National Aeronautics and Space Administration

FY 2024 Volume of Integrated Performance

FY 2022 Annual Performance Report

FY 2023–2024 Agency Performance Plan

FY 2024 Annual Evaluation Plan

www.nasa.gov

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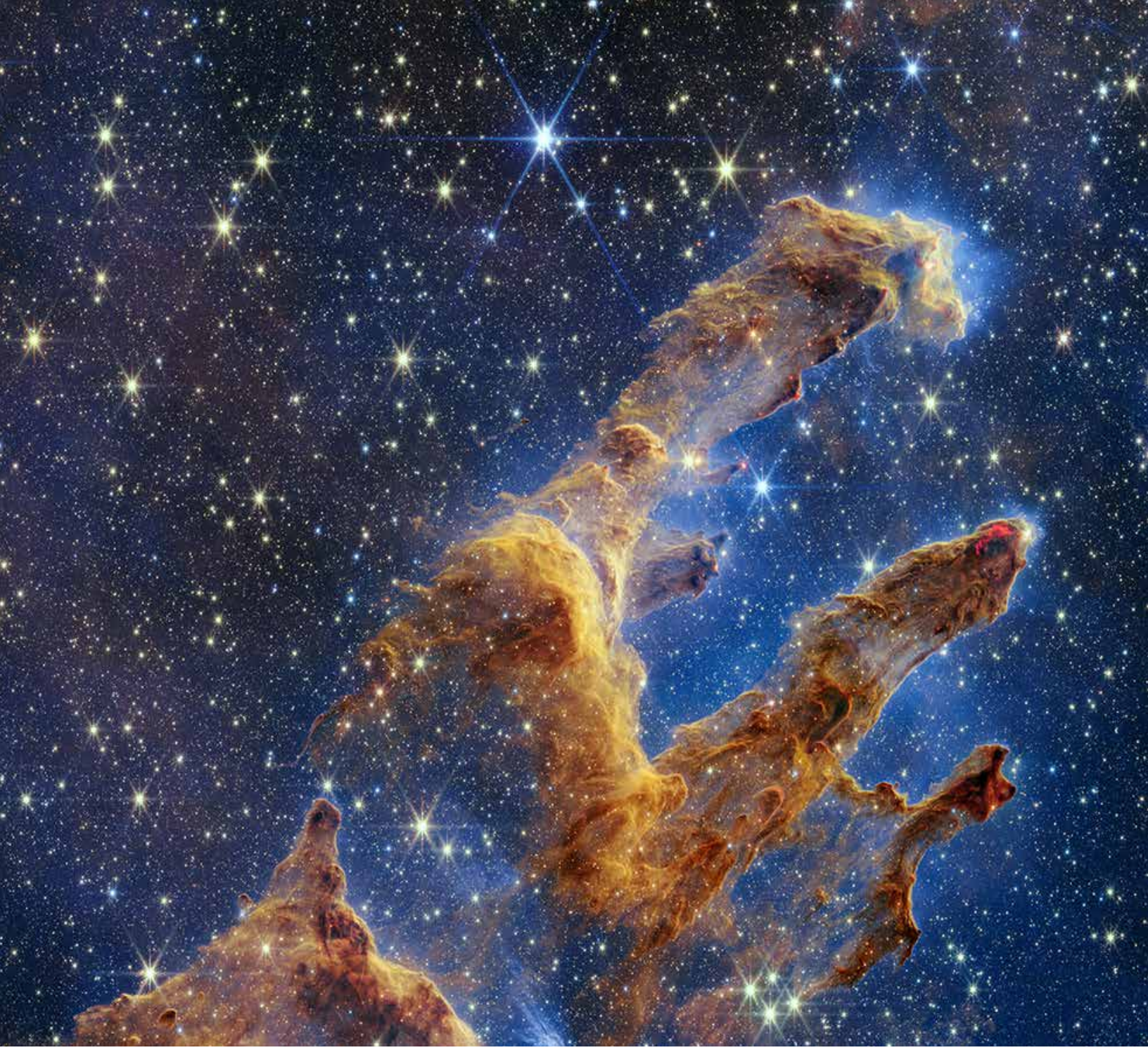
Above: NASA Administrator Bill Nelson delivers remarks during a news conference on NASA's Sustainable Flight Demonstrator project, Wednesday, Jan. 18, 2023, at the Mary W. Jackson NASA Headquarters building in Washington, DC. Through a Funded Space Act Agreement, The Boeing Company and its industry team will collaborate with NASA to develop and flight-test a full-scale Transonic Truss-Braced Wing demonstrator aircraft. Image Credit: NASA/ Joel Kowsky

The FY 2024 Volume of Integrated Performance was managed and produced by the Strategic Investments Division of the Office of the Chief Financial Officer at NASA Headquarters, with contractor support from Deloitte Consulting, LLP. Performance content is provided by Mission Directorates and Mission Support Offices at NASA Headquarters.



Part 1

Performance Management at NASA

Above: The Pillars of Creation are set off in a kaleidoscope of color in NASA's James Webb Space Telescope's near-infrared-light view. The pillars look like arches and spires rising out of a desert landscape, but are filled with semi-transparent gas and dust, and ever changing. This is a region where young stars are forming – or have barely burst from their dusty cocoons as they continue to form. Image Credit: NASA Images

NASA Performance Foundations

Vision

Exploring the secrets of the universe for the benefit of all.

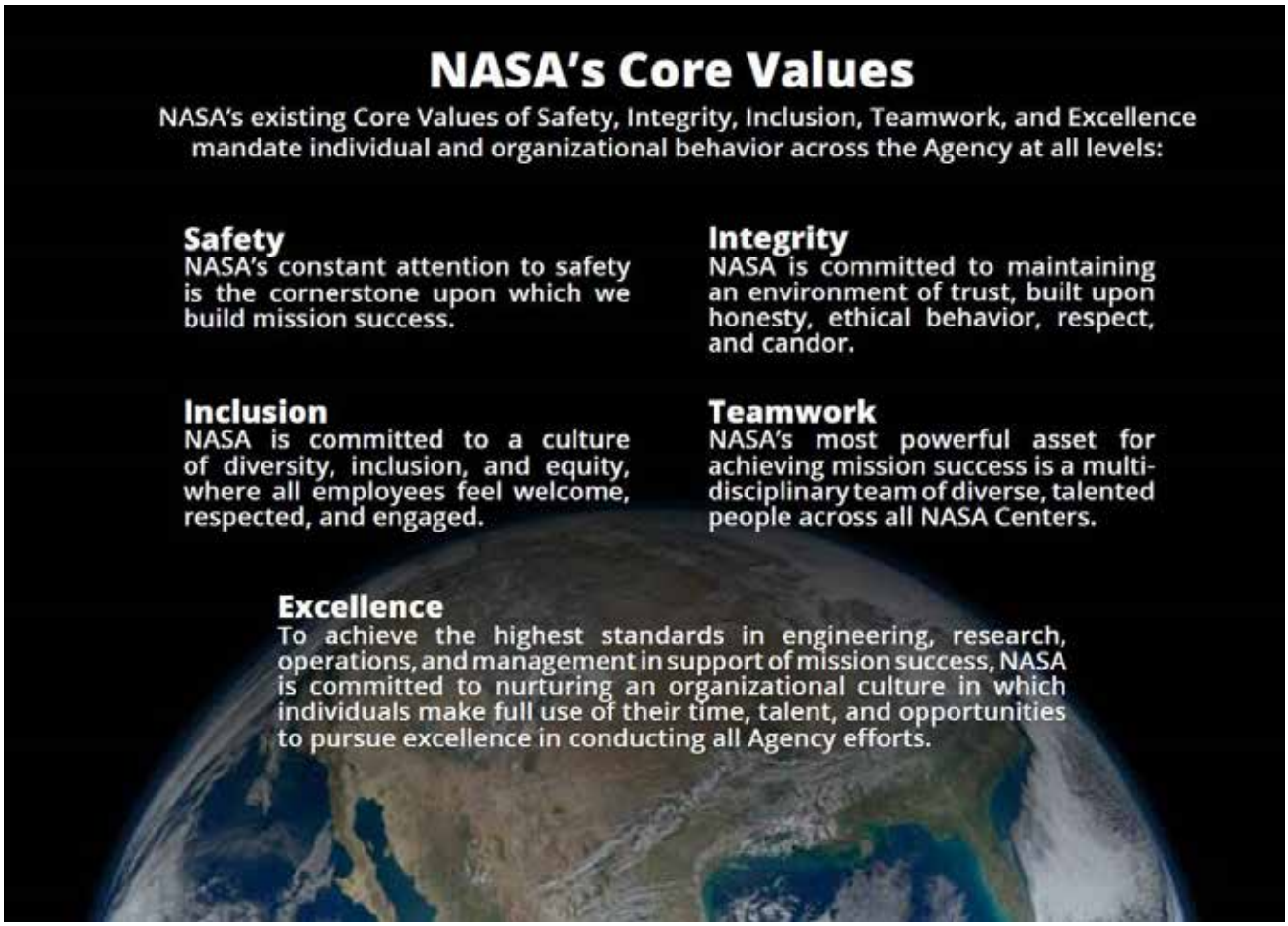
Mission

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Since 1958, NASA has led the peaceful exploration of space by advancing knowledge of Earth while making discoveries about the furthest reaches of the universe. NASA research has advanced aeronautics, developed the commercial space industry, and strengthened the U.S. economy through innovative partnerships with American businesses. With the increasing threat of climate change, NASA's efforts to study and understand the Earth system are of critical global significance. NASA's partnerships with academic institutions support the development of a robust science, technology, engineering, and mathematics (STEM) workforce, and promote diversity, equity, and inclusion in the fields of science and technology.

NASA's long-term success will be determined by the strategic decisions and investments we make today, as well as committed adherence to our five guiding Core Values.

Above: The United Launch Alliance (ULA) Atlas V rocket with the Landsat 9 satellite onboard is seen on Sunday, Sept. 26, 2021, at Vandenberg Space Force Base in California. The Landsat 9 satellite, a joint NASA/U.S. Geological Survey mission that is continuing the legacy of monitoring Earth's land and coastal regions, launched on September 27. Image Credit: NASA/Bill Ingalls

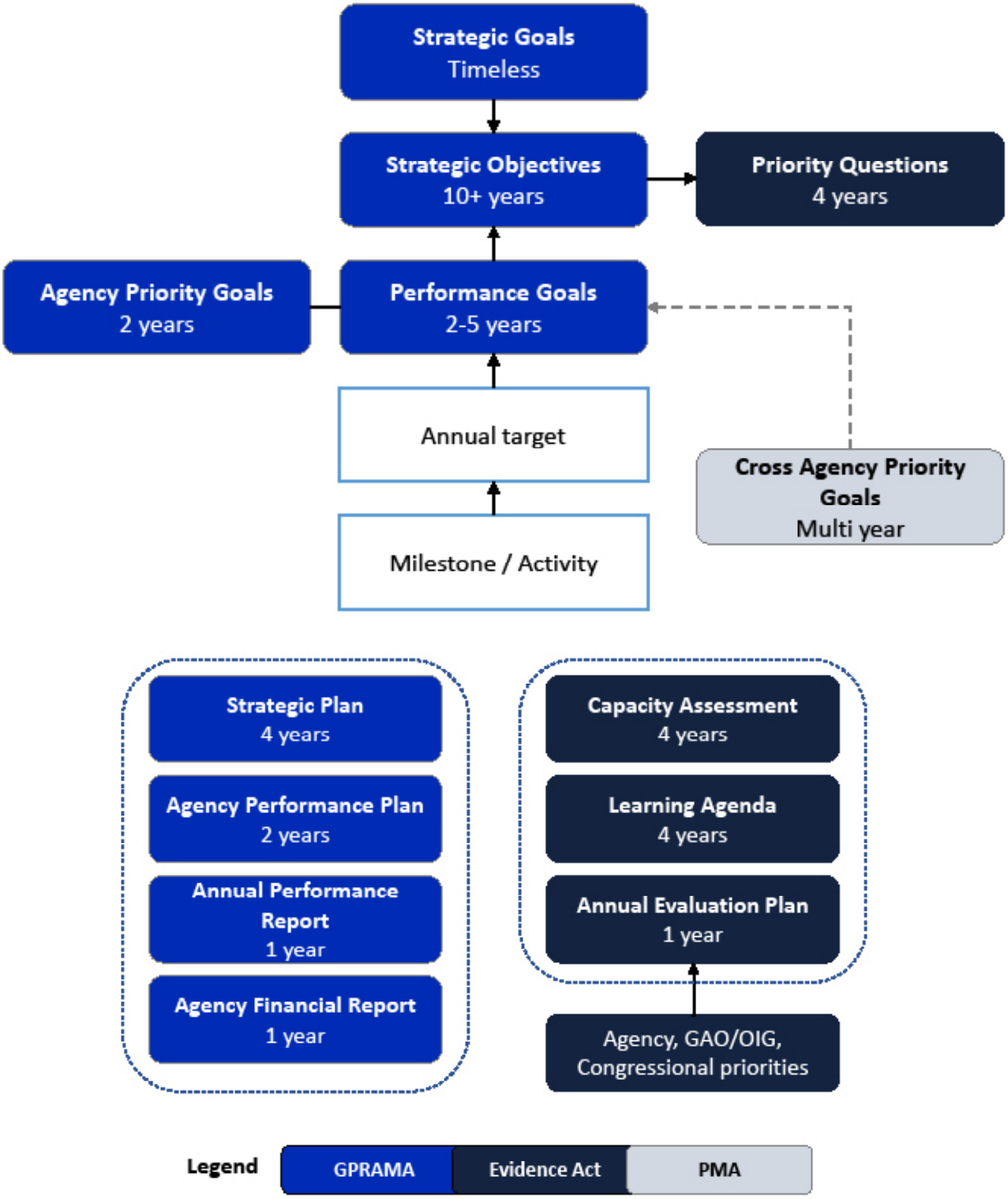


The Agency's success is supported by continually evolving and strengthening our performance management discipline. We use best practices from business and government to proactively establish expectations and assess and improve performance on an ongoing basis. We use data and evidence to inform investment decisions at all levels, ranging from day-to-day operations to selecting major missions and establishing the necessary infrastructure to pursue goals that may take a generation or longer to realize.

During FY 2022, NASA implemented several efforts described in the "2022 High Risk Corrective Action Plan" (see page 18 in "Strategies for Improvement" for more information) to strengthen our program and acquisition management. For example, we established a Chief Program Management Officer (CPMO) function, located in the Office of the Administrator, to enact measurable, enduring improvement in program and project performance through cross-enterprise coordination. Additionally, NASA elevated the role of Chief Acquisition Officer to the Deputy Administrator, who, among other initiatives, released a memorandum of intent to Agency leaders detailing acquisition priorities for enabling our Moon to Mars Objectives.

NASA aims to comply fully with the requirements on performance reporting and accountability, in accordance with the Government Performance and Results Act (GPRA) Modernization Act of 2010. NASA's commitment to performance reaches further than compliance, however, embedding our workforce culture with monitoring and improvement at the core. We are conducting evidence-building activities and making evidence-based decisions in accordance with the Foundations for Evidence-Based Policymaking Act of 2018 (Public Law 115–435, also known as the Evidence Act). We have an ingrained culture of self-evaluation, using findings from studies and

NASA's 2022 Strategic-Performance-Evidence Framework



assessments to improve the Agency in the short-term and position NASA for long-term success.

The *NASA 2022 Strategic Plan* outlines our plans for human and robotic space exploration, aeronautics, technology development, and Agency operations, providing a clear and unified direction for our programs and projects. This direction is captured in NASA's Vision and Mission statements—why NASA exists, what we aspire to explore, and how we expect to achieve societal benefits.

The information reported in this document is aligned with the NASA 2022 Strategic Plan and the FY 2024 Congressional Justification, in accordance with the requirements of the GPRA Modernization Act, as described below.

Performance-Evidence Framework

Our quadrennial Strategic Plan outlines a framework that consists of Strategic Goals aligned to our Mission; Strategic Objectives describing our long-term strategies for achieving the Strategic Goals; and multiyear, outcome-oriented Performance Goals. Annual targets and milestones allow NASA to measure and track incremental progress towards achieving the Performance Goals.

Learning Agenda, Capacity Assessment, and Annual Evaluation Plan

Congress signed the Evidence Act into law in January of 2019. The Evidence Act establishes a framework for agencies to organize evidence building, data management, and data access functions to ensure an integrated connection to data and evidence in decision making. The NASA 2022 Strategic Plan includes NASA's first-ever Learning Agenda and Capacity Assessment, supporting this new requirement.

The Learning Agenda is a roadmap for NASA to systematically plan evidence-building activities that will allow the Agency to make evidence-based policy decisions. The Learning Agenda identifies a set of broad questions NASA sees as urgent to moving our operations and Mission forward over the next four years. When answered, these questions will help us work more effectively and efficiently, using evidence to make decisions relating to missions, programs, and investments.

The Capacity Assessment reviews NASA's ability to conduct evidence-building activities and identifies where resources are needed to develop and improve our capacity. Led by NASA's Evaluation Officer, in conjunction with the Statistical Officer and Chief Data Officer, five criteria guide NASA's evidence culture: coverage, quality, methods, effectiveness, and independence. This process supports the Agency's needs for learning and management, performance and strategic management, interagency and private sector coordination, and oversight and accountability.

The Annual Evaluation Plan (see Appendix A: FY 2024 Annual Evaluation Plan) identifies specific evaluations that the Agency plans to undertake over the next fiscal year. This plan cultivates data sharing and resources between NASA organizations and provides information to help support our evidence-driven culture.

Agency Performance Plan

NASA's Agency Performance Plan describes our multiyear Performance Goals (including annual targets consistent with program and project budget requests) and which Strategic Goals and Objectives they support. Every fiscal year, NASA reevaluates and updates, as needed, the existing Performance Goals and targets to ensure they accurately reflect NASA's budget, priorities, strategies, and programmatic plans.

Agency Priority Goals are a selected subset of Performance Goals that highlight high-priority, high-profile activities we plan to accomplish within a two-year timeframe. Agency Priority Goals highlight challenging, high-risk areas with the potential for major technical, scientific, and societal benefit.

Performance Assessment Criteria

NASA's Performance Goals consist of outcome-based performance statements and the measurable performance targets to be achieved each fiscal year.

To indicate progress based on targets, we assign one of the color ratings described below. A Green rating indicates that NASA achieved the targeted level of performance for the fiscal year and is on track to complete the Performance Goal by the end of its timeframe. A Yellow rating indicates that NASA is slightly below the target but is still on track to complete the Performance Goal by the end of its timeframe. We assign a Red rating when performance is significantly below the target, affecting

the overall progress for the Performance Goal. We use internal success criteria for each Performance Goal to determine the thresholds for a Yellow or Red rating.

Green Achieved Annual Target and on Track for completion	NASA achieved the annual target and is on track to achieve the Performance Goal/Agency Priority Goal
Yellow Missed Annual Target	NASA missed the annual target but was in a middle performance range according to established success criteria. NASA remains on track to achieve the Performance Goal/Agency Priority Goal
Red Significantly Missed Target/ At Risk	NASA significantly missed the annual target and is at risk of not achieving the Performance Goal/Agency Priority Goal
White Cannot be Assessed	NASA was unable to assess the Performance Goal/ Agency Priority Goal due to lack of data or changes to the associated work

The ratings discussed in Part 2 of this volume (Performance Planning and Reporting) are the final ratings assigned to each Performance Goal, and have been updated from the preliminary ratings summarized in NASA's *FY 2022 Agency Financial Report*, published before the ratings were submitted and approved.[1]

Agency Priority Goals

NASA assesses progress toward achieving Agency Priority Goals every quarter, per GPRA Modernization Act guidance. In addition to reporting progress to external stakeholders at Performance.gov.

At the end of FY 2022, NASA was at the halfway point for our two-year Agency Priority Goals. A summary of the results is provided below. Detailed progress is discussed in Part 2.

Agency Priority Goal Statements	FY 2022 Rating	Responsible Program
1.1.4: Use the global vantage point of space to advance our understanding of the Earth system, its processes, and changing climate. *By September 30, 2023, NASA will advance climate change research by delivering two new observing systems and an upgrade to NASA's primary global Earth systems model.*	**Yellow (4 of 5 milestones completed)**	Science Mission Directorate (Earth Science Division)

1 In the FY 2022 Agency Financial Report, 8 of NASA's 51 Performance Goals (2 under Strategic Objective 1.1 and 6 under Strategic Objective 1.2) were unrated because data needed to assess progress was not available before publication. The ratings for those Performance Goals are included in this document.

1.2.10: After launch, deployment, and start of science operations, the James Webb Space Telescope will study every phase in the history of our universe, ranging from the first luminous glows after the Big Bang, to the formation of other stellar systems capable of supporting life on planets like Earth, to the evolution of our own solar system. *By September 30, 2023, NASA will complete commissioning of the James Webb Space Telescope, the most powerful and complex space telescope ever built, and begin Webb's Cycle 2 observations.*	**Green (4 of 4 milestones completed)**	Science Mission Directorate (Cosmic Origins)
2.1.1: Advance America's goal to land the first woman and the first person of color on the Moon and pursue a sustainable program of exploration by demonstrating capabilities that advance lunar exploration. *By September 30, 2023, NASA will launch Artemis I, deliver the Core Stage for Artemis II to Kennedy Space Center for processing, and have multiple companies under contract to develop systems for sustainable human lunar exploration.*	**Yellow (3 of 4 milestones completed)**	Exploration Systems Development Mission Directorate (Common Exploration Systems Development and Artemis Campaign Development)
3.1.5: Ensure American global leadership in space technology innovations through increased partnering with industry and demonstrating key lunar surface and deep space technologies. *By September 30, 2023: NASA will demonstrate leadership in space technology by:* • *Enhancing partnerships with industry through delivery or completion of milestones for at least 4 Tipping Point opportunities, and at least 3 critical small business technology transitions to develop capabilities that support NASA and commercial needs;* • *Delivering at least 3 new technologies that will be demonstrated on the lunar surface or in lunar orbit; and* • *Completing at least 2 major milestones for projects that increase the Nation's capabilities in deep space.*	**Yellow (3 of 4 milestones completed)**	Space Technology Mission Directorate (Early Stage Innovation and Partnerships, Technology Demonstrations, Technology Maturation, and Small Business Innovation Research/Small Business Technology Transfer)

*See https://www.performance.gov/agencies/nasa/ for more information about our Agency Priority Goals.

President's Management Agenda

The President's Management Agenda (PMA) defines Government-wide management priorities for improving how Federal agencies operate and perform. The Biden Administration PMA, issued in November 2021, focuses on strategies to advance three core priorities: 1) Strengthening and empowering the Federal workforce; 2) Delivering excellent, equitable, and secure federal services and customer experience; and 3) Managing the business of Government to build back better.

The work of the PMA comprises sustained, multiyear, Federal government-wide efforts to advance each of the three PMA priorities, their supporting strategies, and Cross-Agency Priority Goals. Through the PMA, cross-agency teams seek stakeholder input, define workstreams, set work plans and measures, advance collaborative efforts, and assess and measure progress across Government organizations.

To ensure effective leadership and accountability across the ederal government, each priority has one senior leader within the Executive Office of the President, and another sitting within one or more of the key delivery agencies. Per the GPRA Modernization Act's requirement to address Cross-Agency Priority Goals in the Strategic Plan, the Agency Performance Plan, and the Annual Performance Report, please refer to www.Performance.gov for our contributions to those goals and progress, where applicable. NASA is not a key delivery agency but currently contributes to Priority 1 and 3.

Performance Management in Action

Following the passing of the Evidence Act, the Biden Administration published the inaugural PMA Learning Agenda in September 2022, identifying government-wide evidence gaps related to advancing PMA priorities. It not only reinforces a focus on learning, but also serves to bridge silos and catalyze innovation to stimulate coordination of evidence building across Federal agencies, state and local governments, tribal governing

bodies, researchers, and practitioners from across the country.

The PMA Learning Agenda has three specific areas of focus which are, 1) Workforce, 2) Service Delivery, and 3) Equity. Each focus area has one main priority question and several sub-questions meant to guide evidence-building efforts. It is important to note that while these three focus areas do involve every Federal agency, these areas are not meant to be comprehensive and representative of all the evidence-building that is happening or needs to happen to improve how the government operates and performs.

Performance Management in Action

NASA is committed to remaining a good steward of the taxpayer's numerous investments entrusted to our care. This includes maintaining a culture of data-driven performance management, evidence-building activities, and evaluation that continually improve our accountability, transparency, oversight, and decision making. This approach supports evidence-based strategic and performance planning across organizations, leads to more consistent performance reporting, and ensures the optimal use of our resources.

NASA plans and evaluates performance in a continuous cycle, spanning multiple fiscal years, in conjunction with the annual planning, programming, budgeting, and execution process used to ensure that resource alignment supports mission and operational needs. This ongoing feedback loop ensures that plans reflect performance expectations and performance results inform planning decisions.

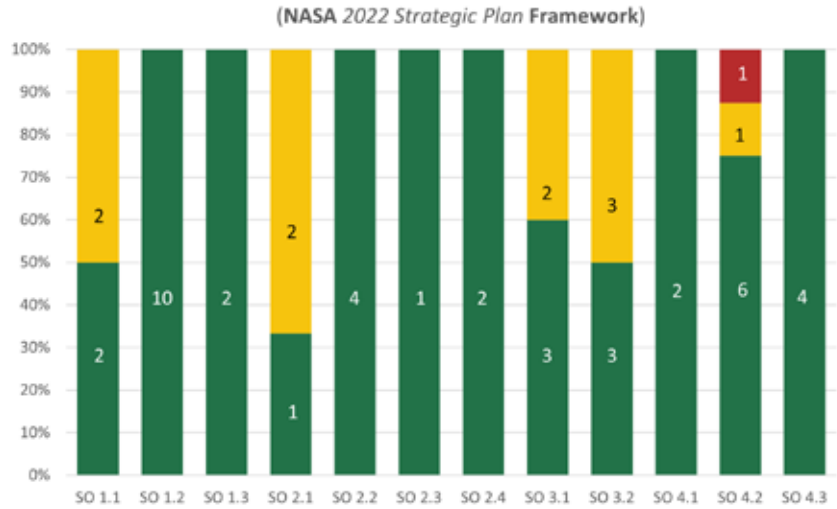
Annual Strategic Reviews

The annual Strategic Review process encompasses a comprehensive retrospective and prospective review of the strategies for achieving our 12 Strategic Objectives and the health of the contributing programs. NASA measures progress towards achieving each Strategic Objective through near-, mid-, and long-term success criteria for all supporting program portfolios. As of the publication of the *NASA 2022 Strategic Plan*, at least 50 percent of the success criteria in each timeframe were quantitative. NASA also assesses:

- Available opportunities that could enable successful programs and projects;
- Approaches for addressing risks, including those identified through enterprise risk management capabilities (see Enterprise Risk Management below);
- Resources, including budget and workforce allocations; and
- Ongoing or planned program evaluations, performance measurement, policy analysis, and other evidence-building activities.

The lead organization and contributing programs conduct the analysis and recommend whether their Strategic Objective demonstrates noteworthy progress, satisfactory performance,

Summary FY 2022 Performance Goal Ratings by Strategic Goal and Objective*



*SO = Strategic Objective

or is a focus area for improvement. NASA's Chief Performance Management Officer and Performance Improvement Officer determine final ratings and next step with the Agency Summary of Findings, reported to the Chief Operating Officer as part of the Baseline Performance Review (see Baseline Performance Review below). NASA then submits final ratings as part of the Strategic Review Summary of Findings to the Office of Management and Budget for review and comment.

The Strategic Review inputs, findings, and results inform our budget process and are inputs to the next performance planning cycle. In addition, NASA may adjust Strategic Objective strategy and supporting success criteria based on Strategic Review results.

NASA's 2022 Strategic Review baselined progress towards achieving the Strategic Objectives released in the *NASA 2022 Strategic Plan*. The ratings from the review and the Summary of Progress by Strategic Objective are provided in Part 2.

Annual Performance Assessments

During the third and fourth quarters of each fiscal year, NASA program officials assess progress towards achieving the Performance Goals listed in the Agency Performance Plan. They determine whether targets and any supporting milestones were met as anticipated, assign the appropriate color rating, and provide an explanation to support the rating. NASA's Performance Improvement Officer reviews the performance assessment results and provides feedback and determines final ratings when needed.

NASA publishes a summary of preliminary fiscal year performance ratings in the annual Agency Financial Report, in accordance with OMB Circular A-136 guidance. We publish the final fiscal year performance ratings in the Annual Performance Report, which becomes part of this publication, the Volume of Integrated Performance.

Of the 51 Performance Goals in FY 2022, NASA rated 41 Green (80 percent achieved), 9 Yellow (18 percent missed annual target), and 1 Red (2 percent missed the annual target/at risk). We did not rate any Performance Goals White (cannot be assessed) for this fiscal year (See the summary chart). Overall, NASA's performance was stronger than FY 2021[2], which resulted in 79 percent of NASA's 48 Performance Goals achieved (Green), 13 percent missed their annual target (Yellow), two percent significantly missed their annual target (Red), and six percent could not be assessed (White) because the data needed to review the Performance Goals (in this case, the results of the Federal Employee Viewpoint Survey) were not available.

Part 2 of this volume presents the individual FY 2022 ratings and supporting performance explanations. It also provides past Performance Goal ratings for FY 2020 and FY 2021. While some Performance Goals have existed for longer, NASA used a different measurement approach prior to FY 2020 that utilized separate multiyear measures (Performance Goals) and annual measures (Annual Performance Indicators). For FY 2020, NASA added annual targets to the Performance Goals and eliminated Annual Performance Indicators. Some of these Annual Performance Indicators were transformed into multiyear Performance Goals with annual targets.

Performance Management Goals and Mandates

Several pieces of legislation have been passed over the years that build on the GPRA Modernization Act's framework for performance management.

The key pieces of legislation that have impacted performance reporting are the Evidence Act, the 2016 update on enterprise risk management (M-16-17) to OMB Circular A-123, and the 2018 update (M-18-19) to the Program Management Improvement Accountability Act of 2016 (PMIAA). Together these inform all aspects of performance management goals and mandates.

2 FY 2021 performance supported the NASA 2018 Strategic Plan. FY 2022 performance supported the NASA 2022 Strategic Plan.

FY 2024 Budget Request by Strategic Objective ($M)

Strategic Goals	Strategic Objectives	Requested
1. Expand human knowledge through new scientific discoveries	1.1 Understand the Earth system and its climate	$1,973.8
	1.2 Understand the Sun, solar system, and universe	$5,788.0
	1.3 Ensure NASA's science data are accessible to all and produce practical benefits to society	$499.0
2. 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	$7,971.1
	2.2 Develop a human spaceflight economy enabled by a commercial market	$3,487.6
	2.3 Develop capabilities and perform research to safeguard explorers	$255.5
	2.4 Enhance space access and services	$791.5
3. Catalyze economic growth and drive innovation to address national challenges	3.1 Innovate and advance transformational space technologies	$1,391.6
	3.2 Drive efficient and sustainable aviation	$995.8
4. Enhance capabilities and operations to catalyze current and future mission success	4.1 Attract and develop a talented and diverse workforce	$111.6
	4.2 Transform mission support capabilities for the next era of aerospace	$3,702.3
	4.3 Build the next generation of explorers	$166.9

*Does not include Office of Inspector General

The 12 Strategic Objectives from the 2022 Strategic Plan are mapped to NASA's FY 2024 President's Budget Request. The table above provides the FY 2024 budget request for each Strategic Objective. Detailed budget tables provided in Part 2 include the FY 2022 actual, FY 2023 enacted, and outyear budget numbers through FY 2028. The budget numbers for FY 2022 and FY 2023 represent actual budget authority and the budget numbers for FY 2024 through FY 2028 are based on the requested budget.

The funding amounts shown combine multiple programs and projects that together support the Strategic Objective. The budget numbers are rounded and will not add up to NASA's total budget request. Funds for the Office of Inspector General are not included in any Strategic Objective funding line.

Enterprise Risk Management

In July 2016, the Office of Management and Budget released a memorandum updating Circular A-123[3] to ensure that agencies manage risks arising from enterprise operations and activities that could affect achievement of Strategic Objectives. The memorandum required each agency to implement an enterprise risk management capability in coordination with its strategic planning and strategic review processes. The enterprise risk management process provides insights on how to effectively prioritize and manage risks to mission delivery while also providing an enterprise-wide, strategically aligned portfolio view of organizational risks, challenges, and opportunities.

NASA has integrated enterprise risk management with the strategic planning and Strategic Review processes to provide an analysis of the risks and opportunities we face in accordance with Office of Management and Budget guidance. We have a program management integration function with

3 OMB Circular No. A-123, "Management's Responsibility for Enterprise Risk Management and Internal Control" (M-16-17), July 15, 2016.

matrixed support from the Office of the Chief Engineer and Office of the Chief Financial Officer and in partnership with the Mission Directorates and Centers. While we cannot mitigate all risks related to achieving our Strategic Goals and Objectives, we are using these risk-management strategies to identify, measure, and assess challenges related to mission delivery to the greatest extent possible.

Improved Program and Project Management

In early 2022, NASA established the role of the Chief Program Management Officer (CPMO) in the Office of the Administrator to implement initiatives addressing the Agency's high-risk areas identified by the Government Accountability Office (see the "2022 High Risk Corrective Action Plan" on page 19. The new CPMO role incorporates responsibilities of the previous Program Management Improvement Officer (PMIO) role, expanding the functions recommended by a Tiger Team on the subject in December 2021.

The CPMO, who reports to NASA's Associate Administrator, collaborates across enterprise organizations and Centers to strengthen enterprise-wide oversight, management, and implementation of program management policies and best practices. The CPMO function continues to mature as it undertakes efforts, such as reconstituting the Program/Project Management Board and establishing communities of practice, mentoring, internship, and detail opportunities.

Oversight and Accountability

In setting goals and establishing plans to achieve mission success, NASA leaders rely on information from multiple sources. Rigorous independent assessments, both internal and external to the Agency, are an essential tool in ensuring the integrity of data necessary to make well-informed investment decisions. Independent verification and validation in planning and executing programs or projects provides greater confidence and improves expected outcomes. In many cases, these assessments include a routine measure of progress against a predetermined set of indicators, a baseline, or other targets that effectively establish an early warning system so that issues can be more quickly and easily identified and addressed.

Governance Councils

NASA uses four senior leadership councils to govern the Agency. Councils provide high-level oversight, set requirements and strategic priorities, and guide key assessments of the Agency. The council members evaluate issues and support decision authorities when issues involve or require high levels of difficulty, integration, visibility, and approval.

- The Executive Council determines our strategic direction, assesses our progress toward achieving the NASA Vision, and serves as our senior decision-making body for Agency-wide decisions.
- The Mission Support Council serves as our senior decision-making body regarding the integrated Agency mission support portfolio, and mission support plans and implementation strategies (including facility, infrastructure, workforce, and associated investments); and determines and assesses mission support requirements to enable successful accomplishment of our missions.
- The Agency Program Management Council serves as our senior decision-making body regarding the integrated Agency mission portfolio; and baselines and assesses performance of NASA projects, programs, mission directorate portfolios, and the integrated Agency portfolio to ensure achievement of our Strategic Goals.
- The Acquisition Strategy Council approves acquisition approaches for large, high-profile programs as recommended by the sponsoring Mission Directorate; decides work assignments to Centers and updates to Center roles; and evaluates mission needs and Agency workforce capacity.

Below: U.S. President Joe Biden and Vice President Kamala Harris preview the first full-color image from NASA's James Webb Space Telescope, the highest-resolution image of the infrared universe in history on July 11, 2022, in the White House complex in Washington. Joining the President and Vice President was Director of the White House Office of Science and Technology Policy (OSTP) Alondra Nelson, left, NASA Administrator Bill Nelson, and NASA James Webb Space Telescope Operations Project Scientist Jane Rigby, right, as well as (on screen) NASA Associate Administrator for the Science Mission Directorate Thomas Zurbuchen, top, Deputy Director of the Space Telescope Science Institute (STScI) Nancy Levenson, and NASA James Webb Space Telescope Program Director Greg Robinson, bottom. Image Credit: NASA/Bill Ingalls

Technical Authorities

Our Technical Authorities (Engineering, Safety and Mission Assurance, and Health and Medical) are a key part of NASA's overall system of checks and balances and provide independent oversight of programs and projects in support of safety and mission success.

Technical Authority originates with the Administrator, ensuring work on critical performance areas adheres to Agency policy, requirements, and standards. The fundamental aspects of Technical Authority are:

- Provide an independent view of program/project activities;
- Ensure direction to the program or project reflects the view of the Center or, where appropriate, the view of the NASA Technical Authority community;
- Adjudicate requests for relief (via waivers) from the Technical Authority technical baseline; and
- Implement the dissenting opinion process, to support full and open discussion of substantive disagreement with a decision or decisions regarding the Technical Authority's technical baseline.

Baseline Performance Reviews

The Baseline Performance Review (BPR) is a monthly forum where NASA's executive leadership track program and project performance against Agency plans and priorities. In FY 2022, NASA reformulated BPR to summarize key performance information, such as the portfolio risk profile and in-depth discussions about cost, schedule, technical, and programmatic risks for major projects. Other information previously included at BPR is now part of other forums, such as Directorate Program Management Council meetings.

BPR includes performance progress updates for Agency Priority Goals and Performance Goals. Each Mission Directorate or Mission Support Office provides a performance assessment of the activity it manages, and Agency-level analysts conduct independent assessments. NASA's Technical Authorities provide oversight and an additional level of control. We also conduct our annual Strategic Review at the BPR to take advantage of the existing top-level forum for performance discussion and decision making.

NASA Flight Project Lifecycle Phases, Key Decision Points, and Milestones*

Key Decision Point (KDP) Review	Associated Milestone	Milestone Review Objectives	Overall Expected Maturity State at KDP
KDP-A	Mission Concept Review (MCR)	To evaluate the feasibility of the proposed mission concept(s) and its fulfillment of the program's needs and objectives. To determine whether the maturity of the concept and associated planning are sufficient to begin Phase A.	Project addresses critical NASA need. Proposed mission concept(s) is feasible. Associated planning is sufficiently mature to begin Phase A, and the mission can likely be achieved as conceived.
KDP-B	System Requirements Review (SRR)	To evaluate whether the functional and performance requirements defined for the system are responsive to the program's requirements on the project and represent achievable capabilities.	Proposed mission/system architecture is credible and responsive to program requirements and constraints, including resources. The maturity of the project's mission/system definition and associated plans is sufficient to begin Phase B, and the mission can likely be achieved within available resources with acceptable risk.
	Mission Definition Review (MDR) or System Definition Review (SDR)	To evaluate the credibility and responsiveness of the proposed mission/system architecture to the program requirements and constraints, including available resources. To determine whether the maturity of the project's mission/system definition and associated plans are sufficient to begin Phase B.	
KDP-C	Preliminary Design Review (PDR)	To evaluate the completeness/consistency of the planning, technical, cost, and schedule baselines developed during Formulation. To assess compliance of the preliminary design with applicable requirements and to determine if the project is sufficiently mature to begin Phase C.	Project's planning, technical, cost, and schedule baselines developed during Formulation are complete and consistent. The preliminary design complies with its requirements. The project is sufficiently mature to begin Phase C, and the cost and schedule are adequate to enable mission success with acceptable risk.
KDP-D	Critical Design Review (CDR)	To evaluate the integrity of the project design and its ability to meet mission requirements with appropriate margins and acceptable risk within defined project constraints, including available resources. To determine if the design is appropriately mature to continue with the final design and fabrication phase.	Project is still on plan. The risk is commensurate with the project's payload classification, and the project is ready for Assembly, Integration, & Test (AI&T) with acceptable risk within its Agency baseline cost.
	Production Readiness Review (PRR)	To evaluate the readiness of system developer(s) to produce the required number of systems within defined project constraints for projects developing multiple similar flight or ground support systems. To evaluate the degree to which the production plans meet the system's operational support requirements.	
	System Integration Review (SIR)	To evaluate the readiness of the project and associated supporting infrastructure to begin system AI&T, evaluate whether the remaining project development can be completed within available resources, and determine if the project is sufficiently mature to begin Phase D.	
KDP-E	Operational Readiness Review (ORR)	To evaluate the readiness of the project to operate the flight system and associated ground system(s) in compliance with defined project requirements and constraints during the operations/sustainment phase of the project life cycle.	Project and all supporting systems are ready for safe, successful launch and early operations with acceptable risk within the Agency baseline cost.
	Mission Readiness Review (MRR) or Flight Readiness Review (FRR)	To evaluate the readiness of the project and all project and supporting systems for a safe and successful launch and flight/mission.	
	Launch Readiness Review (LRR)	To evaluate a program/project and its ground, hardware, and software systems for readiness for launch.	

*An overview of lifecycle reviews for programs and projects is available in "NASA Procedural Requirements (NPR) 7120.5F: NASA Space Flight Program and Project Management Requirements."

Program and Project Key DecisionPoint Reviews

As stated above, NASA requires internal independent assessments on the progress of programs and projects through their life cycles. Senior leaders convene a series of formal gatekeeping key decision point reviews, requiring managers to provide assessments of how the programs and projects are performing in key areas. Such key decision points are specific milestones at which managers must provide Agency leadership with information about program maturity and readiness to progress to the next stage of the life cycle (see the figure above).

The mandatory reviews at key decision point milestones focus on the program or project's assessment of status, as well as that of the Standing Review Board or mission directorate independent review team. Multiple stakeholder organizations also can weigh in on the information presented. Other reviews may be scheduled, in accordance with the lifecycle schedule of that project and depending on the formulation, development implementation, or construction plan. Additionally, NASA senior leaders monitor overall performance monthly through the Baseline Performance Review. NASA provides Congress, OMB, and the Government Accountability Office with cost and schedule updates for major projects with an estimated lifecycle cost of $250 million or greater.

NASA Office of Inspector General and the Government Accountability Office

Two independent organizations, the NASA Office of Inspector General and the Government Accountability Office, conduct both broadly and narrowly focused evaluations of how well the Agency is achieving outcomes and performing to expectations. Evaluations cross all types of NASA work, from planning new initiatives, managing major programs, implementing necessary infrastructure modernization, to the potential impact of legislation and policy.

The Office of Inspector General and contracted independent auditors are also employed to review the Agency's financial record keeping systems, compliance with requirements, and financial controls. We have received an unmodified "clean" opinion on our financial statements, with no reported material weaknesses, for 12 consecutive years, as reported in the *FY 2022 Agency Financial Report*. We review the resulting reports, such as the annual auditor's report on NASA's financial statements and OIG Report on NASA's Top Management and Performance Challenges, and provide feedback on how the Agency will take corrective actions or make improvements.

Strategies for Improvement

We've outlined the internal assessments and evaluations that NASA undertakes to aid in maintaining, managing, and improving operations and program performance.

Periodic external assessments focus management attention on areas of high risk or potential challenges. The Government Accountability Office (GAO) and the NASA Office of Inspector General (OIG) conduct such external assessments, identifying trouble spots and recommending how to address them. Issues raised by GAO and OIG represent high-priority areas for management attention.

High Risk Areas Identified by the GAO

GAO assesses activities across the federal government and identifies areas that carry a risk for fraud, waste, abuse, mismanagement, or otherwise requiring transformation. GAO's biennial High Risk List, which is issued publicly and delivered to each newly elected Congress, has included NASA's acquisition management since the inaugural report issued in 1990. GAO established five criteria that GAO uses to evaluate progress against the High-Risk area and that, if sufficiently addressed, would lead GAO to remove the High-Risk area from the subsequent report:

- **Leadership Commitment:** Demonstrated strong commitment and top leadership support.
- **Capacity:** Agency has the capacity (i.e., people and resources) to resolve the risk(s).
- **Action Plan:** A corrective action plan exists that defines the root cause, solutions, and provides for substantially completing corrective measures, including steps necessary to implement recommended solutions.
- **Monitoring:** A program has been instituted to monitor and independently validate the effectiveness and sustainability of corrective measures.

Above: NASA's Space Launch System (SLS) rocket with the Orion spacecraft aboard is seen atop the mobile launcher as it rolls out to Launch Pad 39B, on November 4, 2022, at NASA's Kennedy Space Center in Florida. NASA's Artemis I flight test is the first integrated test of the deep space exploration systems: the Orion spacecraft, SLS rocket, and supporting ground systems. The Artemis I uncrewed flight test launched on November 16. Image Credit: NASA/Joel Kowsky

- **Demonstrated Progress:** Ability to demonstrate progress in implementing corrective measures and resolving high-risk areas.

As part of the 2021 update for NASA, "High-Risk Series: Dedicated Leadership Needed to Address Limited Progress in Most High-Risk Areas" (GAO-21-119SP), GAO included a scorecard detailing which of these criteria for improving acquisition management have been met, partially met, or have not been met. NASA fully met the criteria for leadership commitment, a corrective action plan, and monitoring and has partially met the criteria for capacity and demonstrated progress. The 2021 report reflects a significant improvement in the leadership commitment and monitoring areas over the previous 2019 report, a fact that was noted by GAO in the report's cover letter (page 24). The 2023 High Risk report is anticipated to be released early 2023.

NASA's responses to the challenges GAO has identified have yielded more credible cost and schedule baselines, and both GAO and OIG have observed that NASA's management of its small- and medium-class major flight projects has improved. The effectiveness of these tools is particularly evident for the smaller (under $1 billion lifecycle cost) projects. However, there is broad recognition that NASA needs to continue to improve management of its larger, more complex projects, which typically involve the development of a significant number of new technologies, greater integration risk, and challenges with early cost and schedule estimation. In response to the need to improve acquisition management of these larger, more complex projects, NASA increased the emphasis on review of their performance during the Baseline Performance Reviews, described on page 15.

A Corrective Action Plan for Acquisition Management Improvements

With approval from the Associate Administrator, NASA released an updated "High Risk Corrective Action Plan" (CAP) in August 2022 in response to the continued inclusion of NASA's acquisition practices on GAO's High Risk report, as well as recent challenges in cost schedule growth experienced by several of NASA's highest profile missions. The two-year CAP is developed in support of the Agency's steadfast commitment to good governance and effective stewardship of the resources entrusted to it.

The GAO High Risk report interprets Acquisition Management broadly, including program and project management concerns and the strategy and decision-making around Make/Buy/Partner considerations prior to procurement. The CAP reflects GAO's broad definition, illustrating actions NASA has already taken to improve acquisition management and program management and highlighting planned work in these disciplines. The CAP contains a set of six initiatives geared toward advancing these disciplines, providing more details, next steps, challenges, and goals. The 2022 CAP initiatives are: Schedule Database; Ensure Schedule Capability; Enhance Standing Review Board Implementation; Increase Deep Space Exploration Systems' Transparency of Cost and Schedule; Firm Fixed Price Data Collection; and Realistic Proposal Cost Estimating.

The 2022 CAP builds upon the previous corrective action plans, which were developed in 2007, 2018, and 2020. The initiatives from those previous plans, including steps taken for closure on the initiatives, are detailed in an appendix of the 2022 plan.

NASA Chief Acquisition Officer's Intent and Expansion of Acquisition Priorities

In September 2022, NASA published the *Moon to Mars Objectives* describing the "what" and "why" of our plans for deep space exploration before prescribing the "how," with specific technologies, capabilities, and acquisition approach (Visit the Moon to Mars Objectives Executive Summary).

In November 2022, NASA's Chief Acquisition Officer released an intent memorandum to NASA leaders describing acquisition and procurement priorities that will allow the Agency to obtain or advance the development of systems, services, research, construction, and supplies to fulfill our Moon to Mars Mission and statutory objectives. To this end, the Chief Acquisition Officer charged NASA Officials-in-Charge and leaders to ensure resource and workforce alignment with two major priorities—"Acquisition Innovation and Rigor" and "Workforce and Culture".

Acquisition Innovation and Rigor – NASA will improve its acquisition rigor through strict application of its robust existing rules and policies, promoting consistency and developing communities of practice as an available resource. We will use the insightful data provided in every procurement

transaction to better sharpen our technical reviews, requests, and decision-making in the future. Senior leadership will continue to reimagine performance reviews and decisional council meetings to ensure clear framing, consistency in application of policies and exemptions, and documentation of decisional outcomes.

Workforce and Culture – To continue to improve the Agency's acquisition management, we are investing in our workforce and cultivating their expertise through Agency-wide communities of practice with access to the most up-to-date tools, networks, and best practices. NASA will promote greater collaboration, consistency, use of tools, and access to training across functions, including procurement, finance, legal, program management, program planning and control, and others, that collectively enable our acquisition mission. Alongside honing our technical skills, we will continue to foster a culture of engagement, encouraging honest communication, knowledge sharing, collaborative problem solving across disciplines, and data-driven decision making.

Management Challenges Identified by the OIG

Each fiscal year, NASA's OIG issues the "2022 Report on NASA's Top Management and Performance Challenges" summarizing what the Inspector General considers to be NASA's most serious management and performance challenges, as well as a brief assessment regarding the Agency's progress in addressing those challenges. NASA leverages the results of this and other OIG recommendations to improve the overall efficiency and effectiveness of our programs, projects, and functional activities.

NASA has implemented a comprehensive program of follow-up intended to ensure that recommendations issued by the OIG are resolved and implemented in a timely, responsive, and effective manner. NASA's follow-up program is a key element in improving the overall efficiency and effectiveness of NASA's programs, projects, and operations. The Administrator's response to the OIG's recommendations are detailed on page 94 of NASA's FY 2022 *Agency Financial Report*.

The OIG's report continues the seven challenges originally identified in 2020: *Returning Humans to the Moon; Improving Management of Major Programs and Projects; Sustaining a Human Presence in Low Earth Orbit; Managing and Mitigating Cybersecurity Risks; Improving Oversight of Contracts, Grants,* and *Cooperative Agreements; Attracting and Retaining a Diverse and Highly Skilled Workforce;* and *Managing NASA's Outdated Infrastructure and Facilities*. The report also links each challenge to one or more Strategic Goal and Objective. The relevant Performance Goals and significant evaluations are provided below.

OIG Management Challenge: Returning Humans to the Moon

The OIG states the Artemis program—currently NASA's most ambitious and costly ongoing activity—is projected to cost NASA $93 billion by FY 2025 and will require decades-long engagement from NASA and our commercial and international partners to build and support multiple human and robotic exploration systems, conduct research and technology demonstrations to return humans to the Moon, and prepare for an eventual crewed mission to Mars.

Artemis is a multi-mission program that allows NASA to extend the length and complexity of lunar missions over time. Each Artemis mission involves multiple systems managed by different entities on varying development timelines in which coordination and interoperability—the ability of a system to work with another system—is critical and deeply challenging. These systems include the Space Launch System (SLS) heavy-lift rocket and Orion Multi-Purpose Crew Vehicle (Orion) capsule that will transport astronauts to lunar orbit, the Human Landing System (HLS) that will ferry astronauts to the lunar surface, next-generation spacesuits that will enable astronauts to operate outside their spacecraft and on the lunar surface, and a Moon-orbiting permanent outpost known as Gateway. For Artemis III, the Orion capsule—with four astronauts on board—will dock in lunar orbit with an HLS to transport two astronauts to the lunar surface. Significantly, as part of the Artemis program, NASA intends to land the first woman and first person of color on the Moon.

Progress during FY 2022 fell into one of three categories: the (1) development and (2) procurement of key Artemis systems, as well as initiatives to improve the overall (3) management of the Artemis missions. Below are initiatives and Performance Goals that performance in this area.

For more information see Strategic Objective 2.1: Explore the Surface of the Moon and Deep Space

OIG Management Challenge: Improving Management of Major Projects

NASA has an extensive portfolio of programs and projects in science, space exploration, technology development and innovation, and aeronautics research. These programs and projects include satellites equipped with advanced sensors to study Earth; rovers to collect soil and rock samples on other celestial bodies; telescopes that explore the far reaches of the universe; and complex systems to support transportation of humans to the ISS, Moon, and beyond. The overall management of a program or project requires expertise with cost, schedule, transparency of external reporting, development risks, staffing and training, and program and project requirements. Effectively managing NASA's portfolio of major programs and projects has been a continuous challenge for the Agency, with cost and schedule overruns being particular areas of concern.

Historically, NASA's portfolio of major programs and projects have cost significantly more and taken much longer to complete than initially planned. As the OIG notes, NASA completed six major programs and projects in 2021, including the James Webb Space Telescope, but collectively the Agency's major programs and projects exceeded their cost estimates by almost $3 billion and surpassed their collective schedules by almost 10 years.

NASA continues to focus on improving management of its major programs and projects. The Landsat 9 and Lucy missions collectively cost $196 million less to develop than planned and both launched early, according to their Agency Baseline Commitments. GAO's 2022 High Risk Series report listed NASA's acquisition management as one of only six high-risk areas throughout the entire federal government that showed progress toward meeting criteria for removal from the High-Risk List.

For more information see Strategic Objective 1.1: Understand the Earth system and its climate; Strategic Objective 1.2: Understand the Sun, solar system, and universe; Strategic Objective 2.1: Explore the surface of the Moon and deep space; Strategic Objective 3.1: Innovate and advance transformational space technologies; and Strategic Objective 3.2 Drive efficient and sustainable aviation.

OIG Management Challenge: Sustaining a Human Presence in Low Earth Orbit

NASA's activities in low Earth orbit (LEO)—the region in space from about 100 to 600 miles above Earth's surface—consume approximately one-third of the Agency's annual human space flight budget. This level of expenditure will likely continue with International Space Station (ISS) operations expected to be extended through 2030.

NASA plans to sustain a human presence in LEO beyond the retirement of the ISS by becoming a customer of one or more commercially owned and operated space destinations. The OIG states that the transition to commercial destinations will require a sustained, but largely undetermined, financial investment by NASA and private companies, as well as growth in non-NASA demand for these services to ensure their long-term financial viability. Avoiding a gap between the advent of a commercial LEO destination and the end-of-life for the ISS by 2030 is the crux of this challenge.

Within the past couple of years, NASA has experienced advancements related to transportation to LEO, with SpaceX successfully providing routine crew services to the ISS. In June 2022, a Northrop Grumman Cygnus spacecraft docked to the ISS and fired its main engine to complete the first limited adjustment to ISS's orbit. This procedure adds a critical capability to help maintain and support the ISS.

Furthermore, NASA will be finalizing a study to evaluate crew certification requirements for commercial LEO in FY 2024. This evaluation, which is described in detail in "Appendix A, NASA's FY 2024 Annual Evaluation Plan," will obtain and analyze feedback from various stakeholders on draft Commercial LEO Destination Crew Certification Requirements and Overall Service Summary documents that discuss the assumptions NASA is considering with regards to the utilization of these potential commercial LEO destination systems. The requirements and assumptions will eventually support NASA's purchase of contracted services.

For more information see Strategic Objective 2.2: Develop a human spaceflight economy enabled by a commercial market.

OIG Management Challenge: Managing and Mitigating Cybersecurity Risk

NASA's work ranges from space missions to advanced electric aircraft designs to studying climate change, making the Agency a top target for both foreign and domestic hackers. The OIG notes that within NASA's FY 2022 $2 billion-plus information technology (IT) budget, the Office of the Chief Information Officer (OCIO) is allocated $667 million, of which $137 million is designated for institutional cybersecurity in support of Agency operations. Separate from the OCIO, mission organizations invested almost $215 million on mission-based cybersecurity at locations around the country.

For more than two decades, the OIG has identified efforts to secure NASA IT systems as a top management challenge due, in large part, to the Agency's lack of an enterprise-wide approach to cybersecurity. Given the increasing number of cyber threats across its Centers and facilities, the difficulty of ensuring the security and reliability of IT systems and strengthening its cybersecurity program remains a top Agency challenge. In addition, as technology's role in the workplace continues to evolve with an increasingly hybrid and remote workforce, NASA's IT services are vital to enabling and protecting the Agency's activities.

For more information see Strategic Objective 4.2: Transform mission support capabilities for the next era of aerospace.

OIG Management Challenge: Improving Oversight of Contracts, Grants, and Cooperative Agreements

OIG notes that NASA remains challenged to ensure funds are appropriately spent to achieve agreed-upon goals and taxpayers receive good value for their investments. NASA is increasingly utilizing public-private partnerships and alternative acquisition approaches to achieve cost savings and accelerate development of new technologies, including several key systems for the Artemis missions.

The IG notes that more broadly, oversight of contracts, grants, and cooperative agreements are long-standing challenges as evident in GAO's continued designation of NASA's acquisition management as a high-risk area since 1990. These same challenges are common findings in the OIG's audit work, as well.

Considering several recent economic pressures facing the country (i.e., record inflation, weather-related delays/shortages, pandemic related supply chain issues), NASA has partnered with the Department of Commerce to conduct a study of the factors that drive efficiency in the NASA and U.S. civil space supply chain network. This evaluation, which is described in detail in "Appendix A, NASA's FY 2024 Evaluation Plan," aims to identify gaps, shortages, and/or pending issues affecting the aerospace supply chain network. The intent of this study is to be able to better forecast pressures, anticipate risks, and develop mitigation plans to drive adaptability and enhance decision making.

For more information see Strategic Objective 3.1: Innovate and advance transformational space technologies; and Strategic Objective 4.3: Build the next generation of explorers.

OIG Management Challenge: Attracting and Retaining a Diverse and Highly Skilled Workforce

NASA is actively seeking to identify, recruit, and retain a diverse, multi-generational workforce that possesses the technical skills critical to our varied mission portfolio. However, the Agency remains challenged to ensure its workforce has the requisite skills and is sufficiently diverse. To address this challenge, we are working to prioritize and implement strong diversity, equity, inclusion, and accessibility (DEIA) initiatives.

The OIG states that their prior work has shown that NASA faces interrelated workforce challenges, including a static pipeline of women and minorities into science, technology, engineering, and mathematics (STEM) positions; an aging workforce; and a growing shortfall of employees qualified in technical areas. This is just one of the reasons NASA has decided to perform a barrier analysis that will hopefully identify root causes and underlying conditions that may be contributing to the disproportionately low number of women and minorities in Government Schedule (GS)-14 and higher positions. A detailed explanation of this evaluation can be found in "Appendix A, NASA's FY 2024 Annual Evaluation Plan."

For the past 10 years, NASA has been voted the best large agency to work for in the federal government according to the Partnership for Public Service's

Federal Employee Viewpoint Survey (FEVS). At the same time, the Agency continues to pursue the strategic goal of cultivating a diverse, motivated, and highly qualified workforce through modernizing human capital processes and talent acquisition systems; increasing workforce agility and flexibilities; and implementing a robust DEIA approach to ensure systematic and sustainable fairness, impartiality, and equity in our business practices.

For more information see Strategic Objective 4.1: Attract and develop a talented and diverse workforce; Strategic Objective 4.3: Build the next generation of explorers; and the Internship Outcomes Assessment Study in the NASA FY 2024 Annual Evaluation Plan.

OIG Management Challenge: Managing NASA's Outdated Infrastructure and Facilities

NASA is one of the largest property holders in the federal government, with $47 billion in physical assets and an inventory of more than 5,300 buildings and structures across 12 states and the District of Columbia, according to the OIG. Of these, over 75 percent are beyond their original design life and the Agency faces a deferred maintenance backlog estimated at $3 billion as of 2022. Deferring maintenance until equipment or facility fails has resulted in repair and replacement costs up to three times more than if NASA had been able to conduct regular maintenance.

NASA's Construction of Facilities (CoF) program is working with limited resources to modernize the Agency's infrastructure into fewer, more sustainable facilities and repair and replace failing infrastructure to reduce overall maintenance costs.

For more information see Strategic Objective 2.1: Explore the surface of the Moon and deep space; Strategic Objective 2.4: Enhance space access and services; and Strategic Objective 4.2: Transform mission support capabilities for the next era of aerospace.

Organized for Success and Sustainability

NASA is organized for success, with a leadership model that optimizes strategic direction at the Agency level, facilitates management at the functional levels in the mission directorates and mission support offices, and enables a wide range of activities at centers and facilities. The distributed and diverse nature of our work is unified by an integrated performance culture that engages employees and stakeholders at all levels.

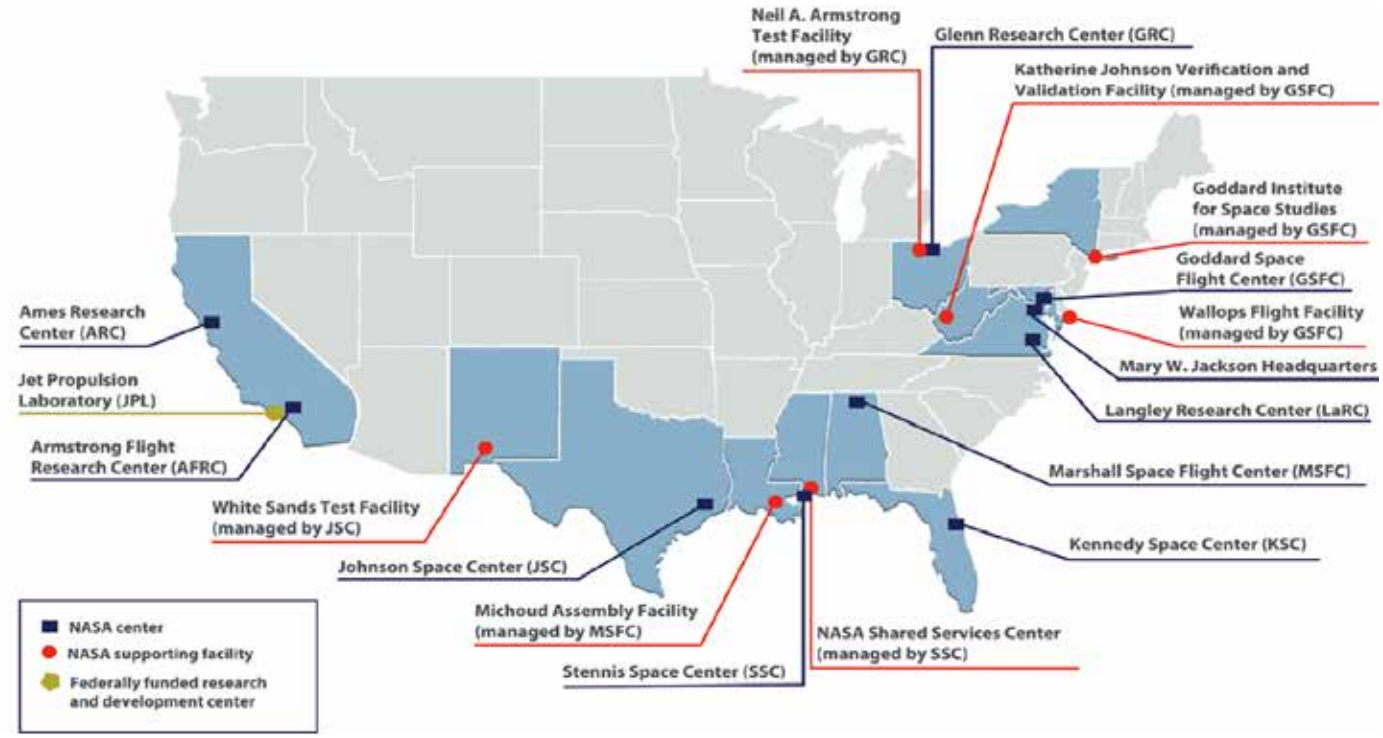
The innovative, responsive, and dynamic nature of our work benefits from the relationships within and between Mission Directorates, Mission Support Offices, and Centers. This organizational model ensures our leaders can take both a holistic and more narrowly focused approach to programmatic, operational, business, and safety management.

Centers and Facilities Nationwide

NASA's best asset for achieving mission success is a diverse, multidisciplinary, and skilled workforce across all Centers and facilities. NASA's approach to performance management is based on the premise that each team member brings unique experience and important expertise to projects. NASA is committed to nurturing an organizational culture in which individuals make full use of their time, talent, and opportunities to pursue the highest standards in engineering, research, operations, and management.

Above: Artemis Mission Development Manager Mike Sarafin, and Artemis Mission Integration Manager Sheela Logan raise Artemis flags Wednesday, Nov. 23, 2022, at the Mary W. Jackson NASA Headquarters building in Washington. Image Credit: NASA/Keegan Barber

NASA's Centers and Facilities



The NASA workforce of 17,962[1] civil servants (including full-time, part-time, term appointment, student, and other non-permanent employees) is distributed across its Centers, facilities, and Headquarters (see figure). A contractor workforce supports each location by providing technical and business operations services.

The Administrator and senior officials lead NASA by providing top-level strategy, policy, and direction. NASA's Office of the Chief Financial Officer leads the Agency's budget development, execution, and organization-wide performance management activities.

Mission Directorates and Mission Support Offices at Headquarters manage decisions on programmatic investments and guide operations of the Centers. Provided below are brief descriptions of NASA's Mission Directorates and select offices.

The **Aeronautics Research Mission Directorate (ARMD)** conducts research to advance the safety, capacity, and efficiency of the air transportation system, reduce emissions, and sustain U.S. technological leadership in the aviation industry.

The **Space Technology Mission Directorate (STMD)** invests in transformational technologies that help offset future mission risk, reduce cost, advance capabilities that enable NASA's missions, and support space industry growth and high-quality job creation. STMD identifies and promotes research and technology development, demonstrates applicability, and supports the infusion of these technologies into NASA's exploration and science missions as well as commercial space activities.

The **Science Mission Directorate (SMD)** conducts scientific exploration enabled by observatories that view Earth from space, observe, and visit other bodies in the solar system, and gaze out into the galaxy and

1 NASA Workforce Profile, Workforce Information Cubes for NASA (WICN). Last updated February 11, 2023.

beyond. NASA's science programs focus on three interdisciplinary objectives: discovering the secrets of the universe, searching for life in the solar system and beyond, and safeguarding and improving life on Earth.

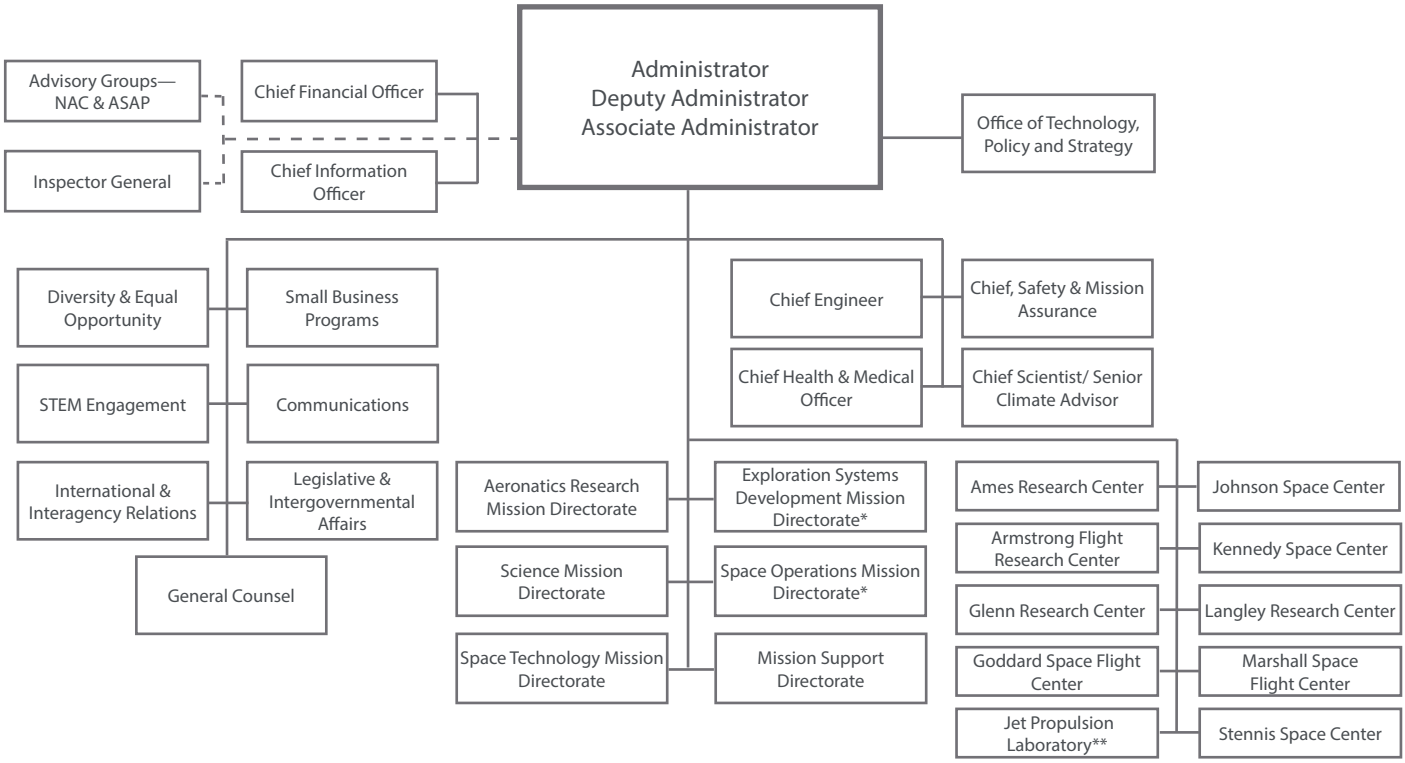
The **Exploration Systems Development Mission Directorate (ESDMD)** defines and manages the systems development for programs critical to the Artemis lunar exploration initiatives. ESDMD is responsible for developing the Space Launch System, the Orion spacecraft, and Exploration Ground Systems. ESDMD also is responsible for developing technologies and capabilities to support sustainable human deep space exploration.

The **Space Operations Mission Directorate (SOMD)** focuses on launch and space operations, including launch services, space communications and navigation, and eventually, sustaining operations on and around the Moon. SOMD also manages the International Space Station (ISS) and commercial space capability development and on-going operations, such as commercial crew and cargo flights and the program to develop the commercial space stations that will replace the ISS.

The **Mission Support Directorate (MSD)** enables the Agency's missions by managing institutional services, capabilities, and critical mission support resources. MSD is actively reducing institutional risk to NASA's current and future missions by improving processes, stimulating efficiency, and providing consistency and uniformity across institutional standards and practices.

Part 1 of this document detailed NASA's commitment and approach to performance management. Part 2 presents a granular look at every Performance Goal across the Agency, with ratings and narrative details for each.

NASA Organization



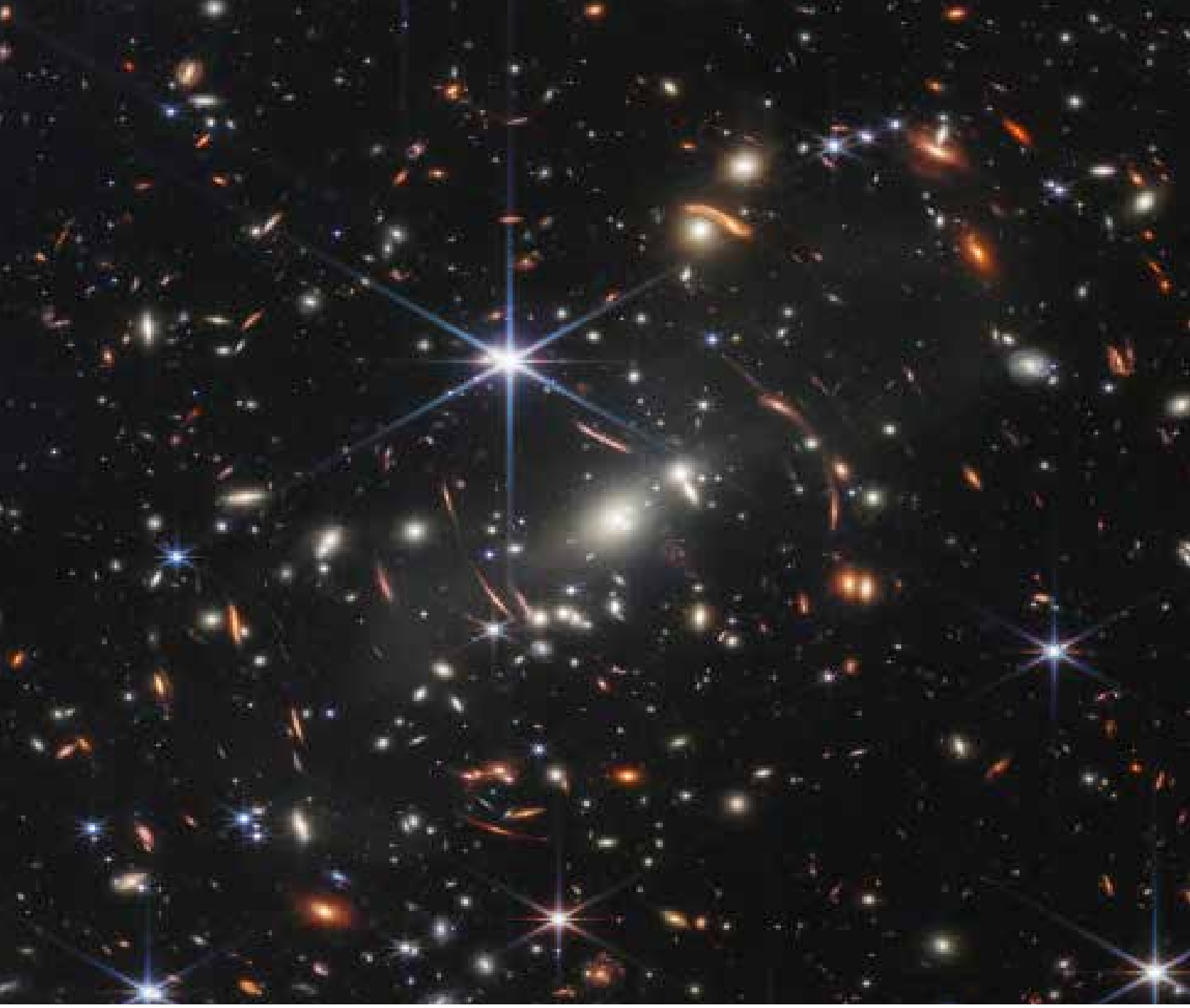
*The Human Exploration and Operations Mission Directorate reorganized into two Mission Directorates at the beginning of FY 2022

**JPL is a Federally Funded Research and Development Center (FFRDC) managed by the California Institute of Technology (Caltech) with oversight by NASA's Office of JPL Management and Oversight

Dotted lines indicate independent advisory or oversight organizations

NASA Advisory Council (NAC)

Aerospace Safety Advisory Panel (ASAP)



Part 2

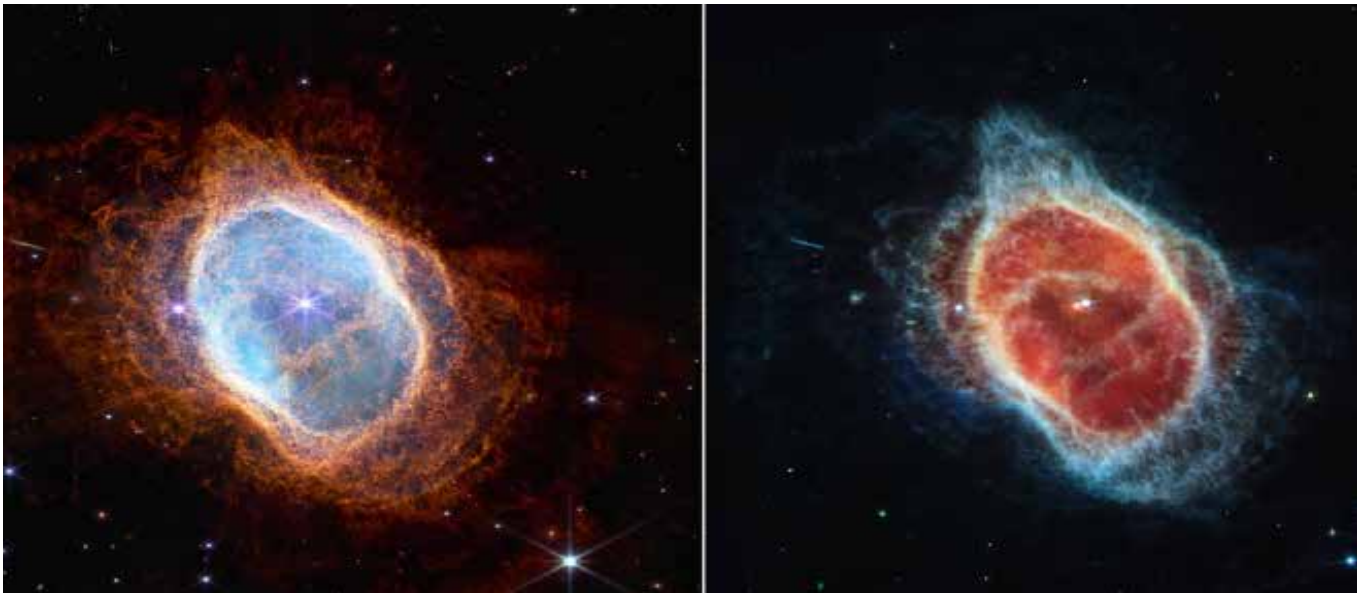
Performance Planning and Reporting

NASA's James Webb Space Telescope has produced the deepest and sharpest infrared image of the distant universe to date. Known as Webb's First Deep Field, this image of galaxy cluster SMACS 0723 is overflowing with detail.

Thousands of galaxies – including the faintest objects ever observed in the infrared – have appeared in Webb's view for the first time. This slice of the vast universe covers a patch of sky approximately the size of a grain of sand held at arm's length by someone on the ground. Image Credit: NASA, ESA, CSA, and STScI Images

Strategic Goal 1

Expand human knowledge through new scientific discoveries.



Top: The dimmer star at the center of this scene has been sending out rings of gas and dust for thousands of years in all directions, and NASA's James Webb Space Telescope has revealed for the first time that this star is cloaked in dust. Image Credit: NASA, ESA, CSA, and STScI Images

Bottom: This landscape of "mountains" and "valleys" speckled with glittering stars is actually the edge of a nearby, young, star-forming region called NGC 3324 in the Carina Nebula. Captured in infrared light by NASA's new James Webb Space Telescope, this image reveals for the first time previously invisible areas of star birth. Image Credit: NASA, ESA, CSA, and STScI Images

FY 2022 Performance Goals and Ratings Supporting Strategic Goal 1

Organized by Strategic Objective

Strategic Objective	Performance Goal	Description	Rating
1.1	**Understand the Earth system and its climate.**		
	1.1.1	Demonstrate progress in characterizing the behavior of the Earth system, including its various components and the naturally occurring and human-induced forcings that act upon it.	Green
	1.1.2	Demonstrate progress in enhancing understanding of the interacting processes that control the behavior of Earth system, and in utilizing the enhanced knowledge to improve predictive capability.	Green
	1.1.3	Achieve critical milestones for the Science Mission Directorate's Earth system major projects.	Yellow
	1.1.4	Use the global vantage point of space to advance our understanding of the Earth system, its processes, and changing climate. (APG)	Yellow
1.2	**Understand the Sun, solar system, and universe.**		
	1.2.1	Demonstrate progress in exploring and advancing understanding of the physical processes and connections of the Sun, space, and planetary environments throughout the solar system.	Green
	1.2.2	Demonstrate progress in exploring and probing the origin, evolution, and destiny of the galaxies, stars, and planets that make up the universe.	Green
	1.2.3	Demonstrate progress in exploring, observing, and understanding objects in the solar system in order to understand how they formed, operate, interact, and evolve.	Green
	1.2.4	Demonstrate progress in discovering and studying planets around other stars.	Green
	1.2.5	Demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere, exploring and finding locations where life could have existed or could exist today, and exploring whether planets around other stars could harbor life.	Green
	1.2.6	Demonstrate progress in developing the capability to detect and knowledge to predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.	Green
	1.2.7	Demonstrate progress in identifying, characterizing, and predicting objects in the solar system that pose threats to Earth or offer resources for human exploration.	Green
	1.2.8	Demonstrate progress in understanding the properties of physical and biological systems in spaceflight environments to advance scientific knowledge, enable space exploration, and benefit life on Earth.	Green
	1.2.9	Achieve critical milestones of Science Mission Directorate's heliophysics, planetary science, and astrophysics major projects.	Green
	1.2.10	Complete commissioning of the James Webb Space Telescope, the most powerful and complex space telescope ever built, and begin Webb's Cycle 2 observations. (APG)	Green
1.3	**Ensure NASA's science data are accessible to all and produce practical benefits to society.**		
	1.3.1	Accelerate the accessibility and use of NASA's science data and tools.	Green
	1.3.2	Apply insights from Earth science to benefit the economy, health, quality of life, and environment around the globe.	Green

APG = Agency Priority Goals

Strategic Objective 1.1

Understand the Earth system and its climate.

LEAD OFFICE
Science Mission Directorate (SMD)

GOAL LEADER
Karen Flynn, Deputy Associate Administrator for Management, SMD

Budget

	FY	$M
Op Plan	2022	$1,648.3
Enacted	2023	$1,780.7
Requested	2024	$1,973.8
Outyear	2025	$2,096.2
	2026	$2,215.7
	2027	$2,258.1
	2028	$2,297.9

NASA integrates and advances knowledge of Earth as a system to meet the challenges of environmental change, strengthen our Nation and improve life for all people. Earth's changing environment impacts every aspect of life on our planet and has profound implications on society and our Nation's well-being. Climate adaptation and mitigation efforts cannot succeed without robust observations and research. As the impacts of global climate change become more numerous and acute, the demand for accurate, timely and actionable data about the Earth system is more pressing than ever.

We are a world leader in the production of data necessary to understand, model, monitor, and ultimately predict environmental change. We are 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. Our 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. We also work with international partner satellites; data from airborne, ship-based and ground network instrumentation; and outputs from operational weather models from the National Oceanic and Atmospheric Administration (NOAA) and other meteorological agencies. We integrate and harness these disparate data sources, enabling scientists to investigate and solve large questions

Below: The photograph above was taken in the late morning on August 31, 2022, by an astronaut on the International Space Station. On September 1, 2022, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite acquired a natural-color image (below) of Hinnamnor. Though the typhoon appeared to be bearing down on Taiwan in the image, it had actually started to turn north and away from the island. Image Credit: NASA Images

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

We are developing the observing systems that will answer the most important science and application questions of the next decade, using the recommendations of the National Academies' 2017-2027 decadal survey for Earth science and applications from Space as a compass and informed by Government-wide priorities. Implementation is achieved through a balanced portfolio of programs, to include the Earth System Observatory, consisting of a new set of Earth-focused missions to provide key information to understand Earth's systems and processes, as well as interactions between the processes on the land, ocean, and in the atmosphere.

We continue to refine our ability to execute missions within cost commitments by implementing improved management techniques and the use of independent review boards and cost estimates. We also continue to address the Supply Chain Management Enterprise Risk, which poses a significant concern for achievement of this Strategic Objective. Risks specific to this Strategic Objective include mega-constellations of low Earth orbit satellites, which could significantly impact science missions. We have begun an assessment of these mega-constellations and will develop a baseline model for use as part of mission concept reviews and subsequent risk tracking and mitigation.

NASA has a solid record for achievement of multi-year Performance Goals supporting this area. Noteworthy accomplishments include the launch of Landsat-9, which is extending our ability to measure changes on the global land surface at a scale where we can separate human and natural causes of change. In their most recent assessment, the Earth Science Advisory Committee again rated our progress toward both of the Strategic Objective 1.1 science goals as having met or exceeded expectations. While the COVID-19 pandemic has had significant impacts, evaluations of near-, mid- and long-term success criteria provide ample evidence to support a rating of Satisfactory Progress for Strategic Objective 1.1.

1.1.1: NASA shall demonstrate progress in characterizing the behavior of the Earth system, including its various components and the naturally-occurring and human-induced forcings that act upon it.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.1.1.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.1.1.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.1.1.

Lead Organization: Science Mission Directorate (SMD)

Top: The false-color image was composed from shortwave infrared, near-infrared, and green light. This band combination (6-5-3) cuts through the smoke to reveal burn scars (brown). From ignition on July 29 through the time of this image, the McKinney Fire burned more than 60,000 acres (243 square kilometers) of timber, brush, and grass. It was 40 percent contained by midday on August 8. Notice the smaller burn scar to the west. This land was burned by Yeti Complex fires (Yeti and Alex), which were ignited by lightning in the Klamath National Forest on the same day as the McKinney Fire. By August 6, the Yeti Complex had burned more than 7,000 acres (28 square kilometers) and was not contained on any side. Image Credit: NASA Images

Bottom: The natural-color image (left) primarily shows smoke. Some of the smoke that day billowed from the McKinney Fire (east), but a significant amount poured from the Yeti Complex (west). Communities along the Klamath River, including Seiad Valley and Klamath River, saw air quality decline to "very unhealthy" levels. More smoke streamed from newer fires to the southwest of McKinney, visible in this wide view acquired on August 6, 2022, by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite. Note that the white patches close to the coast are marine stratus clouds. Image Credit: NASA Images

FY 2022 Performance Progress

The Earth Science Advisory Committee determined in October 2022 that NASA has remained on track toward achievement of this Performance Goal, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

A study applied Global Ecosystem Dynamics Investigation (GEDI) data along with environmental and biogeographical variables to explain global patterns in tree species richness. They found that forest structure information from GEDI explained 66 percent of the variation in global tree species richness in natural forests without a history of recent disturbance. Understanding and predicting variations in tree species diversity is important because of the ecosystem services it provides,

such as productivity and carbon sequestration. Researchers used Ice, Cloud and land Elevation Satellite (ICESat)-2 and CryoSat-2 sea ice free board measurements to examine the variability of monthly Arctic Sea ice snow depth, thickness, and volume between October 2018 and April 2021. Over the roughly three-year measurement period, a decline in mean springtime Arctic Sea ice thickness on the order of 30 centimeters is likely the result of roughly 50 centimeters of average thinning of multiyear sea ice. Snow depth estimates from each of these sensors reveal an overall thinner sea ice pack in the Arctic in the fall as well. These new observations add to a decades-long satellite record that shows a loss of one-third of the winter sea ice volume in the Arctic, largely driven by the decline of multiyear (versus first year) sea ice coverage.

Researchers found evidence in Ozone Mapping and Profiler Suite (OMPS) Limb Profiler ozone and aerosol measurements to support the hypothesis that the 2020 and 2021 Antarctic ozone holes were influenced by two extraordinary events: the Australian wildfires of early 2020 and the eruption of La Soufriere in 2021. They argue that both ozone holes were associated with changes in Southern Hemisphere surface climate consistent with the established climate impacts of Antarctic ozone depletion. Together, the results provide suggestive evidence that injections of both wildfire smoke and volcanic emissions into the stratosphere can lead to hemispheric-scale changes in surface climate.

1.1.2: NASA shall demonstrate progress in enhancing understanding of the interacting processes that control the behavior of the Earth system, and in utilizing the enhanced knowledge to improve predictive capability.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.1.2.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.1.2.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.1.2.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

The Earth Science Advisory Committee determined in October 2022 that NASA has remained on track toward achievement of this Performance Goal, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

A number of studies published in the past year investigated the physics of the ocean's extreme events, interpreting the underlying mechanisms of the extremely active 2020 hurricane season in the Gulf of Mexico. Intensification of Hurricanes Marco and Sally in 2020 is attributed to a combination of strong winds and downwelling ocean currents, which pump the heat from the surface towards the bottom of the shelf. The continued reheating of the upper ocean and offshore transport of the warm coastal waters further enhanced shelf thermal energy, intensifying the subsequent storm. The compound mechanism explains the rapid intensification of both Hurricanes Marco and Sally before their landfalls, which caused more than $7 billion in damage to the coastal communities.

Researchers studied the abrupt onset and swift intensification which characterize flash droughts and proposed a new method for near-real-time characterization of droughts using soil moisture stress (indicative of drought stress) and relative rate of drydown (indicative of drought stress intensification rate). We developed these parameters using global surface soil moisture from NASA's Soil Moisture Active Passive satellite for March 2015–May 2021. Soil moisture stress and relative rate of drydown are nonlinearly combined to develop a new Flash Drought Stress Index (FDSI) to characterize emerging flash droughts.

These indices were used to evaluate flash droughts in the Northern Great Plains, Central South Africa, and Eastern Australia. About 5.6 percent of the Earth's landmass experienced flash droughts of varying intensity and duration from 2015 through 2021, primarily in global drylands. FDSI shows high skill in forecasting vegetation health with a lead of zero to two weeks, with exceptions in irrigated croplands and mixed forests. The developed index has no dependence on model simulations and is a robust tool for global near-real-time flash drought monitoring using soil moisture stress.

1.1.3: Achieve critical milestones for the Science Mission Directorate's Earth system major projects.

Number of critical milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	3 of 3	3 of 3	3 of 4
Areas Completed	2		
Rating	Yellow		

List of critical milestones for FY 2022

1. Complete Sentinel-6B mission Pre-Storage Review.
2. Complete the Surface Water and Ocean Topography (SWOT) mission Operational Readiness Review (ORR).
3. Deliver the NASA-Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR) Radar Antenna Boom integration and alignment onto the Radar Structure.
4. Initiate the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Observatory Integration and Test (I&T).

List of critical milestones for FY 2023

1. Deliver the NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) mission Integrated Radar Payload to ISRO.
2. Complete the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission Key Decision Point (KDP)-D review.
3. Launch the Tropospheric Emissions: Monitoring Pollution (TEMPO) mission.

List critical milestones FY 2024

1. Launch the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission.
2. Complete the NASA-Indian Space Research Organisation (ISRO) Synthetic Aperture Radar (NISAR) mission Pre-Ship Review (PSR).
3. Complete the Atmosphere Observing System (AOS) System Requirements Review (SRR).
4. Complete the Surface Biology and Geology (SBG) mission Preliminary Design Review (PDR).

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA completed the NASA-Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR) Antenna Boom integration and alignment onto the Radar Structure in May. The NISAR mission will deliver measurements at unprecedented levels of precision, providing critical information on Earth's crust, ice sheets, and ecosystems. The Sentinel-6B mission, which will provide ongoing measurements of global sea level rise, one of the most important indicators of human-caused climate change, when launched in 2025, completed its Pre-Storage Review in July. Planned development activities for two other missions, Surface Water and Ocean Topography (SWOT) and Plankton, Aerosol, Cloud, ocean Ecosystem (PACE), were delayed. NASA had planned initiation of the PACE observatory integration and test (I&T) in FY 2022, but commenced in early FY 2023, on November 7, 2022. The delay was due to a combination of factors, including inclement weather closures of Goddard Space Flight Center, schedule conflicts with other projects for common use facilities, and technical issues that required additional work and analyses before continuing the workflow.

The SWOT Operational Readiness Review (ORR) was initially shifted from July to September 2022 in order to better coordinate joint schedules with NASA's international partner, France's Centre National d'Etudes Spatiales (CNES). The review was subsequently moved one month beyond FY 2022, from September to October, due to the loss of the Ukrainian Antonov-124 aircraft intended to transport the spacecraft to the launch site, and the resulting need to identify and adapt to an alternative mode of transportation. NASA procured a U.S. Air Force C-5C to replace the Antonov, and the ORR was completed on October 27.

NASA successfully launched SWOT on December 16, 2022. Due to the shifting schedules for PACE and SWOT, the Performance Goal received a Yellow rating.

1.1.4: Use the vantage point of space, airborne, and surface observations to advance our understanding of the Earth system, its processes, and changing climate. (Agency Priority Goal)

Number of critical milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022 Agency Priority Goal	FY 2023	FY 2024
Target # of Areas	5 of 5	4 of 4	TBD
Areas Completed	4		
Rating	Yellow		

This two-year Performance Goal/Agency Priority Goal will be completed on September 30, 2023. NASA may develop a follow-on Climate Change Research goal for the FY 2024-2025 Agency Priority Goal cycle. If so, the goal statement, annual target, and supporting critical milestones for FY 2024 and FY 2025 will be identified for inclusion in the FY 2024-2025 Agency Performance Plan.

List of critical milestones for FY 2022

1. Release Landsat first light images.
2. Competitively select Earth Venture Mission (EVM)-3.
3. Release Equity and Environmental Justice research opportunity solicitation.
4. Deliver Earth Surface Mineral Dust Source Investigation (EMIT) for launch on the International Space Station (ISS).
5. Initiate Phase A for at least two of Earth System Observatory missions addressing four designated observables from the 2017 Decadal (Atmosphere; Clouds, Convection, and Precipitation; Surface Biology and Geology; and Mass Change).

List of critical milestones for FY 2023

1. Develop and release Version 4 of the NASA GISS Model E Earth system model.
2. Complete the Libera Critical Design Review (CDR).
3. Launch the Surface Water Ocean Topography (SWOT) mission.
4. Deliver Polar Radiant Energy in the Far InfraRed Experiment (PREFIRE) CubeSats.

List of critical milestones for FY 2024

To be developed for FY 2024-2025 Agency Priority Goal

Lead Organization: Science Mission Directorate (SMD)

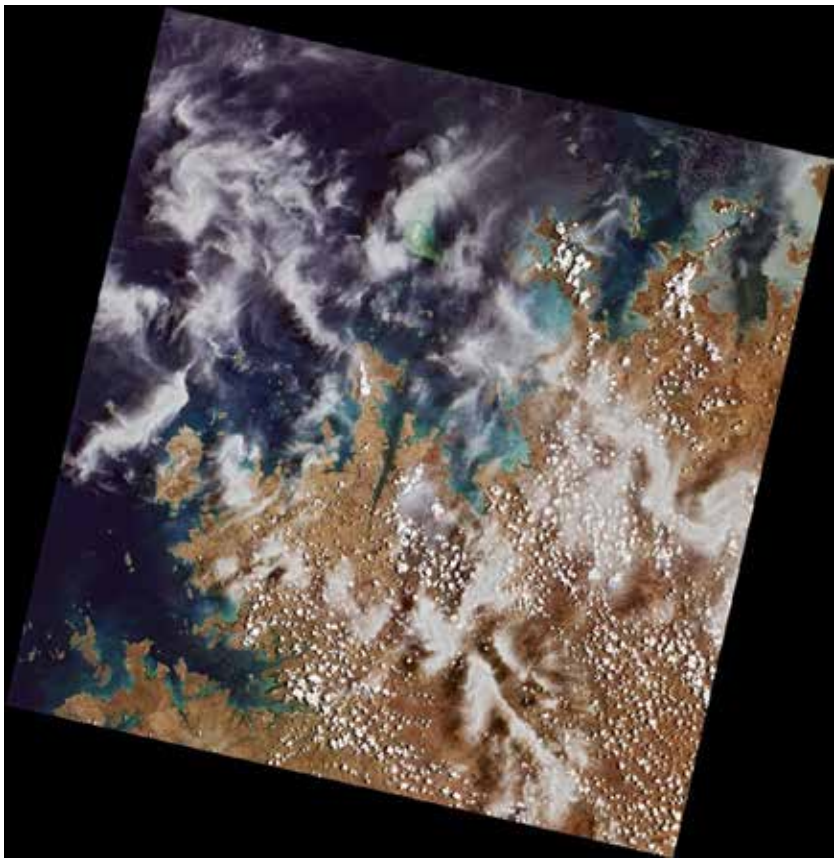
FY 2022 Performance Progress

NASA completed milestones 1 through 4 as planned during FY 2022. However, the fifth planned milestone was delayed to FY 2023, resulting in a Yellow Performance Goal rating. In January 2023, NASA achieved this fifth milestone with the completion of the Key Decision Point-A (KDP-A) reviews for two Earth System Observatory missions, the Atmosphere Observing System (AOS) and Surface Biology and Geology (SBG). The observatory seeks to implement recommendations from the 2017 Earth Science Decadal Survey by the National Academies of Sciences, Engineering, and Medicine, which lays out ambitious but critically necessary research and observation guidance for our changing planet. Successful completion of the KDP-A reviews will initiate the concept and technology development phase— known as Phase A—resulting in proposed mission architectures. NASA delayed the reviews from the fourth quarter of FY 2022 to early FY 2023 in order to incorporate Independent Review Board recommendations, which resulted in adjustments to the AOS mission. We use independent reviews for early-stage strategic missions to put these important and complex science missions on the path to success.

Efforts in support of this goal included completion of the on-orbit checkout and commencement of operations for Landsat 9, a joint mission with the U.S. Geological Survey (USGS) which will extend an unparalleled data record that spans nearly 50 years of space-based observation of Earth. Early in FY 2022, NASA released the "first light" images, providing a preview of how the mission will help people manage vital natural resources and understand the impacts of climate change. NASA also installed the Earth Surface Mineral Dust Source Investigation (EMIT) on the International Space Station in July. EMIT determines the mineral composition of natural sources that produce dust aerosols around the world. By measuring in detail which minerals make up the dust, EMIT is helping to answer the essential question of whether this type of aerosol warms or cools Earth's atmosphere.

NASA also advanced our Earth system models that enable the US to understand, predict and plan for climate change by delivering a significant upgrade to our primary global model. Work on Version 4

of the NASA GISS Model E Earth system model has continued with progress on the coupling of the atmosphere to the higher resolution ocean model, which is required to consistently represent surface fluxes at higher resolutions. Atmospheric composition treatment within the new atmospheric cloud routines is now complete. Ocean simulations with eddy-resolving resolution (approximately 1/8th degree) show promising results compared to observations. Some work remains to be done on the sea ice dynamics, but code integration and testing is underway, supporting anticipated release of Version 4 of the model in the second quarter of FY 2023.



Above: The image shown above—part of Landsat 9's "first light" images collected on October 31, 2021—was cropped from the very first natural-color image taken by Landsat 9. It shows the Coronation Islands along the Kimberly coast in the state of Western Australia. Image Credit: M. Radcliff, using Landsat data from the U.S. Geological Survey.

Strategic Objective 1.2

Understand the Sun, solar system, and universe.

LEAD OFFICE
Science Mission Directorate (SMD)

GOAL LEADER
Karen Flynn, Deputy Associate Administrator for Management, SMD

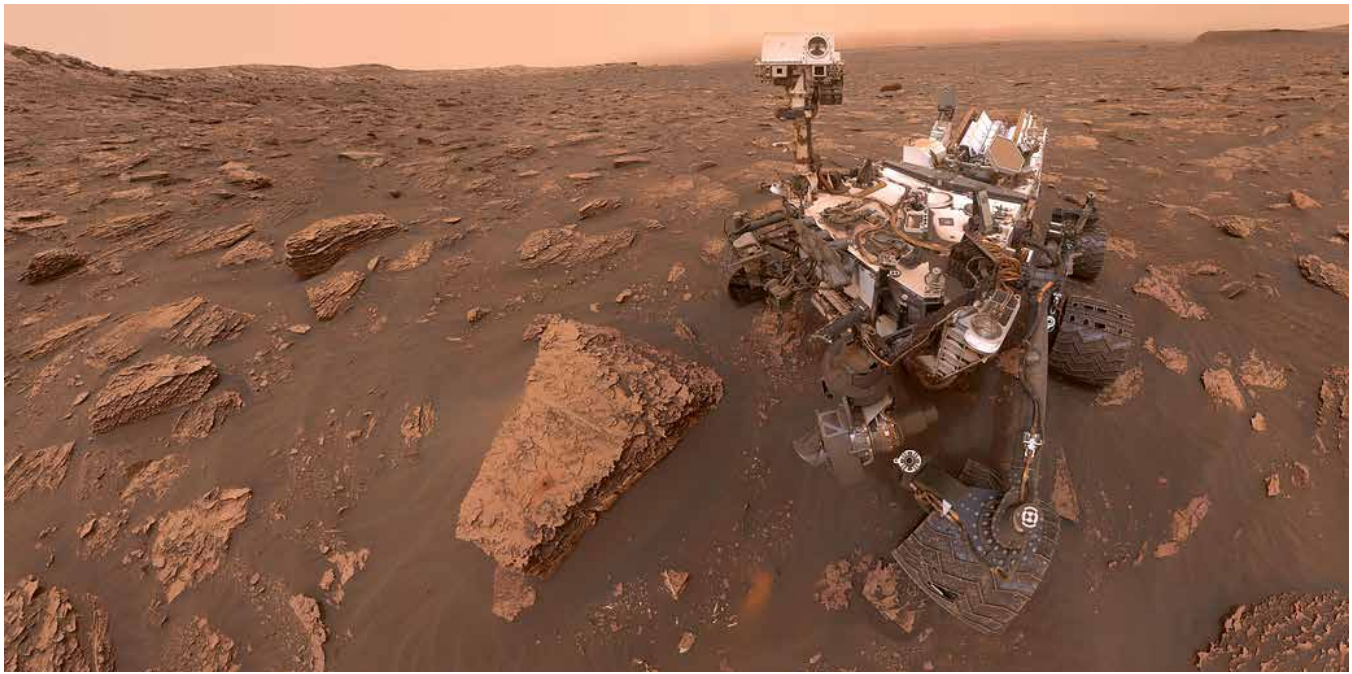
	Budget	
	FY	$M
Op Plan	2022	$5,549.7
Enacted	2023	$5,600.0
Requested	2024	$5,788.0
Outyear	2025	$5,828.5
	2026	$5,864.5
	2027	$5,975.2
	2028	$6,092.7

In pursuit of Strategic Objective 1.2, NASA conducts scientific studies of the Sun and solar system, using space as a laboratory, peering out into the vast reaches of the universe and playing 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. 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? Heliophysics embraces arguably the original "first light" of scientific wonder (the Sun) and how it influences the very nature of space. 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. Biological and Physical Sciences pioneer scientific discovery and enable space exploration by using the spaceflight environment, in and beyond low Earth orbit, to conduct experiments that cannot be done on Earth.

Our strategy for this objective includes research and development that will provide the foundation for new missions, inventing and using new space-based observing and sampling capabilities and creating capabilities to interpret mission data.

Below: The rover, Curiosity, has climbed more than 2,000 feet (612 meters), reaching progressively younger rocks that serve as a record on how Mars has evolved from a wet, habitable planet to a cold desert environment. Image Credit: NASA Images



Supporting programs and projects have clear strategies in place to achieve their objectives and are on track to achieve 100 percent of related multiyear Performance Goals. In their most recent assessments, the relevant advisory committees again rated NASA's progress toward all eight science goals supporting this objective as having met or exceeded expectations. Other recent accomplishments include the enormously successful launch and deployment of the James Webb Space Telescope, the most powerful and complex space telescope ever built, 13 Mars samples taken by the Perseverance Rover in preparation for the Mars Sample Return campaign, and 13 perihelions[1] by Parker Solar Probe, the fastest and closest to the Sun a spacecraft has ever gone. Evaluations of near-, mid-, and long-term success criteria provide ample evidence that NASA projects are making Noteworthy Progress in support of Strategic Objective 1.2.

We continue to refine our ability to execute missions within cost commitments by implementing improved management techniques (particularly on large strategic missions) and the use of independent review boards and cost estimates. We also continue our efforts to address risks (supply chain management, cybersecurity, workforce, orbital debris, and COVID-19 impacts) that pose a significant concern for achievement of this Strategic Objective. Risks specific to this Strategic Objective include mega-constellations of low Earth orbit satellites, which could significantly impact science missions. We have begun assessing these mega-constellations and will develop a baseline model for use as part of mission concept reviews and subsequent risk tracking and mitigation. Finally, to position missions supporting Strategic Objective 1.2 for success, NASA continues to pursue opportunities in access to space, partnerships and knowledge transfer/succession planning, in addition to other areas.

1 The point in the orbit of a planet, asteroid, or comet at which it is closest to the Sun.

1.2.1: Demonstrate progress in exploring and advancing understanding of the physical processes and connections of the Sun, space, and planetary environments throughout the solar system.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	2 of 2	1 of 1	1 of 1
Areas Completed	2		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.1.
2. Complete the Parker Solar Probe (PSP) mission success criteria.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.1.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.1.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA achieved the FY 2022 target for this multiyear Performance Goal, as determined by the assessment of progress led by the Heliophysics Advisory Committee in September 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022. The selected results demonstrate significant progress in our understanding of the inter-connections shaping the space environment at Earth, at Mars, in interstellar space, and in the vicinity of exoplanets.

The 15 January 2022 epic eruption of the Hunga Tonga-Hunga Ha'apai volcano revealed strong coupling between extreme events on Earth's surface and ionospheric disturbances at the edge of space. The eruption generated shock waves, sonic booms, tsunami waves, and a variety of atmospheric gravity waves extending from the troposphere to the ionosphere that circled the globe several times. For the next 12 hours, heat released from water and hot ash in the plume remained the largest source of atmospheric gravity waves worldwide. The remarkable coupling during this event was captured by combining observations from atmospheric and heliospheric satellites. A unique disturbance pattern appeared in the equatorial ionosphere approximately 14,000 kilometers away from the epicenter twisting the equatorial ionization peaks, which normally runs parallel on either side of the magnetic equator, into an "X" pattern.

Important advances were made last year in our understanding of magnetic reconnection, a fundamental physical process that explosively releases energy stored in magnetic fields. Our Magnetospheric Multiscale (MMS) mission helped to solve a 60-year-old mystery that explains how rapidly reconnection occurs. Meanwhile, the interface region spectrograph imager observed the pattern of emission produced during flares, which is consistent with a recent model of how the reconnection energy release begins.

Switchbacks are kinks in the solar wind magnetic field that may be associated with substantial acceleration of plasma and enhanced turbulent energy transfer. In situ measurements from Parker Solar Probe recently revealed that switchbacks are much more prevalent closer to the Sun. Furthermore, imaging observations from Solar Orbiter indicate that switchbacks may be formed by interchange reconnection between the coronal loops of solar active regions and adjacent open-field regions. This discovery is important for understanding the origin of slow solar wind.

1.2.2: Demonstrate progress in exploring and probing the origin, evolution, and destiny of the galaxies, stars, and planets that make up the universe.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.2.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.2

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.2

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

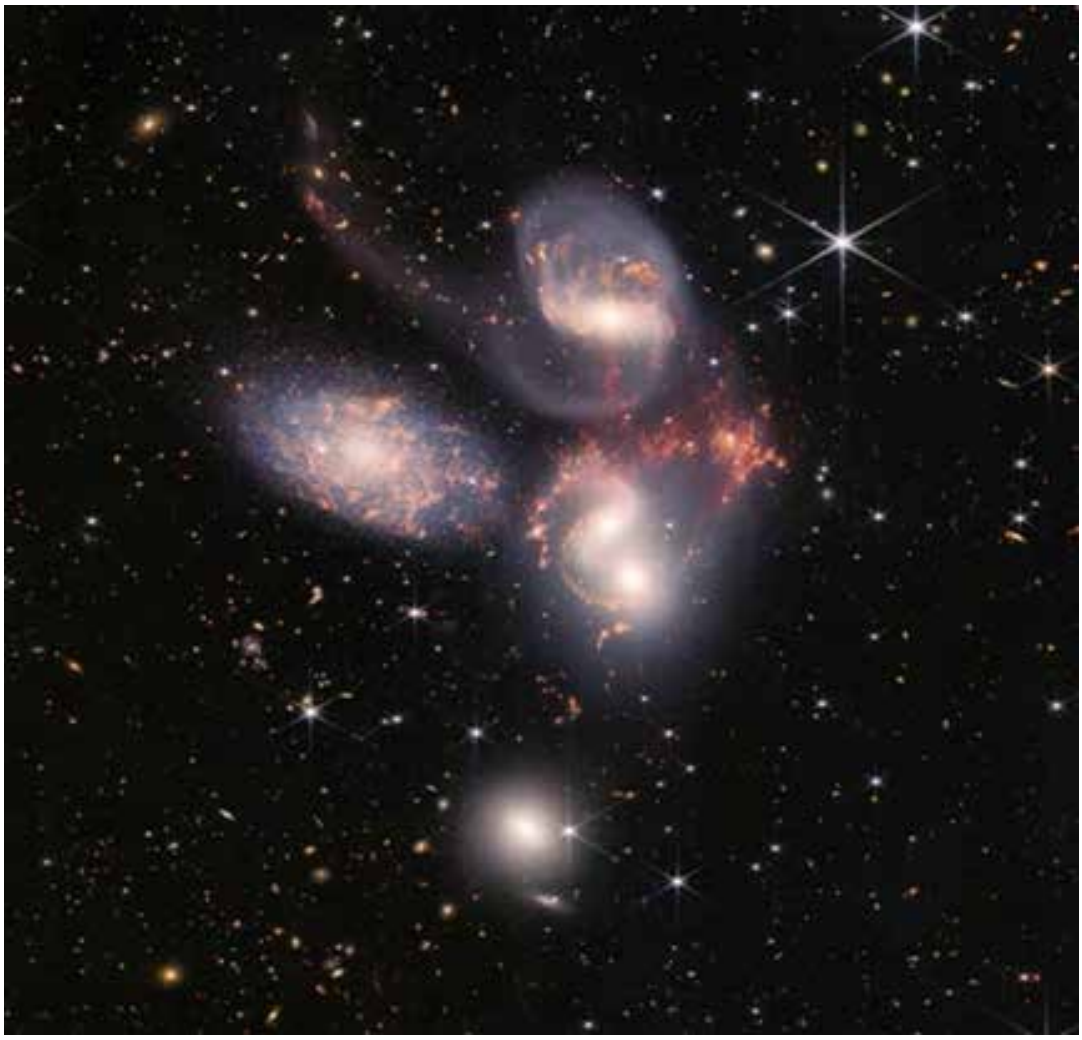
NASA achieved the FY 2022 target for this multiyear Performance Goal, as determined by the assessment of progress led by the Astrophysics Advisory Committee in October 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

With its powerful infrared vision and extremely high spatial resolution, our James Webb Space Telescope shows never-before-seen details of the galaxy group "Stephan's Quintet." The proximity of the galaxies in this group provides astronomers a ringside seat for witnessing the merging and interactions between galaxies that are so crucial to all of galaxy evolution. Rarely do scientists see in such detail how interacting galaxies trigger star formation in each other, and how the gas in these galaxies is being disturbed.

A rare and enigmatic outburst from the galaxy IES 1927+654, 236 million light-years away, may have been sparked by a magnetic reversal, a spontaneous flip of the magnetic field surrounding its central black hole. Astronomers have linked the eruption's unusual characteristics to dramatic changes in the black hole's environment that could be triggered by such a magnetic switch. The research team analyzed new and archival data across the spectrum. NASA's Neil Gehrels Swift Observatory and ESA's (European Space Agency's) X-ray Multi-Mirror Mission (XMM-Newton) satellite provided UV and X-ray measurements. Visible light and radio observations came from ground-based observatories.

To investigate the physics underpinning white dwarf evolution, astronomers compared cooling white dwarfs in two massive collections of stars: the globular clusters M13 and M3, using the unique near ultraviolet imaging capability of the Hubble Space Telescope. Two populations were revealed, standard white dwarfs and those which have managed to hold on to an outer envelope of hydrogen, allowing them to burn for longer and hence cool more slowly. Comparing observations with computer simulations of stellar evolution in M13 indicates roughly 70 percent of the white dwarfs in M13 are burning hydrogen on their surfaces, slowing down the rate at which they are cooling. This discovery could have significant consequences for how astronomers measure the ages of stars in the Milky Way.

NASA's Chandra X-ray Observatory has imaged a beam of both matter and antimatter that is 40 trillion miles (7 light years) long. Located in our Milky Way Galaxy about 1,600 light years from Earth, the beam is emitted by a pulsar, a cosmic lighthouse powered by a rapidly rotating collapsed star with an immensely strong magnetic field. The discovery of this beam's tremendous scale may help solve a long-standing and critically important mystery surrounding the Milky Way's abundant population of positrons, the antimatter counterparts to electrons.



Above: The image of the galaxy group “Stephan’s Quintet” is a composite of images taken by Webb’s Near Infrared Camera (NIRCam) and Mid-InfraRed Instrument (MIRI) image. Stephan’s Quintet is a fantastic “laboratory” for studying processes of star formation fundamental to all galaxies. Image Credit: NASA, ESA, CSA, STScI

1.2.3: Demonstrate progress in exploring, observing, and understanding objects in the solar system in order to understand how they formed, operate, interact, and evolve.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.3.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.3.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.3.

Lead Orginization: Science Mission Directorate (SMD)

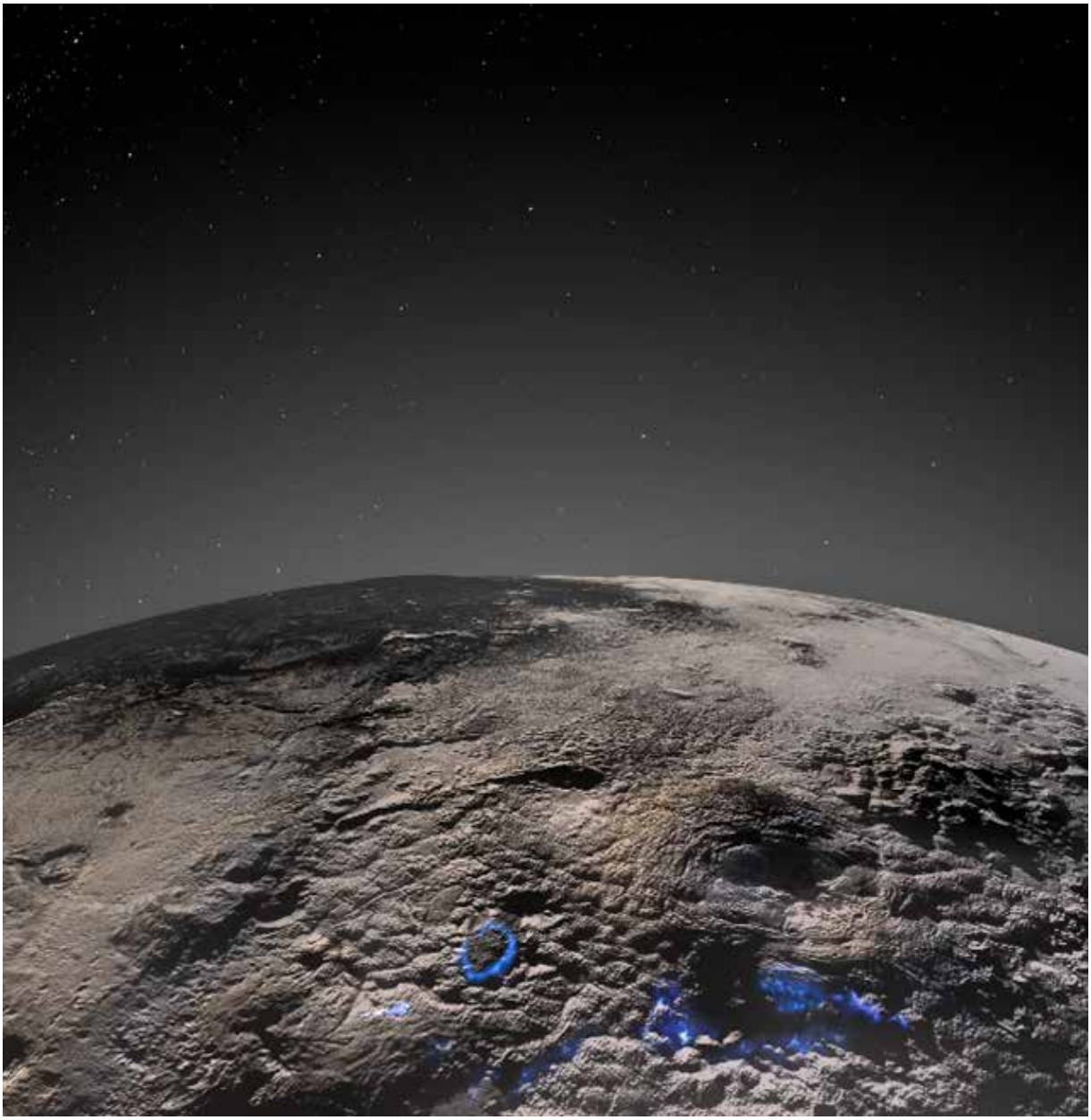
FY 2022 Performance Progress

NASA NASA achieved the FY 2022 target for this multiyear Performance Goal as determined by an assessment of progress led by the Planetary Advisory Committee in October of 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

New Horizons, launched in 2006, continues to unlock mysteries of the outer solar system. Recently published research described the discovery of a large field of ice volcanos on Pluto's surface that are individually up to 4.5 miles high and 100 miles across. They require multiple eruption sites and a large volume of icy material to form. This study implies more heat is present inside Pluto today than previously expected and may allow for liquid water close to the surface.

In the inner solar system, data from the InSight mission prompted a study that sought to better understand the composition and evolution of the Martian core. Mars is thought to have a core with a large radius. Previously, it was thought that sulfur could be the main light element composing the core. However, InSight data indicates this might not be the case. Hydrogen is abundant in the solar system and iron-sulfur and iron-hydrogen systems have been studied individually in the past. This new research combines these systems to study an iron-sulfur-hydrogen system at temperatures and pressures analogous to the core of Mars. The results could be valuable in interpreting the structure and dynamics of Mars's core and the cores of Mars-sized exoplanets.

Closer to Earth, the Lunar Crater Observation and Sensing Satellite (LCROSS) reported interesting findings from the Moon. Volatiles in the Moon's permanently shaded regions (PSRs) provide a record of the history of volatiles in the Earth-Moon system. The LCROSS impact plume contained water and carbon-, nitrogen-, and sulfur-bearing molecules, but connecting them to sources is challenging. In this study, the mixture of sources was determined by using elemental ratios and modeling how processes fractionate these ratios. This model rules out any contribution of volcanic gas to the volatiles sampled, suggesting that any volcanic volatiles present in the Moon's PSRs must be buried deeper. Based on these results, this study concluded that the source was most likely cometary, suggesting comets were the dominant impactors at the time of delivery of these volatiles.



Above: Blue shaded areas show New Horizons's view of Pluto's icy volcanic region. These ice volcanos are unique in our solar system—geologically young, enigmatic, and possibly still active. Image Credit: NASA /Johns Hopkins University Applied Physics Laboratory /Southwest Research Institute /Isaac Herrera / Kelsi Singer

1.2.4: NASA shall demonstrate progress in discovering and studying planets around other stars.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.4.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.4.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.4.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA achieved the FY 2022 target for this multi-year Performance Goal as determined by the assessment of progress led by the Astrophysics Advisory Committee in October 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

In March 2022, we confirmed detection of over 5,000 exoplanets, representing a 30-year journey of discovery led by our space telescopes. The biggest leaps in exoplanet-hunting technology have come from the now-retired Kepler Space Telescope and the currently operating Transiting Exoplanet Survey Satellite. The NASA exoplanet archive records exoplanet discoveries that appear in peer-reviewed scientific papers and that have been confirmed using multiple detection methods or by analytical techniques. The 5,000-plus planets found so far include small, rocky worlds like Earth, gas giants many times larger than Jupiter, and "hot Jupiters" in scorchingly close orbits around their stars. There are "super-Earths," which are possible rocky worlds bigger than our own, and "mini-Neptunes," smaller versions of our system's Neptune.

Scientists have used numerical simulations to examine the tidal evolution scenarios for the seven planets that orbit the ultracool M-dwarf, TRAPPIST-1. Details of the TRAPPIST-1 system were first revealed in 2017, using a combination of results from NASA's Spitzer Space Telescope, the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile, and other ground-based telescopes. Based on observations, the orbits of these planets appear to be slightly eccentric and are caught in multiple three-body resonances. Resonance refers to bodies that exert periodic gravitational influence on one another as they progress through their orbits. The study provides insight into the origins of the observed eccentricities, the spacing of the TRAPPIST planets, and the architecture of this fascinating exoplanet system replete with Earth-like worlds.

There is growing evidence that the magnetic activity of host stars impacts the habitability of orbiting exoplanets. Using the NASA Solar Dynamics Observatory (SDO), scientists have established a strong association between coronal mass ejections and coronal dimmings. Extending this approach to stars in archive data from the NASA Chandra X-Ray Observatory and EUVE satellite led to the identification of stellar dimming events in other stars, suggesting that those stars have ejections like coronal mass ejections. The knowledge transfer of solar coronal mass ejections and coronal dimmings to stellar studies will help improve our understanding of stellar eruption and its influence on the habitability of exoplanets.

1.2.5: Demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere, exploring and finding locations where life could have existed or could exist today, and exploring whether planets around other stars could harbor life.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.5.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.5.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.5.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA achieved the FY 2022 target for this multiyear Performance Goal as determined by an assessment of progress led by the Planetary Science Advisory Committee in October 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

Amino acids are the building-block of proteins and may have been originally brought to Earth by asteroids and meteorites. Scientists searched for and found multiple amino acids in the material returned by the Japanese Aerospace Exploration Agency's Hayabusa mission, which visited asteroid Itokawa. These results are the first evidence of plausibly extraterrestrial amino acids in asteroid material from a sample-return mission and demonstrate the capabilities of the analytical protocols used to study such asteroid samples. The presence of these amino acids in the returned samples may indicate that asteroids could have delivered molecules necessary for life to the primordial Earth and elsewhere in the solar system.

The Sample Analysis at Mars (SAM) instrument onboard the Curiosity rover collected and characterized seven rock samples, searching for key indicators of habitable environments. The SAM investigation indicated the presence of various organic compounds, including the first observation on Mars of some sulfur-containing and ring-structured organics, and the highest abundance of sulfur organics observed to date. The results confirm that ancient organic matter is preserved in the clay mineral-bearing sediments of Glen Torridon. Its origin (meteoritic/abiotic/biotic) has yet to be established.

Astrobiologists have shown that cyanide could have enabled important metabolic reactions in the early history of life on Earth. A recent study focused on a series of chemical reactions called the reverse tricarboxylic acid (r-TCA) cycle, which some bacteria on Earth use to turn carbon dioxide and water into carbon compounds used in cells. This cycle could have occurred on the early Earth to form molecules that were necessary for the origin of life. However, today's version of the r-TCA cycle uses proteins that wouldn't have been available early in Earth's history. This study demonstrated the presence of cyanide in the early Earth's atmosphere, and that it could act in the place of proteins and other metals that weren't then available. The finding also provides insight into the possibility of alternate biochemistries that life might use on other worlds.

1.2.6: Demonstrate progress in developing the capability to detect and knowledge to predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	2 of 2	2 of 2	2 of 2
Areas Completed	2		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review determination of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.6.
2. External expert review panel determination indicating whether expectations for research program have been fully met or exceeded in advancing scientific understanding of background solar wind, solar wind structures, and coronal mass ejections, which can be integrated into key models used to predict the arrival time and impact of space storms at Earth.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review determination of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.6.
2. External expert review panel determination indicating whether expectations for research program have been fully met or exceeded in advancing scientific understanding of background solar wind, solar wind structures, and coronal mass ejections, which can be integrated into key models used to predict the arrival time and impact of space storms at Earth.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review determination of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.6.
2. External expert review panel determination indicating whether expectations for research program have been fully met or exceeded in advancing scientific understanding of background solar wind, solar wind structures, and coronal mass ejections, which can be integrated into key models used to predict the arrival time and impact of space storms at Earth.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA achieved the FY 2022 target for this multiyear Performance Goal as determined by the assessment of progress performed by the Heliophysics Advisory Committee in September 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022. The studies highlighted directly address the extreme space weather events that have the potential to cause substantial harm to national security, the economy, and crewed and unmanned space activities and support better understanding of background solar wind, solar wind structures, and coronal mass ejections.

A study combining data from larger scale Time History of Events and Macroscale Interactions during Substorms (THEMIS) and smaller scale CubeSat (ELFIN) NASA missions revealed that interactions between energetic charged particles in near-Earth space and a special type of plasma waves result in rapid precipitation of those energetic particles into the atmosphere. By incorporating these plasma waves and their occurrence rates, improved models are being developed linking space weather events and their effects in the lower atmosphere.

Our Ionospheric Connection (ICON) Explorer mission made the first direct observation of the ionospheric dynamo in which waves propagating upward from the lower atmosphere perturb the equatorial ionosphere. This confirmed the fundamental theoretical relationship between the circulation of neutral gas in a magnetic planetary ionosphere, including how the transfer of neutral gas motion to charged particles creates an electric field.

As we pursue the goal of human exploration of the moon, determination of the near lunar environment, including dust lofting and surface charging, which can impact technological systems, is needed. A recent study utilizing data from the Acceleration, Reconnection, Turbulence, and Electrodynamics (ARTEMIS) satellites determined that micrometeorite impacts, especially at dawn, reduce the

surface potential significantly. This effect can now be modeled, providing improved surface charging predictions that may be used for planning future lunar activities.

Opportunities to observe solar transients from multiple vantage points have been leveraged to test and improve forecasting models. For example, a flux rope observed by Parker Solar Probe was later seen downstream at Solar Terrestrial Relations Observatory (STEREO-A). The flux rope was compressed in radial extent due to an overtaking high-speed stream, but the overall magnetic structure was preserved. Radial alignment between Solar Orbiter and Earth provided an opportunity to predict its arrival time at Earth, which was in reasonable agreement with observations.

1.2.7: Demonstrate progress in identifying, characterizing, and predicting objects in the solar system that pose threats to Earth or offer resources for human exploration.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	2 of 2	3 of 3	2 of 2
Areas Completed	2		
Rating	Green		

Areas contributing to performance goal in FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.7.
2. Identify and catalogue 10,300 near-Earth asteroids that are 140 meters in diameter or larger.

Areas contributing to performance goal in FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.7.
2. Identify and catalogue 10,700 near-Earth asteroids that are 140 meters in diameter or larger.
3. Complete the Double Asteroid Redirection Test (DART) mission success criteria.

Areas contributing to performance goal in FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.7.
2. Identify and catalogue 11,200 near-Earth asteroids that are 140 meters in diameter or larger.

Lead Organization: Science Mission Directorate (SMD)

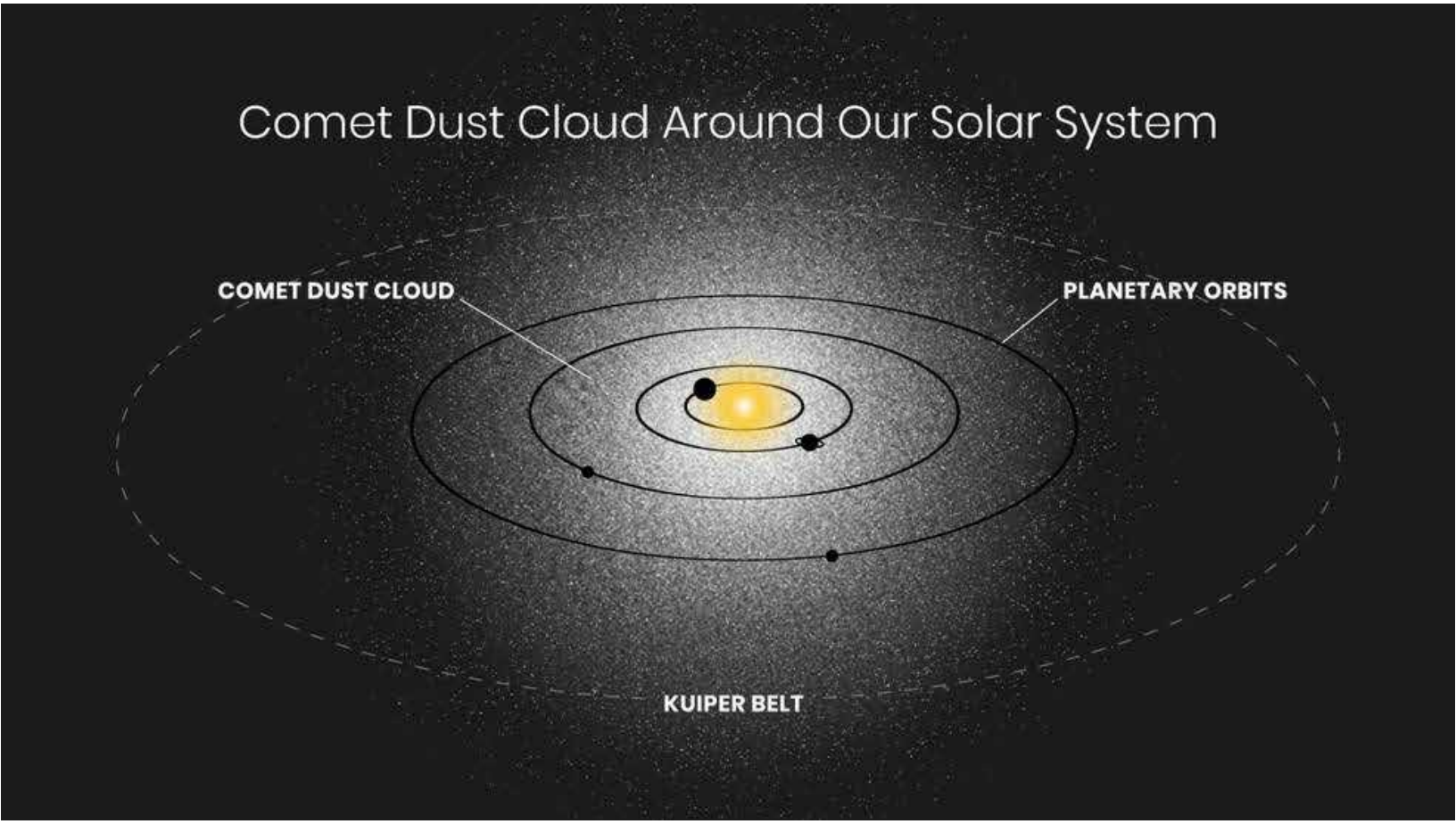
FY 2022 Performance Progress

NASA achieved the FY 2022 target for this multiyear Performance Goal as determined by an assessment of progress led by the Planetary Science Advisory Committee in October 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

In this fiscal year, asteroid search teams funded by NASA's Near-Earth Object Observations (NEOO) Program found an additional three asteroids larger than one km in size with orbits that can come within Earth's vicinity. These teams also found 2,565 smaller asteroids less than one kilometer in size. This brings the total known population of near-Earth asteroids to 30,135 as of September 30, 2022. The high-precision orbit predictions computed by the Center for Near-Earth Object Studies (CNEOS) at NASA's Jet Propulsion Laboratory show that none of these objects is likely to strike the Earth in the next century. However, 2,281 small bodies (of which 151 are larger than one kilometer in diameter) are in orbits that could become a hazard in the more distant future and warrant continued monitoring.

A small asteroid hit Earth's atmosphere over the Norwegian Sea before disintegrating on March 11, 2022. Two hours before the asteroid, 2022 EB5, made impact, the Piszkéstető Observatory in northern Hungary first reported observations of the small object to the Minor Planet Center. NASA's "Scout" impact hazard assessment system then took these early measurements to calculate the trajectory of 2022 EB5. As soon as Scout determined that 2022 EB5 was going to hit Earth's atmosphere, the system alerted the CNEOS and NASA's Planetary Defense Coordination Office (PDCO), flagging the object on the Scout webpage to notify the near-Earth object observing community.

Scout successfully projected that 2022 EB5 would enter the atmosphere southwest of Jan Mayen, a Norwegian island nearly 300 miles off the east coast of Greenland. U.S. government sensors and Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) infrasound detectors confirmed the impact occurred at the predicted time and location. This real-world event with a very small asteroid allowed the planetary defense community to exercise capabilities and provided confidence that the impact prediction models at CNEOS are highly capable of informing the response to the potential impact of a larger object.



Above: Aside from a tapestry of glittering stars, and the glow of the waxing and waning Moon, the nighttime sky looks inky black to the casual observer. But how dark is dark? To find out, astronomers decided to sort through 200,000 images from NASA's Hubble Space Telescope and made tens of thousands of measurements on these images to look for any residual background glow in the sky, in an ambitious project called SKYSURF. This would be any leftover light after subtracting the glow from planets, stars, galaxies, and from dust in the plane of our solar system. Image Credit: NASA Images

1.2.8: Demonstrate progress in understanding the properties of physical and biological systems in spaceflight environments to advance scientific knowledge, enable space exploration, and benefit life on Earth.

Number of critical areas completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Areas	1 of 1	1 of 1	1 of 1
Areas Completed	1		
Rating	Green		

Areas for FY 2022

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.8.

Areas for FY 2023

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.8.

Areas for FY 2024

1. Significant progress demonstrated as determined by annual external expert review of programs, missions, and published, peer-reviewed research contributing to Performance Goal 1.2.8.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA achieved achieved the FY 2022 target for this multiyear Performance Goal as determined by an assessment of progress led by the Biological and Physical Sciences Advisory Committee in November 2022, leading to a Green Performance Goal rating. Below are examples of scientific progress reported in FY 2022.

Plants are an integral component to the future human exploration of space, requiring focused research efforts to grow and optimize plants under both ground and spaceflight conditions. One of this year's major advances in the ground-based research experiments was the demonstration that the small flowering plant, Arabidopsis thaliana, a member of the mustard family, could grow in lunar regolith. Examination of the stress responses of the seedlings will enable a precise analysis of the interactions between the Lunar material and plants, which will help improve the growth of plants on the Moon and under spaceflight conditions.

Critical research also addressed ways to store and care for seeds and plants. A recent study showed that hydrogels can serve as a low-cost medium for plant cultivation, thereby demonstrating new ways to cultivate plants under simulated microgravity conditions that minimize the need for watering by the crew. Additionally, the Materials International Space Station Experiment (MISSE)-Seed experiment, in which seeds from several edible crops (e.g., lettuce, radish, tomato) were exposed to the space environment outside of the ISS to examine how seed quality is affected by seed storage conditions, will help optimize storage conditions to maximize growth of plants during future missions.

The Cold Atom Lab aboard the International Space Station (ISS) cools atoms to near zero temperature and allows them to be studied in the absence of gravity for longer durations than what's possible on Earth, providing new insights into novel quantum physics. For example, the Cold Atom Lab examined ultracold atomic bubbles which are unable to be formed on Earth and are an intriguing application of placing so-called "fifth state of matter" Bose-Einstein Condensates into new geometries and topologies. These efforts could lead to new insights into the nature of quantum matter and development of new technologies.

Physical Sciences research advances also included new methods on the ISS to develop larger colloidal crystals suitable for various signal processing applications. Other breakthroughs involved potentially dramatic increases to the speed of electric vehicle charging. Laboratory experiments using knowledge gained from the NASA Flow Boiling and Condensation Experiment, which helps cool the conductor within the charging cable, enabled a rapid delivery of electrical current to the vehicle and may have widespread applications on Earth.

1.2.9: Achieve critical milestones of Science Mission Directorate's heliophysics, planetary science, and astrophysics major projects.

Number of critical milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestones	At least 10 of 12 83%	At least 6 of 8 75%	At least 10 of 13 77%
Results	10		
Rating	Green		

List of major projects critical milestones FY 2022

1. Launch the Lucy mission.
2. Complete the Volatiles Investigating Polar Exploration Rover (VIPER) Critical Design Review (CDR).
3. Complete the Europa Clipper System Integration Review (SIR).
4. Launch the Double Asteroid Redirection Test (DART) mission.
5. Complete the Psyche mission Pre-Ship Review (PSR).
6. Complete one Dragonfly mission instrument Preliminary Design Review (PDR).
7. Complete the Mars Sample Return (MSR) program Key Decision Point (KDP)-B review.
8. Complete tone Geospace Dynamics Constellation (GDC) mission instrument selections.
9. Complete the Interstellar Mapping and Acceleration Probe (IMAP) CDR.
10. Complete the Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) CDR.
11. Complete the telescope for the Nancy Grace Roman Space Telescope.
12. Award two Commercial Lunar Payload Services (CLPS) delivery task orders.

List of major projects critical milestones FY 2023

1. Complete the Volatiles Investigating Polar Exploration Rover (VIPER) Key Decision Point (KDP)-D review.
2. Initiate stacking and system-level tests of the integrated Europa Clipper spacecraft.
3. Complete the Dragonfly KDP-C review.
4. Complete tthe Mars Sample Return (MSR) Sample Retrieval Lander (SRL) Preliminary Design Review (PDR).
5. Complete the Interstellar Mapping and Acceleration Probe (IMAP) Mission Operations Review (MOR).
6. Complete the Nancy Grace Roman Space Telescope instrument carrier.
7. Initiate assembly of the Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) bus subsystem.
8. Award two Commercial Lunar Payload Services (CLPS) delivery task orders.

List of major projects critical milestones FY 2024

1. Complete the Europa Clipper Pre-Ship Review (PSR).
2. Initiate the Dragonfly mission Critical Design Review (CDR).
3. Complete the Mars Sample Return (MSR) Sample Retrieval Lander (SRL) Critical Design Review (CDR).
4. Complete the MSR Capture, Containment and Return System (CCRS) Critical Design Review.
5. Complete the Volatiles Investigating Polar Exploration Rover (VIPER) Pre-Ship Review.
6. Complete the DAVINCI mission instrument System. Requirements Reviews (SRRs).
7. Complete the NEO Surveyor instrument (telescope) Critical Design Review (CDR).
8. Deliver the Nancy Grace Roman Space Telescope (Roman) spacecraft Outer Barrel Assembly (OBA) structure.
9. Complete the Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) System Integration Review (SIR).
10. Complete the Interstellar. Mapping and Acceleration Probe (IMAP) instrument deliveries.
11. Complete the Multi-Slit Solar Explorer (MUSE) Preliminary Design Review (PDR).
12. Award two Commercial Lunar Payload Services (CLPS) delivery task orders.
13. Complete assembly and test of the Payloads and Research Investigations on the Surface of the Moon (PRISM)-1b payloads.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

NASA achieved 10 of the 12 milestones planned for FY 2022, leading to a Green Performance Goal rating.

Milestones completed in FY 2022 included the launch of the Lucy and DART missions, selection of instruments for the Geospace Dynamics Constellation mission, and the award of two CLPS mission task orders for delivery to the surface of the Moon. Other critical missions successfully completed key review milestones: the Europa Clipper SIR, VIPER CDR, SPHEREx CDR, Psyche PSR, MSR

KDP-B, and the first Dragonfly instrument PDR, for its DrACO (Drill for the Acquisition of Complex Organics) sample acquisition and delivery system.

Although the Mars Sample Return mission completed its KDP-B review, NASA will reassess the Mars Sample Return architecture this year, and will consider potential descopes such as the elimination of one of the mission's two helicopters, in order to improve the cost posture of the mission.

Below: This image taken with the NASA/ESA Hubble Space Telescope shows Terzan 1, a globular cluster that lies about 22,000 light-years from Earth in the constellation Scorpius. Image Credit: NASA Images

1.2.10: Complete commissioning of the James Webb Space Telescope, the most powerful and complex space telescope ever built, and begin Webb's Cycle 2 observations. (Agency Priority Goal)

Number of critical milestones completed.

This two-year Performance Goal/Agency Priority Goal will be completed on September 30, 2023, and NASA does not plan to develop a follow-up Agency Priority Goal for the FY 2024-2025 cycle. The James Webb Space Telescope will continue to support NASA's science strategies.

	Execution	Planned	
Fiscal Year	FY 2022 Agency Priority Goal	FY 2023	FY 2024
Target	4 of 4	4 of 4	N/A
Results	4		
Rating	Green		

List of development milestones for FY 2022

1. Launch James Webb Space Telescope.
2. Perform all deployments of the observatory.
3. Initiate commissioning and operations for all science instruments.
4. Complete science instrument commissioning and begin normal operations.

List of critical milestones for FY 2023

1. Make early release science products available in public archive.
2. Receive Cycle 2 proposals for second year of Webb operations.
3. Conduct review of Cycle 2 proposals.
4. Begin Cycle 2 observations.

List of critical milestones for FY 2024

N/A

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

During FY 2022, NASA completed all four scheduled milestones, including launching the telescope on December 25, deploying the sun shield and mirror, and preparing the instruments for operations, resulting in a Green Performance Goal rating for this Agency Priority Goal.

By the end of FY 2022, NASA and the international mission team had begun normal Cycle 1 science observations and made early release science products available in a public archive, completing the first milestone for FY 2023 ahead of schedule. The observatory continues to exceed all its mission level requirements for sensitivity, spatial resolution, ability to track moving targets, and expected mission lifetime. Over 120 science papers using Webb data had been submitted for peer review as of the end of FY 2022.

Scientific discoveries based on Webb observations are shared with the public in the form of news releases, which report on results that have undergone peer review, and have been accepted for publication by a reputable scientific journal. However, because this process takes time, NASA also shares with the public observations and preliminary analyses as Early Highlights—a "sneak peek" into groundbreaking discoveries. Both the news releases and Early Highlights are available at highlights. The Webb operations site is available at webbtelescope.org.

Above: Shells of cosmic dust created by the interaction of binary stars appear like tree rings around Wolf-Rayet 140. The remarkable regularity of the shells' spacing indicates that they form like clockwork during the stars' eight-year orbit cycle, when the two members of the binary make their closest approach to one another. Image Credit: IMAGE: NASA, ESA, CSA, STScI, NASA-JPL, Caltech

Strategic Objective 1.3

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

LEAD OFFICE
Science Mission Directorate (SMD)

GOAL LEADER
Karen Flynn, Deputy Associate Administrator for Management, SMD

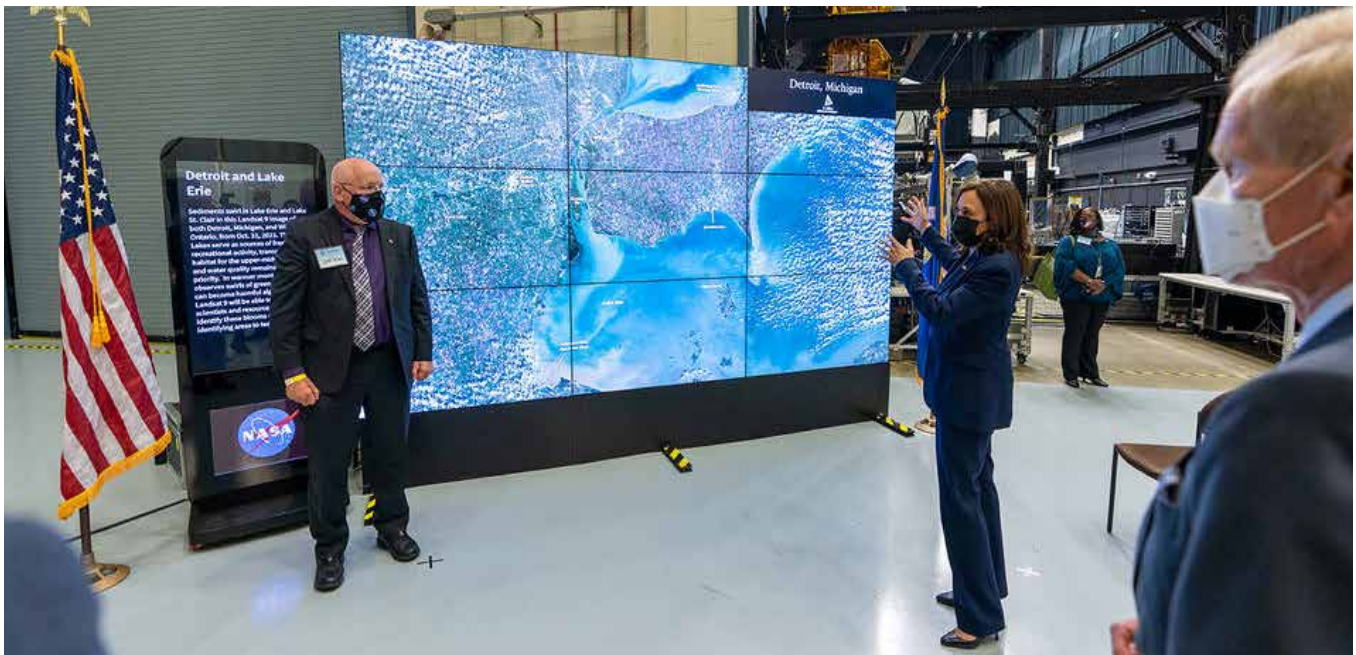
Budget

	FY	$M
Op Plan	2022	$412.9
Enacted	2023	$414.3
Requested	2024	$499.0
Outyear	2025	$501.2
	2026	$514.3
	2027	$533.1
	2028	$551.1

NASA's science 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. We 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 several years, we will substantially increase the size of data archives as the volume of data generated by new missions increases from approximately 10 petabytes per year to over 100 petabytes[1] per year in 2026.

1 250 bytes; 1024 terabytes, or a million gigabytes

Below: Vice President Kamala Harris shares her enthusiasm, alongside Goddard Center Director Dennis Andrucyk and NASA Administrator Bill Nelson, for the results of current satellite missions using Goddard's Hyperwall on November 5, 2021, at the NASA Goddard Space Flight Center in Greenbelt, Maryland. NASA's Hyperwall is a video wall capable of displaying multiple high-definition data visualizations and/or images simultaneously across an arrangement of screens. Functioning as a key component at many NASA exhibits, the Hyperwall is used to help explain phenomena, ideas, or examples of world change. Image Credit: NASA



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.

We are investing in three key areas to ensure success in the newly established Strategic Objective 1.3: 1) capabilities to enable open-source science; 2) continuous evolution of data and computing systems; and 3) community and strategic partnerships for innovation. These data initiatives will accelerate the accessibility and use of science data by both existing and new user communities and are focused on making actionable data accessible to other Federal agencies, relevant decision-makers, stakeholders and the public. The following are several of the initiatives that support a rating of Satisfactory Progress for this Strategic Objective.

We have begun planning for an Earth Information Center that will integrate data from a variety of sources. These efforts will be implemented in coordination with other agencies and partners.

In the upcoming years, NASA's Earth Science Data System (ESDS) program will expand its capabilities to support data from new missions. The Common Metadata Repository will continue to expand and become more flexible in FY 2023 and the ESDS will continue to see its adoption by other agencies. The ESDS will also continue to evolve the Earth Observation dashboard for environmental change with interactive data and stories. Additionally, ESDS will continue developing new data system capabilities for the Multi-Mission Algorithm and Analysis Platform (MAAP) and making critical data available for use within the platform and supporting user needs and work as a liaison to support Machine Learning adoption. The team will also develop generalizable machine learning pipelines for rapid prototyping of science problems.

NASA's Open-Source Science initiative will deploy a pilot version of the SMD information catalog and will initiate a data science internship program to support students in related science fields, with a particular focus on historically underrepresented populations.

The Satellite Needs Working Group (SNWG) Management Office will coordinate the implementation of the highest priority satellite data products from the 2020 assessment process of the U.S. Group on Earth Observations SNWG across multiple partners.

1.3.1: Accelerate the accessibility and use of NASA's science data and tools.

Number of critical milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Activities	1 of 1	1 of 1	2 of 2
Results	1		
Rating	Green		

List of activities for FY 2022

1. Develop and release a prototype interdisciplinary science data search engine that allows users to discover 70 percent of NASA's scientific data.

List of activities for FY 2023

1. Deploy an operational interdisciplinary science data search engine to allow users to discover 85 percent of NASA's scientific data.

List of activities for FY 2024

1. Continue work on an operational interdisciplinary science data search engine to allow users to discover at least 95 percent of NASA's scientific data.
2. Train 2000 members of the scientific community in Open Science principles, practices, and tools.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

In FY 2022, NASA completed the development of a prototype interdisciplinary science data search engine. Known as the Science Discovery Engine (SDE), it contains over one million metadata records and documents from Astrophysics, Biological and Physical Sciences, Earth Science, Heliophysics, and Planetary Science. The prototype was initially made available for testing in April 2022 and included data from Biological and Physical Sciences, Earth Science, and Heliophysics. The full prototype, which includes data from all five disciplines, was released for wider testing in September 2022, supporting a Green rating for this Performance Goal.

The SDE makes the wealth of NASA's open science data and information more accessible to an ever-growing community of users in the U.S. and around the world, opening new pathways to scientific discovery. The prototype can be accessed at this link. The total number of data documents included will grow in coming years as NASA identifies new sources.

1.3.2: Apply insights from Earth science to benefit the economy, health, quality of life, and environment around the globe.

Number of critical milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target # of Activities	2 of 2	2 of 2	2 of 2
Results	2		
Rating	Green		

List of activities for FY 2022

1. 40 percent of Earth science applications projects advance one Applications Readiness Level (ARL) with 3 projects advancing to ARL 8 or 9, when an application has been incorporated into regular use and decision-making.
2. Deliver an Earth science applications guidebook to share knowledge in using Earth science information to inform decisions and provide benefits to society.

List of activities for FY 2023

1. 40 percent of Earth science applications projects advance one Applications Readiness Level (ARL) with 3 projects advancing to ARL 8 or 9, when an application has been incorporated into regular use and decision-making.
2. Engage 14,500 people across the Nation and around the world to build skills in applying Earth science information to benefit society.

List of activities for FY 2024

1. 40 percent of Earth science applications projects advance one Applications Readiness Level (ARL) with 3 projects advancing to ARL 8 or 9, when an application has been incorporated into regular use and decision-making.
2. Engage 15,500 people across the Nation and around the world to build skills in applying Earth science information to benefit society.

Lead Organization: Science Mission Directorate (SMD)

FY 2022 Performance Progress

The Applied Sciences Program uses NASA data to benefit the economy, security, health, and environment across the globe. The Program exceeded its performance targets for FY 2022, as 61 percent of the projects tracked (46 of 76) advanced at least one Applications Readiness Level (ARL). Nine projects advanced to a readiness level 8 or 9, which means the application user has approved the application as complete and qualified it for their use (ARL 8) or that the partner has fully integrated the application into their decision-making and is using it repeatedly (ARL 9). These results supported a Green rating for Performance Goal 1.3.2.

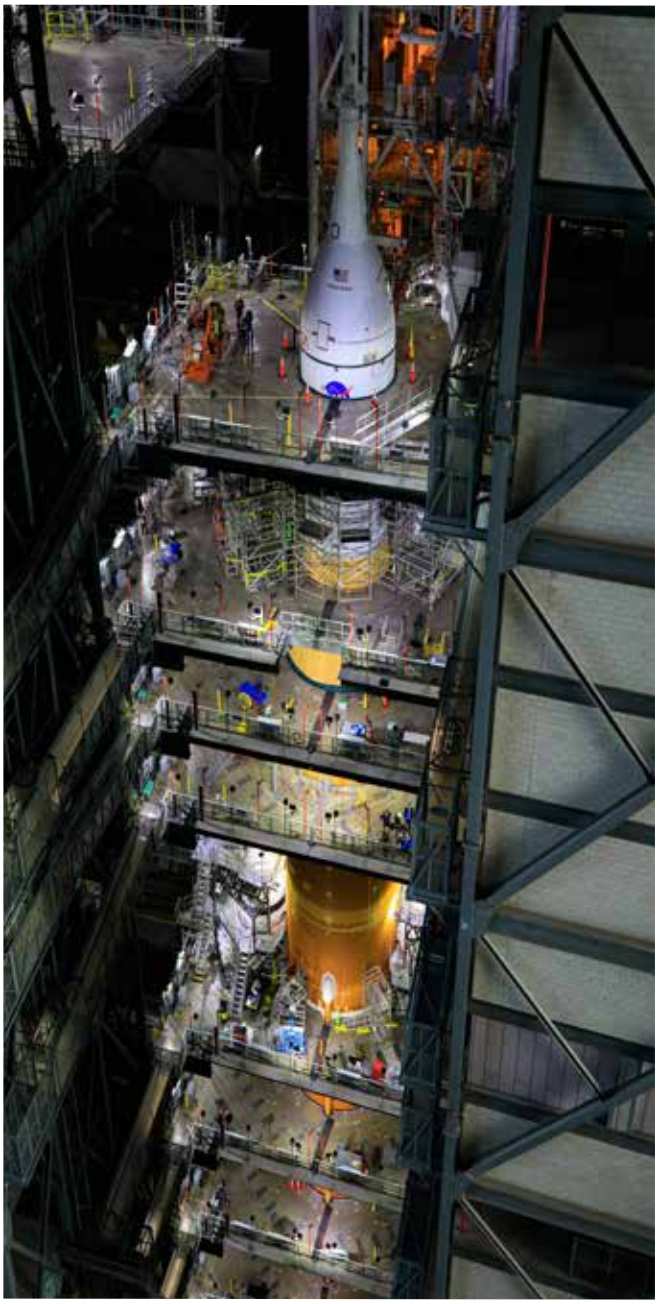
In the past year, the Earth Applied Sciences Program expanded to formally include an additional four program elements: Climate and Resilience, Energy, Equity and Environmental Justice, and Wildland Fires. Projects ranged from providing information to help prepare for, understand, and support responses to flooding, hurricanes, and other disasters; to participating in ongoing interagency efforts to use science and technology capabilities to help mitigate the humanitarian crisis caused by the war in Ukraine, such as using satellite data to understand food supply chain issues. A Health and Air Quality project progressed to ARL 8 with the release of the Vibrio Prediction Hub and cholera risk map viewer, contributing to ongoing monitoring of cholera risk in Ukraine (image below).

The Applied Remote Sensing Training Program conducted 17 trainings. The SERVIR program (managed jointly with the U.S. Agency for International Development) worked with its global network to conduct 64 projects and 94 trainings that reached over 2,300 individuals from 54 countries. The DEVELOP Program, a workforce development effort, conducted 69 feasibility projects and engaged 315 young professionals.

Applied Sciences also released a first-ever Earth Science Applications Guidebook. This new, web-based resource captures decades of experience of putting Earth science into action. It includes interactive and multimedia content, including use cases narrated by principal investigators.

Strategic Goal 2

Extend Human Presence to the Moon and on towards Mars for Sustainable Long-term Exploration, Development, and Utilization.



Left: Teams retracted the first two of 20 platforms surrounding the Space Launch System rocket and Orion spacecraft that allow work on the integrated system in High Bay 3 inside the Vehicle Assembly Building at NASA's Kennedy Space Center in Florida. Image Credit: NASA Images

Right: The Moon is seen rising behind NASA's Space Launch System (SLS) rocket with the Orion spacecraft aboard atop a mobile launcher as it rolls out to Launch Complex 39B for the first time, Thursday, March 17, 2022, at NASA's Kennedy Space Center in Florida. Image Credit: NASA Images

FY 2022 Performance Goals and Ratings Supporting Strategic Goal 2

Organized by Strategic Objective

Strategic Objective	Performance Goal	Description	Rating
2.1	**Explore the surface of the Moon and deep space.**		
	2.1.1	Advance America's goal to land the first woman and first person of color on the Moon by demonstrating capabilities that advance lunar exploration. (APG)	Yellow
	2.1.2	Develop the capabilities and infrastructure necessary to transport humans from Earth to cis-lunar space.	Green
	2.1.3	Complete the exploration activities that will support missions with human crew members to the lunar surface.	Yellow
2.2	**Develop a human spaceflight economy enabled by a commercial market.**		
	2.2.1	Expand commercial activities in low Earth orbit (LEO) and stimulate the human spaceflight economy, with a focus on deploying commercial LEO destinations that can be used by NASA and other customers.	Green
	2.2.2	Provide support for and utilization of commercial facilities onboard the International Space Station (ISS) for NASA, other Government agencies, and academic and industry users, including the ISS National Laboratory to expand the space economy.	Green
	2.2.3	Provide operational resources to enable the closure of capability gaps in support of deep space exploration.	Green
	2.2.4	Provide NASA crew transportation through commercial partners to the International Space Station (ISS) and low Earth orbit.	Green
2.3	**Develop capabilities and perform research to safeguard explorers.**		
	2.3.1	Identify activities that will mitigate the highest risks to crew health and performance.	Green
2.4	**Enhance space access and services.**		
	2.4.1	Complete Launch Services Program (LSP) commercial non-crewed launch services objectives for NASA-Managed science, exploration, U.S. Government, and Government-sponsored missions.	Green
	2.4.2	Maintain the proficiency of Space Communications network services.	Green

APG = Agency Priority Goals

Strategic Objective 2.1

Explore the surface of the Moon and deep space.

LEAD OFFICE
Exploration Systems Development Mission Directorate (ESDMD)

GOAL LEADER
Ned Penley, Deputy Associate Administrator for Management, ESDMD

Budget

	FY	$M
Op Plan	2022	$6,790.7
Enacted	2023	$7,468.9
Requested	2024	$7,971.1
Outyear	2025	$8,130.5
	2026	$8,293.1
	2027	$8,459.0
	2028	$8,628.2

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.

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

Below: In this image, Orion captures a unique view of Earth and the Moon, seen from a camera mounted on one of the spacecraft's solar arrays. Source: NASA Images

On November 16 (in FY 2023), NASA launched Artemis I, which took a 25.5-day journey around the Moon and returned to Earth on December 11. We continued to work toward an Artemis II launch, with excellent progress on both Orion and Space Launch System (SLS) hardware. We also mated the Artemis II Crew Module adapter to the European Service Module. The adapter will allow us to mate the Crew Module/European Service Module to the SLS. We selected SpaceX in April 2021 to develop an Human Landing System (HLS) to land astronauts on the Moon for Artemis III through the Next Space Technologies for Exploration Partnerships (NextSTEP)-2 Appendix H Option A contract. NASA determined this Strategic Objective showed Satisfactory performance at the 2022 Strategic Review.

2.1.1: Advance America's goal to land the first woman and first person of color on the Moon by demonstrating capabilities that advance lunar exploration. (Agency Priority Goal)

Number of milestones met.

	Execution	Planned	
Fiscal Year	FY 2022 Agency Priority Goal	FY 2023	FY 2024
Milestones	4 of 4	4 of 4	TBD
Results	3		
Rating	Yellow		

This two-year Performance Goal/Agency Priority Goal will be completed on September 30, 2023. NASA may develop a follow-on Artemis goal for the FY 2024-2025 Agency Priority Goal cycle. If so, the goal statement, annual target, and supporting critical milestones for FY 2024 and FY 2025 will be identified for inclusion in the FY 2024-2025 Agency Performance Plan.

List of milestones for FY 2022

1. Complete Artemis II Crew Module/Service Module mate.
2. Complete the Artemis II Interim Cryogenic Propulsion Stage.
3. Artemis III Forward Skirt Structural Weld Complete.
4. Launch Artemis I.

List of milestones for FY 2023

1. Complete Artemis II Booster Segment stacking.
2. Announce awards for sustaining lander development.
3. Deliver the Artemis II Core Stage to Kennedy Space Center.
4. Habitation and Logistics Outpost (HALO) systems Critical Design Review (CDR) closeout.

Lead Organization: Exploration Systems Development Mission Directorate (ESDMD)

FY 2022 Performance Progress

NASA made appreciable progress on the first three Artemis missions, but of the four milestones planned for FY 2022, one was delayed into FY 2023. A second milestone, launch of Artemis I, was scheduled for completion before the end of the FY; however, due to the safety concerns caused by Hurricane Ian, NASA was forced to delay the Artemis I launch attempt until the November launch window, and rolled the vehicle back to the Vehicle Assembly Building at Kennedy Space Center to protect it from the inclement weather. NASA successfully launched Artemis I on November 16 (the first quarter of FY 2023). Ultimately, while this Performance Goal needed to complete three milestones for a Yellow rating, NASA awas prepared for launch at the end of September and, ultimately completed the launch during the next optimal launch window. NASA anticipates completing the second outstanding milestone—complete the Artemis II Interim Cryogenic Propulsion Stage—during the second quarter of FY 2023.

NASA performed two launch attempts of the Artemis I mission. The first launch attempt was scrubbed after teams were not able to chill down the four RS-25 engines with liquid hydrogen to a cryogenic level of approximately minus 420 degrees Fahrenheit, with engine three showing higher temperatures than the other engines. Teams also found a hydrogen leak. The second launch attempt was scrubbed due to a new hydrogen leak. Both launch attempts yielded a wealth of lessons learned on cryogenic loading operations, which will be applied for subsequent Artemis missions.

Below: Standing atop the mobile launcher, NASA's Space Launch System (SLS) rocket and Orion spacecraft arrive at Launch Pad 39B at the Agency's Kennedy Space Center in Florida on Nov. 4, 2022. The Artemis I stack was carried from the Vehicle Assembly Building to the pad – a 4.2-mile journey that took nearly 11 hours to complete – by NASA's crawler-transporter 2 ahead of the uncrewed launch. Image Credit: NASA Images

NASA completed the Artemis II Crew Module Adapter and European Service Module structural mate in October 2021. The European Service Module will supply Orion with electricity, propulsion, thermal control, air, and water during missions. NASA delayed completion of the Artemis II Interim Cryogenic Propulsion Stage until winter of FY 2023 to align with a change of the Artemis II launch date. The four Artemis II Core Stage engines were delivered to Michoud Assembly Facility in Louisiana and the solid rocket motor segments were cast and placed in storage.

NASA completed the Artemis III Forward Skirt (which sits atop the Core Stage) structural weld in March 2022. This activity is key to delivery of the Core Stage Forward Skirt.

In early November 2021, the U.S. Court of Federal Claims denied Blue Origin's bid protest, upholding NASA's selection of SpaceX to develop and demonstrate a modern human lunar lander. This decision allowed NASA to begin meaningful execution of the Human Landing System (HLS) contract and interaction with SpaceX. At the end of FY 2022, NASA released a solicitation for proposals for sustainable lunar lander development and demonstration (called HLS Sustaining Lunar Development) as the Agency continues to pursue efforts in support of a series of Moon landings. (More information is available in NASA's press release.)

NASA announced the selection of Axiom Space to deliver an exploration extravehicular activity system (xEVAS) for the Artemis III mission. This is the first task order to develop a next-generation Artemis spacesuit and supporting systems and to demonstrate their use on the lunar surface during Artemis III. In June, NASA announced the award pf xEVA contracts to Axiom Space and Collins Aerospace to develop suits for both the ISS and Artemis lunar missions that will advance spacewalking capabilities and be provided as a service.

2.1.2: Develop the capabilities and infrastructure necessary to transport human missions from Earth to cislunar space.

Percent of milestones or activities completed, as identified on the Enterprise Cross-Program Integration Teams Schedule.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestones	5 of 5	5 of 5	5 of 5
Results	5		
Rating	Green		

List of milestones for FY 2022
1. Mate the Artemis II Crew Module (CM) Adapter to the European Service Module (ESM).
2. Exploration Ground Systems break ground on the Emergency Egress System at Pad-B.
3. Complete the Core Stage 2 Liquid Hydrogen tank.
4. Complete integration of Artemis II Crew Module Part 1.
5. Complete the Artemis II Core Stage liquid hydrogen (LH2) tank and forward section mate.

List of milestones for FY 2023
1. Artemis II Booster aft skirts ready for Acceptance Checkout (ACO).
2. Artemis II Launch Vehicle Stage Adapter complete.
3. Artemis III Crew Module Adapter (CMA) complete.
4. Artemis IV Space Launch System (SLS) Core Stage engines available.
5. Artemis III Core Stage Forward Skirt complete.

List of milestones for FY 2024
1. Artemis II Crew Module (CM)/ Service Module (SM) vacuum performance testing complete.
2. Mobile Launcher-1 ready for Artemis II crewed operations.
3. Artemis III Booster Aft Skirts ready for Acceptance Checkout (ACO).
4. Artemis III Crew Module initial power on.
5. Start Artemis IV Exploration Upper Stage production.

Lead Organization: Exploration Systems Development Mission Directorate (ESDMD)

FY 2022 Performance Progress

During FY 2022, NASA completed the five capabilities and infrastructure milestones supporting Artemis exploration missions from Earth to the area within the Moon's orbit, leading to a Green rating.

These efforts, which include construction of system elements and infrastructure, support the activities described for Agency Priority Goal 2.1.1.

NASA continued to work toward an Artemis II launch, with excellent progress on both Orion and SLS hardware. NASA mated the Artemis II Crew Module adapter (shown below) to the European Service Module. The adapter will allow NASA to mate the Crew Module/European Service Module (see Agency Priority Goal 2.1.1) to the SLS. The Service Module, Crew Module, Launch Abort System, and adapter together form the Orion spacecraft for Artemis II.

By summer, teams were nearing full integration of the European Service Module with the Crew Module. On June 13, technicians powered on the Orion spacecraft and began checking that power and data could be routed throughout the capsule.

Below: An artist's concept drawing shows the components of the Orion spacecraft. For more information on the Orion spacecraft, read the "Meet NASA's Orion Spacecraft" feature. Image Credit: NASA Images

In March, NASA connected two major parts of the SLS Core Stage—the 130-foot liquid hydrogen tank and the 66-foot forward assembly (completed in December 2021)—in preparation for Artemis II. The engine section will be the last section added to complete the Core Stage.

NASA broke ground on the Emergency Egress System (EES) at Pad 39B. In case of an emergency on the pad, the EES will be able to move crew quickly from the top of the launch vehicle down to a landing zone next to a concrete bunker, where they can either take shelter or drive away in an armored vehicle.

2.1.3: Complete the exploration activities that will support missions with human crew members to the lunar surface.

Percent of milestones or activities completed, as identified on the Enterprise Cross-Program Integration Teams Schedule.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestones	5 of 5	5 of 5	5 of 5
Results	4		
Rating	Yellow		

List of milestones for FY 2022

1. Complete the Exploration Extravehicular Activity (xEVA) development validation testing unit.
2. Execute the Human Landing System (HLS) Option A contract after the stay of performance.
3. Award xEVA contract(s).
4. Issue sustaining lander development Request for Proposals.
5. Establish Key Decision Point (KDP)-1 and the Agency baseline commitment for lifecycle cost, schedule, and technical parameters for Gateway.

List of milestones for FY 2023

1. Complete the Human Landing System (HLS) Option A (SpaceX) incremental HLS design update.
2. Complete the primary structure build for the Habitation and Logistics Outpost (HALO).
3. Conduct Exploration Extravehicular Activity Services (xEVAS) Certification Baseline Review.
4. Select/ award Next Space Technologies for Exploration Partnerships (NextSTEP)-2 Appendix P: Sustaining Lunar Development contract.
5. Award the Lunar Terrain Vehicle (LTV) phase 1 contract(s).

List of milestones for FY 2024

1. Complete Human Landing System (HLS) Option A (SpaceX) Prop transfer flight test.
2. Complete Gateway International Habitation Module (I-HAB) Critical Design Review (CDR).
3. Complete Exploration Extravehicular Activity Services (xEVAS) Artemis Suit Preliminary Design Review (PDR).
4. Complete HLS Next Space Technologies for Exploration Partnerships (NextSTEP)-2 Appendix P: Sustaining Lunar Development design review milestone (TBD).
5. Complete LTV phase 1 contract(s) design review milestone (TBD).

Lead Organization: Exploration Systems Development Mission Directorate (ESDMD)

FY 2022 Performance Progress

NASA completed 4 of 5 milestones and activities planned for FY 2022, resulting in a Yellow Performance Goal rating. While Gateway element manufacturing is underway, the KDP-1 review—which would have established the Agency baseline commitment for lifecycle cost and schedule, as well as the technical parameters, for the Gateway program—will be held no earlier than the third quarter of FY 2023. The Gateway program is comprised of several projects, including the Habitation and Lunar Outpost and the Power and Propulsion Element.

In April 2021, NASA selected SpaceX to develop an HLS to land astronauts on the Moon for Artemis III through the Next Space Technologies for Exploration Partnerships (NextSTEP)-2 Appendix H Option A contract. The U.S. Government Accountability Office (GAO) placed a stay of performance on the contract, stopping activities in support of the contract, until they issued a decision on a protest filed by other competitors. On July 30, 2021, the GAO denied the protests, allowing SpaceX to begin work. SpaceX completed several contract milestones during FY 2022, including system architecture and design reviews, landing software demonstrations, and Raptor engine cold start demonstration. SpaceX achieved a rate of producing seven Raptor engines in one week.

We released a request for proposals for sustaining lander development on March 23 through a new NextSTEP Appendix P. Under this approach, multiple U.S. companies will develop landing systems to carry astronauts between lunar orbit and the lunar surface after Artemis III. In addition, we awarded a contract modification to SpaceX (Option B) to further develop its Starship HLS to support sustaining lander development.

On June 1, NASA announced the selection of Axiom Space and Collins Aerospace to develop new, advanced spacewalking systems to work outside of the International Space Station (ISS). The two companies, selected from the Exploration Extravehicular Activity Services (xEVAS) contract, will compete for task orders to demonstrate an

EVA system and certify the system to support NASA programs. NASA completed an xEMU design verification test unit in October 2021, which will be used to validate technologies and fundamental requirements for EVA systems. We will share the technical and risk-reduction information with our EVA partners.

Strategic Objective 2.2

Develop a human spaceflight economy enabled by a commercial market.

LEAD OFFICE
Space Operations Mission Directorate (SOMD)

GOAL LEADER
Tonya McNair, Deputy Associate Administrator for Management, SOMD

Budget

	FY	$M
Op Plan	2022	$3,080.8
Enacted	2023	$3,270.1
Requested	2024	$3,487.7
Outyear	2025	$3,522.3
	2026	$3,641.0
	2027	$3,806.8
	2028	$3,913.0

Since 2000, NASA has ensured access to a human-rated platform in low Earth orbit (LEO) that extends U.S. human presence and expands the American foothold in space. The continuous operation of a research and technology demonstration platform in space is critical to achieving the Nation's goals in science, technology, and human space flight. NASA determined at the 2022 Strategic Review that this Strategic Objective demonstrated Noteworthy performance in enabling a commercial human spaceflight economy. In FY 2022, NASA began releasing Request for Information (RFI) documents and has met with industry to collect comments on the feasibility of the requirements and assumptions to aid NASA in the development of safe, reliable, and cost-effective space destination capabilities.

Since its inception, industry, academia, and our international partners have used the International Space Station (ISS) as a testbed for research and

Below: Crew-4 astronauts wave after walking out through the double doors below the Neil A. Armstrong Building's Astronaut Crew Quarters at NASA's Kennedy Space Center in Florida on April 27, 2022. They will make their way to the customized Tesla Model X cars that will take them to their spacecraft at Launch Complex 39A. From left are: mission specialist Jessica Watkins, pilot Bob Hines, commander Kjell Lindgren, and mission specialist Samantha Cristoforetti. SpaceX's Crew Dragon, powered by the company's Falcon 9 rocket, will carry the four-person crew to the International Space Station as part of NASA's Commercial Crew Program. Image Credit: NASA/Kim Shiflett

the development and maturation of state-of-the-art systems that increase access to space. NASA is supporting new space stations from which a variety of 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. To ensure continued access to space, in FY 2022, NASA announced intentions to issue a sole source modification to SpaceX to acquire up to three additional crew flights to the ISS as part of its Commercial Crew Transportation Capabilities contract.

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 commercial activities on the ISS, the number and types of companies taking advantage of those opportunities will likely increase, which will in turn create more demand.

Below: A SpaceX Falcon 9 rocket carrying the company's Crew Dragon spacecraft is launched on NASA's SpaceX Crew-5 mission to the ISS with NASA astronauts Nicole Mann and Josh Cassada, Japan Aerospace Exploration Agency (JAXA) astronaut Koichi Wakata, and Roscosmos cosmonaut Anna Kikina onboard, October 5, 2022, at NASA's Kennedy Space Center in Florida. This was the fifth crew rotation mission of the SpaceX Crew Dragon spacecraft and Falcon 9 rocket to the International Space Station as part of the Agency's Commercial Crew Program. Image Credit: NASA/Joel Kowsky

Left: Norm Knight, Director of Flight Operations at NASA's Johnson Space Center, left, Emily Nelson, NASA's Chief Flight Director, second from left, Sarah Walker, Director of Dragon Mission Management for SpaceX, second from right, and David Allega, Mission Manager for Mission Management and Integration in NASA's Commercial Crew Program, right, monitor the launch of a SpaceX Falcon 9 rocket carrying the company's Crew Dragon spacecraft on the Crew-5 mission with NASA astronauts Nicole Mann and Josh Cassada, JAXA astronaut Koichi Wakata, and Roscosmos cosmonaut Anna Kikina onboard, October 5, 2022, in firing room four of the Rocco A. Petrone Launch Control Center at NASA's Kennedy Space Center in Florida. Image Credit: NASA/Joel Kowsky

2.2.1: Expand commercial activities in low Earth orbit (LEO) and stimulate the human spaceflight economy, with a focus on deploying commercial LEO destinations that can be used by NASA and other customers.

Percentage of milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestone	3 of 3	4 of 4	4 of 4
Results	3		
Rating	Green		

List of development milestones for FY 2022

1. Complete required partnership agreements with other government agencies for commercial activities.
2. Initialize the free-flyer project milestones.
3. Successfully complete the second provider commercial test flight launch.

List of development milestones for FY 2023

1. Release Commercial LEO Development (CLD)-related white papers to industry through NASA Request for Information process.
2. Execute a private astronaut mission to the International Space Station (ISS).
3. Complete one major milestone for Commercial Destinations on ISS (CDISS).
4. Complete three major milestones—one on each of the Commercial Destinations Free Flyers (CDFF) Space Act Agreements (SAAs).

List of development milestones for FY 2024

1. Release initial set of Commercial LEO Development (CLD) Requirements.
2. Execute a private astronaut mission to the International Space Station.
3. Complete one major milestone for CDISS (Commercial Destinations on ISS).
4. Complete three major milestones, one on each of the CDFF (Commercial Destinations Free Flyers) Space Act Agreements (SAA).

Lead Organization: Space Operations Mission Directorate (SOMD)

FY 2022 Performance Progress

NASA focused on developing a firm foundation for commercial activities in FY 2022 and completed all three milestones, achieving a Green rating for this Performance Goal.

NASA is partnering with the commercial space sector to develop one or more platforms to serve as follow-ons to the ISS, maintaining an uninterrupted U.S. presence in LEO. During the first quarter of FY 2022, NASA awarded three funded Space Act Agreements to Blue Origin, Nanoracks, and Northrop Grumman to develop designs for space stations and other commercial destinations in space.

NASA released a white paper documenting the Agency's current assumptions and expectations on commercial destinations. We also released the first of several Request for Information (RFI) documents, that contain draft crew certification requirements. The RFI was intended to gather industry comments on the feasibility of the requirements and assumptions to aid NASA in the development of safe, reliable, and cost-effective space destination capabilities.

In support of this Performance Goal, Axiom Mission 1 (Ax-1), the first all-private astronaut mission to the ISS, launched on April 8. The SpaceX Dragon spacecraft docked with the ISS on April 9, and the four Axiom astronauts spent eight days aboard the space station. In August, NASA and Axiom Space signed a mission order for a second private mission, planned for FY 2023.

In October 2021, we released the NASA Research Announcement "Research Opportunities for ISS Utilization" for In Space Production Applications (InSPA) flight demonstrations. NASA selected eight InSPA proposals to enable U.S. businesses, institutions of higher learning, and other organizations to raise the technological readiness level of their manufacturing technologies and products, move them to market, and propel U.S. industry toward developing a sustainable, scalable, and profitable non-NASA demand for products and services in low Earth orbit.

2.2.2: Provide support for and utilization of commercial facilities onboard the International Space Station (ISS) for NASA, other Government agencies, and academic and industry users, including the ISS National Laboratory to expand the space economy.

Percentage of milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestone	1 of 1	1 of 1	2 of 2
Results	1		
Rating	Green		

List of development milestones for FY 2022

1. Launch 20 commercial facilities to the ISS and conduct experiments.

List of development milestones for FY 2023

1. Launch 20 commercial facilities to the ISS and conduct experiments.

List of development milestones for FY 2024

1. Launch 20 commercial facilities to the ISS and conduct experiments.
2. Select and sponsor at least 30 flight investigations, including at least 5 investigations focused on in space production areas.

Lead Organization: Space Operations Mission Directorate (SOMD)

FY 2022 Performance Progress

During FY 2022, at least 20 commercial facilities were operational on the ISS, leading to a Green rating for this Performance Goal. In support of commercial goals, the Center for the Advancement of Science in Space (CASIS) solicited commercial flight projects through a Cooperative Agreement with NASA. Examples of these facilities include the following:

- The Materials ISS Experiment Flight Facility (MISSE FF), owned by Aegis Aerospace, is attached to the outside of the ISS, allowing researchers to test materials (e.g., paints, coatings, polymers) or other larger experiments in the extreme environment of space. Samples are exposed to extreme temperature variations, vacuum, unfiltered ultraviolet radiation, atomic oxygen, and electromagnetic radiation, and micro-meteoroids in low Earth orbit.
- The Space Automated Bioprocessing Lab (SABL), owned by Bioserve, is an incubator and freezer designed to support a wide variety of investigations in the life, physical, and materials sciences, with a focus on supporting research in biological systems and process. SABL also can support secondary functions, such as physical science experiment support and food storage.
- The Multi-use Variable-gravity Platform (MVP), owned by Techshot, is designed for research with different kinds of organisms and cell types, such as fruit flies, flatworms, plants, fish, and protein crystals. MVP includes two carousels that can produce up to 2g of artificial gravity, while controlling for temperature, light cycles, and humidity.

Below: MISSE FF installed on the Japanese Experiment Module Exposed Facility (JEM EF) on the exterior of the ISS. MISSE FF is sponsored by the U.S. National Laboratory. Image Credit: NASA Images

2.2.3: Provide operational resources to enable the closure of capability gaps in support of deep space exploration.

Percentage of milestones completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestones	1 of 1	1 of 1	1 of 1
Results	1		
Rating	Green		

List of development milestones for FY 2022

1. Initiate and operate 5 technologies on-orbit.

List of development milestones for FY 2023

1. Initiate and operate at least 5 technology demonstrations on the International Space Station (ISS) to advance deep space exploration.

List of development milestones for FY 2024

1. Initiate and operate at least 5 technology demonstrations on the International Space Station (ISS) to advance deep space exploration.

Lead Organization: Space Operations Mission Directorate (SOMD)

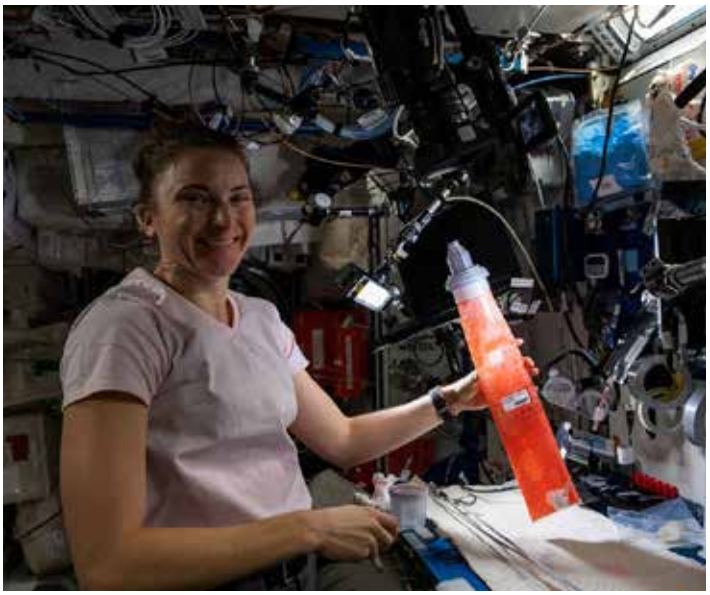
FY 2022 Performance Progress

NASA is using the ISS to develop and test new technologies that will support exploration beyond low Earth orbit. During FY 2022, NASA initiated five technologies aboard the ISS leading to a Green rating: Universal Waste Management System (UWMS); BioSentinel; Exposed Root On-Orbit Test System (XROOTS); Advanced Hydrogen Sensor Technology Demonstration for Oxygen Generation Assembly (OGA); and Collapsible Contingency Urinal (CCU).

The UWMS demonstrates the technology and long-term use of a compact toilet and the Urine Transfer System (UTS). UWMS is designed to be a smaller, more comfortable, and more reliable waste-disposal method allowing the crew to focus on other activities and enable further exploration in space. Biosentinel measures the effects of radiation and microgravity on budding yeast to provide a picture of potential damage accumulated over several months to understand how long-term missions to deep space may affect humans. XROOTS uses techniques to grow plants without soil or other growth media, providing a vital alternative for plant systems to contribute to future space exploration. Advanced Hydrogen Sensor Technology Demonstration for OGA tests a more reliable and longer shelf-life sensor than the current sensor on OGA, providing a more stable configuration and reducing the number of spaces needed on long duration space missions. CCU provides a contingency method to collect urine in a small space, such as the Orion Capsule, in case the waste management system is under repair.

Below: NASA astronauts Jessica Watkins and Robert "Bob" Hines work on XROOTS, which used the ISS's Veggie facility to test liquid- and air-based techniques to grow plants rather than traditional growth media. These techniques could enable production of crops on a larger scale for future space exploration.

Below: NASA Astronaut Kayla Barron works on the CCU demonstration in the Harmony Module observing fill and drain cycles on two different designs. Image Credit: NASA



2.2.4: Provide transportation through commercial partners to support the International Space Station (ISS) and low Earth orbit.

Number of Commercial Crew missions launched.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Missions	2 missions launched	2 missions launched	2 missions launched
Results	2		
Rating	Green		

Lead Organization: Space Operations Mission Directorate (SOMD)

FY 2022 Performance Progress

NASA has contracted for commercial crew transportation to the ISS and returning safely to Earth with SpaceX and Boeing. In FY 2022, SpaceX launched two crewed missions to the ISS for NASA's Commercial Crew Program, leading to a Green rating. Boeing's capabilities continue to mature, in anticipation of an FY 2023 first crewed flight.

The SpaceX Crew-3 mission launched on November 10, 2021, carrying NASA astronauts Raja Chari, Tom Marshburn, and Kayla Barron, as well as European Space Agency (ESA) astronaut Matthias Mauer. On May 5, the Crew-3 astronauts safely returned to Earth aboard the SpaceX Dragon spacecraft.

The next SpaceX Crew-4 mission—carrying NASA astronauts Kjell Lindgren, Bob Hines, and Jessica Watkins and ESA astronaut Samantha Cristoforetti—launched to the ISS on April 27, 2022. The Crew-4 astronauts safely splashed down on October 14.

Boeing—NASA's second provider for commercial crew services—successfully conducted their uncrewed Orbital Flight Test (OFT)-2 mission to and from the ISS in May, clearing the way for a planned crewed flight test.

Below: Boeing and NASA teams work around Boeing's CST-100 Starliner spacecraft after it landed at White Sands Missile Range's Space Harbor on May 25, 2022, in New Mexico. Boeing's OFT-2 is Starliner's second uncrewed flight test to the ISS as part of NASA's Commercial Crew Program. OFT-2 serves as an end-to-end test of the system's capabilities. Image Credit: NASA/B. Ingalls

Strategic Objective 2.3

Develop capabilities and perform research to safeguard explorers.

LEAD OFFICE
Space Operations Mission Directorate (SOMD)

GOAL LEADER
Tonya McNair, Deputy Associate Administrator for Management, SOMD

	Budget	
	FY	$M
Op Plan	2022	$240.8
Enacted	2023	$252.7
Requested	2024	$255.5
Outyear	2025	$260.4
	2026	$259.3
	2027	$259.3
	2028	$259.4

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 challenges, as well as food, medicines, and shelf-life constraints. Each of these challenges are being addressed to ensure crew members are safe and healthy as we move beyond low Earth orbit. At the 2022 Strategic Review, NASA determined that this Strategic Objective made Satisfactory progress.

NASA is pursuing new technologies that will help manage the effects of extended stays in space on human health and performance. Throughout FY 2022, the Human Research Program (HRP)

Below: NASA astronaut Serena Auñón-Chancellor provides a saliva sample on the International Space Station. Her sample will be used to measure stress hormones and other biomarkers of health that can reveal how her immune system changes in space. Image Credit: NASA Images

pursued ground-based, analog, and International Space Station (ISS) research, which led to significant successes and progress to advance safe human exploration. Examples of risk mitigation progress include validating requirements for Orion's waste management system, evaluating different CO2 levels for contingency surface Extravehicular Activity (EVA) scenarios, development of a Gateway Crew Health and Performance System, and Autonomy standards for the new Lunar Terrain Vehicle (LTV) project. Each advance in our knowledge can provide basic human needs, including oxygen and water, along with the ability to maintain and repair critical systems. We 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.

We emphasize 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.

Below: Megan McArthur removes Kidney Cells-02 hardware inside the Space Automated Bioproduct Laboratory and swaps media inside the MSG. The experiment uses a 3D kidney cell model known as a tissue chip to study the effects of microgravity on formation of microcrystals in kidney tubules. Results could support design of better treatments for conditions such as kidney stones and bone loss for astronauts and osteoporosis for people on Earth. Image Credit: NASA Images.

2.3.1: Identify activities that will mitigate the highest risks to crew health and performance.

Funded investigations and/or published papers.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	160 peer-reviewed papers published	150 peer-reviewed papers published	150 peer-reviewed papers published
Results	280 peer-reviewed papers published		
Rating	Green		

List of development milestones for FY 2022

1. 160 peer-reviewed papers published.

List of development milestones for FY 2023

1. 5 new investigations funded.
2. 150 peer-reviewed papers published.

List of development milestones for FY 2024

1. 5 new investigations funded.
2. 150 peer-reviewed papers published.

Lead Organization: Space Operations Mission Directorate (SOMD)

FY 2022 Performance Progress

NASA surpassed the FY 2022 target of 160 peer-reviewed papers for this Performance Goal by publishing more than 280 papers and funding six new investigations, leading to a Green rating.

Our Human Research Program conducts ground- and space-based research to support safe, productive human space travel.

Below: NASA astronaut Victor Glover, seen here on the International Space Station (ISS), observes and records the density of a microbial colony after its incubation period. To ensure crew safety, NASA scientists carefully monitor the microbiome of the ISS. They have two main goals: To map and keep track of microbes present through time and to discover any patterns of microbial growth that could potentially affect the crew's health and safety. Image Credit: NASA Images.

Strategic Objective 2.4

Enable space access and services.

LEAD OFFICE
Space Operations Mission Directorate (SOMD)

GOAL LEADER
Tonya McNair, Deputy Associate Administrator for Management, SOMD

Budget

	FY	$M
Op Plan	2022	$717.7
Enacted	2023	$727.2
Requested	2024	$791.5
Outyear	2025	$842.6
	2026	$817.5
	2027	$746.1
	2028	$736.1

This Strategic Objective is comprised of essential services that support human and robotic missions: The Launch Services Program (LSP), and Space Communications and Navigation (SCaN). The activities these programs manage range from acquiring launch vehicles for U.S. Government civil sector and robotic missions, to communicating with both crewed and uncrewed missions. NASA determined this Strategic Objective demonstrated Noteworthy performance at the 2022 Strategic Review.

NASA provides safe, reliable, and cost-effective launch services for NASA and NASA-sponsored payloads seeking access to space on U.S. com¬mercial launch vehicles. As the launch agent of the U.S. civil space sector, NASA relies on 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

Below: A United Launch Alliance Atlas V rocket with the Lucy spacecraft aboard is seen as it is rolled out of the Vertical Integration Facility to the launch pad at Space Launch Complex 41, October 14, 2021, at Cape Canaveral Space Force Station in Florida. Lucy will be the first spacecraft to study Jupiter's Trojan Asteroids. Like the mission's namesake – the fossilized human ancestor, "Lucy," whose skeleton provided unique insight into humanity's evolution – Lucy will revolutionize our knowledge of planetary origins and the formation of the solar system. Image Credit: NASA/Bill Ingalls

Directorates, a wide range of educational organizations, and other customers. They are the Agency's recognized experts in all aspects of commercial launch services, including acquisition, certification, and mission management. LSP successfully launched three scientific spacecraft, including Lucy, Double Asteroid Redirection Test (DART), and Imaging X-ray Polarimetry Explorer (IXPE) missions. LSP also launched NOAA's Geostationary Operational Environmental Satellite (GOES), in addition to one technology demonstration, the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission from Mahia, New Zealand.

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. We engage 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 continue to mature, and we envision a commercial communications market where near-Earth customers will have access to suitable commercial services and where NASA is one of many customers. NASA clearly demonstrated its commitment to surpass operational performance goals by exceeding its network proficiency Performance Goal throughout FY 2022, delivering across all networks at an average proficiency of 99.5 percent against the 95.0 percent target.

2.4.1: Complete Launch Services Program (LSP) commercial non-crewed launch services objectives for NASA-Managed science, exploration, U.S. Government, and Government-sponsored missions.

Percentage of launch objectives met.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	100% met	100% met	100% met
Results	100%		
Rating	Green		

Lead Organization: Space Operations Mission Directorate (SOMD)

FY 2022 Performance Progress

We achieved all of our launch objectives in FY 2022, leading to a Green rating, as NASA successfully launched four planned robotic science missions:

- The Lucy spacecraft launched from Space Launch Complex 41 at Cape Canaveral Space Force Station, Florida, on October 16, 2021.
- The Double Asteroid Redirection Test (DART) mission launched on November 24, 2021, from Space Launch Complex 4 at Vandenberg Space Force Base, California.
- The Imaging X-ray Polarimetry Explorer (IXPE) launched on December 9, 2021, from Launch Complex 39A at Kennedy Space Center, Florida.
- The National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite-T (GOES-T) launched on March 1, 2022, from Space Launch Complex 41 at Cape Canaveral Space Force Station, Florida.

NASA also acquired the launch service for NASA's Nancy Grace Roman Space Telescope mission under the NASA Launch Services II contract.

Above: A United Launch Alliance Atlas V rocket with the Lucy spacecraft aboard is seen as it is rolled out of the Vertical Integration Facility to the launch pad at Space Launch Complex 41, October 14, 2021, at Cape Canaveral Space Force Station in Florida. Lucy will be the first spacecraft to study Jupiter's Trojan Asteroids. Like the mission's namesake – the fossilized human ancestor, "Lucy," whose skeleton provided unique insight into humanity's evolution – Lucy will revolutionize our knowledge of planetary origins and the formation of the solar system. Image Credit: NASA/Bill Ingalls

2.4.2: Maintain the proficiency of Space Communications network services.

Percent of network proficiency.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	95.0%	95.0%	95.0%
Results	99.5%		
Rating	Green		

Lead Organization: Space Operations Mission Directorate (SOMD)

FY 2022 Performance Progress

NASA's communications networks—the Deep Space Network (DSN) and the Near Space Network (NSN), which has relay and direct-to-Earth (DTE) components—achieved 99.5 percent service delivery, exceeding the FY 2022 target of a minimum 95 percent network proficiency, leading to a Green rating.

NASA's communications networks serve more than 100 NASA and non-NASA missions. The DSN enables missions that explore the furthest points of our solar system, utilizing three ground stations located approximately 120 degrees apart on Earth. The NSN provides services for near-Earth missions, including DTE services and relay capabilities.

Strategic Goal 3

Catalyze economic growth and drive innovation to address national challenges.

Top: University students conduct a technology demonstration under zero-gravity conditions on a NASA-sponsored flight provided by Zero Gravity Corporation. Image Credit: NASA Images

Bottom: Flight simulators help enable urban flights NASA's Langley Research Center in Hampton, Virginia, and the Adaptive Aerospace Group (AAG) recently completed a round of evaluations and demonstrations for the FAA and the United States Air Force (USAF) using advanced simulators for the Fly-By-Wire Mission Task Element Development and Certification (FlyTEC) study. Image Credit: NASA Images

FY 2022 Performance Goals and Ratings Supporting Strategic Goal 3

Organized by Strategic Objective

Strategic Objective	Performance Goal	Description	Rating
3.1	Innovate and advance transformational space technologies.		
	3.1.1	Foster a diverse U.S engineering and technology talent base, expand commercial opportunities in the space industry, and advance innovative technology solutions.	Green
	3.1.2	Mature technology projects that offer significant improvement to existing solutions or enable new capabilities.	Yellow
	3.1.3	Rapidly develop and demonstrate technologies for exploration, discovery, and the expansion of space commerce through partnerships with U.S. industry and academia.	Green
	3.1.4	Demonstrate new technologies and cross-cutting capabilities that are of direct interest and use to NASA missions and the commercial space sector.	Green
	3.1.5	Ensure American global leadership in space technology innovations through increased partnering with industry, broadening the base of innovation, and demonstrating key lunar surface and deep space technologies. (APG)	Yellow
3.2	Drive efficient and sustainable aviation.		
	3.2.1	Develop solutions that will enable the integration of a diverse range of non-traditional vehicles and operations into the National Airspace System by means of a scalable, service-oriented architecture.	Yellow
	3.2.2	Demonstrate the ability to reduce the perceived loudness of sonic booms and enable future industry innovation in commercial supersonic aircraft.	Yellow
	3.2.3	Advance airframe and engine technologies to enable the development of future generations of ultra-efficient air vehicles that minimize environmental impact and accelerate towards net-zero carbon emissions including opportunities to transition to alternative propulsion and energy.	Yellow
	3.2.4	Advance airframe and propulsion technologies to enable the development of vertical take-off and landing (VTOL) vehicles that minimize noise and maximize safety, including electric vehicle propulsion systems.	Green
	3.2.5	Define and demonstrate solutions that predict, identify, and mitigate emerging safety risks and address the national need to safely transform the National Airspace System.	Green
	3.2.6	Contribute toward the safe introduction of on-demand Urban Air Mobility (UAM) and other emerging operations by developing, applying, demonstrating, and validating advanced autonomy and automation technologies and providing methods or research results that support certification of autonomous systems.	Green

APG = Agency Priority Goals

Strategic Objective 3.1

Innovate and advance transformational space technologies.

LEAD OFFICE
Space Technology Mission Directorate (STMD)

GOAL LEADER
Mike Green, Deputy Associate Administrator for Management, STMD

	Budget	
	FY	$M
Op Plan	2022	$1,100.0
Enacted	2023	$1,200.0
Requested	2024	$1,391.6
Outyear	2025	$1,419.4
	2026	$1,447.8
	2027	$1,476.8
	2028	$1,506.3

As NASA embarks on its next era of discovery and exploration, the advancement of transformational space technologies serves as a trailblazer for 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 investments center around technologies that enable our science and human exploration missions, as well as foster growth in the commercial space economy. We harness innovation and entrepreneurship through partnerships with universities, small businesses and other government agencies. Through leadership in space technology, we will contribute to growing the U.S. industrial and academic base by transferring space technology into the space economy, continuing the Nation's economic leadership and strengthening our national security.

Below: The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) undergoes final construction before being shipped to its launch location in New Zealand. Image Credit: NASA Images

NASA's 2022 Strategic Review resulted in a continued rating of Satisfactory Performance. While there continued to be challenges due to the COVID-19 pandemic, as well as programmatic impacts that are to be expected in high-risk technology development and demonstration programs, we have continued to develop and demonstrate these technologies and transfer and transition technologies within the Agency, throughout the federal government and to a variety of academic institutions and industry partners. We remain focused on building public-private partnerships with the U.S. aerospace industry to develop capabilities that support the needs of the varied mission architectures of its vast array of stakeholders. Specific examples of accomplishments under this Strategic Objective include:

- The successful launch of Laser Communications Relay Demonstration (LCRD); Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment's (CAPSTONE) successful launch from New Zealand and subsequent Small Satellite Mission of the Year award from the American Institute of Aeronautics and Astronautics (AIAA);
- Introduction of Tech Transfer University (T2U) into a Big Ten school (Kelley School of Business at Indiana University);
- Development and release of Envisioned Future Priority packages alongside an Request for Information (RFI) to solicit space community feedback to show the development path for each technology capability area within STMD;
- Selection of Microchip to develop a High-Performance Spaceflight Computing (HPSC) processor;
- The transition of 4 Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) funded projects incorporated into the Volatiles Investigating Polar Exploration Rover (VIPER);
- Nearly 15 technologies to be demonstrated through NASA CLPS missions;
- 11 STMD-funded projects infused into Artemis-related missions;
- Significant progress made towards demonstration of a range of space technologies (e.g., Solar Electric Propulsion (SEP), On-orbit Servicing, Assembly and Manufacturing 1 (OSAM-1) and OSAM-2).

While some projects are experiencing cost, schedule, technical and/or programmatic challenges, overall, our portfolio is on track to meet this Strategic Objective and includes several technology demonstrations planned for the next few years. In the mid- to long-term, we have identified 18 technology capability areas as priority areas of focus, each of which addresses anticipated gaps across multiple stakeholder architectures.

3.1.1: Foster a diverse U.S engineering and technology talent base, expand commercial opportunities in the space industry, and advance innovative technology solutions.

Percentage of critical activities completed for Early Stage Innovation and Partnerships (ESIP) program supporting the Performance Goal.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Milestones	5 of 5	4 of 5	4 of 5
Results	5		
Rating	Green		

List of development milestones for FY 2022

1. Achieve at least 1 knowledge transition for a minimum of 75 percent of research grants.
2. Offer 45 new opportunities to broaden NASA's innovation community through prizes, challenges, and crowdsourcing.
3. Achieve 60 innovative Small Business Technologies that receive external funding to further advance technologies.
4. Achieve 3,600 licenses and software usage agreements.
5. Complete benchmarking of diversity, equity, and inclusion data for ESIP portfolio.

List of development milestones for FY 2023

1. Achieve at least 1 knowledge transition for a minimum of 75 percent of research grants.
2. Offer 45 new opportunities to broaden NASA's innovation community through prizes, challenges, and crowdsourcing.
3. Achieve 60 innovative Small Business Technologies that receive external funding to further advance technologies.
4. Achieve 3,600 licenses and software usage agreements.
5. Conduct 10 strategic engagement opportunities to underserved and underrepresented communities.

List of development milestones for FY 2024

1. Achieve at least 1 knowledge transition for a minimum of 75 percent of research grants.
2. Offer 50 new opportunities to broaden NASA's innovation community through prizes, challenges, and crowdsourcing.
3. Obtain 60 commitments from external partners for funding to further advance small business technologies.
4. Achieve 5,000 licenses and software usage agreements.
5. Conduct 15 strategic engagement opportunities to underserved and underrepresented communities.

Lead Organization: Space Technology Mission Directorate (STMD)

FY 2022 Performance Progress

NASA achieved the FY 2022 target for this multi-year Performance Goal as the Agency continued to foster, expand, and advance the U.S. space technology economy. NASA achieved the FY 2022 target for this Performance Goal by meeting the targets for all 5 milestones leading to a Green rating for this Performance Goal. These investments and activities ensure a healthy base of promising early-stage solutions for further development by other programs and organizations.

Our Space Technology Research Grants (STRG) Program continued to challenge academic researchers, from graduate researchers to senior faculty members, to contribute to our goal of creating innovative new space technologies, specifically in areas where academia is ideally suited to provide significant innovations. Of the 86 projects that were part of the 2017 cohort planned to have close-out reviews in FY 2022, 81 were completed as of the end of FY 2022. Five projects were not completed due to additional, COVID-19-related no-cost extensions. All 86 projects were assessed and 86 percent (74 projects) achieved at least one knowledge transition. These knowledge transitions capture the technologies, ideas, and expertise created by these projects for use by NASA, other government agencies (OGA), and industry. They include published journal articles, patents, licensing, New Technology Reports (NTRs), open-source software, and NASA Space Technology Graduate Research Opportunities (NSTGRO) researcher hiring.

We started 69 new Prize, Challenge, and Crowdsourcing (PCC) activities in FY 2022. Of the new challenges started, 45 were through the NASA Tournament Lab (NTL), which facilitates the use of crowdsourcing to tackle our challenges through a variety of open innovation platforms to create the most innovative, efficient, and optimized solutions for specific, real-world problems facing us and other federal agencies. Exciting public challenges

that started in FY 2022 included Phase 2 of the Break the Ice Lunar Challenge designed to help us excavate ice on the Moon; Phase 2 of the Deep Space Food Challenge in partnership with the Canadian Space Agency to help bring innovative food production technologies to space and here on Earth; and the NASA TechRise Student Challenge in partnership with the Flight Opportunities Program.

We provided opportunities for small, highly innovative companies and research institutions through the Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program. We created 123 post-Phase II opportunities, compared to the targeted 45 opportunities, including 44 Phase II-E awards, six Civilian Commercialization Readiness Pilot Program opportunities, seven Sequential Phase II awards, and 66 Phase III awards. These follow-on awards substantiate that innovate technologies are being developed that are sought and resonate with other programs.

To ensure that technologies developed for missions in exploration and discovery are broadly available to the public, and to maximize the benefit to the Nation, we set a new target this year to achieve at least 3,600 licenses and software usage agreements through its Technology Transfer Program. We exceeded this goal by executing 178 patent licenses, 11 copyright licenses, and 5,025 new software usage agreements.

In order to develop a more thorough understanding of how NASA's Early-Stage Innovations and Partnerships (ESIP) portfolio can improve and expand its Diversity, Equity, Inclusion, and Accessibility (DEIA) efforts, the Agency set a target for FY 2022 to complete an assessment of current data availability and limitations for ESIP DEIA benchmarking as well as the current process improvements in place to streamline existing data and collect missing data. This assessment was completed in FY 2022 and provides the ESIP portfolio a strong set of observations and recommendations for areas of improvement that can be used over the coming years to improve and expand its DEIA footprint.

3.1.2: Mature technology projects that offer significant improvement to existing solutions or enable new capabilities.

Percentage of planned key performance parameters* that met requirements.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Requirements	60.0% met	60.0% met	60.0% met
Results	41.3%		
Rating	Yellow		

*This program tracks dozens of key performance parameters every fiscal year. For example, the program is tracking 75 key performance parameters that plan to close during FY 2023. They include but are not limited to the following:

- COLDArm COLDArm Actuator Min Operational Temp
- COLDArm Cold Motor Drivers Minimum Operating Temperature
- COLDArm Actuator Heater Energy
- Hopper-TP Excursion Data Downlinked (1)
- Hopper-TP Longest Flight Capability
- Hopper-TP PSR Survival Limits
- Hopper-TP Landing Capability (2)
- Hopper-TP Power Margin (3)
- PRIME-1 Regolith sample-depth resolution
- PRIME-1 Volatile species identification
- PRIME-1 Water detection accuracy for regolith
- TALOS Axial Propellant Operating Temp (C)
- TALOS Axial Minimum Impulse Bit (N-sec)
- TALOS Axial Thrust to Weight (ratio)
- TALOS ACS Thrust to Weight (ratio)
- TALOS ACS Propellant Operating Temp (C)

Lead Organization: Space Technology Mission Directorate (STMD)

FY 2022 Performance Progress

NASA did not achieve this Performance Goal target (i.e., 60 percent of planned key performance parameter (KPP) events) due to lower than expected appropriations levels resulting in project cancellations and testing delays, as well as a combination of project-specific development challenges and facility constraints which brought the rating for this Performance Goal to Yellow. However, the KPPs' thresholds that NASA met or exceeded during FY 2022 each represent technology advancement that may lead to entirely new mission approaches and provide solutions to national needs.

We met KPPs in eight of its Game Changing Development projects such as Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS), Bulk Metallic Glass Gears (BMGG), and Deployable Composite Booms (DCB). ARMADAS successfully completed a ground demonstration of an integrated system of three robots, structural materials, and autonomy to assemble a specified structure.

STMD has continued its partnership with Commercial Lunar Payload Services (CLPS) providers, and has further matured eight technologies planned to launch with those partners in the coming years. One of the technologies planned to launch in 2023 is Polar Resources Ice Mining Experiment-1 (PRIME-1). It will be the first in-situ resource utilization demonstration on the moon, and it will be the first time NASA will robotically sample and analyze for ice from below the surface. PRIME-1 is made up of two components which will be mounted to the CLPS lander – The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) and the Mass Spectrometer observing lunar operations (MSolo). TRIDENT was developed via NASA's SBIR program by Honeybee Robotics in 2016.

As part of our Safe and Precise Landing – Integrated Capabilities Evolution (SPLICE) technology maturation project, the Game Changing Development program made significant improvements on a previously demonstrated Navigation Doppler Lidar (NDL) technology. In 2017, NDL was commercialized through the Technology Transfer program to Psionic, and in 2022 won the NASA Commercial Invention of the Year. It is also planned to fly on two CLPS landers with Intuitive Machines and Astrobotic.

While our Technology Maturation Portfolio made significant advancements on a variety of technology projects, we did face challenges in a number of projects that lead to a Yellow rating for this Performance Goal. For example, the Thruster for the Advancement of Low-temperature Operation in Space (TALOS) project had five KPPs planned to complete in FY 2022, and all five were delayed due to facility testing constraints. Smartphone Video Guidance Sensor (SVGS) was canceled as part of the FY 2022 budget shortfalls and had been scheduled to complete three KPPs. Spacecraft Oxygen

Recovery had six planned KPPs to meet; four of them were delayed into FY 2023, and two of them did not meet the threshold due to technical challenges. Although these challenges caused a Yellow rating for the year, we continued to make significant progress towards its goal of maturing technologies that will revolutionize space exploration.

3.1.3: Rapidly develop and demonstrate technologies for exploration, discovery, and the expansion of space commerce through partnership with U.S. industry and academia.

Number of technologies tested suborbitally or orbitally.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Technologies Tested	40	45	40
Results	48		
Rating	Green		

Test of peer to peer navigation at the Moon by the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission, circa Q2 FY 2023.

Test of thirteen lunar gravity payloads on a Blue Origin New Shepard suborbital flight in FY 2023 (pending the Federal Aviation Administration (FAA) and Blue Origin return to flight activities).

Launch of the Starling small spacecraft mission and initiation of testing its multiple distributed system and autonomous operations technologies in late FY 2023 (pending finalization of launch provider schedule).

The Flight Opportunities program is currently tracking 46 tentative suborbital flights. The actual timeline for those flights is dependent on each commercial flight provider's schedule and typically varies significantly.

Lead Organization: Space Technology Mission Directorate (STMD)

FY 2022 Performance Progress

NASA FY 2022 achievements included the testing of 48 technologies in suborbital and orbital environments by the Small Spacecraft Technology (SST) and Flight Opportunities (FO) programs, leading to a Green rating for this Performance Goal.

The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) mission launched on June 28, 2022. On November 13, 2022, the 12U CubeSat will enter a near-rectilinear halo orbit (NRHO) at the Moon to test navigation technologies and verify NRHO orbital dynamics. Two technologies have already been demonstrated by this mission: Stellar Exploration Inc.'s hydrazine propulsion system, the first of its type for CubeSat use, and Rocket Lab's Interplanetary Photon stage that delivered CAPSTONE to trans-lunar injection.

The TeraByte InfraRed Delivery (TBIRD) communications system was launched on May 25, 2022 on the Pathfinder Technology Demonstrator 3 mission. TBIRD demonstrated a 100 Gbps optical data downlink rate and is targeting 200 Gbps by late 2022.

The portfolio also supported suborbital flight testing for various applications, including in-space manufacturing, climate observation, sustaining human health in space, payload-return capabilities, and small spacecraft systems.

The three winners of the inaugural NASA TechLeap Prize used high-altitude balloon flights with Aerostar to test small spacecraft technologies for autonomous detection and tracking of transient events on Earth and beyond. The portfolio also partnered with NASA's Small Business Innovation Research (SBIR) program to test methods for 3D printing of electronics in microgravity.

Several technologies secured additional testing or mission infusion based on suborbital test results. Carthage College's Modal Propellant Gauging, tested on parabolic flights from Zero Gravity Corporation (Zero-G) and suborbital rocket flights with Blue Origin, has been adopted by Airbus for its zero-emission commercial passenger jet program and Intuitive Machines in its Nova-C lunar lander test articles. Space Fibers 3 from FOMS, Inc. and the Orbital Fiber Optic Production Module from Mercury Systems used flight tests with Zero-G to prepare for demonstrations of on-demand, automated optical fiber manufacturing aboard the International Space Station.

3.1.4: Demonstrate new technologies and cross-cutting capabilities that are of direct interest and use to NASA missions, as well as the commercial space sector.

Major milestones (e.g., key decision points, major reviews, and technology demonstrations) completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	7	8	6
Results	8		
Rating	Green		

This program tracks numerous development milestones every fiscal year. For example, milestones below include but are not limited to the following for FY 2023:

- Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Launch Readiness Date (LRD)
- On-orbit Servicing, Assembly, and Manufacturing (OSAM)-1 servicing payload integration start
- ULA 2020 Tipping Point Preliminary Design Review (PDR)
- Radio Frequency Mass Gauge (RFMG) launch on Commercial Lunar Payload Services (CLPS)
- SpaceX 2020 Tipping Point demonstration
- OSAM-1 spacecraft delivery to Goddard Space Flight Center
- Solar Electric Propulsion (SEP) Key Decision Point (KDP)-D
- Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) operations complete
- Cryogenic Fluid Management (CFM) annual assessment review
- Eta Space Tipping Point payload delivery to spacecraft integration)
- Fission Surface Power Phase I Interim Reviews

Lead Organization: Space Technology Mission Directorate (STMD)

FY 2022 Performance Progress

During FY 2022, NASA had several impactful successes in its technology demonstration portfolio, and met eight major milestones in Technology Demonstration Missions (TDM), exceeding the targeted seven leading to a Green rating for this Performance Goal.

TDM's On-Orbit Servicing and Manufacturing 1 (OSAM-1), OSAM-2, and Solar Electric Propulsion (SEP) projects all completed their Critical Design Reviews (CDR), crucial steps in the lead-up to planned launches in 2026, 2024, and 2024, respectively. The first Annual Assessment Review (AAR) of the Cryogenic Fluids Management (CFM) Portfolio Project was completed in FY 2022, as well as successfully completing several important design milestones for the CFM Tipping Points. This review included presentations of performance against technical, schedule, financial, and programmatic baselines, and an assessment by an Independent Review Team.

In our nuclear portfolio, both the Fission Surface Power (FSP) and Space Nuclear Propulsion (SNP) successfully completed their annual technical assessment reviews conducted by independent review boards. Both projects implemented project activities which address the findings and recommendations of their respective boards. Additionally, SNP also completed the Phase I industry contracts for the design of a Nuclear Thermal Propulsion (NTP) reactor and have entered into an extension of those efforts to include testing of key high-temperature components to demonstrate feasible operation. The FSP project also implemented their Phase I industry contracts for the design of an integrated FSP system.

In FY 2022, Low Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) completed its Pre-Ship Review (PSR), Mission Readiness Review (MRR), and KDP-E in preparation for its November 2022 launch. The LOFTID technology demonstration is poised to transform the way NASA and industry deliver substantial payloads to planetary destinations with atmospheres in support of human exploration and commercial applications from low Earth orbit.

The TDM Laser Communications Relay Demonstration (LCRD), a relay satellite that utilizes optical communications to send data to Earth with data rates 10 to 100 times better than current radio systems, revolutionizing the way NASA communicates with spacecraft, passed its KDP-E. It launched as a hosted payload aboard a Department of Defense (DOD) Space Test Program Satellite-6 (STP Sat-6) by an Atlas V rocket on December 7, 2021. In the first few month of operations on-orbit, LCRD successfully completed its power-on and checkout activities, and established optical communications

between both optical ground stations. In May, LCRD successfully transitioned as per originally planned to being managed by NASA's Space Operations Mission Directorate and will be utilized with communications payloads on the Inernational Space Station.

Left: Preparations for Joint Polar Satelite System-2 (JPSS-2) and LOFTID continue with a fit check of the payload fairing inside an Astrotech high bay at Vandenberg Space Force Base. Image Credit: NASA Images

3.1.5: Ensure American global leadership in space technology innovations through increased partnering with industry, broadening the base of innovation, and demonstrating key lunar surface and deep space technologies. (Agency Priority Goal)

Critical activities completed.

	Execution	Planned	
Fiscal Year	FY 2022 Agency Priority Goal	FY 2023	FY 2024
Activities	4	4	TBD
Results	3		
Rating	Yellow		

This two-year Performance Goal/Agency Priority Goal will be completed on September 30, 2023. NASA may develop a follow-on Space Technology Leadership goal for the FY 2024-2025 Agency Priority Goal cycle. If so, the goal statement, annual target, and supporting critical milestones for FY 2024 and FY 2025 will be identified for inclusion in the FY 2024-2025 Agency Performance Plan.

Critical activities for FY 2022

1. Final assembly of the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) spacecraft in preparation for pre-shipment testing.
2. Complete Solar Electric Propulsion (SEP) Critical Design Review (CDR).
3. Deliver the Polar Resources Ice Mining Experiment (PRIME)-1 to Intuitive Machines for integration with their Commercial Lunar Payload Services (CLPS) lander, in preparation for their mission.
4. Complete 3 early design milestones for Cryogenic Fluid Management (CFM) Tipping Point projects.

Critical activities for FY 2023

1. Transition 3 SBIR/STTR sequentials planned to be completed in CY 2022 to stakeholder programs for planned follow-on use/development and integration into future systems and demonstrations.
2. Deliver the LTE Proximity Communications Tipping Point with Nokia to Intuitive Machines for integration to their CLPS Lander.
3. Complete Environmental Testing for the Cooperative Autonomous Distributed Robotic Explorers (CADRE).
4. Initiate primary mission operations of the Deep Space Optical Communications (DSOC).

Critical activities for FY 2024

To be developed for FY 2024-2025 APG

Lead Organization: Space Technology Mission Directorate (STMD)

FY 2022 Performance Progress

NASA completed three of the four milestones for FY 2022, leading to a Green Performance Goal rating. We delayed delivery of PRIME-1—designed to robotically sample and analyze ice from below the lunar surface—to Intuitive Machines for integration with their CLPS mission until early FY 2023.

NASA completed assembly of the CAPSTONE spacecraft in preparation for pre-shipment testing. CAPSTONE will be a pathfinder for Gateway, validating innovative navigation technologies and verifying the dynamics of a unique, elliptical lunar orbit.

NASA completed the Critical Design Review for SEP on March 8-10. The project is developing critical technologies—advanced solar arrays, high-power Hall thrusters, and others—to extend the length and capabilities of new exploration and science missions. The CDR determined that the project design was appropriately mature and able to meet mission requirements with acceptable risk based on the cost, schedule, and technical commitments established during the project's Key Decision Point (KDP)-C review. With CDR completed, SEP entered the final design and fabrication phase.

Throughout FY 2022, NASA completed three early design milestones for CFM Tipping Point projects[1]: the Technical Design Review for SpaceX's project on November 18, 2021; the Preliminary Design Review for Eta Space's project on February 23, 2022; and the Systems Readiness Review for the United Launch Alliance on March 21.

1 In October 2020, NASA selected the projects discussed here as part of our fifth competitive Tipping Point solicitation. Our goal is to partner with industry to build mission-ready technologies and capabilities to support sustainable presence on the Moon and future human missions to Mars.

Strategic Objective 3.2

Drive efficient and sustainable aviation.

LEAD OFFICE
Aeronautics Research Mission Directorate (ARMD)

GOAL LEADER
William Harrison, Portfolio Analysis & Management Office, Director, ARMD

Budget

	FY	$M
Op Plan	2022	$880.7
Enacted	2023	$935.0
Requested	2024	$995.8
Outyear	2025	$1,015.7
	2026	$1,036.0
	2027	$1,056.7
	2028	$1,077.8

Air is a primary mechanism for physically connecting countries across the world, air transportation is an integral part of today's U.S. and global economies. Aviation enables U.S. enterprises to operate on a global scale, providing safe, high-speed transport of people and goods. It accounts for around $1.8 trillion of U.S. economic activity each year and generates a positive trade balance of $78 billion in 2019. The aviation industry also supports nearly 11 million direct and indirect jobs, including more than one million high-quality manufacturing jobs. Twenty-five million tons of freight were moved worldwide by U.S. air carriers in 2021. Our mission is to serve the future needs of civil aviation by conducting research into and developing solutions for the problems of flight.

We organize our aeronautics research portfolio around six Strategic Thrusts, which represent our prioritization of aeronautics objectives in response to three identified mega-drivers—Global Growth in Demand for High-Speed Mobility;

Below: Researchers carry an small unmanned aerial system, or sUAS, out to the launch area of the City Environment Range Testing for Autonomous Integrated Navigation (CERTAIN). CERTAIN allows different research teams to fly various autonomous vehicles for a variety of autonomous system testing. Image Credit: NASA Images

Affordability, Sustainability and Energy Use; Technology Convergence—and feedback from the aviation community. The six Strategic Thrusts and the future state they would yield when the aviation community applies our results into their operations are:

1) Safe, Efficient Growth in Global Operations: Achieve safe, scalable, routine high tempo airspace access for all users

2) Innovation in Commercial High-Speed Aircraft: Achieve practical, affordable, environmentally friendly commercial high-speed air transport

3) Ultra-Efficient Subsonic Transports: Realize revolutionary improvements in economics and environmental performance for subsonic transports with opportunities to transition to alternative propulsion and energy

4) Safe, Quiet, and Affordable Vertical Lift Air Vehicles: Realize extensive use of vertical lift vehicles for transportation and services including new missions and markets

5) In-Time System-Wide Safety Assurance: Predict, detect and mitigate emerging safety risks throughout aviation systems and operations

6) Assured Autonomy for Aviation Transformation: Safely implement autonomy in aviation applications.

ARMD focuses on high—impact research investments. Major technology emphases include electrified aircraft propulsion using non-carbon-based fuels, supersonic flight over land, automation and autonomy, fostering new aviation applications in Advanced Air Mobility, and fundamental research involving high-speed flight.

NASA Strategic Review awarded this Strategic Objective a Satisfactory rating for FY 2022. The majority of our FY 2022 success measures, which are used to determine near-, mid-, and long-term progress on our strategy, are on track for successful on-time and on-budget completion. However, as of the end of FY22, the first flight of the X-59 low boom flight demonstrator aircraft was anticipated to occur between February 2023 and May 2023. As of January 2023, current projections are between August 2023 and January 2024 due to delayed completion of wiring and continuity checks. The path to first flight is continuing to be evaluated and updates are anticipated in the third quarter of FY 2023.

We continue to hold the Key Decision Point (KDP) reviews prescribed by NASA Project Management standards for our flight and research and technology projects. Results of KDP reviews are documented in decision memoranda and ARMD project plans.

3.2.1: Develop solutions that will enable the integration of a diverse range of non-traditional vehicles and operations into the National Airspace System by means of a scalable, service-oriented architecture.

Supporting development activities completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Activities	2	1	1
Results	1		
Rating	Yellow		

Development milestones for FY 2022

1. Develop a community-supported Sky for All Vision of the future aviation system.
2. Conduct National Campaign-1 (NC-1) and demonstrate operational scenarios with industry partners across vehicle, airspace, and infrastructure to inform requirements for a UAM Maturity Level-1 (UML-1) system.

Performance activities for FY 2023

1. Research, develop, test, and evaluate a UAM arrival/departure scheduler.

Performance activities for FY 2024

1. Evaluation of Cooperative Operating Practices for intent sharing in Upper Class E airspace.

Lead Organization: Aeronautics Research Mission Directorate (ARMD)

FY 2022 Performance Progress

NASA partially achieved the FY 2022 milestones for this Performance Goal leading to a Yellow rating. The "Sky for All" team successfully developed a community supported vision which included community inputs through webinars, workshops, and other events, which reinforced and supplemented the web portal stakeholder engagement. Throughout this process, "Sky for All" achieved a significant amount of community engagement as a total of 2,335 web portal visitors were recorded.

The National Campaign (NC-1) completed all required work to support expected testing during this time. However, the availability of external partner flight test resources, partner flight test safety reviews, or unexpected partner safety-related incidents drove some delays in conducting the flight tests. In addition, one of the major partners, Joby, suffered hull-loss of their test vehicle. Given the high-risk, cutting-edge nature of technology development in this emergent aviation area, the availability of vehicles for flight trials is a high-risk endeavor.

With the completion of data collection in NC-Developmental Testing in September of 2021 and complicated by the loss of Joby's prototype vehicle, NASA decided that the collaboration with Joby would involve data collection using their proprietary flight simulator. This was successfully conducted in mid-September 2022. The test team completed more than three scenarios encompassing multiple phases of flight (departure, enroute, and arrival) as well as multiple missed approach scenarios. Multiple pilots flew these scenarios, and all test points were completed with corresponding data collected. We will transfer the data to the FAA and it will be used to define requirements for flight procedures for Urban Air Mobility (UAM) aircraft. The remaining flight tests with the other partners will be completed in FY 2023.

3.2.2: Demonstrate the ability to reduce the perceived loudness of sonic booms and enable future industry innovation in commercial supersonic aircraft.

Development milestone(s) completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	2	1	3
Results	1		
Rating	Yellow		

Development milestone for FY 2022

1. First flight of the Low Boom Flight Demonstrator (LBFD) aircraft.
2. Deliver a validated F-15-based test capability that enables in-flight Schlieren images of the LBFD shock structure.

Performance activities FY 2023

1. F -15 platform ready to support X-59 high altitude and high-speed flights.

Performance activities FY 2024

1. Sytem Acceptance Review for the X-59 aircraft.
2. Mobile Operations Facility for Quest Mission Phase III Community Response Testing is complete, tested, and ready to deploy to community response test locations in CONUS.
3. X-59 aircraft acoustic signature validation data collected. Acoustic prediction tools validated. Plans for community testing complete. Technical readiness to move forward with initial non-deployed community response test.

Lead Organization: Aeronautics Research Mission Directorate (ARMD)

FY 2022 Performance Progress

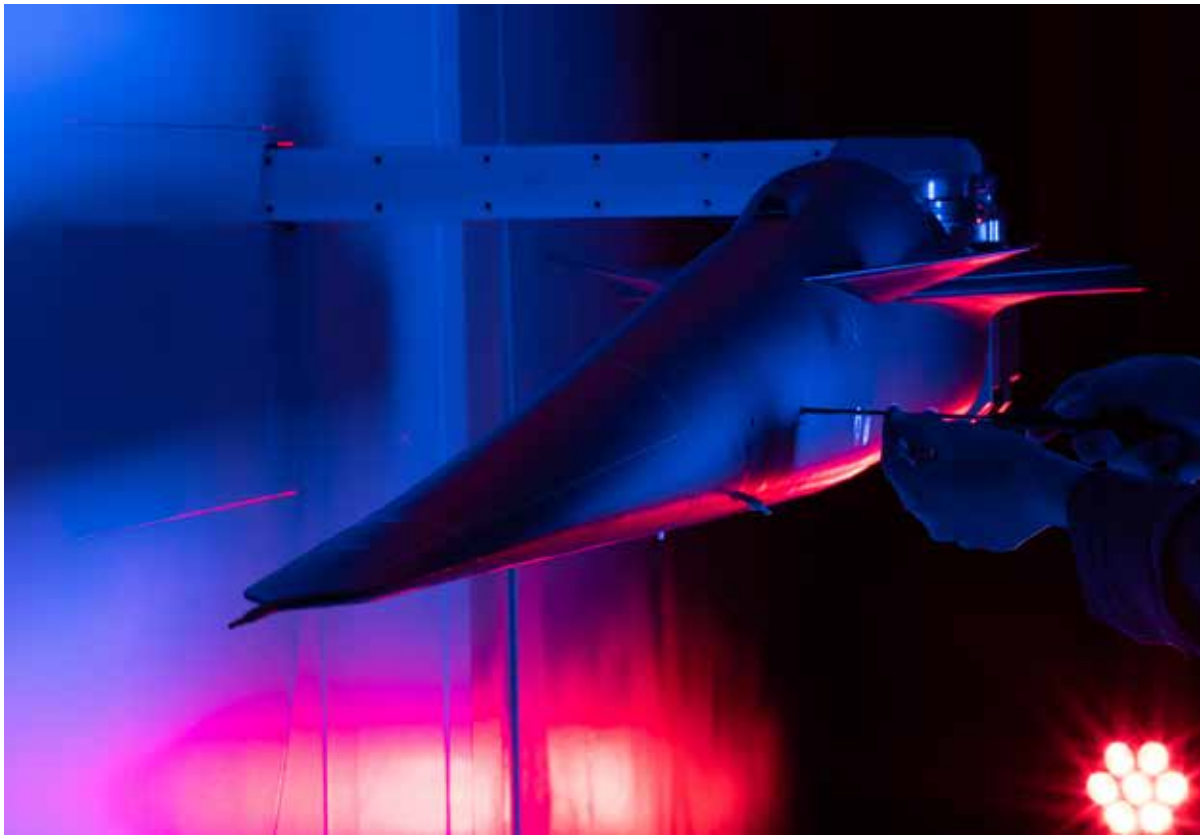
NASA partially achieved the FY 2022 milestones for this Performance Goal leading to a Yellow rating. The annual performance milestone of first flight of the Low Boom Flight Demonstrator aircraft was anticipated to be complete between February and May 2023; however, as of January 2023, current projections for the first flight are between August 2023 and January 2024 due to delays in completion of wiring installations and continuity tests. The path to first flight is continuing to be evaluated and updates are anticipated in the third quarter of FY 2023.

Contractor performance delays resulted in a slip of the X-59 aircraft milestone to ship the aircraft from Lockheed Martin Palmdale to Lockheed Martin Fort Worth for structural proof loads and fuel systems calibration testing. These tests were successfully completed, and the X-59 aircraft returned to Lockheed Martin Palmdale in April 2022. To meet the end-of-year ship date, many System Checkouts (SCOs) were delayed until return to Palmdale. These delays have rippled through the schedule for remaining activities required before the Flight Readiness Review (FRR) and first flight. Despite these challenges, significant progress was made at the end of FY 2022 toward powered-on SCOs.

NASA mitigation actions included teaming with the prime contractor to assist with some design and testing tasks, negotiating cost sharing features in the contract, supporting replanning with more realistic assumptions, providing NASA experts on-site, and continued NASA executive-level engagement with prime contractor counterparts.

In FY 2022, NASA made great progress on the in-flight Schlieren measurement capability required to validate the total aircraft shock wave structure of the X-59 supporting the Quesst Mission. The validated F-15 based test capability that enables in-flight Schlieren images of the X-59 shock wave structure was on track to support X-59 flight operations. NASA developed a system called the Airborne Location Integrating Geospatial Inertial Navigation Systems (ALIGNS) to enable in-flight Schlieren imaging and developed the ASPS Airborne Schlieren Photography System (ASPS2) to observe the shock structure under and around the X-59 aircraft. In FY 2022, NASA completed three ALIGNS/ASPS2 flights.

Below: Before NASA's quiet supersonic X-59 aircraft can take to the skies, plenty of testing needs to happen to ensure a safe first flight. One part of this safety check is to analyze data collected for the X-59's flight control system through low-speed wind tunnel tests.The X-59 is central to NASA's Quesst mission to expand supersonic flight and provide regulators with data to help change existing national and international aviation rules that ban commercial supersonic flight over land. The aircraft is designed to produce a gentle thump instead of a sonic boom. A technician works on the X-59 model during testing in the low-speed wind tunnel, in February of 2022. Image Credit: Lockheed Martin



3.2.3: Advance airframe and engine technologies to enable the development of future generations of ultra-efficient air vehicles that minimize environmental impact including electric aircraft propulsion concepts. [Completion = End of FY 2023]

Supporting development activities completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target Activities	5	5	N/A
Results	3		
Rating	Yellow		

Performance activities for FY 2022

1. Establish feasibility for megawatt, kilovolt fault management devices for electrified aircraft propulsion (Technology Readiness Level [TRL]-4).
2. Design and fabricate a semi-span model of an advanced Transonic Truss Braced Wing (TTBW) configuration, conduct a wind tunnel test to further investigate the buffet boundary of the configuration, and compare experimental results with the computational predictions of structural response and buffet boundary to improve (or calibrate) methods for this non-traditional wing architecture.
3. Complete screening of materials and manufacturing technologies to be considered under the High-rate Composite Aircraft Manufacturing (HiCAM) effort; requirements definition for a full-scale, component-level test article; and evaluate high-rate materials and manufacturing concepts at the coupon and element levels.
4. Preliminary design complete for at least one integrated, 1MW class electric powertrain flight demonstration.
5. Complete X-57 Mod II flight campaign and release performance analysis.

Performance activities for FY 2023

1. Design, build, test, evaluate a suite of electrified aircraft propulsion (EAP) components to TRL-6 that are relevant for demonstrators and small EAP aircraft.
2. Design, build, and evaluate a suite of novel manufacturing technologies to TRL-4 that are relevant for high-rate, lightweight metallic fuselage manufacturing.
3. Critical Design Review (CDR) complete of at least one integrated, 1MW class electric powertrain flight demonstration.
4. Award of the Funded Space Act Agreement (FSAA) for the SFD aircraft design, development, and flight tests.
5. Develop and flight test a mission-controlled deployable and retractable Shape Memory Alloy Reconfigurable Technology-Vortex Generator (SMART-VG) "2nd Generation" system that demonstrates drag reduction and commensurate fuel savings and economic benefits on a commercial transport-class aircraft.

Performance activities for FY 2024

N/A

Lead Organization: Aeronautics Research Mission Directorate (ARMD)

FY 2022 Performance Progress

NASA partially achieved the FY 2022 milestones for this Performance Goal leading to a Yellow rating. NASA completed three performance milestones, while two milestones are behind their planned schedule.

In FY 2022, we established the feasibility for megawatt, kilovolt fault management devices for electrified aircraft propulsion, at TRL-4. The objective was to design, build, and test breadboard circuit interrupters that meet established key performance parameters (KPPs).

We also designed and fabricated a semi-span model of an advanced Transonic Truss Braced Wing (TTBW) configuration, conducted a wind tunnel test to further investigate the buffet boundary of the configuration, and compared the experimental results with the computational predictions of structural response and buffet boundary to improve (or calibrate) methods for this non-traditional wing architecture.

We also completed formulation of the Hi-Rate Composite Airframe Manufacturing (HiCAM) Project, with a goal to enable widespread use of composite materials in next generation transport vehicles to reduce weight and support advanced configurations yielding economic and environmental benefit.

The Electric Powertrain Flight Demonstrator (EPFD) project successfully completed the General Electric Preliminary Design Review on September 1, 2022,

and no major concerns were identified. NASA rated this activity Yellow because the planned schedule was to complete at least one Preliminary Design Review of one integrated, 1MW class electric powertrain flight demonstration during the third quarter of FY 2022.

The X-57 Maxwell Mod II Flight Campaign did not complete in FY 2022 therefore NASA rated this activity as red. Despite this, the X-57 has made significant progress in identifying and resolving technical challenges as a pathfinder for designing, integrating, and testing electric propulsion aircraft. As of the end of FY 2022, NASA was projecting the first flight to occur in December 2022 however, due to resolving cruise motor design challenges, the first flight is now anticipated to occur in the fourth quarter of FY 2023 with the release of performance analysis following. The path to first flight continues to be evaluated and updates are anticipated in the third quarter of FY 2023.

3.2.3: Advance airframe and engine technologies to enable the development of future generations of ultra-efficient air vehicles that minimize environmental impact and accelerate towards net-zero carbon emissions including opportunities to transition to alternative propulsion and energy. [New in FY 2024]

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target Activities	N/A	N/A	4
Results			

Performance activities for FY 2024

1. Develop, test, and apply a model-based systems analysis & engineering (MBSA&E) framework for integrated, multi-fidelity vehicle concept design optimization and technology assessments.
2. Advance maturity and confidence in transonic truss-braced wing (TTBW) configuration fuel burn benefit.
3. Design, build, test, evaluate a suite of composite manufacturing technologies at technical and manufacturing readiness level of 4 (TRL/MRL 4) that are relevant to high-rate, low-cost manufacturing of lightweight large composite airframe structures.
4. Successful completion of the Sustainable Flight Demonstrator Preliminary Design Review (PDR).

Below: With 14 electric motors turning propellers and all of them integrated into a uniquely-designed wing, NASA will test new propulsion technology using an experimental airplane now designated the X-57 and nicknamed "Maxwell." This artist's concept of the X-57 shows the plane's specially designed wing and 14 electric motors. NASA Aeronautics researchers will use the Maxwell to demonstrate that electric propulsion can make planes quieter, more efficient and more environmentally friendly. NASA's aeronautical innovators hope to validate the idea that distributing electric power across a number of motors integrated with an aircraft in this way will result in a five-time reduction in the energy required for a private plane to cruise at 175 mph. Image Credit: NASA Langley/Advanced Concepts Lab, AMA, Inc.

3.2.4: Advance airframe and propulsion technologies to enable the development of vertical take-off and landing (VTOL) vehicles that minimize noise and maximize safety. [Completion = End of FY 2023]

Annual performance activities completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Activities	1	1	N/A
Results	1		
Rating	Green		

Development milestone for FY 2022

1. Assessment of Urban Air Mobility vehicle noise operating in realistic trajectories with a second generation (Gen-2) noise-power-distance database that includes loading, thickness, and broadband self-noise for a mix of vehicles.

Performance activities for FY 2023

1. Conduct a workshop open to US industry to foster transition and provide training for best-practice use of NASA-developed toolchain for Advanced Air Mobility (AAM) and Urban Air Mobility (UAM) aeromechanics and acoustic analysis.

Lead Organization: Aeronautics Research Mission Directorate (ARMD)

FY 2022 Performance Progress

In FY 2022, NASA fully achieved this Performance Goal by developing the ability to use FAA's Aviation Environmental Design Tool (AEDT) to generate noise footprints for UAM vehicle fleets consisting of two different aircraft over multiple flight trajectories leading to a Green rating. This is done while incorporating loading, thickness, and broadband self-noise sources from the vehicle rotors to generate acoustic footprint predictions over the area of operations. The route structure and high volume of operations allowed an in-depth assessment of noise exposure in the vicinity of vertiports. Differences in noise exposure for different fleet mixes were traceable to differences in source noise. It should be noted that the assessments are not indicative of what the noise exposure will be for any particular future scenario but demonstrate the capability that NASA has developed to assess the noise impact of this general class of vehicles.

The main results were documented in the publication "Second-Generation Uam Community Noise Assessment Using The Faa Aviation Environmental Design Tool," by S.A. Rizzi and M. Rafaelof presented at the American Institute of Aeronautics and Astronautics (AIAA) SciTech Forum, San Diego, CA, January 2022.

3.2.4: Advance airframe and propulsion technologies to enable the development of vertical take-off and landing (VTOL) vehicles that minimize noise and maximize safety, including electric vehicle propulsion systems. [New in FY 2024].

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Activities	N/A	N/A	1
Results			
Rating			

Performance activities for FY 2024

1. Apply and document reliability prediction for high reliability motor concept.

3.2.5: Define and demonstrate solutions that predict, identify, and mitigate emerging safety risks and address the national need to safely transform the National Airspace System.

Supporting development activities completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Activities	1 of 1	1 of 1	1 of 1
Results	1		
Rating	Green		

Development milestones for FY 2022

1. Complete simulations and flight tests of automated in-time safety/risk assessment with alternate proactive and responsive mitigation methods.

Performance activities for FY 2023

1. Analyze aircraft data and make recommendations for applying NASA's developed monitoring, assessment, and mitigation techniques to future aviation operations.

Performance activities for FY 2024

1. Complete final testing and provide summary findings and recommendations to external stakeholders on implementation of In-Time System-Wide Safety Assurance data architecture to achieve required assurance levels.

Lead Organization: Aeronautics Research Mission Directorate (ARMD)

FY 2022 Performance Progress

NASA made significant progress advancing this Performance Goal in FY 2022 leading to a Green rating. In-time risk assessment, anomaly detection, and precursor identification algorithms have been developed that provide for assessment across five hazards and may be used during pre-flight planning or in-flight.

The specific hazards addressed are related to battery/power conditions, flight over people, navigation systems, communications systems (i.e., lost link), geo-spatial constraints, and wind. Proactive mitigation methods support both semi-autonomous (supervisory) and fully autonomous (auto-pilot based) flight. The latter is implemented using run-time assurance principles that help to provide deterministic behavior when or if risk exceeds acceptable thresholds. Initial simulations and flight tests have been completed using small, unmanned aircraft systems (UAS).

Simulation and flight tests were completed to meet requirements for software assurance (i.e., NASA classification standards) and to evaluate the algorithms operating open-loop for two use-cases. Subsequent tests will demonstrate the methods across additional use-cases and conditions while engaging automated risk mitigation functions. At the June AIAA Aviation Forum 2022, NASA presented 12 research papers describing progress by the team and its partners.

The System Wide Safety (SWS) Project successfully worked with other projects within the Airspace Operations and Safety Program by incorporating research requirements into SWS flight tests through use of their routes and vertiport placements into the SWS flight scenarios. SWS also tested a Dynamic Density safety metric by collecting data by interfacing with a prototype urban air mobility airspace system. NASA is analyzing the data that was collected during these tests.

3.2.6: Contribute toward the safe introduction of on-demand Urban Air Mobility (UAM) and other emerging operations by developing, applying, demonstrating, and validating advanced autonomy and automation technologies and providing methods or research results that support certification of autonomous systems.

Supporting development activities completed.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	3	3	3
Results	3		
Rating	Green		

Performance activities for FY 2022

1. Enable informed investment decisions for future development of increasingly automated vehicles and airspace operations.
2. Delivery of draft evidence and recommendations for the robustness of failover plans; and the use of run-time monitoring to the FAA, Unmanned Aircraft Safety Team, and Flight Safety Foundation that can be used in regulatory guidance to industry and in standards committees.
3. Demonstration through flight testing of automated aircraft vertiport operations using operational scenarios.

Performance activities for FY 2023

1. Develop a prototype Digital Information Platform that will improve access to aviation data critical for the development of machine learning and artificial intelligence services that can improve the sustainability of aviation operations.
2. Demonstrate algorithms for checking safety standards for systems relying on untrusted components for autonomous surface operations and autonomous drone flight operations.
3. Demonstrate automated aircraft vertiport operations using operational scenarios through the Scalable Autonomous Operations simulation and flight test execution.

Performance activities for FY 2024

1. Demonstrate an airspace service that applies machine learning to improve the sustainability of aviation operations.
2. Delivery of final evidence and recommendations for the FAA, UAST, and Flight Safety Foundation on a process for certification of learning-enabled components in aerospace systems.
3. Demonstrate automated integrated aircraft/airspace operations using operational scenarios in the Integrated Automation Systems-1 (IAS-1) flight test.

Lead Organization: Aeronautics Research Mission Directorate (ARMD)

FY 2022 Performance Progress

NASA made significant progress advancing this Performance Goal in FY 2022 leading to a Green rating. In support of enabling informed investment decisions for future development of increasingly automated vehicles and airspace operations, NASA conducted simulations and assessments of increasingly autonomous operations to identify airspace integration challenges and potential solutions to those challenges. We also completed a systems assessment of increasingly autonomous operations to identify airspace integration challenges and potential solutions to those challenges. This included both infrastructure and traffic levels at regional airports. Airspace integration use cases were completed and used to identify community-informed airspace integration challenges and gaps. This led to the completion of a concept description document in September, which included airspace integration challenges and potential procedural and technological solutions that can help enable airspace integration of increasingly autonomous operations.

In support of the delivery of draft evidence and recommendations for the robustness of failover plans and the use of run-time monitoring to the FAA, the Unmanned Aircraft Safety Team and Flight Safety Foundation delivered a report summarizing all of NASA's findings to the FAA System Wide Safety (SWS) Research Transition Team and to the Flight Safety Foundation in September for their review and comment. This information can be used in regulatory guidance to industry and in standards committees. Lastly, a flight test using automated small Unmanned Aircraft Systems (sUAS) flying nominal and at least two off-nominal approach and landing operational scenarios was successfully conducted in April. Analysis of the data is complete and being prepared for publication.

Strategic Goal 4

Enhance capabilities and operations to catalyze current and future mission success.

Above: John Inness, front left, leads the North Carolina State University team to the launch pad during NASA's 2016 Student Launch Challenge. Inness applied his six years of experience competing in Student Launch toward becoming a full-time employee at NASA's Marshall Space Flight Center in Huntsville, Alabama. He currently works as a Guidance, Navigation, and Controls (GNC) engineer, supporting many NASA projects such as the Space Launch System (SLS) rocket, Solar Cruiser, Smartphone Video Guidance Sensor, and more. Image Credit: NASA Images

Below: Students from California State University, Long Beach, prepare to compete in the 2019 Student Launch. Image Credit: NASA Images

FY 2022 Performance Goals and Ratings Supporting Strategic Goal 4

Organized by Strategic Objective

Strategic Objective	Performance Goal	Description	Rating
4.1	**Attract and develop a talented and diverse workforce.**		
	4.1.1	Improve diversity in the Agency's overall civil service workforce composition and occupations and across employee lifecycles.	Green
	4.1.2	Decrease overall Agency time to hire.	Green
4.2	**Transform mission support capabilities for the next era of aerospace.**		
	4.2.1	Minimize the number and severity of employee injuries and illnesses to support the next era of aerospace.	Green
	4.2.2	Reduce damage to NASA assets (excluding launched flight hardware).	Red
	4.2.3	Ensure the health and safety of NASA astronauts and pilots.	Green
	4.2.4	Safeguard NASA's information resources through critical enhancements to confidentiality, integrity, and availability.	Green
	4.2.5	Maximize the availability of the Space Environment Testing Management Office (SETMO) portfolio of assets to meet NASA's current and future test facility needs.	Green
	4.2.6	Demolish or eliminate obsolete/unneeded facilities to reduce the Agency's infrastructure footprint.	Green
	4.2.7	Improve NASA's ability to operate facilities sustainably and reduce overall resource demands.	Yellow
	4.2.8	Demonstrate increased facility reliability for current and future mission needs through investments in preventative maintenance that reduce unscheduled maintenance.	Green
4.3	**Build the next generation of explorers.**		
	4.3.1	Create unique opportunities for a diverse set of students to contribute to NASA's work in exploration and discovery.	Green
	4.3.2	Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content, and facilities.	Green
	4.3.3	Attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work.	Green
	4.3.4	Promote equal opportunity compliance and encourage best practices among NASA grant recipient institutions to ensure that grantees are providing equal opportunity regardless of race, color, national origin, sex (including pregnancy, sexual orientation, gender identity), age, or disability.	Green

Strategic Objective 4.1

Attract and develop a talented and diverse workforce.

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

GOAL LEADER
Robert Gibbs, Associate Administrator, MSD

Budget

	FY	$M
Op Plan	2022	$99.3
Enacted	2023	$104.8
Requested	2024	$111.7
Outyear	2025	$113.6
	2026	$115.8
	2027	$118.1
	2028	$120.4

NASA strategy for this Objective is two-fold: (1) to equip the Agency for mission success by supporting mission workforce planning, acquiring top talent quickly, enhancing how people work, and growing employees and leaders and (2) advancing diversity, equity, inclusion, and Accessibility (DEIA) in the NASA workforce. We are identifying and removing barriers to DEIA through implementation of the NASA DEIA Strategic Plan, which is focused on improving DEIA outcomes, including strategic integration into the NASA Mission. NASA determined at the FY 2022 Strategic Review that this Strategic Objective was Satisfactory.

In FY 2022, our Office of the Human Capital Officer allocated 20 percent of the awards budget for Special Act Awards, to recognize and award employees in a timely fashion versus only providing awards during the annual performance management process. This change required communication and collaboration with several stakeholder groups, including our unions.

Below: Members of the Artemis I launch team monitor data at their consoles inside Firing Room 1 of the Rocco A. Petrone Launch Control Center at NASA's Kennedy Space Center in Florida during a cryogenic propellant tanking demonstration on September 21, 2022. Image Credit: NASA Images

Those activities were concluded late in FY 2022, therefore, the 20 percent utilization for Space Act Agreements in FY 2022 was made a soft target, with full implementation beginning in FY 2023.

In FY 2022, we implemented a communications campaign to educate hiring managers on the benefits of utilizing existing certificates to save time in filling vacant positions, as well as strengthened and emphasized the Agency-wide direct hire announcement process. This process provides hiring managers continuous active certificates from which they can make selections for the most common positions we fill, and selections from existing certificates have increased by 18.8 percent through the third quarter of FY 2022. We will continue to simplify the process and improve the customer experience in FY 2023.

We took several actions over the past year to equip all leaders to be as effective and efficient with their teams in a hybrid environment, to include developing training focused on hybrid meetings and settings, developing a series of on-demand videos to provide teams opportunities to create working norms in a hybrid environment, and bringing in classes and speakers to provide knowledge and skills needed to lead and manage a hybrid workforce. We will continue to develop and implement training resources focused on leading in a hybrid environment, making this topic a primary focus in leadership courses and development programs, and utilizing existing platforms to communicate lessons learned, best practices, and the latest information to leaders and supervisors.

As part of our DEIA Strategic Plan, we developed a baseline assessment of diversity in its Mission Directorate staffing. In addition, we provided DEIA and Unity training at various Centers across the country to develop culturally competent hiring managers and equip managers with strategies and best practices to identify and hire a broad spectrum of top diverse talent.

We also implemented the U.S. Equal Employment Opportunity Commission's (EEOC's) Management Directive (MD)-715, with our annual plan and report. In FY 2022, we conducted analyses to identify, mitigate, and eliminate barriers to EEO and equity. The Agency anticipates completion of our multi-phase barrier analysis of (1) Asian Americans and Pacific Islanders, and (2) women in NASA physical science occupations in FY 2022, a final report identifying challenges and corrective actions in early FY 2023, and implementation of recommended mitigation strategies beginning thereafter. The barrier analysis identified issues related to grade level and time-in-grade for women in physical sciences, particularly in the Office of Personnel Management (OPM) occupational series 1301 , Physical Scientist. We will include recommended corrective actions in NASA's FY 2022 MD-715 report, which will be submitted to EEOC in early FY 2023.

In terms of the overall diversity of its workforce, NASA saw increases in the number of women in Senior Executive Service (SES) positions (currently 35.7 percent of the Agency's SES workforce). We also saw increases in the diversity of NASA's leadership pipeline, made up of GS-14 and GS-15 positions. The percentage of minorities at the GS-14 or -15 level is at 26.6 percent and the percentage of women is at 31.4 percent. In addition, we met and/or exceeded EEOC goals for the employment of individuals with disabilities (IWD) and individuals with targeted disabilities (IWTD) with IWD at 13.4 percent for GS-11 and above and IWTD at 2.6 percent for GS-11 and above.

4.1.1: Improve diversity in the Agency's overall civil service workforce composition and occupations and across employee lifecycles.

Number of efforts completed (plans and analyses, as well as assessments of their impact on reducing triggers and barriers).

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	3	N/A	N/A
Results	3		
Rating	Green		

Efforts for FY 2022

1. Complete the multi-phase barrier analysis of (1) Asian American and Pacific Islanders and (2) women in NASA physical science occupations and produce a final report identifying challenges and corrective actions addressing each challenge.
2. Complete a baseline assessment of diversity in NASA's Mission Directorates based on staffing (including leadership positions).
3. Complete an analysis of responses to the Federal Employee Viewpoint Survey question on preventing harassment in the workplace4 to identify triggers affecting an inclusive, fair, and safe work environment important for workforce retention.

This Performance Goal has been eliminated as of FY 2023. For FY 2025, NASA may renumber the Performance Goals supporting Strategic Objective 4.1 accordingly.

Lead Organization: Office of Diversity and Equal Opportunity (ODEO)

FY 2022 Performance Progress

As part of its Diversity, Equity, Inclusion, and Accessibility (DEIA) Strategic Plan, NASA developed a baseline assessment of diversity in our mission directorate staffing. The analysis found that between 2017 and 2022, there have been few hiring and promotional opportunities within the NASA mission directorates. The analysis identified gaps in NASA's data collection that will be addressed in the NASA DEIA Strategic Plan. Our personnel data does not map individuals working on specific programs and directorates across our Centers; thus, the baseline assessment could not provide a full picture of diversity within mission directorates or among the mission directorates' leaders. We will focus on the collection of additional data elements needed to measure the employee lifecycle and movements across centers, directorates, and programs. In addition, we provided DEIA and Unity training at various centers across the country to develop culturally competent hiring managers and equip managers with strategies and best practices to identify and hire a broad spectrum of top diverse talent. NASA has achieved a Green rating for this Performance Goal for FY 2022.

We also implemented the U.S. Equal Employment Opportunity Commission's (EEOC) Management Directive (MD)-715, with our annual plan and report. In FY 2022, we conducted analyses to identify, mitigate, and eliminate barriers to EEO and equity. The Agency anticipates completion of our multi-phase barrier analysis of (1) Asian Americans and Pacific Islanders, and (2) women in NASA physical science occupations in early FY 2023, followed by a final report identifying challenges and corrective actions, and implementation of recommended mitigation strategies beginning thereafter. The barrier analysis identified issues related to workforce participation for Asian American and Pacific Islander employees and issues related to career progression for women employees. For Asian American and Pacific Islander employees, an elevated level of attrition was discovered. Internal survey data suggests that this attrition is not accounted for by dissatisfaction with NASA or perceived unfairness within NASA's personnel processes. Most of this attrition was accounted for by a higher percentage of this demographic reaching retirement age. For women, discrepancies were found for grade level and time-in-grade for women in physical sciences, particularly in the Office of Personnel Management (OPM) occupational series 1301, Physical Scientist. Survey data from the Federal Employee Viewpoint Survey and internal survey data suggest that women in these positions perceive NASA as less inclusive than men, have less trust in their supervisors, and have less trust that NASA cares about diversity. A final data collection and analysis is forthcoming that will utilize focus group interaction to further identify root causes and potential corrective actions. Recommended corrective actions will be included in NASA's FY 2022 MD-715 report, which will be submitted to EEOC in early FY 2023.

In terms of the overall diversity of its workforce, we saw increases in the number of women in SES

positions (currently 36.5 percent of the Agency's SES workforce). We also saw increases in the diversity of its leadership pipeline (GS-14 and GS-15 positions), with the percentage of minorities at the GS-14 or -15 level at 26.8 percent and the percentage of women at 31.7 percent. In addition, we met or exceeded EEOC goals for the employment of individuals with disabilities (IWD) and individuals with targeted disabilities (IWTD), which are 12 percent for IWD and 2 percent for IWTD. In FY 2022, IWD accounted for 13.5 percent and IWTD accounted for 2.6 percent for individuals in grades GS-11 and above. For grades GS-10 and below, IWD accounted for 24.9 percent and IWTD accounted for 7.5 percent.

As part of our Anti-Harassment Program efforts, we conducted an analysis of responses to the Federal Employee Viewpoint Survey question on preventing harassment in the workplace to identify triggers affecting an inclusive, fair, and safe work environment, which is important for workforce retention. We determined that, overall, 87.7 percent responded favorably on this question. Non-minorities and men, however, tended to rate this question more positively at most Centers, while women and some minority groups had less favorable responses. For example, 89.4 percent of men responded favorably to the question. In comparison, 85.9 percent of women, 85.4 percent of African Americans, 88.1 percent of Asian Americans and Pacific Islanders, and 85.2 percent of Hispanics responded favorably. We will use these data in developing a second Agency-wide Anti-Harassment Campaign focused on leadership support and communications, and enhanced workforce training modules.

4.1.2: Decrease overall Agency time to hire.

Time between hiring need validation date and enter on duty date for all hires, excluding Pathways and Senior Executive Service (SES) hires, from the FY 2021 baseline of 104 days to a long-term goal of 80 days.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target (decrease time to hire)	<5%	<5% of 78	<5% of FY 2023 Actual
Results (decreased time to hire)	18% (78 days)		
Rating	Green		

NASA's Office of the Chief Human Capital Officer will focus on stabilizing time to hire based on the long-term goal of 80 days. Once stabilized, OCHCO will focus on further reductions to time to hire.

Lead Organization: Office of the Chief Human Capital Officer (OCHCO)

FY 2022 Performance Progress

NASA achieved a Green rating for this Performance Goal for FY 2022, surpassing the target of a 5 percent reduction from the FY 2021 baseline of 104 days. NASA finished FY 2022 with an average time to hire of 85 days, which is 14 days less than the target (99 days). NASA is targeting another 5 percent reduction for FY 2023 (81 days), with a long-term target of 80 days. To reduce the time to hire, NASA is focused on increasing the selections made from existing certificates, implementing efficiencies, and streamlining the hiring process. We must be able to successfully compete for the skills and the diverse talent essential to deliver on our missions in a highly competitive market with a growing commercial aerospace sector. Our success in continuing to reduce time to hire is critical to staying competitive in the labor market.

Strategic Objective 4.2

Transform mission support capabilities for the next era of aerospace.

LEAD OFFICE
Mission Support Directorate (MSD)

GOAL LEADERS
Robert Gibbs, Associate Administrator, MSD; Joel Carney, Association Administrator for OSI; Jeff Seaton, Chief Information Officer, OCIO

	Budget	
	FY	$M
Op Plan	2022	$3,329.5
Enacted	2023	$3,430.3
Requested	2024	$3,702.3
Outyear	2025	$3,776.7
	2026	$3,852.3
	2027	$3,929.4
	2028	$4,008.0

As NASA's missions evolve and increasingly integrate with industry, and hybrid workforces and workplaces become the norm, mission support requirements will change. This is increasingly challenging with the growing complexity of our missions. Much of NASA's infrastructure is from the Apollo-era. To address this, we are re-building, modernizing, and right-sizing NASA's mission-enabling capabilities. For FY 2022, NASA determined that Strategic Objective 4.2 was a focus area for improvement due to budget constraints, reduced purchasing power, and increased mission demands.

PRIORITY AREA 1: Strengthen NASA's Agency Technical Authorities (ATA)

Through our Technical Authorities, NASA ensures independent oversight of programs and projects in support of safety and mission success (SMS) by providing independent engineering, health and medical, and safety insight, oversight, assessment of, and technical expertise to programs to sup-

Below: NASA's Langley Research Center in Hampton, Virginia, unveiled their new Measurement System Laboratory (MSL) on April 21, 2022. The MSL is part of a 20-year revitalization plan for Langley. Image Credit: NASA Images

port successful launch and execution of the Agency's missions and activities.

In FY 2022, we developed, updated, and published policy, standards, guidance, and processes to improve our foundation for SMS and technical excellence. Highlights include:

- Publication of new NASA procedural directives for planetary protection, nuclear flight safety, and collision avoidance of NASA spacecraft
- Update of NASA's orbital debris procedural directive and technical standards consistent with U.S. Government Standard Practices, and streamlined related assessment and compliance evaluation processes
- Publication of a new NASA technical standard for protecting solar system bodies from biological contamination from NASA missions and Earth's biosphere from harmful biological contamination carried on returning spacecraft
- Update of the human rating procedural directive to specifically include independent verification and validation (IV&V) of software in safety and mission assurance plans, and began revision to clarify and streamline the software IV&V process
- Began development of new health and medical policies related to commercial spaceflight, and updates to existing spaceflight and Health and Medical Technical Authority (HTMA) policies
- Institution of a process where evaluation and mission design for resilience occurs early in the project life cycle at the system level
- Began development of a systematic process for identifying, communicating, and deliberating on cross-cutting SMS issues

We continue to provide ample safety and mission assurance, technical, and health and medical learning opportunities, knowledge resources, and communications to our workforce. Technical Authorities to continuously prioritize requirements and work across all program elements to mitigate risks in support of successful launch and execution of priority NASA missions and programs. In FY 2022, we executed Agency-wide Organizational Silence training, offered 180 courses and 11 Agency-wide webinars regarding program and project management (P/PM) and systems engineering , developed a management toolkit to mitigate impacts of program and project management and systems engineering knowledge loss due to retirements and attrition, and began implementation of HTMA Chief Health and Performance Officer training We are also working with other government agencies to develop health and medical training and knowledge sharing for future developments and potential mishap response.

PRIORITY AREA 2: Modernize infrastructure and technical capabilities

The Agency's Master Planning Team completed an Asset Inventory Assessment. NASA's real property assets now have an identified mission relevancy score and corresponding facility condition. These assessments help to inform decisions to direct funding to the highest mission critical requirements and continued right-sizing NASA through footprint reduction, cost-sharing, investment, and modernization to meet future mission needs.

We continue to make progress implementing Condition-Based Maintenance (CBM) at every NASA Center but did not meet our FY 2022 target. The long-term strategy is to transition from a reactive to a proactive maintenance approach through CBM and tiered maintenance, with the implementation of CBM targeting unplanned maintenance, which consumed as much as 30 percent of the total maintenance budget in FY 2022.

In FY21, we explored the feasibility of energy-saving pilot projects in two major Significant Energy User facility types: data centers and wind tunnels. In FY 2022, we initiated a multi-year project to upgrade the Ames Research Center Unitary Plan Wind Tunnel motor drive, a project that will improve the wind tunnel's capability and reliability while also improving energy efficiency. This is the first project of its kind at NASA. If successful, similar motor drive replacement opportunities exist at two Glenn Research Center wind tunnels.

PRIORITY AREA 3: Support our workforce with secure, innovative technology

We are better positioned to support our workforce and programs with secure, innovative technology. We are formulating the FY 2022-2026 NASA IT Strategic Plan in alignment with the 2022 NASA Strategic Plan and related Agency-wide strategies. Over the next five years, the NASA IT community will focus on achieving consistent service delivery, operational excellence, transformational capabilities, and proactive, resilient cybersecurity, all supported by engaged, customer-focused IT teams.

In FY 2022, we completed the initial transition to an enterprise operating model for IT to increase the Agency's effectiveness and efficiency. We established

Agency-level IT offices for customer experience, strategy and architecture, business management, service management, and program management, as well as six IT service lines focused on enterprise delivery of networks, computing, applications, collaboration, information management, and cybersecurity. After completion of a multi-year technical demonstration, NASA's Enterprise Data Platform transitioned into operational service as an initial operating capability in October 2022. This initial operating capability supports continuation of demonstrated services and provides the foundation to onboard capabilities and tools for users to conduct enterprise analytics and obtain insights from key data sets. We also strengthened our cybersecurity posture to reduce risk to our missions in the areas of hardware asset management, High Value Asset (HVA) personal identity verification (PIV) authentication, and intrusion detection and prevention.

Additional progress is provided by the following Performance Goal explanations.

4.2.1: Minimize the number and severity of employee injuries and illnesses to support the next era of aerospace.

Numberof OSHA*-recordable injuries or illnesses compared to industry average** in the following categories:

- All injuries or illnesses—the Total Case Incident Rate (TCIR)—per 100 employees
- Injuries or illnesses per 100 employees that result in days away from work, restricted duty, or transfer of duties—Days Away Restricted or Transferred (DART).

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target per 100 Employees	0.7 TCIR 0.3 DART	0.7 TCIR 0.3 DART	TBD
Results	0.30 TCIR 0.13 DART		
Rating	Green		

*OSHA=Occupational Safety and Health Administration

**Each NASA Center has designated a North American Industry Classification System (NAICS) code (e.g., Space Research and Technology, Nonscheduled Air Transportation). NASA averages TCIR and DART by the industry code for all Centers and compares the results to the most recent Bureau of Labor Statics data for those industry codes.

Lead Organization: Agency Technical Authorities

FY 2022 Performance Progress

NASA measures its ability to minimize employee injury and illness by assessing its total number of OSHA-recordable injuries or illnesses (Total Case Incident Rate, TCIR) and those which result in days away from work or restricted duty (DART) compared to industry averages. Agency rates are averaged across 10 NASA Centers. The Agency's 2022 TCIR of 0.43 and DART or 0.17 are significantly below industry average targets of 0.7 and 0.3, respectively. This is indicative of a world-class occupational safety and health program and is a result of NASA planning and executing a very strong occupational safety and health program. NASA achieved the FY 2022 milestones for this Performance Goal leading to a Green rating.

4.2.2: Reduce damage to NASA assets (excluding launched flight hardware).

Cost of mishaps to NASA assets (excluding launched/operational flight hardware) compared to 5-year median*.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	<$3.8M	<$3.8M	Amount TBD
Results	$5.3M		
Rating	Red		

*The NASA Safety Center analyzes damage mishaps (excluding launched/operational flight hardware) reported by Centers to the NASA Mishap Information System. NASA's analysis includes NASA assets onsite at a Center or involving NASA assets on grounds outside Center property (i.e., including contractor sites) as described in NASA Procedural Requirements 8621.1D, "NASA Procedural Requirements for Mishap and Close Call Reporting," Investigating, and Recordkeeping. Assets in flight or in space operations are not included.

Lead Organization: Agency Technical Authorities

FY 2022 Performance Progress

In FY 2022, NASA's non-mission related damage costs were $5.3 million, which is 30 percent above the historical 5-year average of $3.8 million. As in previous years when the goal was not achieved, the FY 2022 goal exceedance was driven by one event involving high-valued equipment. In this case, foreign object debris (FOD) was unintentionally injected into an F-15 engine during an engine run after maintenance. The extent of the damage required replacement of the core of the engine, an estimated value of $2,550,000. An investigation into the incident has been completed, and a corrective action plan is being developed to prevent reoccurrence. Due to damages sustained, this Performance Goal received a Red rating.

4.2.3: Ensure the health and safety of NASA astronauts and pilots.

Number of non-concurrence determinations by the Health and Medical Technical Authority (HMTA) and percentage of program variances from health and medical policies and standards*.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	0 non-concurrences 5% or fewer variances	0 non-concurrences 5% or fewer variances	0 non-concurrences 5% or fewer variances
Results	0 non-concurrences 5% or fewer variances		
Rating	Green		

*Successful execution of the mission requires adherence to health and medical policies and standards and indicates that the Health and Medical Technical Authority has successfully supported NASA flight programmatics through ongoing observation and documentation of spaceflight and aeronautics activities and evaluation processes, as well as effective implementation of health and medical standards and operations.

A concurrence is a documented agreement by the HMTA that a proposed course of action associated with a program or project position, issue resolution, request for relief from HMTA standards, or program or project level requirements is acceptable.

For every NASA program with a potential impact to humans, the HMTA coordinates with the cognizant program to provide the applicable flow-down of health and medical standards into program requirements. The HMTA discusses with programs any non-concurrences it issues at milestone and Key Decision Point reviews and Joint Cost and Schedule Confidence Level (JCL) meetings.

A variance is any authorized and documented change from prescribed technical requirements for a program or project.

Lead Organization: Agency Technical Authorities

FY 2022 Performance Progress

In FY 2022, the Health and Medical Technical Authority (HMTA) issued no non-concurrences with respect to major program milestones. In addition, the HMTA issued no program variances from the technical standards, leading to a Green Performance Goal rating. Meeting these targets enables NASA mission safety.

The HMTA's mission is to prevent or mitigate adverse health and medical events and provide for the human performance. Required for successful mission execution. HMTA resources have proven critical in the development of appropriate standards, as well as program insight and oversight.

In FY 2022 HMTA continued to apply prioritized, time-critical resources amongst and between programs and in the evaluation of requests for waiver or risk mitigations.

In addition, all measures to prevent COVID-19 infection, as directed by NASA's Office of the Chief Health and Medical Officer, were carefully implemented by essential center civil service and contractor employees.

Based on the increase in programs and the respective content since funding baseline, HMTA anticipates that it will be challenged in FY 2023 to meet Agency needs.

4.2.4: Safeguard NASA's information resources through critical enhancements to confidentiality, integrity, and availability.

Scoring is based on Cybersecurity Scorecard data collected from multiple Agency sources and also feeds the Federal Cybersecurity Dashboard. NASA's cybersecurity scorecard metric is taken from the average of the 20 individual overall scores that span the Missions, corporate organizations, and Centers/Federally Funded Research and Development Centers (FFRDCs) and is supported by 95 "child" metrics:

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target (Cybersecurity Scorecard)	Overall Score of 100%	Overall Score of 100%	Overall Score of 100%
Results (Cybersecurity Scorecard)	80.1%		
Rating	Green		

Target represents the long-term exemplar for this Performance Goal. NASA will assess annual progress based on the following interim targets for overall progress: FY 2023 is 85-100 percent and FY 2024 is 90-100 percent.

Lead Organization: Office of the Chief Information Officer (OCIO)

FY 2022 Performance Progress

NASA exceeded the Agency's FY 2022 cybersecurity performance target with a mean score of 80.1 percent across metrics for hardware asset management, HVA PIV authentication, and intrusion detection and prevention, exceeding our target of meeting a mean score of at least 70 percent in FY 2022.

NASA achieved this performance by strengthening cybersecurity capabilities across the Agency, leading to a Green Performance Goal rating. 92.8 percent of NASA's network is monitored by the Agency's hardware asset management solution. Seventy-three percent of HVAs required the use of PIV for multi-factor authentication on the system or managing the related risk appropriately. Finally, the Agency's average score for cybersecurity intrusion prevention and detection capabilities was 74.5 percent.

This cybersecurity performance goal was based on specific performance criteria established by the Office of Management and Budget (OMB) to implement the Federal Information Security Modernization Act (FISMA). OMB moved away from using these criteria for FY 2023; therefore, NASA will update its cybersecurity performance goal for FY 2023 to address OMB's new criteria. These criteria will drive performance across several key indicators including Operating End of Life systems, Assessment and Authorization, Multi-Factor Authentication, and Vulnerability Management.

4.2.5: Maximize the availability of the Space Environment Testing Management Office (SETMO) portfolio of assets to meet NASA's current and future test facility needs.

Percentage of test availability* of SETMO portfolio of Tier 1 assets**

*Test availability = (planned capacity – unplanned down-time)/planned capacity. Unplanned downtime is total downtime, including downtime that impacts a test.
**Tier 1 assets: portfolio of assets for which SETMO provides annual sustainment funding. Tier 2 assets: port-folio of assets for which SETMO does not provide annual sustainment funding.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target (availability)	90%	N/A	N/A
Results (availability)	100%		
Rating	Green		

This Performance Goal has been eliminated as of FY 2023. For FY 2025, NASA may renumber the Performance Goals supporting Strategic Objective 4.2 accordingly.

Lead Organization: Office of Strategic Infrastructure (OSI)

FY 2022 Performance Progress

NASA NASA maintained 100 percent test availability for the SETMO Tier 1 assets, which included flight simulation, space environments testing, high-enthalpy simulation and testing, and the Thermal Vacuum Test Chamber B at the Johnson Space Center in Houston. In turn, this Performance Goal received a Green rating.

NASA's workforce performs essential preventive maintenance to ensure that key capabilities and critical assets are available on-time when needed and will continue to be available in the future to support the missions that require them.

4.2.6: Demolish or eliminate obsolete/unneeded facilities to reduce the Agency's infrastructure footprint.

Annual reduction in square footage or number of facilities.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	100,000 sq ft or 20 facilities	471,000 sq ft or 20 facilities	100,000 sq ft or 20 facilities
Results	700,000 sq ft or 45 facilities		
Rating	Green		

Lead Organization: Office of Strategic Infrastructure (OSI)

FY 2022 Performance Progress

By eliminating inactive and obsolete facilities, we improve energy efficiency, reduce the Agency's footprint, eliminate safety and environmental lia¬bilities, and make room for new construction that fits NASA's current and future needs. During FY 2022, we also eliminated $28.1 million of deferred maintenance and avoided $11.5 million in maintenance and operations costs. In addition, we reduced the current replacement value by $304.6 million. In turn, this Performance Goal received a Green rating.

4.2.7: Improve NASA's ability to operate facilities sustainably and reduce overall resource demands.

Percentage of sustainability goals met annually in the OMB Scorecard for Efficient Federal Operations/Management*.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	80%	100% with no red ratings**	100% with no red ratings**
Results	71%		
Rating	Yellow		

*A fiscal year's OMB Scorecard for Efficient Federal Operations/Management is released more than 6 months after the close of that fiscal year. Therefore, NASA will use the previous fiscal year's results to assess progress.
**Target represents the long-term exemplar for this Performance Goal. NASA assesses annual progress based on an interim target of 80% for both FY 2023 and FY 2024.

Lead Organization: Office of Strategic Infrastructure (OSI)

FY 2022 Performance Progress

The Office of Management and Budget released NASA's FY 2021 Scorecard for Efficient Federal Operations/Management during the third quarter of FY 2022. We received five Green ratings and two Yellow ratings for the seven categories: facility energy efficiency; water efficiency; renewable energy use; efficiency measures/investment; high-performance sustainable buildings; transportation/fleet management; and sustainable acquisition. This result—71 percent Green with no Red ratings—falls short of the annual target.

NASA received a Yellow rating in Facility Energy Efficiency due to missing the year-over-year reduction goal. However, NASA has significantly exceeded the overall energy intensity reduction goal of 30 percent from the FY 2003 baseline.

NASA received a Yellow rating for Efficiency Measures/Investment because several of our Centers did not complete the required energy and water comprehensive evaluations. Several factors contributed to this, including COVID impacts, funding constraints, and project delays. NASA did meet the second part of metric to implement new energy savings performance contracts each fiscal year.

4.2.8: Demonstrate increased facility reliability for current and future mission needs through investments in preventative maintenance that reduce unscheduled maintenance.

Percentage of maintenance funds dedicated to unscheduled maintenance.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	<20%	<20%	<20%
Results	19%		
Rating	Green		

Lead Organization: Office of Strategic Infrastructure (OSI)

FY 2022 Performance Progress

NASA achieved a ratio of 19.04 percent unscheduled to total maintenance costs for FY 2022, below the annual target of 20 percent, leading to a Green Performance Goal rating.

NASA performs scheduled maintenance on its equipment to keep it in good operating condition. When equipment fails, we must perform unscheduled maintenance to repair it. The percentage of unscheduled maintenance spending to total maintenance spending is an indicator of the overall condition of the equipment. More unscheduled maintenance indicates that the equipment has become unreliable and unplanned failures and outages become more frequent, which can delay mission activities, such as manufacturing and testing. We have deployed tiered maintenance and condition-based maintenance processes across the Agency, which is helping to reduce unplanned downtime and equipment failures.

Strategic Objective 4.3

Build the next generation of explorers.

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

GOAL LEADER
Kris Brown, Deputy Associate Administrator for Strategy and Integration, OSTEM

Budget		
	FY	$M
Op Plan	2022	$145.6
Enacted	2023	$152.2
Requested	2024	$166.9
Outyear	2025	$170.3
	2026	$173.7
	2027	$177.2
	2028	$180.8

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.

We have implemented strategies to broaden student participation to increase diversity, equity,

Below: NASA Administrator Bill Nelson, right, meets with members of the Christine Darden youth chapter of the National Society of Black Engineers during a visit to NASA Langley Feb. 24. Image Credits: NASA Images

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. 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.

NASA was able to support students' STEM skills by supporting the release of 3,413 peer-reviewed publications, papers, and presentations beating the target of 1,800 for FY 2022. We were also able to exceed the target for two categories of student diversity for NASA STEM enrollees for virtual and in-person engagement activities. NASA was able to attract diverse groups of students to engage in authentic STEM learning experiences by piloting an online community of practice facilitating collaboration with NASA and next generation explorers.

To meet the target for diversity, equity, inclusion, and accessibility (DEIA) equal opportunity, NASA provided outreach relating to civil rights and DEIA. We sent a notice to all grantee institutions as a reminder of their obligation to notify us when they act resulting from harassment allegations against a principal investigator or co-investigator on a NASA-funded project. In September 2022, NASA hosted an Equity Action Plan Stakeholder Town Hall event for representatives of equity-focused organizations to discuss NASA's accomplishments and planned actions under the 2022 NASA Equity Action Plan. For FY 2022, NASA determined that Strategic Objective 4.3 demonstrated Satisfactory performance for meeting and exceeding Performance Goal targets.

Above: NASA Administrator Bill Nelson introduces NASA's SpaceX Crew-2 NASA astronauts Shane Kimbrough and Megan McArthur, and Japan Aerospace Exploration Agency (JAXA) astronaut Akihiko Hoshide, during a visit to Arlington Science Focus Elementary School, Friday, June 10, 2022, in Arlington, Virginia. Image Credit: NASA Images

4.3.1: Create unique opportunities for a diverse set of students to contribute to NASA's work in exploration and discovery.

Number of paper presentations and peer-reviewed research publications resulting from STEM engagement investments focused on advancing higher education students' STEM skills.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	1,800	2,000	TBD
Results	3,413		
Rating	Green		

Performance activities for FY 2023

1. Advance higher education students' STEM skills by supporting the release of at least 2000 paper presentations and peer-reviewed research publications through STEM engagement investments.

Performance activities for FY 2024

1. Advance higher education students' STEM skills by supporting the release of at least TBD* paper presentations and peer-reviewed research publications through STEM engagement investments.

Lead Organization: Office of STEM Engagement (OSTEM)

FY 2022 Performance Progress

NASA met the target for Performance Goal 4.3.1. resulting in a Green rating. Results indicate that we achieved this performance goal with a reported total of 3,413 peer-reviewed publications, technical papers, and presentations, exceeding target of 1,800.

Our performance in providing opportunities for students to contribute to our aeronautics, space, and science missions and work was assessed across peer-reviewed publications, non-peer-reviewed technical publications, and invited and self-submitted paper presentations directly resulting from research funded by NASA STEM Engagement grants and awards to higher education institutions.

As a direct result of NASA STEM Engagement investments, Space Grant and Minority University Research and Education Project (MUREP) grantee and awardee institutions published and submitted 841 peer-reviewed papers, published or presented 655 technical papers, and delivered 1,917 invited or self-submitted paper presentations. Notably, 49 percent of the peer-reviewed publications were authored or co-authored by students. Additionally, 28 patents and technology transfers were awarded to higher education institutions as a direct result of their NASA STEM Engagement grants or cooperative agreements.

4.3.2: Build a diverse future STEM workforce by engaging students in authentic learning experiences with NASA's people, content, and facilities.

Meet or exceed target for student diversity for NASA STEM enrollees for both virtual and in-person higher education engagement activities: (1) students across all institutional categories and levels (as defined by the U.S. Department of Education) (2) racially or ethnically underrepresented students, (3) women, and (4) persons with disabilities, at percentages that meet or exceed the national percentages for these populations, as determined by the most recent, publicly available data from the U.S. Department of Education's National Center for Education Statistics.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target (categories)	Meet or exceed at least 2 of 4 categories	Meet or exceed at least 2 of 4 categories	Meet or exceed at least 2 of 4 categories
Results (categories)	3		
Rating	Green		

Performance activities for FY 2023

1. Meet or exceed targets for higher education significant awards** in two of four categories of student diversity for NASA STEM enrollees for both virtual and in-person higher education engagement activities:
   - Meet or exceed 7.6% of student diversity for racially underrepresented students (African Americans, American Indians, Alaska Native, Native Hawaiians and Pacific Islanders)***
   - Meet or exceed 15.9% of student diversity for ethnically underrepresented students (Hispanics and Latinos)***
   - Meet or exceed 44.1% of student diversity for women***
   - Engage students across all institutional categories and levels (as defined by the U.S. Department of Education)
     - 2- and 4-year non-MSI (Minority Serving Institution) HEIs (Higher Education Institutions)
     - 2- and 4-year MSIs (Minority Serving Institutions)
       - Historically Black Colleges and Universities (HBCUs)
       - Hispanic-Serving Institutions (HSIs)
       - Tribal Colleges and Universities (TCUs)
       - Asian American and Pacific Islander Serving Institutions (AAPISIs)
       - Alaska Native and Native Hawaiian Serving Institutions (ANNHs)
       - Native American-Serving Non-Tribal Institutions (NASNTIs)
       - Predominantly Black Institutions (PBIs)

Performance activities for FY 2024

1. Meet or exceed targets for higher education significant awards** in two of four categories of student diversity for NASA STEM enrollees for both virtual and in-person higher education engagement activities:
   - Meet or exceed 7.6% of student diversity for racially underrepresented students (African Americans, American Indians, Alaska Native, Native Hawaiians and Pacific Islanders)***
   - Meet or exceed 15.9% of student diversity for ethnically underrepresented students (Hispanics and Latinos)***
   - Meet or exceed 44.1% of student diversity for women***
   - Engage students across all institutional categories and levels (as defined by the U.S. Department of Education)
     - 2- and 4-year non-MSI (Minority Serving Institution) HEIs (Higher Education Institutions)
     - 2- and 4-year MSIs (Minority Serving Institutions)
       - Historically Black Colleges and Universities (HBCUs)
       - Hispanic-Serving Institutions (HSIs)
       - Tribal Colleges and Universities (TCUs)
       - Asian American and Pacific I slander Serving Institutions (AAPISIs)
       - Alaska Native and Native Hawaiian Serving Institutions (ANNHs)
       - Native American-Serving Non-Tribal Institutions (NASNTIs)
       - Predominantly Black Institutions (PBIs)

* NASA rates this performance goal using data reported on the academic calendar. The FY 2023 rating is based on data from the 2021-2022 academic calendar.

**Higher education significant awards are made through the National Space Grant College and Fellowship Project, Minority University Research and Education Project, Internship and Fellowship programs, and Mission Directorates (funded internships).

***Categories are based on national categories used by the U.S. Department of Education's Center for Education Statistics Integrated Postsecondary Education Database.

****NASA rates this performance goal using data reported on the academic calendar. The FY 2024 rating is based on data from the 2022-2023 academic calendar.

Lead Organization: Office of STEM Engagement (OSTEM)

FY 2022 Performance Progress

NASA met the target for Performance Goal 4.3.2. NASA achieved this performance goal by exceeding national averages in three of four diversity categories in providing significant higher education awards, such as internships and fellowships, for the 2020–2021 academic year, resulting in a Green rating.

FY 2021 data indicate NASA provided 8,764 internships, fellowships, scholarships, and other sustained engagement opportunities (e.g., engineering design challenges, competitions) to 8,006 higher education participants representing 2-year and 4-year institutions and all Minority Serving Institution classifications (Asian American and Native American Pacific Islander-Serving Institutions, Alaskan Native-Serving and Native Hawaiian-Serving Institutions, Historically Black Colleges and Universities, Hispanic-Serving Institutions, Native American-Serving Nontribal Institutions, Predominantly Black Institutions, Predominantly White Institutions, and Tribal Colleges and Universities). These significant awards provided a total of over $40M in direct financial support to higher education participants.

In these opportunities, 17.1 percent of participants identified as racially underrepresented and 19.8 percent of participants identified as ethnically underrepresented . Also, 43.7 percent of the Agency's higher education internships and fellowship positions were filled by women. All three underrepresented statistics (i.e., race, ethnicity, and gender) exceeded the national averages for underrepresented students enrolled in STEM degree programs, as defined by the U.S. Department of Education, National Center for Educational Statistics.

4.3.3: Attract diverse groups of students to STEM through learning opportunities that spark interest and provide connections to NASA's mission and work.

Complete all annual evidence-building activities in support of Performance Goal 4.3.3.

*Annual performance activities are based on findings from the Internship Outcome Assessment Year 2 Study, which (among several areas) addressed how NASA can continue to broaden participation of students from historically underrepresented groups in STEM fields. An area of evaluation included the insights that mentors provide on the intern program.

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	2	1	1
Results	2		
Rating	Green		

Performance activities for FY 2022

1. Develop and pilot strategies and/or systems to improve access, navigability, and usability of NASA STEM Engagement K-12 products and learning opportunities (including the Office of STEM Engagement's Next Gen STEM project and Mission Directorate K-12 activities) aimed at attracting diverse groups of students to STEM.
2. Conduct external K-12 stakeholder needs assessment and gap analysis.

Performance activities for FY 2023

Establish a baseline for:

1. Demographics of educators by completing an assessment of STEM Engagement Educator Community of Practice.

Performance activities for FY 2024

1. Increase diversity of educators registered in NASA STEM Engagement Community of Practice by TBD%.

Lead Organization: Office of STEM Engagement (OSTEM)

FY 2022 Performance Progress

NASA met the target for Performance Goal 4.3.3. Results indicate NASA has achieved this performance goal by completing the FY 2022 milestones, resulting in a Green rating. The NASA OSTEM Next Gen STEM (NGS) project piloted an online community of practice, Connecting Our NASA Network of Educators for Collaborating Together in STEM (CONNECTS), which facilitates synchronous and asynchronous collaboration among educators and NASA to inspire the next generation of explorers through authentic STEM learning experiences. The online platform provides registered members access to engagement events, networking opportunities, resources (e.g., lesson plans and interactive media), and activities from both the OSTEM's Next Gen STEM project and NASA Mission Directorates. CONNECTS allows educators to ask questions and share lessons learned to improve access, navigability, and usability of NASA STEM Engagement K-12 products and learning opportunities aimed at attracting diverse groups of students to STEM. As of September 2022, CONNECTS reached 713 educators in the community of practice.

4.3.4: Promote equal opportunity compliance and encourage best practices among NASA grant recipient institutions to ensure that grantees are providing equal opportunity regardless of race, color, national origin, sex (including pregnancy, sexual orientation, gender identity), age, or disability.

Percentage of NASA civil rights recommendations or corrective actions that have been implemented within 1 year by the grant recipient institution.*

	Execution	Planned	
Fiscal Year	FY 2022	FY 2023	FY 2024
Target	100%	100%	100%
Results	100%		
Rating	Green		

*NASA reviews 2-3 grant recipient institutions annually (through on-site and desk audits), issuing recommendations and/or corrective actions where needed, to ensure compliance with equal opportunity laws and mandates.

Lead Organization: Office of STEM Engagement (OSTEM)

FY 2022 Performance Progress

To help build a diverse future STEM workforce, NASA conducts compliance reviews under Title IX of the Education Amendments to ensure NASA-funded educational programs are free of discrimination based on sex. NASA also conducts compliance reviews of NASA-funded educational and other programs under Title VI of the Civil Rights Act and under Section 504 of the Rehabilitation Act to ensure NASA-funded programs are free of discrimination based on disability, race, color, or national origin, and to ensure these programs are accessible to individuals with disabilities and to individuals with limited English proficiency.

During FY 2022, NASA completed Title IX compliance reviews of two educational institutions and initiated Title IX compliance reviews of two additional educational institutions. NASA also conducted a Title VI and Section 504 compliance review of an informal learning institution. Each of the completed Title IX compliance reviews identified a deficiency in need of corrective action. NASA also made recommendations to the two institutions on the implementation of a best practice to help ensure diversity in the faculty recruitment process. We are working cooperatively with these institutions to implement the needed corrective actions.

Throughout 2022, NASA provided outreach relating to civil rights and diversity, equity, inclusion, and accessibility (DEIA). NASA sent a notice to all grantee institutions as a reminder of their obligation to notify NASA when they take action resulting from harassment allegations against a principal investigator or co-investigator on a NASA-funded project. In September 2022, NASA hosted an Equity Action Plan Stakeholder Town Hall event for representatives of equity-focused organizations to discuss NASA's accomplishments and planned actions under the 2022 NASA Equity Action Plan. At the Office of STEM Engagement's Better Together 2022 conference (held in November), we provided civil rights and DEIA best practices to STEM education stakeholders. In turn, this Performance Goal received a Green rating.

Above: The NEA Scout and Lunar IceCube secondary payloads are the first to be installed in the Space Launch System (SLS) rocket's Orion stage adapter for the Artemis I mission on July 14 at NASA's Kennedy Space Center in Florida. Image Credit: NASA Images

Appendix

FY 2024 Annual Evaluation Plan

Annual Evaluation Plan

NASA's FY 2024 Annual Evaluation Plan

The Foundations for Evidence-Based Policymaking Act of 2018 (Evidence Act) Title I reinforces and supports Federal evidence-building activities, the Open, Public, Electronic, and Necessary Government Data Act, and the Confidential Information Protection and Statistical Efficiency Act. Title I of the Evidence Act requires CFO-Act Agencies to publish an Annual Evaluation Plan (AEP) that conveys significant evaluations across the Agency each fiscal year, developed in coordination with the Annual Performance Plan. The AEP establishes and informs NASA's key stakeholders about planned evaluations. Evaluations will uncover findings that will inform NASA program budgets, the Strategic Plan and Learning Agenda, annual Strategic Review, ongoing program management and development, and integrate evidence into the performance planning process.

Evaluation Standards

NASA relies on a culture of evidence-based, data-driven research designs and methodologies to evaluate its programs, policies, and organizations across the agency. Evaluation, as defined by the Evidence Act, is an assessment using systematic data collection and analysis of one or more programs, policies, or organizations intended to assess their effectiveness and efficiency. The AEP details only those NASA evaluations that meet the Agency's definition of "significant" evaluations (see Figure 1 below). Led by NASA's Evaluation Officer, in conjunction with the Statistical Officer and Chief Data Officer, five standards guide NASA's evaluation culture: rigor, relevance and utility, independence and objectivity, transparency, and ethics. These standards, in addition to the criteria established for significant evaluations are the foundation that NASA uses to support its array of evaluation activities.

Above: NASA astronaut Stephanie Wilson poses for a portrait, September 16, 2020, in the Blue Flight Control Room at NASA's Johnson Space Center in Houston, Texas. Image Credit: Bill Ingalls/NASA Images

Purpose

The AEP identifies planned significant evaluations from across the Agency. It serves as a means to inform Agency senior officials and the public where the most significant evaluations are conducted, cultivate data sharing and resources between NASA organizations, and provide information to help support the Agency's evidence-driven culture.

Dissemination and Sharing

NASA has long been committed to disseminating and sharing results from its evidence-building activities with the greater scientific community and, when permissible, making this information broadly available to the public. As detailed in NASA Procedural Requirement (NPR) 2200.2D – Requirements for Documentation, Approval and Dissemination of Scientific and Technical Information, the Agency strives for the widest practicable and appropriate dissemination of information concerning its activities and scientific and technical information. NASA will leverage this framework in sharing findings from its significant evaluations.

The Agency's dissemination framework includes an array of symposium presentations, peer reviewed journal publications, and NASA internal and external council discussions. Agency evaluations that provide promising and effective findings are systematically and broadly disseminated to potential beneficiaries and to federal agency partners. Criteria and requirements for the dissemination of symposia lectures and papers, in addition to journal materials beyond the Agency, are detailed in Chapter 5 of NPR 2200.2D to ensure proper review of substantive content, technical accuracy, overall quality, and value to the larger scientific community. The Evaluation Officer, as well as Mission Directorate Associate Administrators and Center Directors, have responsibility for the technical, scientific, and programmatic accuracy of information released externally from the Agency by their respective programs.

While NASA maintains a free exchange of scientific and technological information among scientists and engineers, between NASA staff and the scientific community, and between NASA employees and the public, the AEP is a formal dissemination of significant evaluations. Table 1, below, depicts broad evaluation dissemination methods by stakeholder groups and the formats used to share significant evaluations.

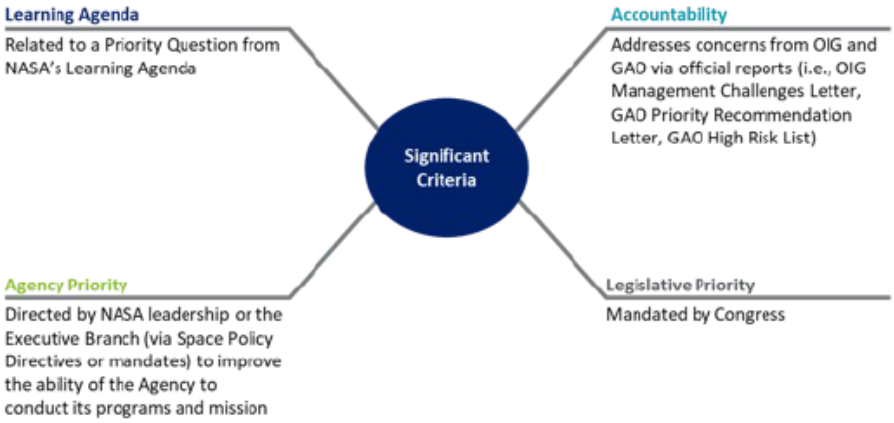
Table 1. Dissemination and Sharing Summary

Stakeholder Group	Dissemination Channel
NASA Senior Officials	Council meetings, Conferences, Reports
Centers and Mission Directorates Leadership	Conferences, Webinars, Performance Reviews
Internal Councils and Symposia	Reports, Briefings, Conferences
External Councils, NASA Advisory Council (NAC)	Conferences, Webinars
Congress	Committee hearings, Briefings
Office of Management and Budget (OMB)	Budget Submission and Reviews, Council Meetings
Public, National Academies	Press releases, Webinars, NAC meetings, Conferences

NASA's Criteria for Defining "Significant" Evaluations

NASA has an extensive evidence culture that leverages the findings from the numerous evaluations performed across the Agency to make evidence-based decisions that support NASA's mission, foster a culture of evaluation, and promote better value for the public. While the Agency considers every evaluation important, some rise to the level to influence policy and program decisions. To determine these significant evaluations, NASA has formulated criteria in accordance with the Evidence Act. These criteria identify NASA's most significant evaluations and include those that fit one or more of the criteria illustrated in Figure 1.

Figure 1. Criteria for NASA's Significant Evaluations



FY 2024 Significant Evaluations

Minorities and Women in GS-14 and Higher Positions

NASA is committed to attracting and retaining a diverse workforce. In order to do this, NASA works to ensure equal opportunity in all aspects of its human capital management, including recruitment, hiring, promotions, awards, etc. The agency monitors its workforce composition data to determine if discrepancies exist in the employment of any demographic group as compared to the National Civilian Labor Force (NCLF) benchmarks. NASA's workforce is highly specialized, as two-thirds of NASA employees are in Science and Engineering occupations. As such, NASA also uses the Federal STEM workforce population for employment demographic comparisons.

NASA regularly conducts trigger analyses of its workforce. A "trigger" is defined as "a trend, disparity, or anomaly that suggests the need for further inquiry into a particular policy, practice, procedure, or condition" to determine if there are barriers to equal employment opportunity (EEO). Accordingly, a low participation rate for any group (in relation to a benchmark) is a "trigger." In other words, low participation (or representation) of a group in certain occupations, or among employees receiving promotions, awards, etc., may indicate that there is an agency policy or practice that limits the full participation of that group. A trigger does not by itself demonstrate a barrier to EEO; it indicates an area to be monitored or further analyzed.

In performing these trigger analyses, NASA discovered a downward trend in the percentage of minorities and women between grades GS-13 and GS-15. In addition, Hispanics, Asian Americans, and Pacific Islanders (AAPI), and Women are underrepresented in SES positions compared to their overall representation in the NASA workforce. Therefore, the Agency is undertaking a barrier analysis in FY 2024-FY 2025 to further explore potential underlying causes of these discrepancies in order to determine the root causes. NASA will utilize the insights obtained through this barrier analysis to formulate equitable workforce policies.

Theory of Change

If NASA can better understand any recurring barriers facing minorities and women when striving for promotions and new hires from GS-13 and above, then NASA may be able to formulate workforce and hiring policies that are more equitable, which will hopefully increase the diversity of individuals in senior civil servant roles.

Evaluation Question(s)

The following evaluation questions may guide the approach and design of this barrier analysis:

1. Do agency responses from FEVS questions or Employee Engagement, Satisfaction, and Inclusion indices indicate negative responses to questions regarding promotion practices? Does this vary between groups?

2. Do hiring officials include supplementary qualifications for positions, in addition to those recommended by OPM?
3. Are promotion and new hire outcomes aligned with the percentages of qualified applicants?
4. Do outcomes differ for minorities and women who are promoted into higher GS grades versus newly hired?
5. How do demographic percentages in the workforce align with Civilian Labor Force and Relevant Civilian Labor Force data?
6. How do demographic percentages in the applicant pool align with Civilian Labor Force and Relevant Civilian Labor Force data?
7. Do promotion rates show gender, race, or ethnicity differences?

Methods to be used and Evaluation Design

NASA will use a multiphase barrier analysis process to systematically assess representation in the higher grades. Phase 1 examines general representation of demographic groups by grade categories. Phases 2 and 3 examine existing personnel data, such as data on losses and hires, to further explore the factors that may be contributing to any discrepancies discovered in Phase 1. At Phase 4, NASA will deploy a systematic set of questions to gather more information about triggers uncovered in Phases 1-3. In Phases 5-6, the Agency will use qualitative and quantitative data collection techniques to obtain input from members of potentially affected demographic groups. Finally, at Phase 7, NASA will identify root causes of potential barriers and develop corrective actions.

Data and Information

The barrier analysis will focus NASA employees at grades GS-13 and above.

Source	Purpose
NASA Personnel Data Warehouse	Landscape of NASA current employment and applicants, broken down by race, gender, age, education, and position type to establish baselines.
NASA USA Staffing Data	Record of competitive promotions within the Agency, to map outcomes from competitive promotions.
Survey Results	Psychometric survey measures to further investigate, validate, and understand where barriers to equal employment opportunity might exist. Staff will distribute the survey to all NASA civil servant Physical Scientists and the data collected will be analyzed using quantitative inferential analytic techniques
Focus Group interviews	Qualitative feedback from impacted populations.
Federal Employee Viewpoint Survey (FEVS)	Employee Engagement, Global Satisfaction, New Inclusion Quotient
Publicly available information	National Civilian Labor Force (NCLF), Federal STEM Workforce

Challenges

Anticipated challenges include correlating statistical data regarding outcomes with everyday practices at the agency, obtaining sufficient sample sizes of minorities and women across various age and ethnic classifications for focus groups, designing questions to solicit honest, actionable feedback from focus group members, and distinguishing the impact of root causes internal to the agency from outside factors.

Dissemination Strategies

A final dissemination plan has not yet been approved. Initial considerations suggest a wide dissemination within NASA to all impacted programs, the Office of Human Capital Officer (OCHCO), the Office of Diversity and Equal Opportunity, and the Office of the NASA Administrator. There are various mechanisms through which these results will be shared including, but not limited to, agency-wide strategic planning, procedural documents, and the Agency's Equity Action Plan.

Timeframe

The timeframe for this evaluation is FY 2024-2025.

Technology Investment

NASA invests in innovative early stage technology concepts that could lead to future breakthrough capabilities and enable new paradigms or new mission types in the longer-term. Through its Learning Agenda, NASA is evaluating its strategy for investments in early stage innovation that helps enable these potential breakthroughs of tomorrow. Diversity is a key aspect of an early stage investment and partnership strategy, and was the focus of NASA's FY 2022 and FY 2023 Annual Evaluation Plans for this Priority Question. Those evaluation plans were designed to complement NASA's wider strategy of reaching underserved and underrepresented communities, through engagement with Historically Black Colleges and Universities (HBCU) and Minority Serving Institutions (MSI). Specifically, the results of those evaluations will help NASA facilitate increased HBCU/MSI participation in NASA early stage innovation research opportunities through Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and other NASA programs. We believe an expanded, more diverse innovation community will result in more novel ideas to seed tomorrow's space technology breakthroughs.

However, the work can't stop there. Once promising concepts have established feasibility through early stage investment, NASA should encourage and facilitate technology maturation wherever possible. The most promising innovations must transition to the next stages of development to ensure eventual implementation of technology breakthroughs. This challenge is not unique to NASA and technology transition is required to bridge the gaps between adjacent stages of development, requiring technology transition.

Building the bridges between early stage innovation and technology maturation (i.e., approximately Technology Readiness Level (TRL) 3) poses a unique challenge for technology development organizations. Early stage innovation often represents high-risk, high-reward investment, and by design, fewer concepts are expected to demonstrate the feasibility and potential impact required for technology transition. Nevertheless, there are often significant barriers to transition for early stage investments. For example, potential customers at early stages might be less obvious than for more mature technology development efforts, limiting transition opportunities. Similarly, even after successful completion of an early stage innovation project, there may be feasibility questions and other technology maturity concerns that temper the enthusiasm of potential transition partners. Thus, this evaluation for the FY 2024 Annual Evaluation Plan focuses on transition of promising early stage investments.

Since 2015, Space Technology Mission Directorate (STMD) has tracked transitions – conclusion of an investment where a technology is handed off for further development – as a measure of success. Through these efforts, we have identified hundreds of early stage transitions, including those eventually infused into space missions. STMD seeks to better understand previous experiences, through evidence-building activities, to facilitate even more opportunities for technology transition leading to breakthrough capabilities. It is worth noting that, through development of the STMD Strategic Framework and other efforts, we also continue to develop other potential measures of impact, both technical and socioeconomic. Technology transition, however, remains an important focus for NASA STMD and a significant indicator that NASA technology investments are helping to maintain American leadership in space technology.

To better facilitate technology transition, NASA STMD continues to assess current and potential mechanisms for technology transition at the program-, portfolio-, and MD-level. We consider technology transition mechanisms to be funded and unfunded approaches to facilitate the transition of a project across STMD programs, NASA directorates, or among industry, or other government agencies (OGA). We plan to leverage these efforts in the FY 2024 Annual Evaluation Plan for early stage investment.

There are several different potential mechanisms through which NASA can encourage and/or facilitate STMD technology transition within or beyond the Agency. For example:

- *Extension:* Advancement of promising technologies through funded project extensions, or phase advancement within a given program
- *Research Solicitation:* Competitive NASA R&D funding opportunities

- *Outside Opportunity Identification:* Proactive identification of potential funding opportunities beyond NASA, including, for example, other OGA research solicitations and venture capital investment opportunities
- *Informal Partnerships:* Relationships that assist the transition of a technology or provide additional funding opportunities
- *Formal Partnerships:* Formal partnership agreements, such as Space Act Agreements, etc.
- Programmatic Decisions: Internal decisions regarding the transition of a technology into another STMD program
- *Integration forums:* Opportunities that showcase the technologies, such as SBIR's Innovation & Opportunity Conference, NASA Innovative Advanced Concepts (NIAC) Symposium, and Space Technology Research Grants (STRG) Space Technology Research Institutes (STRI) Boards

Prior to FY 2024, STMD will continue efforts to characterize barriers to transition, identify potential transition mechanisms, assess policy and process, and improve transition tracking. One key example is an ongoing effort within the SBIR/STTR program. SBIR/STTR is conducting a deep analysis and evaluation of that program's transitions-related policy, process, and impact through a series of surveys and interviews, with the goal of implementing outcome-based program metrics and improving transition rates of SBIR projects. It is worth noting that NASA's technology transition strategy is not limited to Earth Science Information Partners (ESIP) programs. NASA is also exploring capture strategies within its technology maturation and demonstration portfolios, for early stage concepts that may address technology gaps. We will leverage the findings of all such transition efforts to inform the specific design of the 2024 impact evaluation.

Building on our efforts in FY 2022 and FY 2023, NASA will conduct an impact evaluation in FY 2024 to show potential to lower transition barriers for promising early stage innovation projects through proactive intervention. We propose a one-year pilot effort within the STMD ESIP portfolio through which ESIP program offices may nominate their most promising projects to receive deliberate transition facilitation.

These projects may include, for example, promising activities that met their study objectives but have now exhausted sponsor program pathways, OR projects that narrowly missed competitive continuation opportunities, but warrant additional study. Prior to final evaluation design, we will further assess transition barriers to inform the evaluation design, based on experience within STMD, NASA, and other organizations. We will assess and identify specific criteria for project inclusion in this evaluation. NASA will include technology maturation and demonstration program offices, as well as Principal Technologists and Systems Capability Leaders – NASA personnel cognizant of strategic technology gaps for which early stage innovation solutions may play a significant role – in the development of the evaluation design.

We will assess and select one or more options for proactive transition intervention in the FY 2024 impact evaluation. Possible interventions include, but are not limited to:

- Designated budget(s) to fund technology maturation seedling projects beyond the sponsoring program
- Funded extensions within the sponsoring program, with a focus on identifying transition partners
- Championing specific connections with relevant communities within STMD, across NASA, and potentially beyond the agency. For example, invitations to present at Space Mission Directorate (SMD) technology forums; invitations to attend Game Changing Development (GCD), Lunar Surface Innovation Consortium (LSIC), or other STMD-led events; invitations to visit relevant labs at NASA Centers.
- Increased exposure of the concept. For example, features in NASA agency-level social media and communications events, funded participation in relevant scientific/technical conferences and workshops, or training opportunities on product development and commercialization.

Once we have established the interventions to be explored in the evaluation, we will also establish measures of success to enable leadership decision to continue, expand, or modify intervention strategies beyond this evaluation plan. Success measurement of this evaluation plan may include, but is not limited to, project-specific milestones and/or recipient/transition partner surveys.

The FY 2024 evaluation will follow the guidelines set forth in this plan, but the specific design will evolve during FY 2023. The final scope will be informed by further assessment of transition barriers, criteria for

transition potential, and intervention methods, as well as assessment of available budget. Accordingly, the final evaluation design may represent either a small number of selected case studies or assessment of a larger portfolio of projects. Similarly, the tested interventions may range from informal (i.e., generally unfunded) activities to more formal (i.e., generally funded) transition opportunities.

Theory of Change

If NASA can better understand the challenges associated with the future bridges that span the technology gaps, identify promising early stage innovation concepts most in need of transition facilitation, and proactively implement effective transition interventions, then NASA will increase the probability of progressing breakthrough innovations through technology maturation, demonstration, and adoption, profoundly impacting U.S. aerospace capabilities and global leadership in space technology.

Evaluation Question(s)

The following potential evaluation questions may guide the approach of this impact evaluation:

1. What are some of the most promising early stage innovation concepts?
2. Which of those promising early stage innovation concepts are most in need of transition facilitation?
3. How can NASA successfully implement effective transition interventions?

Data and Information

This evaluation will leverage data and information collection across STMD, and where applicable, across NASA and beyond.

Source	Purpose
NASA TechPort and SPAR	Provide programmatic technical information on current and previous NASA space technology investments to better understand the STMD portfolio, existing technology transitions, and potential future transitions
NASA Strategic Framework/ Envisioned Futures	Serve as a reference for NASA space technology strategic outcomes, including potential early stage pathways for meeting future aerospace mission needs and providing desired socioeconomic benefits
NASA STARPort	Provide the connection between existing investments and strategic technology capability needs, enabling gap analysis that can inform effective transition strategies
Technology Maturation and Demonstration Program data and information	Provide coordination with transition efforts complementary to those in the ESIP portfolio. Ensure any findings or recommendations regarding the pull of early stage concepts into technology maturation and/or demonstration are considered on the evaluation design and implementation
2022 ESIP Performance and Accountability Report (PAR) Findings	Inform potential NASA transition strategies, leveraging the findings and recommendations from a recent independent assessment of STMD's Early Stage Innovation and Partnerships portfolio
Ongoing studies and assessments	Leverage existing transition-relevant studies within STMD, including those in individual programs such as SBIR/STTR
Other studies	Leverage information and lessons learned from relevant studies by other federal agencies and other organizations

Methods to be used and Evaluation Design

NASA will undertake an experimental design process evaluation to understand strategies to facilitate technology transition more effectively. This will be a mixed-method evaluation. Qualitative and quantitative

approaches may be used in the implementation study. The detailed design of the evaluation, identification of participating projects, transition interventions, success measurement, and finding and recommendation capture will be developed further in FY 2023. Currently, NASA plans to leverage external evaluation expertise where needed, (e.g., General Services Administration's (GSA) Office of Evaluation Services) to help ensure a robust and credible evaluation design.

Inputs	Criteria for identifying candidate technologies for transition facilitation
	Technology transition mechanisms to inform potential evaluation interventions
	Strategic needs and technology gaps best suited for early stage innovation solutions
	Complementary transition efforts beyond ESIP
Processes	Identification of candidate projects
	Identification of study intervention methods
	Development and application of success criteria and measures
	Implementation of deliberate formal and/or informal interventions
Expected outputs	Assessment of extensibility of results beyond the scope of the evaluation
	Recommended future policy to facilitate technology transition of ESIP concepts

Challenges

Measuring the effectiveness of specific strategies and approaches to early stage investment is particularly difficult, partly because of the long development times necessary to recognize the benefit and impact of early stage concepts. Accordingly, learning from successful case studies of transition can be incredibly useful, but can also require a decade or more to assess. The often complicated development path to ultimate implementation also makes it difficult to trace breakthroughs to originating research. In fact, successful technology development pathways are often non-contiguous and nonlinear. Thus, wherever possible, we plan to focus on nearer term proxy measures of effectiveness that are clearly traceable to the results of this evaluation.

Dissemination Strategies

The results will be shared broadly within NASA. This includes dissemination across all STMD programs and initiatives and across NASA mission directorates. These results could inform programmatic strategies to be considered by other technology programs and portfolios, as the applicability of the results may extend beyond transition of early stage innovation investments. Evaluation results may also benefit other agencies' efforts to enhance technology transition strategies.

Timeframe

The evaluation design will be finalized in FY 2023, and evaluation will occur by the end of FY 2024.

Commercial Low Earth Orbit Destination Crew Certification Requirements

One of NASA's strategic objectives is to develop a human spaceflight economy in Low-Earth Orbit (LEO) enabled by a commercial market. To achieve this objective, NASA is partnering with industry to develop future commercial LEO destinations (CLDs) from which NASA and other customers can purchase services and stimulate the growth of commercial human spaceflight activities.

Since the International Space Station's (ISS) inception, industry, academia, and our international partners have used the ISS as a testbed for research and the development and maturation of state-of-the art systems that increase access to space. As CLDs become available, we intend to implement an orderly transition from current ISS operations to these new CLDs. 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. NASA's investments will ensure access to a platform in LEO to continue U.S. human presence and expand the American foothold in space.

The purpose of this formative evaluation is for NASA to seek feedback from all interested parties on its draft *Commercial LEO Destination Crew Certification Requirements* and the *CLD Overall Service Summary* documents that discuss the assumptions NASA is considering with regards to the utilization of these CLD systems. The requirements and assumptions will eventually support NASA's purchase of contracted services. This evaluation will provide an opportunity for industry participants to provide feedback to NASA's approach to certification as well as an opportunity to challenge and clarify the assumptions presented in the aforementioned documents.

Theory of Change

If NASA can better understand the current commercial capabilities in low-earth orbit related to design, development, testing, and evaluation (DDT&E), then NASA will be able to develop a more informed and comprehensive acquisition strategy for the development of a sustainable commercial human spaceflight economy.

Evaluation Question(s)

The following evaluation questions may guide the approach and design of this evaluation:

1. How accurate are the assumptions within the *Commercial LEO Destination Crew Certification Requirements* and the *CLD Overall Service Summary* documents?
2. Are there other considerations NASA should contemplate within the *Commercial LEO Destination Crew Certification Requirements*?

Data and Information

NASA plans on releasing several Requests for Information to industry.

Source	Purpose
RFI responses	Input from private commercial industry regarding certification requirements for CLD

Methods to be used and Evaluation Design

Further evaluation design details are under discussion, with several options, techniques, and tools under consideration (i.e. focus groups, literature reviews, evidence summaries). This includes identification of feasible and relevant evaluation approaches to address the questions using the results of the RFI and potentially other data sources that will ultimately support this formative evaluation.

Challenges

Anticipated challenges include the willingness of RFI respondents to provide detailed explanations of elements within the *Commercial LEO Destination Crew Certification Requirements* and the *CLD Overall Service Summary* documents. Conversely, NASA could receive a large number of respondents thus making the task of reviewing all responses extremely burdensome.

Dissemination Strategies

NASA reserves the right to share all information received in response to this evaluation within the CLD Program and other NASA program stakeholders, and to use all information submitted in response to this evaluation in the formulation of the final *Commercial LEO Destination Crew Certification Requirements* as well as other technical documentation.

Timeframe

Several Requests for Information will be released to industry, culminating with the final Commercial LEO Destination Crew Certification Requirements that will likely be finalized in FY24.

Industrial Base

NASA and the Department of Commerce's (DOC) Bureau of Industry and Security (BIS), National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), will conduct an evaluation of the factors that drive efficiency in the NASA and United States civil space supply chain network.

This multi-year collaboration will build upon a substantial record of space sector analysis conducted between BIS, NASA and the broader U.S. Government (USG) to identify traits that benefit or impede the current health and competitiveness of the civil segment of the U.S. Space Industrial Base (SIB). Early findings will also inform the planning and execution of the civil space provisions of the 2020 National Space Policy (NSP). NASA and DOC (NOAA) seek visibility into the current and prospective performance of the civil space community to achieve enhanced situational awareness in times of uncertainty.

As NASA and interagency partners develop the civil space industrial base survey, a variety of evidence-building activities will impact the Agency. For example, if survey responses from firms in the sector lead analysts to identify gaps, shortages or pending issues in our supply chain, then we will propose measures to mitigate potential problems and adjust our acquisition strategy to improve Agency risk posture and cost/schedule for missions. Furthermore, survey responses from firms in the sector are expected to help illuminate the impacts of COVID-19, mergers and acquisitions (M&A), disruptive technology, changing workforce dynamics and other supply chain issues.

Theory of Change

If NASA can better understand the civil space industrial base and supply chain, then NASA may be able to better forecast pressures, anticipate risks, and mitigate against issues that impact the aerospace supply chain to drive adaptability and enhance decision making.

Evaluation Question(s)

The following evaluation questions may guide the approach and design of this formative evaluation:

1. What are the traits that benefit the current health and competitiveness of the civil segment of the U.S. Space Industrial Base?
2. What are the traits that impeded the current health and competitiveness of the civil segment of the U.S. Space Industrial Base?
3. What impact has COVID-19 had on the U.S. Space Industrial Base?
4. What impact have mergers and acquisitions had on the U.S. Space Industrial Base?
5. What impact has disruptive technology had the U.S. Space Industrial Base?
6. What impact has changing workforce dynamics had on the U.S. Space Industrial Base?
7. What mitigation techniques can NASA and the USG implement to stabilize the U.S. Space Industrial Base in times of uncertainty?

Data and Information

The survey instrument is currently in work and has not been finalized. Preliminary sources of data are outlined below.

Source	Purpose
Survey responses	Accurate responses from the firms regarding corporate operations, structure, financials and tech development.
Publicly available information	Some publicly-traded firms file annual reports and 10-K filings, providing additional insight into the corporation.

Methods to be used and Evaluation Design

NASA will undertake a non-experimental formative evaluation design to analyze survey results, including a time series analysis of responses over the course of three observation years:

- FY 2021-2022: Survey development, testing, information sharing agreement established, and organization of mailing list and portal hosted by the Census Bureau
- FY 2023: Distribution of Wave 1 survey; survey analysis of roughly 500-750 completed survey responses in Wave 1 compiled, analyzed, briefed and shared; Distribution of Wave 2 survey
- FY 2024: Survey analysis and comparison of roughly ~1,000 completed survey responses in Wave 2 compiled, analyzed, briefed and shared.

Further evaluation design details are under discussion, with several options, techniques, and tools under consideration. Currently, the survey instrument is being finalized, submitted to OMB for Paperwork Reduction Act (PRA) review. The Census Bureau data portal is nearly completed. The survey is forecasted to be released in October 2022, with Wave 1 results expected in late 2022/early 2023.

Challenges

Anticipated challenges include willingness of survey respondents to provide detailed current and historical information regarding performance, financials and supply chain issues. Additional challenges include ability of analysts to evaluate large datasets and assess impacts to NASA and other space agencies.

Dissemination Strategies

A final dissemination plan has not yet been approved. Initial considerations suggest a wide dissemination within NASA to all impacted programs, the broader U.S. civil space community, including primary space agencies and associated partners. In addition, a summary of findings is likely to be disseminated to relevant stakeholders including the Administration, Congress, industry, academia and the public.

Timeframe

The timeframe for this evaluation is FY 2021 – FY 2024.

NASA Communications Services Project: Analysis of Alternatives Evaluation

For years, the task of retrieving data collected from NASA probes throughout the solar system was handled by the Deep Space Network, Near Space Network, and Tracking and Data Relay Satellite (TDRS). Together, these systems have been wholly owned and operated by NASA's Space Communications and Navigation (SCaN) program office. However, the Communications Services Project (CSP) has been formulated to transition legacy SCaN services to robust, reliable, and cost effective commercially available communication and navigation services for near Earth missions by FY 2030.

In order to implement future commercial satellite communications (COMSATCOM) services for a complex organization such as NASA and its many user missions, NASA needs an efficient way to manage the service planning, acquisition, and coordination of communication and navigation services between future NASA user missions and COMSATCOM service providers. The CSP has identified NASA mission needs for COMSATCOM services and gathered information on commercial service provider capabilities.

The Agency is committed to selecting the best solution to meet its current and future needs for utilizing COMSATCOM services. However, there are many alternative service management solutions that can fit the requirements to meet mission service needs. Therefore, an evaluation will be conducted on these various alternatives in order to determine the most effective solution for the implementation of end-to-end COMSATCOM services for future NASA missions. This formative evaluation, also referred to as an Analysis of Alternatives (AoA), will drive the structure, contracting mechanisms, procurement strategy, and rollout of the CSP operations for near-Earth missions.

Theory of Change

If NASA can better understand the various alternatives that exist to implement COMSATCOM services, then the Agency will be able to implement an efficient, cost-effective solution to optimize its transition to a new deep-space communications architecture that can encourage the growth of American industry and fulfill mission needs.

Evaluation Question(s)

The following evaluation questions may guide the approach of this formative evaluation:

1. What is the most effective approach to transition NASA missions to commercial services by FY 2030 or sooner?
2. How should the service acquisition roadmap be structured based on responses from industry?
3. What is the best division of roles and responsibilities between NASA and its private partners?
4. What contracting mechanism is best for the required service management activities?
5. What specifications are required for service capabilities, interfaces, and security?
6. Are there additional alternatives that have not yet been identified by the CSP?

Data and Information

This evaluation will use both quantitative and qualitative methods to analyze survey data.

Source	Purpose
Commercial Development and Demonstration Responses	Responses from the commercial providers regarding their current and upcoming capabilities will inform the development of alternative methods of contracting and service management.
Cost lifecycle data from different sources	Costs from analogous programs will be used for Rough Order of Magnitude (ROM) estimation of operations and maintenance costs. These costs include personnel, equipment, software, contractor, etc.
Goddard Space Flight Center Request for Information	A survey of current best practices, service agreements, design information, and service metrics utilized by NASA's legacy space communications networks will be used as a baseline for formulating next generation architectures.
Trade Studies	Information will be gathered to determine the ability of each alternative to meet service management functions and to provide quality service to each Mission Operations Center (MOC).

Methods to be used and Evaluation Design

Figures of Merit (FOMs) are quantifiable metrics that will be utilized to assess and compare each alternative. Specifically, the information drawn from NASA and commercial partners has been utilized to create Key Performance Parameters (KPPs), Measures of Effectiveness (MOEs), and Measures of Performance (MOPs). Collectively, these form several Performance Measures (PMs) that can qualitatively describe the efficacy of each alternative model, as well as drive improvements to the alternatives themselves.

The following high-Level service management MOEs will be utilized for this evaluation:

MOEs	Definition
Ease of Operations	Simplicity to set up and operate, degree of automation, level of standards and seamless interoperability
Ease of Management	Complexity of management of the option
Quality of Service to Customers	Satisfaction of customers with the services provided, addresses reliability of services
Agility	• The capability to quickly sense and respond to new events, innovations, and manage evolution changes • Ability to adopt to new technologies for service management • Ability to quickly respond to and recover from non-nominal events
Consistency	The achievement of a level of performance that does not vary greatly in quality over time (robustness and reliability)
Security	Level of security trust, degree of compliance
Cost	Price to implement and operate the option

Challenges

Anticipated challenges include gathering the needed information on commercial partner approaches to service management. Gaps in necessary information may remain, and it is possible that commercial partners may not make information available until after the AoA kickoff. Furthermore, Rough Order of Magnitude (ROM) estimations may be constrained by the availability of some cost information due to the Commercial Development and Demonstration schedule, gaps in data from analogous NASA programs, or a lack of publicly available supplemental information.

Dissemination Strategies

A final dissemination plan has not yet been approved. However, because the results of this AoA will form the foundations of NASA's procurement strategy, the results of the evaluation will only be shared with offices and individuals involved with the procurement of these COMSATCOM services.

Timeframe

This evaluation will be completed by the 2nd quarter of FY 2024.

Internship Process Evaluation

The purpose of the Internship Process Evaluation is to understand the pool of individuals who participate in the NASA STEM Internship process and generate insights regarding proportions of applicants in different participation categories and how the process used may facilitate or pose barriers for more equitable distributions within each category of participation. This process evaluation shifts the focus from previous years' Internships Outcome Assessments from understanding the diversity and experiences of selected interns (i.e., program outcomes) to understanding the diversity and experiences of those interested in NASA Internships (i.e., program process). The FY 2022 and 2023 Internship Outcomes Assessment showed that NASA Internships hold great potential in supporting participants' STEM knowledge, identity, and persistence; however, little is known about barriers to the process of becoming a NASA intern. Past investigations of Pathways Internships (Datta & Kincaid, 2022) indicated that while many potential applicants viewed internship opportunities, less than 1% made it through the process from viewing opportunities to being hired into an internship. Statistics such as these indicate the need for an investigation into the efficacy of the process used by those interested in applying for a NASA Internship. Additionally, the levels of diversity within each category must be investigated to not only determine whether the application process poses barriers, but indeed whether barriers are more substantial for some diverse groups of potential applicants.

Theory of Change

If NASA increases the number of interns from underrepresented and underserved communities who apply to and are accepted for a NASA internship, there will be an increase in contributions to NASA's work from diverse viewpoints and lead to full time employment that will strengthen the potential for a more diverse future workforce.

Evaluation question(s)

The following evaluation questions may guide the approach and design of this outcome assessment:

1. What data are collected from the internship Registrants, Applicants, Participants, and Those Who Declined Offers (see Table 1)?
2. What patterns emerge about Registrants, Applicants, Participants, and Those Who Declined Offers in the FY 2022* NASA fall, spring, and summer cohorts?
3. What facilitators and barriers are evidence in the NASA STEM Internship application process?

Table 1. Key Terms

Categories	Definitions
Registrants	Individuals who may have started an application, but it was not submitted
Applicants	Individuals who completed a Gateway profile and submitted an application
Participants	Individuals who accepted offer letters and participated in a NASA STEM Internship
Those Who Declined Offers	Individuals who received offer letters, but declined the offer

*Data utilized for this evaluation is based on data from the 2021-2022 academic calendar.

Data and information

Source	Purpose
NASA STEM Gateway Universal Registration and Application Data	The NASA STEM Gateway Universal Registration and Application system collects data from Registrants, Applicants, Participants, and Those Who Declined Offers. Data collected during FY22 from the system will be quantitively analyzed. This will include demographic information, NASA site affiliation, and application status.
Interviews with NASA STEM Internships applicants	Interviews will be conducted with a sample of NASA STEM Internship Applicants, Registrants, Participants, and those who did not accept an internship to provide insight about facilitators and barriers within the application process. This process will be completed under the guidelines of the Paperwork Reduction Act.

Methods to be used and Evaluation Design

This process evaluation will apply a complementarity mixed methods approach to obtain quantitative demographic data and qualitative interview data to understand the process (Greene et al., 1989; Palinkas et al., 2019) of the Internship application process. The quantitative phase will analyze demographic data from the NASA STEM Gateway to identify the characteristics of Registrants, Applicants, Participants, and those who declined offers. In the qualitative phase, semi-structured interviews will identify elements within the NASA STEM Internship application process that pose as facilitators and barriers.

This evaluation study will use two modes of data collection: 1) descriptive quantitative data and 2) interviews. Quantitative data will be collected through the NASA STEM Gateway using data collected during FY22, including demographic information, NASA site affiliation, and application status. Interviews will be conducted with a sample of NASA STEM Internship Applicants, Registrants, Participants, and those who did not accept an internship to provide insight about facilitators and barriers within the application process. This process will be completed under the guidelines of the Paperwork Reduction Act.

Challenges

We strive to execute a utilization-focused evaluation that provides data that is useful for continual programmatic improvement and evidence-based decision-making. Thus, we anticipate challenges related to the practical trade-offs that must be considered in less than ideal, or "real world" contexts. The table below identifies three common evaluation challenges for utilization-focused evaluation and corresponding pragmatic principles that are relevant to this study (Patton, 2015).

Table 2. Challenges of utilization-focused evaluation (Excerpt from Patton, 2015, p. 156)

Evaluation Challenge	Pragmatic Principle
1. Providing the best possible data in time to affect decisions.	Providing less than perfect data that is available on time to affect decision is better than using more perfect data that is available after decisions have been taken.
2. Providing methodologically rigorous data on important questions.	The meaning of "rigor" depends on context. Rigor includes not just validity and accuracy but whether the findings are actionable and useful.
3. Providing comprehensive findings.	Timeliness trumps comprehensiveness. Less is more when the evaluation can cut to the chase and focus on what is most useful.

Additionally, to ensure a high-quality evaluation is conducted, we have used the program evaluation standards for evaluator credibility (U1 Evaluator Credibility) and conflicts of interest (P6 Conflicts of Interest) to assess the evaluator's potential bias. To address evaluator credibility, the independent contractor conducting the evaluation, has selected highly qualified, experienced program evaluators to design and conduct this study. The individuals selected to design and conduct this evaluation are independent from the policies, decision-making, operations, and/or implementation of the activities which are the subject of this investigation.

Table 3 lists the primary risks associated with the study and the management strategies that will be used to minimize these risks.

Table 3. Risk mitigation strategy

Potential Issues and Risk	Management Strategies
Schedule Slippage	A schedule of tasks and milestones will be created for the study. The schedule will be closely monitored by the evaluator and NASA. Any potential schedule slippage will be addressed.
Evaluator or Researcher Credibility	• This study will meet the Joint Committee on Standards for Educational Evaluation (JCSEE, 2011) Program Evaluation Standard U1: Evaluator Credibility – evaluations should be conducted by qualified people who establish and maintain credibility in evaluation context. • The Evaluators/Researchers are Ph.D.-credentialed staff with expertise in higher education STEM teaching and learning, education program evaluation, and education research. • The data collected during this investigation, data analysis, and findings will be reviewed by two experienced program evaluators.
Conflicts of Interest	• This study will meet the Joint Committee on Standards for Educational Evaluation (JCSEE, 2011) Program Evaluation Standard P6: evaluations should openly and honestly identify and address real or perceived conflicts of interests that may compromise the evaluation. • Potential conflicts of interest between the evaluator's (i.e. independent contractor) implementation and evaluation of NASA's STEM Engagement higher education activities will be openly discussed with NASA. Any perceived or real conflicts of interest will be minimized by the independence of the individuals conducting the evaluation from the policies, decision-making, operations, and/or implementation of the activities which are the subject of this investigation.

Dissemination strategies

The findings of this study will be summarized in an evaluation report. The report will be shared broadly among the NASA STEM Engagement community. The findings will also be presented at the OSTEM Performance and Evaluation Community of Practice, STEM Engagement Council meetings, and to the NASA Advisory Council.

Timeframe

This study will take place in FY 2023 – FY 2024.