



# NASA's Office of Technology, Policy, and Strategy

# A Year in Review

# 2024

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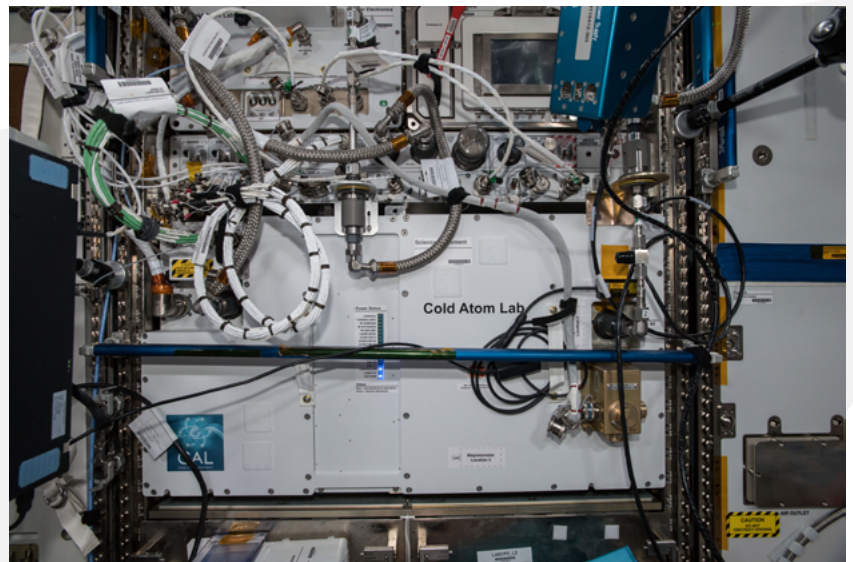




**Front and back image:** The first rays of an orbital sunrise illuminate Earth's atmosphere. (Credit: NASA)



**Front image:** Auroras move through Earth's atmosphere. (Credit: NASA)



**Front image:** Cold Atom Lab. (Credit: NASA)

# From Data to Decisions



## A Letter from Associate Administrator Charity Weeden

Over the years, NASA's Office of Technology, Policy, and Strategy (OTPS) and its predecessor organizations have carried out independent and objective analyses, assessments, and studies that have informed major decisions within the agency. The office has also supported agency leadership by coordinating and aligning strategies, evaluating multiple Moon to Mars architectures, providing economic insights, and emerging geopolitical issues.

This year at NASA, we at OTPS saw great bounds in scientific discovery, technological advances, exploration, and partnerships, benefiting all. What may be less well known are the numerous behind-the-scenes efforts laying the groundwork for future decisions, addressing our greatest challenges, and helping to unlock the unknown in our universe. This is where OTPS figures prominently, acting as a vital knowledge resource for NASA leadership.

Complex strategic decisions at the agency are established through three important factors: data, analyses, and collaboration. It is my privilege to lead OTPS, a team of diverse multidisciplinary experts who specialize in converting complex technology, economics, and policy considerations into pivotal insights that support key leadership decisions about NASA's future.

From an evolving space environment to a growing commercial space economy, OTPS aims to think ahead and look around corners in order to prepare decision-

International collaboration among the principals of the Artemis Accords signatory group during the International Astronautical Congress. (Credit: NASA)

*“It is my privilege to lead OTPS, a team of diverse multidisciplinary experts who specialize in converting complex technology, economics, and policy considerations into pivotal insights that support key leadership decisions about NASA's future.”*



## From Data to Decisions

makers for the toughest challenges facing NASA and humanity. We analyze these challenges, engage with the community, and communicate findings in the form of quick-turn analyses, memos, and reports backed by credible data.

In 2024, we proudly supported the release of NASA's Space Sustainability Strategy and provided the agency with new frameworks to shape future policy. We worked across the agency and with the U.S. government, academia, and industry to host public workshops in the areas of planetary defense, space economics, and trusted autonomy. We convened stakeholders from around the world to discuss lunar best practices and ethical behavior. We welcomed new ideas and encouraged critical thinking about topics central to the agency's mission.

In 2025, we will continue our work as stewards of data-driven policy analysis and collaborators to

inform the agency's consequential future decisions and advance priorities. We look forward to sharing our work further and invite you to join in our efforts as future opportunities to collaborate arise.

I'd like to extend my sincerest gratitude to NASA Administrator Bill Nelson, Deputy Administrator Pam Melroy, and Associate Administrator Jim Free for the chance to lead this impactful office known as OTPS.



**Charity Weeden**

Associate Administrator

NASA Office of Technology, Policy, and Strategy



OTPS leadership team from left to right: Agency Chief Technologist A.C. Charania, Agency Chief Economist Alex MacDonald, Deputy Associate Administrator Ellen Gertsen, Associate Administrator Charity Weeden, and Director of Advanced Programs Erica Rodgers. (Credit: NASA)

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# What is OTPS

## OTPS in Brief

The *Office of Technology, Policy, and Strategy* is the premier analytical organization at NASA dedicated to best positioning the agency for the future. The office works objectively and transparently with stakeholders across NASA, the federal government, and the broader space community to answer pressing questions and inform paths forward.

Housed within the Office of the Administrator, OTPS' team of diverse, multidisciplinary experts delivers a range of analytic, strategic, and decisional insights in the form of quick-turn analyses, memos, and reports. OTPS also organizes numerous information-gathering activities that include tabletop exercises, workshops, and informal discussion sessions; participates in chartered interagency working groups; and funds external research opportunities.

OTPS leverages its core capabilities in the areas of technology, policy, and economics to help NASA meet its missions, further NASA's interests, and

support strategic national priorities. The office is also home to NASA's agency chief technologist (ACT) and agency chief economist (ACE).

- OTPS helps NASA **operate more efficiently and facilitates agency alignment** to national priorities.
- OTPS helps NASA **understand the agency's technology portfolio, articulate its technology development, and optimize its approach to innovative technologies** like quantum science and autonomy.
- OTPS supports NASA's goals to **foster an expanding space economy** by providing strategic expertise on commercial space activities, encouraging international space economic collaboration, and contributing to national economic strategies and priorities.

Given OTPS' unique areas of expertise, OTPS makes a concerted effort to bolster analytical skills and improve policy literacy by engaging with the existing and future NASA workforce through experiential learning opportunities.



The OTPS team poses for a picture at the National Museum of the American Indian in Washington, DC. (Credit: NASA)

# The Faces of OTPS

## The Faces of OTPS—Current Team Members



Alyse Beauchemin\*\*



Dr. Patrick Besh



A.C. Charania



Dr. Thomas Colvin



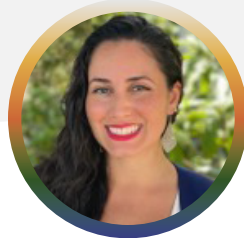
Dr. Sydney Do\*\*



Ellen Gertsen



Elaine Gresham\*\*



Amanda Hernandez\*\*



Dr. Marissa Herron\*



Amanda Hirsch\*\*



Therese Jones



Dr. Moon Kim\*



Dr. Ave Kludze



Renata Kommel\*\*



Lena Little\*



Jericho Locke



Dr. Alex MacDonald



Adrian Manguica



Nathaniel McIntyre



Mando Moreno\*



Dr. Zach Pirtle\*



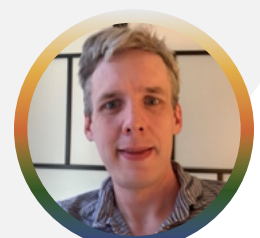
Dr. Grace Ray



Dr. Akhil Rao\*\*\*



Dr. Erica Rodgers



Colin Samples\*\*





Dr. Trey Smith\*



Jordan Sotudeh\*\*



Kristin Vollin\*\*



Charity Weeden



Kenneth Wright

*2024 Outgoing Team Members—OTPS Thanks You for Your Service*



Lina Carrington



Kendrick Glenn\*



Taelor Jones\*\*



Nik Joseph



Gabe Merrill\*



Nicole Pettingill\*



Natasha Riegle\*



Dr. Adam Yingling\*

One asterisk (\*) = detailee  
Two asterisks (\*\*) = contractor  
Three asterisks (\*\*\*) = Intergovernmental Personnel Act (IPA)

# Space Environment Sustainability

## A Strategic, Trusted, Thought Leadership Resource for NASA

Over the last three years, OTPS has established itself within the Office of the Administrator as an integral source of thought leadership and unique expertise. As the go-to experts for applied policy considerations and fact-based insights, OTPS provides vital support to NASA leaders to inform the agency's future. In 2024, the office supported key leadership decisions across a number of varied topics. More specifically, the fields of space environment sustainability and sustained lunar presence were focus areas of primary interest. As home to the agency chief technologist and the agency chief economist, OTPS provides a constant suite of work in the areas of technology disruption and economic strategy.

## Helping NASA Operate More Sustainably in the Future

NASA defines **space sustainability** as the ability to maintain the conduct of space activities indefinitely into the future in a manner that is safe, peaceful, and responsible to meet the needs of the present generations while preserving the outer space environment for future activities and limiting harm to terrestrial life.

For decades, NASA has been a global leader in space sustainability. With rising commercial capabilities, more nations, companies, schools, and others seeing the benefits of going to space, the space environment is rapidly changing. Though all this new activity is positive and exciting, it poses new challenges and greater risk to operations in orbit.



Associate Administrator Charity Weeden led a U.S. government delegation consisting of representatives from the National Oceanic and Atmospheric Administration, the Bureau of Industry and Security, the Department of Defense, the Department of State, and NASA to the NewSpace Africa Conference in Luanda, Angola, in April 2024. (Credit: NASA).

In 2024, OTPS played a critical role in NASA's commitment to space sustainability by supporting several initiatives through the office's tailored expertise.



OTPS Deputy Associate Administrator Ellen Gertsen speaks at the "Orbital Debris Remediation" panel at AIAA ASCEND in Las Vegas, NV. From left to right: Ellen Gertsen, Kristin Shahady, Astroscale. (Credit: AIAA)



OTPS Associate Administrator Charity Weeden participates in a panel hosted by the New Zealand Government and the Embassy of the United States in New Zealand. From left to right: Andrew Johnson, New Zealand Space Agency; Eugene Tu, NASA Ames Research Center; Bob Gibbs, NASA Mission Support Directorate; and Charity Weeden, NASA OTPS. (Credit: New Zealand Space Agency)

## NASA’s Space Sustainability Strategy—Volume 1

NASA has identified four domains in which space sustainability is important to consider: Earth’s orbit, the Earth, cislunar space, and deep space. OTPS cochaired a cross-directorate team chartered under the Space Environment Sustainability Advisory Board to develop volume 1 of “*NASA’s Space Sustainability Strategy*.” This inaugural volume focuses on Earth’s orbit, including renewed attention on space situational awareness and the potential hazards of orbital debris.

Released in April 2024, the strategy identified five challenges that inhibit rapid action and six goals, with associated objectives, that NASA committed to pursuing to address these challenges. OTPS is

collaborating across the agency and the broader space community to cultivate solutions that align with the goals and objectives defined in the strategy, many of which build on previous OTPS work in this area.



Cover of “NASA’s Space Sustainability Strategy; Volume 1: Earth Orbit.”

## Developing New Approaches for Assessing Space Sustainability

NASA’s Space Sustainability Strategy calls for a framework that uses metrics and models for assessing sustainability in Earth’s orbit. OTPS is co-leading an effort with the Office of Safety and Mission Assurance to understand existing frameworks, models, and metrics for sustainability, their relevance to NASA, and how to incorporate these factors into NASA’s decision-making processes going forward. This work will ultimately enable more data-driven decision making across multiple lenses when thinking about how to design and operate our spacecraft.

## Creating Technical Understanding of Remediation Concepts

OTPS' 2023 Cost and Benefit Analysis of Orbital Debris Remediation report found that the two most efficient methods for remediating orbital debris were the removal of small (1- to 10-centimeter) debris and nudging large debris away from predicted collisions; both methods could be performed by high-energy laser systems.

In support of NASA's goal to lower barriers to space sustainability through developing and transferring technology by investing in technologies that support key elements of space sustainability, OTPS is further exploring remediation concepts. OTPS has been assessing a reference mission using ground-based, pulsed lasers to detect, engage, and rapidly deorbit 1- to 10-centimeter debris that would otherwise threaten the safety of the International Space Station and future crewed platforms in low Earth orbit (LEO). By assessing the state of the art, uncertainties, and technical challenges for the entire concept of operations of the reference mission, OTPS can help inform future technology investments.

## A Fresh Look at Ways to Address Orbital Debris

Consistent with NASA's effort to update and develop policies that provide incentives to support space sustainability and to support related economic and policy research, OTPS is working to enable more data-driven decision making.

In May 2024, OTPS released an updated report on the "*Cost and Benefit Analysis of Mitigating, Tracking, and Remediating Orbital Debris*," a continuation



OTPS' Tom Colvin moderated "The Most Cost-Effective Actions for Space Sustainability" panel at the AIAA Aviation Forum and ASCEND Conference in July. From left to right, Belinda Marchand, Slingshot Aerospace; Jericho Locke, OTPS; Anne Bennett, Northrop Grumman Space; and Tom Colvin, OTPS. (Credit: NASA)

of the office's work to address the technical and economic uncertainties associated with orbital debris.

The report directly estimated the risk posed by space debris, measured the risks in dollars, and simulated how the orbital debris environment would evolve over 30 years. The analysis reexamined conventional wisdom regarding the relative effectiveness of different approaches to responding to orbital debris, helping to minimize uncertainties about orbital debris and operations in the space environment. It also lowers barriers to space sustainability through developing and transferring technology by highlighting opportunities for potential forward work.

Based on feedback from the community, OTPS is refining its orbital environment risk model to

include development costs and account for the timing of the costs and benefits.

## Supporting Research into New Generations of Technology

Through NASA's Research Opportunities in Space and Earth Science (ROSES-24), OTPS is funding research proposals from three university-based teams to analyze critical economic, social, and policy issues related to orbital debris and space sustainability.

A team from the University of Colorado based in Boulder, Colorado, will work on "Integrated Economic-Debris Modeling of Active Debris Removal to Inform Space Sustainability and Policy." A team from the Massachusetts Institute of Technology (MIT) based in Cambridge, Massachusetts, will work on "Avoiding the Kessler

Syndrome Through Policy Intervention." A team from Princeton University based in Princeton, New Jersey, will work on "Analysis of Cislunar Space Environment Scenarios, Enabling Deterrence and Incentive-Based Policy."

Previous teams from ROSES-22 and ROSES-23 have published their work in top space journals, including the *Journal of Spacecraft and Rockets*." The teams have presented their work domestically at major conferences, including the Advanced Maui Optical and Space Surveillance Technologies Conference and the American Institute of Aeronautics and Astronautics (AIAA) SciTech. Internationally, the teams have presented at the International Astronautical Congress (IAC) and the Organization for Economic Co-operation and Development (OECD) Space Forum.

## Collaborating Across NASA to Ensure that Policies Support Space Sustainability

OTPS is working with representatives from the Orbital Debris Program Office, the Office of International and Interagency Relations, and other stakeholder offices to review and prepare for an update of the U.S. Government Orbital Debris Mitigation Standard Practices.

## Acting as an Ambassador for NASA's Space Sustainability Efforts

NASA knows that a sustainable future requires global awareness, teamwork, and commitment. NASA's sustainability strategy aims to continue



Patrick Beshka, OTPS, hosted an agencywide workshop on Space Sustainability where three academic groups who conducted OTPS-funded research over the last year via Research Opportunities in Space and Earth Science (ROSES)-23 presented their work. (Credit: NASA)

and improve coordination and collaboration outside NASA.

Since NASA publicly released the Space Sustainability Strategy in April, OTPS has served as an ambassador of the strategy to other domestic and international government agencies and the broader space community. Through briefings, lectures, panel discussions, industry roundtables, and media interviews across the world, OTPS actively works to disseminate, educate, and inform relative stakeholders and the public about NASA's commitment to a sustainable future.

With space sustainability top of mind for the space community, these engagement opportunities provide a forum for NASA to share the agency's work, learn about the broader community's work, and identify potential future collaborations.



OTPS Associate Administrator Charity Weeden discusses Space Sustainability with Tom Temin on "The Federal Drive" in May 2024. (Credit: The Federal News Network)



Charity Weeden and A.C. Charania pose with NASA early-career personnel at a visit to NASA Ames Research Center. (Credit: NASA)

## Thinking Holistically About Sustainability

In 2024, OTPS hosted two internal agency challenges to generate ideas about how to make NASA's missions more sustainable and how to leverage the increasing debris environment to enable new science and technology. Over 500 NASA employees participated in the two challenges, which generated 45 ideas on a wide range of topics.

In anticipation of work on future volumes of the NASA Sustainability Strategy, OTPS has provided important thought leadership regarding sustainability in cislunar space and on the lunar surface. OTPS will continue to work closely with NASA leadership on the successful implementation of volume 1 of the strategy and the framing of subsequent volumes to come.

# Sustained Lunar Presence

## Navigating NASA Through the Policy Implications of Sustained Lunar Presence

When NASA released its “*Moon to Mars Strategy*” in April 2023, it provided a blueprint of the agency’s plans to explore the universe for the benefit of all. Working together with international partners and industry enablers, NASA plans to return to the Moon to stay, to use it as a “test bed,” and to eventually send humans to Mars and beyond.

Fortunately, the space industry has evolved to make NASA’s goals more attainable than ever before. The space economy extends from low Earth orbit to cislunar space and continues to develop. We share global partnerships with spacefaring nations that champion common goals rooted in science, discovery, and positive ventures for humans.

In 2020, NASA, the U.S. Department of State, and seven other initial signatory nations established the Artemis Accords to provide a common set of principles to ensure a safe, peaceful, and prosperous future in space. The Artemis Accords community champions a cooperative ethos, fostering innovative and creative solutions to the complex challenges we face in space exploration.

But where plans and endeavors live, so do questions of policy, procedure, and lasting impact. OTPS has spent 2024 helping the agency answer those questions and informing its path forward, particularly when it comes to a sustained lunar presence.

## Providing NASA and the Space Community with a Framework for Policy Questions

In January 2024, to understand the variety of potential impacts of our exploration plans, OTPS released the “*Policy Questions Framework for Missions*,” a tool to help decision makers think through policy implications of mission and program life cycles. Using the high-level categories from the “*Moon to Mars Objectives*” as a guide, OTPS identified potential impacts to NASA, national, or international space community interests in science and exploration.



OTPS Director of Advanced Programs Erica Rodgers gives a keynote speech at AIAA SciTech. (Credit: AIAA)

The framework identifies 12 policy questions that can serve as a road map for future missions, with profound implications for program or project implementation because relevant policy issues need consideration during the earliest stages of mission planning. The list of questions can extend beyond NASA and require engagement from the

broader national, international, and commercial space communities to influence their collective future actions.



Cover of “NASA’s Moon to Mars Objectives.”

## Supporting the Exploration and Use of Cislunar Space Responsibly, Peacefully, and Transparently

Through Artemis, NASA will land its first woman, first person of color, and first international partner on the Moon. International collaboration is an essential part of peaceful and productive space exploration, where building norms of responsible behavior is key. OTPS has made extensive progress in 2024 toward helping NASA to understand, evaluate, and define what a responsible, sustainable lunar presence looks like.

## Advancing a Collective Framework for International Stakeholders

OTPS has used its expertise to garner findings, feedback, and sentiment to help inform NASA’s cislunar policy decisions and the Artemis Accords.

OTPS sought feedback from NASA and the academic, international, and commercial communities to develop and update definitions regarding contamination, interference, and deconfliction on the lunar surface. At the Lunar Surface Innovation Consortium held in April, OTPS led two breakout sessions to gather community feedback on the terms “contamination” and “interference” to provide mission examples for non-interference, and the importance of mitigating interference.



OTPS team members led two breakout sessions at the Lunar Surface Innovation Consortium in April 2024. From left to right: Grace Ray, Therese Jones, Charlotte Davis, Marissa Herron, and Adam Yingling. (Credit: NASA)



In May, the office released a public questionnaire seeking further input from the lunar community. OTPS is developing a taxonomy framework that will support NASA strategic decision making regarding the protection of lunar science exploration sites and that international stakeholders can leverage to minimize contamination and interference at the Moon.

In May 2024, NASA participated in the second international face-to-face Artemis Accords workshop in Montreal, Canada. The workshop featured space officials from more than two dozen nations focused on advancing a collective framework for the Artemis Accords principles.



Representatives from 24 of the Artemis Accords signatories met May 21–23, 2024, for a workshop hosted at the John H. Chapman Space Centre (Canadian Space Agency Headquarters) in Longueuil, Quebec. (Credit: Canadian Space Agency)

OTPS participated in the workshop, authored and presented an Accords discussion paper on non-interference, and conducted a tabletop exercise on non-interference facilitated by Johnson Space Center’s Business Development and Technical Integration Office. A non-interference taxonomy from the public questionnaire was presented at the



Therese Jones, OTPS, gives a paper presentation at the International Astronautical Congress in Milan, Italy. (Credit: NASA)

International Astronautical Congress in October to pursue the collective goal of a safe, sustainable, and transparent future for peaceful exploration of space.

## Helping NASA Understand the Ethical, Legal, and Societal Implications of Space Activities

As space exploration continues to rise, so does the impact of the human and Earthly footprint in space. Whether exploration is done by people, robots, governments, or private companies traveling beyond our planet, it yields short- and long-term ethical, legal, and societal implications (ELSI).

In July, OTPS facilitated an international panel and discussion session during the 2024 International Space University (ISU) Space Studies Program



OTPS' Zachary Pirtle organized International Space University's Ethics theme day at the 2024 Space Studies Program at Rice University, with students from around the globe. (Credit: ISU)

held at Rice University. Seventy ISU students participated in discussions on responsible lunar and Martian exploration. Students provided their perspectives on key ethical and societal considerations for exploration and policy processes and approaches to deal with these considerations.

## Connecting and Collaborating with the Broader Space Community

OTPS acts as a bridge between NASA and the rest of the space community. Through several engagements in 2024, OTPS prompted discussion, gained insight, and invited contributions from key stakeholders to understand cislunar space issues and help NASA work toward solutions.

This year at Space Foundation's Space Symposium, OTPS conducted an industry roundtable with the Commercial Lunar Payload Services vendors to gather input on policy

considerations pertinent to the future of a NASA sustained lunar presence. The dialogue covered topics on transparency, challenges, and lessons learned.

## Fostering Research into New Technology to Support Lunar Surface Sustainability

Through NASA's ROSES-24, OTPS is funding two research proposals focusing on lunar surface sustainability. The proposals will address key policy questions, including the protection of valuable locations and human heritage sites and other technical, economic, or cultural considerations that may factor into mission planning.

A team from the University of Maryland based in College Park, Maryland, will work on "A RAD Framework for the Moon: Applying Resist-Accept-Direct Decision-Making." A team from MIT based in Cambridge, Massachusetts, will work on "Synthesizing Frameworks of Sustainability for Futures on the Moon."



OTPS team members visit the Neutral Buoyancy Laboratory at Johnson Space Center. From left to right: Ellen Gertsen, Charity Weedon, Lina Carrington, Therese Jones, Natasha Riegle, and A.C. Charania. (Credit: NASA)

# Economic Strategy



Lina Carrington, Ronnie Clayton, Therese Jones, Natasha Riegle, and Marissa Herron pose with the NASA Docking System Block 0 (NDS-B0) Hard Capture System (HCS) during a visit to Johnson Space Center. (Credit: NASA)

## Understanding and Guiding NASA's Engagement with the Space Economy

NASA's economic impact reaches far and wide, across our nation, the world, and beyond. From fueling American industry and job growth to providing invaluable science and data innovation, NASA offers enormous value through the work it does to benefit humanity.

Home to the agency chief economist, OTPS serves as a direct source of thought leadership, economic analyses, and strategic tools that support NASA's economic goals.

## Providing the Agency with Strategic Expertise on Commercial Space Activities

With the International Space Station retiring in 2031 and commercial space activities on the rise, NASA remains steadfast in its commitment as a leader and partner in a changing space environment. OTPS provides NASA leadership with key insights that inform agency management and decision making to achieve its goals.

In September, OTPS published a report titled "*Commercial LEO Destinations Asset and Liability Insurance: Findings and Options.*" The report identifies the challenges that Commercial LEO Destination providers are facing when it comes to obtaining insurance for their proposed destinations and provides potential options for addressing those concerns.



Akhil Rao tests out a flight simulator at Langley Research Center. (Credit: NASA)

A major accomplishment in 2024 was the report “*Enabling America on the Space Frontier*,” which described NASA’s wide and varied toolkit for enabling commercial space activities. In the first report of its kind, OTPS analyzed 17 different mechanisms for enabling commercial space activities across four historical eras at NASA to show the ways in which NASA’s support for the U.S. space industry both dates back to its origins and has evolved over time.

OTPS also leverages external market analysis products and performs market assessments related to commercial space activities for internal use to inform agency-level decision making on issues related to commercial space activities.

### Fostering International Collaborations on Economic and Social Science Topics

As the global space economy grows, NASA is increasingly one space agency among many, with nearly 70 space agencies now operational around the world. Correspondingly, the commercial space economy is increasingly global as well, with U.S. commercial companies that serve NASA also seeking to serve international customers, all of which can strengthen the U.S. space industrial base. As part of understanding the global space economy, the work of developing comparable international economic statistics is crucial, and OTPS leads NASA’s engagement with the Organisation for Economic Co-operation and Development (OECD) Space Forum in aid of improving global space statistics.



OTPS team members pose in front of a full-scale model of the Mars Perseverance Rover at the Jet Propulsion Laboratory. (Credit: NASA)

### Helping Space Agencies Statistically Measure the Economy

The OECD Space Forum collects and evaluates data and socioeconomic indicators to provide evidence-based analysis for agencies and governments. The OECD’s “*Handbook for Measuring the Space Economy*” was the first international effort to systematically define and measure the space economy and its constituent activities. Building upon this work, the OECD is currently building the world’s most comprehensive statistical database for space economic data, with contributions from dozens of nations. Such an accomplishment would be a milestone in the field of space economics and policy.

The OECD also conducts workshops, studies, and analyses related to NASA priorities, including

the economics of orbital debris and space sustainability, measuring the space industry, and refining the economic and policy analysis tools used by practitioners worldwide.

## Understanding Global Commercial Space Activities

OTPS strives to exchange best practices and lessons learned in commercial space with closely allied space partners, such as the European Space Agency, and enhance mutual understanding of our respective commercial programs. Topics include NASA's Commercial Space Strategy, the Commercial Cargo and Crew Program, the Commercial Lunar Payload Services, and the U.S. Space Industrial Base and Supply Chain.



OTPS' Akhil Rao moderates a panel at the Symposium on the Macroeconomics of Space. From left to right: Shawn Kantor, Arnaud Dyèvre, Andrew Fieldhouse, and Alexander MacDonald. (Credit: NASA)

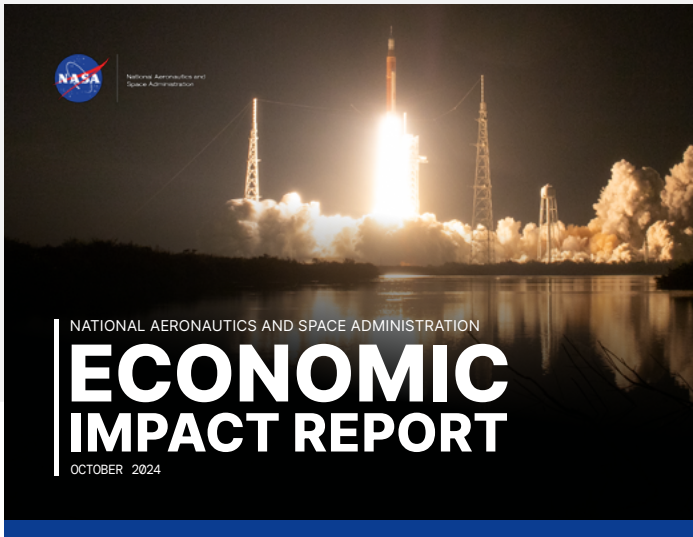
## Contributing to National Economic Strategies and Priorities

In September, OTPS hosted a first-of-its-kind *Symposium on the Macroeconomics of Space* at the James Webb Auditorium at NASA Headquarters in Washington, DC, with more than 250 in-person and virtual attendees.

Open to the public, the symposium brought together civil servants and leading researchers of the economic impacts of public research and development (R&D) spending to discuss the macroeconomics of space investments. The event bridged multiple perspectives, from annual employment impacts to decades-long effects on aggregate productivity, and offered an unprecedented level of comprehensive insight into the macroeconomic impacts of NASA investments.

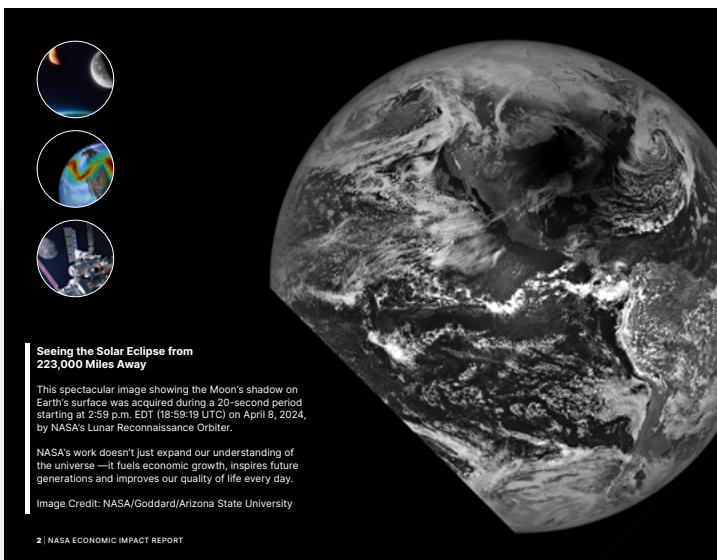
The event featured a keynote speech by Heather Boushey from the Council of Economic Advisers, academic presentations, and a panel discussion titled "Space in the Federal R&D portfolio."

OTPS also completed a major, multi-year U.S. Civil Space Industrial Base Survey in partnership with the Department of Commerce. With supplier inputs from across the agency, including mission directorates, offices, and centers, the survey is currently the most comprehensive look at the health of the space industrial base. NASA and interagency partners will analyze the data to improve our measurement of the space economy, refine acquisition strategy, and mitigate supply chain issues.



Cover of the “NASA Economic Impact Report.”

The agency chief economist also leads the development of the biennial “*NASA Economic Impact Report*,” released this year in October, covering FY23, in collaboration with the Office of the Chief Financial Officer and the Office of Communications. In the latest report, NASA’s FY23 economic output was \$75.6 billion and over 300,000 jobs were estimated to have been supported. The report is the highest resolution of data that NASA releases related to the geographic distribution of its expenditures across the American economy. The report also feeds the state fact sheets that identify state-by-state economic statistics related to NASA’s activities.



Pages 2 and 3 of the “NASA Economic Impact Report.”

INTRODUCTION

To invest in NASA is to invest in American workers, American innovation, the American economy, and American economic competitiveness. As NASA’s Economic Impact Report for fiscal year 2023 (FY23) shows, NASA’s leadership on the future of space exploration, scientific discovery, cutting-edge technology, climate observation, the next generation of aeronautics, and so much more brings value to the American people day in and day out—from supporting quality, high-paying jobs to fueling industry growth.

This report showcases economic activity driven by our Moon-to-Mars campaign and investments in climate change research and technology. The report’s brochure also highlights the International Space Station’s groundbreaking research, NASA’s wide-ranging international partnerships, NASA’s innovations in aeronautics, NASA’s leadership to develop a robust low Earth orbit economy, and our agency’s technological advancements, among others. During FY23, using an investment of less than one-half of 1% of the federal budget, NASA’s activities generated more than \$75 billion in total economic output, supported more than 304,000 jobs nationwide, and made an economic impact in all 50 states and the District of Columbia.

In FY23, through the Artemis campaign, NASA’s commitment to long-term exploration on the Moon and in space generated nearly \$24 billion in economic output and supported more than 96,000 jobs. In addition, in FY23, NASA continued to work with a wide range of U.S. companies to advance our Moon-to-Mars efforts. From cutting-edge research on rocket propulsion to developing new technology for sustained presence on the lunar surface, NASA’s work on the Moon-to-Mars campaign accrues important economic benefits to the

American people—all as we prepare for human missions to the Red Planet.

NASA’s economic impact also emerges from NASA’s STEM investments, sustainable aviation technologies, and climate monitoring.

Our investments in research and technology related to climate change, for instance, continue to provide important benefits to the American people, supporting more than 32,000 jobs nationwide and generating nearly \$8 billion in economic output in FY23. Through NASA’s fleet of more than two dozen Earth-observing satellites and instruments—and more than six decades of Earth observations—NASA provides a unique and indispensable vantage point to study our changing planet. We share that data freely and fully with all of humanity to help the world understand climate change and take action.

NASA’s work doesn’t just expand our understanding of the universe—it fuels economic growth, inspires future generations, and improves our quality of life. As we embark on the next great chapter of exploration, we are proud to help power economic strength, job creation, scientific progress, and American leadership on Earth, in the skies, and in the stars.



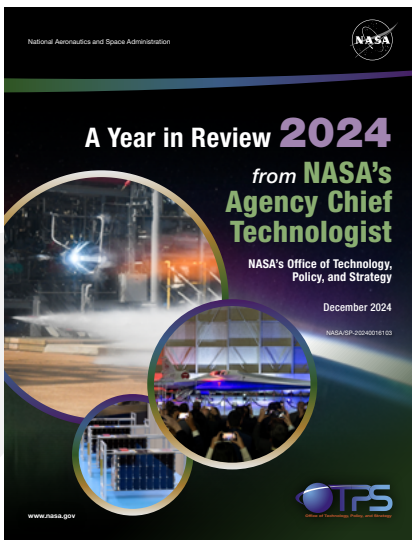
**Bill Nelson**  
Administrator  
National Aeronautics and Space Administration



# Technology Disruption

## Accelerating Technology Innovation

NASA's agency chief technologist (ACT) resides within OTPS and serves as a resource for NASA leadership to understand how technology impacts NASA's missions. Supported by a team within OTPS and NASA's Center Technology Council, consisting of the center chief and deputy center chief technologists from all NASA centers and the Jet Propulsion Laboratory, the ACT's specific goals include three major endeavors: understanding NASA's technology investments, working across the agency to jump-start new advances, and championing technology infusion.



Cover of OTPS' "A Year in Review 2024 from NASA's Agency Chief Technologist."

[Read our companion report](#) for a deeper look at OTPS' technology work this year.

## Understanding NASA's Technology Investments

This year, the ACT worked to establish an annual process to understand and analyze the agency's

technology inventory that supports data-driven decision making and improves transparency to industry, government, academia, and the American public. Referred to as the Technology Analytics Research & Development Inventory Study (TARDIS), this process aims to provide leadership with an annual pre-decisional memo and a top-level external snapshot of NASA's inventory. The first *TARDIS snapshot* was published in July and announced at the AIAA Aviation Forum and ASCEND Conference.

The ACT is also collaborating with multiple NASA mission directorates to ensure that TechPort, NASA's public-facing technology database, represents a comprehensive, robust data repository to use for the annual TARDIS process. The collaboration has resulted in a better set of inputs to the TechPort database and a renewed effort to improve tracking technology activities.

## Updating NASA's Technology Nomenclature

NASA engages in a variety of technology development activities to enable NASA missions by broadening knowledge of and capabilities in aeronautics, science, and space. NASA uses a structured taxonomy to identify, organize, and communicate technology areas relevant to advancing the agency's mission. This year, OTPS partnered with the Space Technology Mission Directorate to release the *2024 NASA Technology Taxonomy*, a limited update to the 2020 taxonomy that builds on previous releases and includes insights from subject matter experts across the agency.



Agency Chief Technologist A.C. Charania announces updates to NASA's Technology Taxonomy at the AIAA ASCEND in Las Vegas, Nevada. (Credit: NASA)

## Understanding the Quantum Landscape for NASA and the Nation

Quantum sensors are a core component of Quantum Information Science (QIS) that offer potential benefits in many NASA applications. Quantum sensors can enable highly precise measurements of magnetic fields, electric fields, frequency, rotations, temperature, pressure, acceleration, and time, and also enable higher-resolution imaging and mapping. The U.S. National Quantum Initiative is a federal program to ensure U.S. leadership in QIS. The National Quantum Initiative Act adds NASA as a lead agency for carrying out quantum research and development.

In 2023, the Space Science and Technology (S&T) Partnership Forum, consisting of NASA, the National Reconnaissance Office (NRO), and the United States Space Force (USSF), kicked off

a study to accelerate the deployment of space-based quantum sensors. The findings contained within this work provide insight into quantum sensing and quantum enabling technology work across the S&T Partnership Forum to inform technology development and identify potential government, industry, and academic coordination and collaboration opportunities in quantum sensing. The findings also point to the intent of the S&T Partnership Forum agencies to lean into the development of quantum sensing technology in which the three agencies have mutual near-term interest, including crosscutting enabling component technologies.

Complementary to the above S&T study, the ACT's team developed a top-level inventory of quantum sensing efforts across the agency and identified areas of research within NASA. OTPS also produced a comprehensive list of facilities and a framework to assist in a potential future quantum strategy.



OTPS' Ave Kludze (center) poses with Upendra Singh (left) from the NASA Engineering and Safety Center and Richard Slonaker from Goddard Space Flight Center after a panel moderated by Kludze on the "Quantum Landscape at NASA" at AIAA ASCEND in July. (Credit: NASA)





OTPS 2024 Solver-in-Residence Adam Yingling presents at the Lunar Autonomy Mobility Pathfinder in Las Vegas, Nevada. (Credit: NASA)

## Unifying NASA's Approach to Maturing Autonomous Technology

To lead the world back to the Moon and then on to Mars, NASA will continue to employ higher levels of autonomy to perform missions and sustain humanity's presence off Earth. Autonomy refers to a system's ability to perform tasks independently, and it requires technologies such as artificial intelligence, sensors, augmented reality, and analytical capabilities to do so. In 2024, OTPS' solver-in-residence focused on researching the barriers that NASA faces with developing autonomous technology and worked with internal and external subject matter experts to find potential solutions.

In November, OTPS hosted the *Lunar Autonomy Mobility Pathfinder* public workshop in Las Vegas, Nevada, organized by the ACT in coordination with STMD. The workshop provided a forum for

interested participants to discuss topics including lunar modeling and simulation capabilities, challenges to developing trusted autonomy, and the digital transformation needed to benefit lunar autonomy efforts across the globe.

## Spotlighting Ultra-High-Definition/4K Lunar Surface Imagery for the Moon to Mars Missions

OTPS partnered with the Moon to Mars Program Office in August to deliver findings to NASA leadership about the status and opportunities for high-resolution, near-real-time lunar surface imagery on Artemis III and IV. The focus of their work was to achieve the ultra-high-definition or 4K spatial-resolution standard.

The outputs of the study highlighted the accomplishments of NASA and its partners for these missions and identified unique opportunities for further enhancement. Such capabilities showcase the way in which the Moon can be a prime place to demonstrate and test potential Mars technologies for communications and public engagement.

## Identifying and Celebrating Innovation Across NASA Through the Invention and Software of the Year Awards



Members of the NASA Orbital Debris Program Office and support staff. Some members of the office were not available for the photo. (Credit: NASA)

In October 2023, OTPS assumed leadership of the Inventions and Contributions Board (ICB), with the agency chief technologist designated board chair. The ICB was chartered by Congress within the “*National Aeronautics and Space Act of 1958*” and placed within NASA. It provides recommendations for waiving NASA’s property rights in inventions and for monetary awards to any person making a significant scientific or technical contribution to the conduct of aeronautical and space activities.

For fiscal year 2024, the ICB’s goals were to develop search strategies to find the best award candidates within NASA, to improve ICB processes, and to increase overall awareness of the awards and the winners. The ACT and their team have been working to improve overall

operation of the ICB, clarify the processes, and champion the major award winners.

The annual Invention of the Year program recognizes inventions that have significantly contributed to NASA programs or that exemplify NASA’s mission to transfer cutting-edge technology to U.S. industry. The Software of the Year award gives recognition to developers of exceptional software created for or by NASA.

The ACT, on behalf of OTPS, publicly recognized this year’s award winners at the AIAA Aviation Forum and ASCEND Conference in Las Vegas. Invention of the Year went to the Thrust Chamber Liner and Fabrication Method team from Marshall Space Flight Center based in Huntsville, Alabama. Software of the Year had two winners this year: The Prognostics Python Packages team from Ames Research Center in Mountain View, California, and the *NASA Orbital Debris Engineering Model* team from Johnson Space Center in Houston, Texas.



A.C. Charania and the NASA Chief Technologists Council present the 2024 NASA ICB Software of the Year Award for ProgPy at AIAA ASCEND in July. (Credit: NASA)

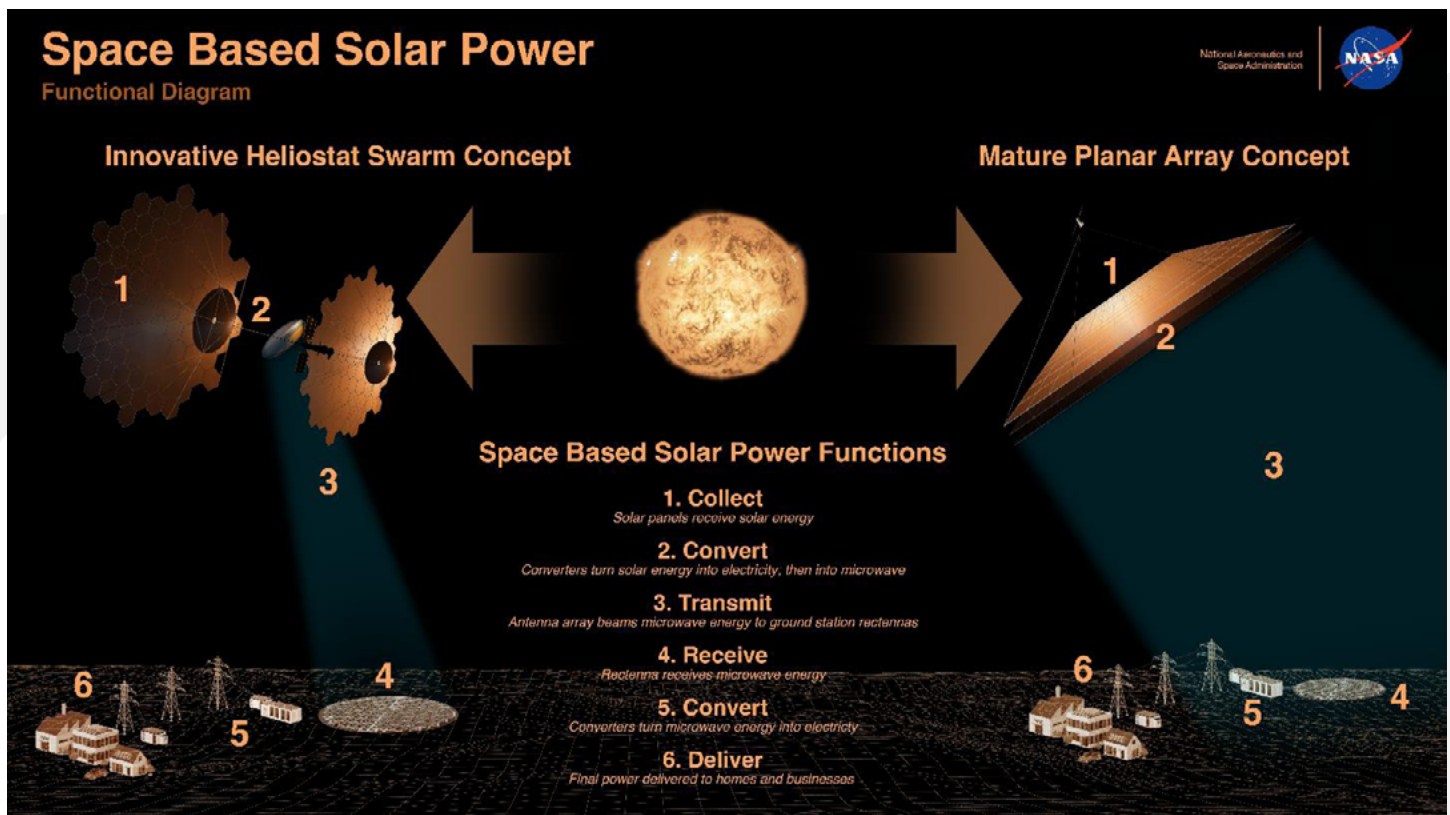
## A Space-Based Solar Power Cost-Benefit Analysis

In the future, orbital collection systems could harvest energy in space and beam it wirelessly back to Earth to supplement the terrestrial power transmission infrastructure required across the world. In January, OTPS released the “*Space-Based Solar Power*” (SBSP) report that examined the life-cycle costs and carbon emissions for an SBSP system being operational by 2050.

The report looked at which conditions could make SBSP a competitive cost and emissions option

compared to other terrestrial sustainable solutions and the technical and operational approaches for such systems.

Using two existing older reference technical concepts, the report found that while NASA is developing some technologies that will indirectly benefit space-based solar power, significant capability gaps and launch and manufacturing costs would need addressing. The report highlighted the need for further study in other areas, including potential lunar power applications.



Functional Decomposition of SBSP Design Reference Systems. (Credit: NASA)

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