new techniques such as chatbots.

NASA will also implement or increase the availability and use of DEIA training programs for employees, managers, and leadership. Such training programs should enable knowledge of systemic and institutional racism and bias against underserved communities, provide support in building skillsets to promote respectful and inclusive workplaces and eliminate workplace harassment, and increase understanding of implicit and unconscious bias, the effects and impact of privilege, historic discrimination, and misrepresentation.

Contributing Programs and/or Program Activities

Mission Enabling Services.

Strategic Objective 4.2

Transform mission support capabilities for the next era of aerospace.

Re-build, modernize, and right-size NASA's mission enabling capabilities to ensure mission readiness and cultivate a reliable foundation for the future innovations in aerospace and science.

Lead Office
Mission Support Directorate (MSD)

Objective Overview
As NASA's missions evolve and increasingly integrate with industry, and hybrid workforces and workplaces become the norm, mission support requirements will change. In alignment with NASA's Core Values, mission support's top priority is ensuring mission success—safely and securely. This is increasingly challenging with the growing complexity of our missions. Much of NASA's infrastructure is from the Apollo-era. It is time to re-build, modernize, and right-size NASA's mission-enabling capabilities.

To advance an environment of inclusion, integrity, teamwork, and excellence required for the Artemis era, we must strengthen our technical authorities and modernize our physical and information technology (IT) infrastructure. NASA will focus on the following three priority areas:

- Strengthen NASA's Agency Technical Authorities
- Modernize infrastructure and technical capabilities
- Support our workforce and programs with secure, innovative technology

Objective Strategy
Strengthen NASA's Agency Technical Authorities - *Protect the Agency, public, and orbital and planetary environments from potential harm, while reaching mission success through innovative technical excellence.*

Below: Chief of the Test, Launch and Recovery Operations Branch within the Exploration Ground Systems Program Jeremy Graeber, (left) and Artemis I Launch Director Charlie Blackwell-Thompson (right), along with civil servant and contractor members of the Artemis I launch team, monitor activities during the ninth formal terminal countdown simulation inside Firing Room 1 in the Launch Control Center at NASA's Kennedy Space Center in Florida on June 24, 2021. This is part of a series of simulations to help the team prepare for the launch of Artemis I, the uncrewed first flight of the Space Launch System rocket and Orion spacecraft. Image credit: NASA/Kim Shiflett

With increasing mission complexity and a rapidly changing aerospace industry, NASA must evolve policies and practices that continue to protect the health and safety of our workforce and the public. NASA must also mitigate the technical risk to our missions and the space environment. NASA's Agency Technical Authorities advise Agency leaders and partners on programmatic and technical readiness and risk to ensure mission success. They must have the tools to ensure safety, security, and technical excellence objectives are met. The Agency Technical Authority role remains crucial and will play an important role in NASA's future missions, partnerships, and status as a leader in aerospace.

NASA is evolving mission enabling and oversight capabilities to successfully implement our missions in human exploration, climate research, and other objectives. Specifically, NASA will:

- Advance our ability to identify and mitigate new risks to personnel, both on the ground and in flight, as we continue to provide innovative support capabilities in aerospace, science, technology, and exploration to both protect and enhance performance across our entire workforce and our partners.
- Modernize our policies, standards, tools, and expertise to ensure that health and safety, security, and mission assurance practices are adaptable and woven into the design and development of increasingly complex missions and operations by NASA and its partners.
- Increase organizational resilience by assuring success through independent assessments and evaluations of mission threats through the development and dissemination of mitigation strategies.
- Continue to foster relationships with other Government agencies, such as the Federal Aviation Administration and Space Force, industry leaders, and international partners through interagency, Government-industry, and international working groups and committees aimed at the advancement of space industry practices, reduction of risk by implementing medical policy related to spaceflight, and state-of-the-art advances in aviation and spaceflight health and performance.

Modernize infrastructure and technical capabilities - *Rebuild and right-size NASA's infrastructure and technical capabilities to advance the Nation's science and aerospace leadership, while supporting environmental stewardship, sustainability, and enhancing resource conservation efforts.*

A Marshall Space Flight Center transportation specialist stands alongside two new, fully electric cars using Marshall's 240-volt charging station. NASA is acquiring zero emission vehicles (ZEV) and charging infrastructure to reduce greenhouse gas emissions in our fleet operations and align with the President's goal of achieving a fully ZEV Federal fleet.

Resilient and ready infrastructure is critical for mission success. Much of NASA's current infrastructure dates back to Apollo-era space exploration, with 83 percent of facilities beyond design life. The demands on the NASA infrastructure continue to increase as our commercial partnerships increase and our missions become more complex. NASA will prioritize and transform our asset management to ensure that our mission critical infrastructure and facilities are available and reliable in the Artemis era and beyond.

Guided by our Agency Master Planning process, we are taking an Agency-wide and mission-driven approach to ensure critical capabilities and assets are mission-ready, reliable, and affordable. At the same time, we are investing in the long-term asset health, sustainability, and physical footprint reductions that ensure NASA's future mission success. This mission-driven approach, utilizing data-driven and risk-informed methodologies, will ensure that NASA prioritizes sustainment and investment in mission critical infrastructure, divestment of unneeded infrastructure, and the leasing of assets to commercial partners where practical. We will continue our right-sizing efforts by demolishing and eliminating obsolete facilities to reduce our overall physical footprint, resource consumption, maintenance costs, and aging infrastructure risk, as well as enable our ability to re-new and rebuild modern

and sustainable infrastructure to support future mission success.

We will also continue to implement and improve sustainable best practices and outcomes in the management of our facilities, fleet, and cross-cutting operations, as well as our compliance with environmental laws. NASA is committed to sustained (year-over-year) reduction of our overall energy and water consumption. By identifying and quantifying facilities which are significant energy users and developing initiatives to reduce energy and water consumption in these facilities, eliminating unneeded and redundant facilities, and reducing our carbon footprint as we transform to increasingly hybrid work environments and fully transition to a zero-emission vehicle Federal fleet.

NASA will establish, implement, and manage an Agency-level plan to better align aircraft operational capabilities with NASA mission requirements across the Agency, strategically manage our aircraft capabilities to meet long-term Agency needs, and support NASA's leadership in aerospace and science. The domain of this plan includes NASA aircraft, associated infrastructure, support equipment, Unmanned Aircraft Systems, and the acquisition of Commercial Aircraft Services. This more robust, responsive, and agile approach to aircraft capability management and development will enable the Agency to optimally deploy aircraft capabilities and resources when and where needed, prioritize sustainment of current NASA aircraft capabilities, and support investment and divestment decisions. It will also empower the Agency to better leverage commercial and other Government aircraft capabilities to support achievement of NASA strategic goals and objectives.

Support our workforce and programs with secure, innovative technology - *Address rapidly changing IT, expanding data collections, and increasing cybersecurity threats*

NASA depends heavily on secure digital processes, technology, and accessible data to achieve mission success. The Agency will transform business processes, IT, and data management to effectively meet our mission needs, while keeping pace with evolving technologies and threats. Strengthened engagement between our IT organization and our customers will lead to a shared understanding of IT needs, and evaluation of customer satisfaction will determine if those needs were met. NASA will focus on consistent IT service delivery, reliable operations, expanded digital capabilities, and proactive and resilient cybersecurity, all supported by engaged, customer-focused IT teams.

This transformation will depend on the harmonization of business practices across NASA's centers to reach effectiveness and efficiency goals. Timely, secure data sharing and support for the Agency's partnerships with industry remain critical to the success of NASA's missions. Modernization of the Agency's IT infrastructure will enable seamless, reliable, and secure collaboration across NASA's workforce and partners and will foster innovation in our expanding digital environment.

As IT evolves globally, cybersecurity threats are increasing in frequency and sophistication. This trend has the potential to exploit the complexity and interconnectedness of NASA's systems and data, placing the Agency's missions at risk. We will reinforce our operational resilience through strategic cybersecurity risk management and by modernizing IT capabilities. We will support our geographically hybrid workforce seamlessly and securely while strengthening the security and privacy of our data. NASA's transition to an enterprise operating model for IT will amplify these outcomes by strengthening customer engagement, service planning and delivery, and cost-effective management.

Contributing Programs and/or Program Activities

Priority Area 1: Agency Technical Authority; Center Engineering, Safety, & Operations

Priority Area 2: Infrastructure & Technical Capabilities; Exploration Construction of Facilities (CoF); Institutional CoF; Science CoF; Space Operations CoF; Environmental Compliance and Restoration

Priority Area 3: Information Technology

Contributing Support Program: Mission Enabling Services

Strategic Objective 4.3

Build the next generation of explorers.

Engage students to build a diverse future STEM workforce.

Lead Office

Office of Science, Technology, Engineering, and Mathematics (STEM) Engagement (OSTEM)

Objective Overview

NASA makes vital investments toward building a diverse STEM workforce. The scope of our STEM engagement comprises all endeavors to attract, engage, and educate students and to support educators and educational institutions.

Given the Nation's need for a skilled STEM workforce and projected demand, NASA clearly has a vested interest in attracting, engaging, and preparing its future STEM professionals. The national STEM ecosystem will benefit from NASA contributions to attract and retain students on STEM pathways, with increased attention on underserved and underrepresented students. Recent national and international tests show that in the last decade, U.S. students have demonstrated little or no growth in mathematics and remain ranked in the middle of advanced economies on international science and mathematics assessments.[1]

NASA will implement strategies to broaden student participation to increase diversity, equity, inclusion, and accessibility (DEIA) in STEM through NASA opportunities and activities. While the number of women and underrepresented minorities earning STEM degrees has grown in broad science and engineering occupations over the last decade, significant underrepresentation remains in areas critical to NASA like engineering and computer and mathematical sciences.[2]NASA is committed to building a diverse, skilled future STEM workforce—our next generation of explorers with the technical skills needed to carry forward our Nation's vital mission and work in aeronautics and space into the future.

1 Science Board, National Science Foundation. 2020. Science and Engineering Indicators 2020: The State of U.S Science and Engineering. NSB-2020-1. https://ncses.nsf.gov/pubs/nsb20201/

2 National Science Foundation, National Center for Science and Engineering Statistics. 2019. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2019. Special Report NSF 19-304.

Below: Student Launch provides a research-based, competitive experiential exploration opportunity for university, middle and high school student teams across the nation. One of NASA's Artemis Student Challenges aimed to engage students in NASA's work in science and exploration, Student Launch challenges student teams to design, build and fly a high-powered rocket containing a science or engineering payload. Image Credit: NASA

Objective Strategy

NASA is committed to engaging students in its mission, with the aim to immerse students in NASA's work and inspire the next generation to explore. To that end, NASA will continue to make vital contributions in STEM engagement. NASA's work in STEM Engagement is a collaborative endeavor which encompasses efforts across the OSTEM, the Mission Directorates, and the Field Centers.

We will sustain our track record of inspiring, attracting, and engaging students through a strategy that will support Federal STEM education priorities and drive Agency efforts to:

- Attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work;
- Create unique opportunities for a diverse set of students to contribute to NASA's work in exploration and discovery; and
- Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content, and facilities

This strategy is also centered on five design principles to guide the planning and execution of the Agency's efforts: (1) developing and deploying mission-driven authentic STEM experiences, (2) using evidence-based practices, (3) driving scalability, (4) measuring outcomes, and (5) focusing on DEIA.

NASA will implement STEM engagement initiatives, programs, and activities that serve students, and provide unique support to educators and educational institutions. NASA's STEM engagement efforts are ultimately focused on attracting, retaining, and supporting students on STEM pathways. Recognizing that attracting students to STEM is the foundation of a successful model to build a diverse future STEM workforce, we will place a focus on evidence-based opportunities that attract students, leveraging our unique and exciting mission and work. We will provide mission-driven student opportunities and activities along the continuum of STEM pathways; immersive, experiential learning experiences that lead to STEM academic pursuits; and extra-curricular and work experiences that support higher education students in preparation for successful workforce entry. The scope of student opportunities includes challenges and competitions, NASA-unique learning opportunities, educational products, and work experiences including internships and fellowships.

Hawaii Space Flight Laboratory undergraduate students, summer interns and engineers integrating the Neutron-1 3-U CubeSat in a cleanroom. NASA Space Grant, MUREP, and EPSCoR will continue to fund a wide spectrum of competitive student and institutional research opportunities to enable contributions to NASA's work in science and exploration. Image Credit: University of Hawaii at Manoa

Moving ahead, NASA will drive progress to expand student work experiences, anchored to the Agency's missions and programmatic work with mentors from the technical workforce. This includes enhancing the internships program, with objectives to broaden and enrich student participation.

In addition to a broad portfolio of efforts dedicated to students, NASA will support educators and educational institutions. This includes providing mission-unique content, resources, and support to educators; contributing to classroom and out-of-school learning experiences; building capacity at minority-serving institutions (MSIs) and within jurisdictions that have not participated equitably in competitive aerospace and aerospace-related research activities; creating informal educational opportunities for learning and programs; and enabling mission-driven research for students and institutions.

NASA will continue to magnify reach and impact through strategic partnerships. To facilitate intentional design of opportunities that meet needs and to scale distribution, we will leverage networks and build connections within the national STEM education ecosystem. We will also develop educational tools and platforms to significantly enhance the digital footprint to better reach students and educators.

NASA is placing an intense focus on broadening student participation, with concerted efforts toward engaging more underserved and underrepresented students in NASA STEM engagement programs and activities. To accomplish this, NASA will:

- Enhance communications and stakeholder engagement to build networks and relationships;
- Strengthen practices and systems;
- Build a solid foundation for a focus on metrics and evaluation to effectively measure progress, and;
- Create a culture and drive a collective focus across NASA's STEM engagement community on broadening student participation, and foster a commitment to DEIA in student opportunities and programs.

NASA is committed to an evidence-driven model and will continue to engage in evidence-building activities specifically focused on underserved and underrepresented students and communities using a comprehensive performance assessment and evaluation framework. The framework includes a learning agenda and an evidence-based decision-making process that engages both internal and external stakeholder audiences.

NASA is well positioned within the Nation's STEM ecosystem to collaborate with other Federal agencies, state and local Government, industry, institutions, and the non-profit sector to contribute to a shared goal of a globally competitive workforce. Our unique contributions are vital to attract and build a vibrant and diverse next generation STEM workforce that will continue the Nation's legacy of exploration and discovery. To execute our STEM engagement efforts, we will leverage our community of talented and dedicated education professionals and its technical workforce, who together can inspire and engage youth and students in STEM.

NASA conducts STEM engagement efforts through a diverse portfolio of opportunities, activities, products, and resources for students, educators, and educational institutions. OSTEM is responsible for the strategic direction, operational integration, and assessment and evaluation of STEM engagement. OSTEM implements the STEM Engagement Program, consisting of four projects: the National Space Grant College and Fellowship Project (Space Grant); Minority University Research and Education Project (MUREP); Established Program to Stimulate Competitive Research (EPSCoR); and Next Generation STEM project (Next Gen STEM). NASA Mission Directorates create opportunities for students to actively engage in NASA's work. These include mission-driven learning opportunities, challenges and competitions, work experiences, and competitive student research opportunities.

NASA will continue to make strategic investments in STEM engagement. NASA implements Space Grant, a national network of colleges and universities with over 1,000 affiliate institutions and organizations working to expand opportunities for students to participate in NASA's aeronautics and space projects. Space Grant is made up of 52 consortia located in all 50 states, the District of Columbia, and Puerto Rico. Moving forward, Space Grant will continue to provide valuable learning experiences for undergraduate and graduate students and build delivery of experiential opportunities for middle and high school students.

NASA EPSCoR establishes partnerships with Government, higher education, and industry that are designed to drive sustainable improvements in research and development capacity and competitiveness in eligible jurisdictions.

MUREP provides support via competitive opportunities and awards to MSIs. MUREP investments enhance the research, academic, and technology capabilities of MSIs through multiyear cooperative agreements, bolstering their capacity in educating and preparing students for STEM careers. MUREP will continue to expand competitive opportunities to address specific gaps needs while building capacity at institutions.

Next Gen STEM develops and deploys evidence-based STEM learning opportunities that provide a platform for students to learn via NASA's endeavors in exploration and discovery. Through Next Gen STEM, NASA makes vital investments in K-12 and informal education. This includes competitive awards to the Museum and Informal Education Alliance, comprised of more than 2,000 member organizations, including museums, science centers, parks, libraries, planetariums, nature centers, and after-school groups. Looking ahead, Next Gen STEM will strengthen efforts to engage K-12 students, build networks within the formal education ecosystem, engage educators through the NASA CONNECT community of practice, train NASA STEM experts to expand work with students, and expand challenges and competitions to broaden student participation.

NASA will continue to build collaborative efforts and facilitate connections to better serve stu-

dents and educators. The Mission Directorates will continue to create mission-centered learning opportunities and drive student contributions to NASA's work. The Aeronautics Research Mission Directorate in collaboration with MUREP, will offer unique research opportunities in critical challenges facing aviation, while efforts with Space Grant will increase award opportunities to university students proposing entrepreneurial solutions to make aviation more sustainable. Partnership efforts between the Earth Sciences Division and MUREP will foster MSI contributions and build capacity in climate change research. NASA will cultivate broadened participation from underserved communities through connections between existing networks to programs such as Science Mission Directorate's Science Activation, which supports a cooperative network of competitively selected teams that work together to connect NASA science experts, unique content, and authentic experiences with diverse communities across the Nation. In addition, efforts to build connections between the Global Learning and Observations to Benefit the Environment Program and NASA STEM engagement networks will broaden student contributions to understanding the Earth system and climate change. Finally, OSTEM and the Mission Directorates will expand collaborations to enable student contributions to NASA's missions, building upon Artemis Student Challenges, the Breakthrough, Innovative and Game-Changing Idea Challenge, and the University Student Research Challenge.

NASA's STEM workforce demonstrates a unique level of dedication to building the next generation of explorers. In addition to OSTEM, NASA Mission Directorates and their programs, as well as the STEM disciplinary organizations, provide exciting student opportunities and access to NASA's STEM professionals and their expertise.

NASA's compelling and exciting STEM engagement opportunities and efforts will inspire students to reach for the stars and build our Nation's next generation of explorers.

How NASA Engages and Works with Partners

NASA has a rich history of collaborating across the Nation's STEM ecosystem to foster innovative student learning experiences that leverage our unique mission, people, and facilities. NASA collaborates with partners to:

- Engage students across the United States in opportunities connected to our missions, themes and STEM engagement efforts;
- Foster innovative models, methods, or approaches tied to national and Agency STEM education goals; and
- Broaden participation of students from groups traditionally underrepresented in STEM.

We conduct strategic partnerships with a wide range of external STEM engagement stakeholder organizations through formal Space Act Agreements. Generally, these provide unfunded collaborators with access to NASA mission data and imagery, subject matter expertise in scientific and technical disciplines connected to our Mission, and support with curation of NASA education resources, products, and materials. Through these efforts, we coordinate with industry, educational institutions, and non-profit organizations to support development of high-quality opportunities for both youth outside of the classroom and students in pre-kindergarten through graduate school.

NASA also works in partnership with other Federal agencies to coordinate efforts and to collaborate on specific initiatives. For example, NASA works with the U.S. Department of Education to provide students with access to scientific and technical mentors and equip educators with STEM resources that can be used both inside and outside of the classroom. We also collaborate with the National Science Foundation to advance diversity and inclusion goals through coordination of fellowship programming and undergraduate student engagements.

Contributing Programs and/or Program Activities

STEM Engagement Program (NASA Space Grant; EPSCoR; MUREP; Next Gen STEM); Mission Enabling Services (Center STEM Engagement).