



# **NATIONAL LOW EARTH ORBIT RESEARCH AND DEVELOPMENT STRATEGY**

*Product of the*  
LOW EARTH ORBIT SCIENCE AND TECHNOLOGY  
INTERAGENCY WORKING GROUP

*of the*  
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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## **About Low Earth Orbit Science and Technology Interagency Working Group**

The Low Earth Orbit Science and Technology Interagency Working Group, under the auspices of OSTP, coordinates science and technology policy, strategy, and Federal research and development (R&D) pertaining to space-based research and platform access to enable a robust and sustainable ecosystem in Low Earth Orbit (LEO). This coordinated effort aims to ensure that U.S. leadership in the development and use of LEO for scientific research and technological applications is sustained and expanded for future use. This working group develops and maintains goals for R&D capabilities required of commercially-owned LEO platforms, facilitates engagement with platform providers and Federal departments and agencies to ensure such capabilities remain available or are developed, and supports establishing priorities and joint efforts in conjunction with the LEO National Lab.

## **About this Document**

This document provides an interagency strategy and action plan to enable U.S. Government-wide collaboration and support of public-private partnerships to ensure continuity of access and sustainable LEO research and development (R&D) activities. The Strategy supports the United States Space Priorities Framework with a focus on scientific and technological innovation, economic growth, commercial development, and space-related STEM education and workforce development.

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## Executive Summary

The United States holds the preeminent global position in space research due to its long-term, steadfast investments in space research and technology development and its strategic partnerships and collaborations. As the United States leads the world in the exploration of the Moon and Mars, maintaining U.S. preeminence in space research is important as the use of Low Earth Orbit (LEO) grows and the development of space enters a new era. This Strategy presents a vision for U.S. leadership in future research and development (R&D) in LEO that will advance science and technology; strengthen U.S. Government collaborations; promote market sustainability; expand international partnerships; engage the public; and support the continued development of the U.S. space workforce.

Innovative public-private collaborations and increased commercial access to LEO have sparked a growing interest in space research and development. The increased potential for rapid discoveries is expanding the commercial market at the same time the International Space Station (ISS) is beginning its phased retirement to be replaced by lower cost commercial alternatives. As a result of this changing landscape, the U.S. Government needs to plan strategically for the post-ISS world especially for the employment of commercial state-of-the-art autonomously-operated and human-occupied outposts. Opportunities remain in research conducted on government LEO platforms ahead of the upcoming transition. A national approach is needed to realize and institutionalize the scientific, economic, educational, and diplomatic benefits of LEO research platforms for the future.

This Strategy prioritizes the use of LEO for the benefits of humanity. It will also enable a sustained human presence in space. This Strategy outlines five policy objectives and supporting activities in LEO:

1. **Advance groundbreaking science and technology** by conducting transformational R&D and enabling rapid, repeatable science in space;
2. **Strengthen U.S. Government collaboration and partnerships** by encouraging new entrants in R&D through a LEO National Laboratory, promoting data sharing, and prioritizing sustainable access to LEO;
3. **Promote market opportunities, innovation, and sustainability** by adapting non-traditional use cases, enabling equitable access on future platforms, and addressing economic and regulatory barriers to market space-based R&D;
4. **Expand international cooperation** by exploring more opportunities for international collaboration, and implementing human spaceflight safety coordination;
5. **Stimulate science, technology, engineering, and mathematics (STEM) education and workforce development**, including by increasing opportunities for people from backgrounds underrepresented in STEM, and building capacity in institutions.

With these objectives and activities, the United States demonstrates its commitment to advancing research in LEO by leveraging the nation's commercial enterprise to develop the infrastructure needed to grow the space economy. R&D in LEO and beyond will leverage academic, government, and commercial capabilities to sustain U.S. leadership in space.

## Introduction

The United States empowers ground-breaking national, international, commercial, and academic scientific research and technological development through sustained investment and providing access to Low Earth Orbit (LEO). Increasing numbers of commercial and non-traditional participants in activities in LEO are enabling more rapid discoveries via experimental satellite and payload demonstrations, innovative launch vehicles, ground systems, and space-based laboratories.

The International Space Station (ISS) stands as an impressive achievement of international scientific and technical cooperation and has paved the way for future commercial alternatives or platforms in LEO. These LEO platforms, called “commercial LEO destinations,” will be privately-owned and operated facilities in space with the capacity for conducting research. The work that the National Aeronautics and Space Administration (NASA) and partner space agencies have accomplished in LEO over the past two decades has demonstrated to researchers and investors alike the potential benefits of conducting research and manufacturing in space. The importance of continuing international collaboration initiated under the ISS program is underscored by the emergence of potential alternatives to U.S.-led facilities in LEO.

Many unanswered scientific questions can only be answered through experiments in the microgravity environment of LEO. For instance, the impact of long-duration exposure to microgravity, high vacuum, space weather effects on artificial and physiological systems, and how the space environment affects other phenomena in space (e.g., additive manufacturing, material interactions, and the efficiency of systems). Understanding the effects of solar and galactic radiation on both humans and microelectronics is necessary to achieve the goal of enabling human transportation and settlement within the solar system. Some experiments can take place in actual or simulated free fall conditions, including on orbital and suborbital platforms, parabolic and balloon flights, from drop towers, and other ground-based simulators. A microgravity research ecosystem is needed to conduct these experiments and develop optimized physical systems and improved physiological countermeasures for exploration missions to the Moon and beyond. The microgravity ecosystem also provides a platform for investigating the effects of weightlessness in physics, chemistry, biology, medicine, materials, and many other disciplines.

On December 31, 2021, the United States announced its intention to extend ISS operations through 2030. Following the retirement of the ISS, the U.S. Government will rely on commercial space stations for crewed and autonomous on-orbit research. The extension of ISS operations through 2030 allows critical time to realize benefits from the ISS while permitting a smooth transition to follow-on commercial LEO destinations without a gap in a U.S. human presence in LEO. To catalyze this shift, NASA has awarded contracts for commercial crew and cargo transportation services to the ISS. In 2020 and 2021, as a result of NASA’s success with its commercial crew and cargo transportation program and in recognition of the need for future platform development, NASA signed agreements with four U.S. companies to develop designs for commercially-owned and operated space stations that will become available prior to the decommissioning of the ISS.

This upcoming transition from the ISS to U.S. commercial platforms coupled with U.S. commercial launch capabilities marks an entirely new era for spaceflight and space research, paving the way for new innovations and opportunities. Where appropriate, and in concert with civil agencies, the national security departments and agencies will also support the growing demand for space research and infrastructure for national security purposes, and the increase in commercial space activity. It will promote a market for space-based research by public and private U.S. entities due to the increasing need for reliable and more affordable access through innovative launch vehicles, and frequent spaceflights. These efforts require infrastructure such as ground systems, satellite systems, potentially in-space assembly, and reusable vehicles. The national security departments and agencies will also expand opportunities for non-traditional researchers.

An emphasis on reusability and more diverse market demand promises to lower launch costs and barriers to entry for users and ultimately move us closer to making living and working in space commonplace. This new ecosystem may consist of uncrewed, intermittently crewed, and permanently crewed platforms for a wide range of times spent in space. Some platforms may be designed for specific activities, like in-space production, while others may accommodate human activities, including R&D, STEM outreach, tourism, and other commercial activities. These activities include support for future human and robotic space exploration and development, national security research, and advancing science and technology to benefit humans on Earth.

As the U.S. Government makes this transition, it must address a number of challenges. To this end, the U.S. Government will:

- maintain the necessary capabilities and human presence in LEO during the transition from the ISS to commercial successors;
- attract new, impactful research from the U.S. Government, academia, and international partners;
- support the development of commercial R&D and in-space manufacturing before and after the retirement of the ISS;
- maintain a leadership role in the evolution of capabilities supporting a sustained human presence in space and leveraging commercial and, when necessary, civil outposts and infrastructure;
- promote opportunities for underserved communities and more diverse research in LEO; and
- use LEO to encourage the study of STEM and the expansion of the space workforce.

The LEO Science and Technology Interagency Working Group of the National Science and Technology Council (NSTC) developed this policy with input from leaders across academia, non-profit, and commercial sectors. The objectives and implementation activities presented in this Strategy will focus on the U.S. Government's role in the effective use and sustainment of orbital platforms to expand the benefits of space-based research and applications beyond the ISS to future commercial platforms.

## Strategic Policy Objectives

### 1. Advance Groundbreaking Science and Technology Development

The LEO environment provides opportunities to leverage microgravity and the unique vantage point of space to unlock scientific discoveries and applied research pathways not possible on Earth. R&D in LEO should consist of balanced portfolios of peer-reviewed science, technology development to increase government and commercial capabilities, and opportunity-driven commercial applications. Where appropriate, long-term research studies and technology development begun on the ISS will continue using future LEO commercial platforms. This research will support the growth of the U.S. space industry, create good-paying jobs, increase our scientific knowledge, and better enable sustainable human exploration to the Moon, Mars, and beyond. Activities to realize this strategic objective include:

**1.1 Conduct transformational R&D.** The U.S. Government will continue a biological and physical sciences program to make transformational space-related scientific discoveries to improve life on Earth and in space. Building upon the legacy of the ISS, the U.S. Government will work with private entities in developing a wide portfolio of LEO research capabilities and opportunities to implement the government’s national objectives in LEO research and infrastructure. (Lead: NASA; Support: HHS, USDA, DOE, DOD, DOC, DOS, DOT, NSF)

**1.2 Enable rapid, repeatable experiments in space.** Researchers on Earth conducting ground-based investigations are able to alter one element of an experiment and re-run it. Working with commercial space facilities, the U.S. Government will better enable researchers to repeat experiments quickly with equitable opportunities for the research and engineering communities. The U.S. Government will support efforts related to:

- advances in automation to enable the substitution of autonomous research hardware for human interventions; and
- advances in in-situ sample preparation and advanced in-situ analysis hardware, coupled with science-based astronaut missions, when appropriate, to facilitate a rapid, iterative research capability in LEO;

Public and private investment in advanced technologies (e.g., on-orbit sample handling capabilities, in-space analysis and instrumentation, high bandwidth communications, in-space data processing and storage, robotics, human-machine interfaces, electrical power generation and storage) will drive scientific discoveries and innovation and support late-stage R&D prototyping. (Lead: NASA; Support: DOE, DOS, DOD, NSF, HHS, USDA)

### 2. Strengthen U.S. Government Collaboration and Partnerships

The United States encourages the use of LEO as a unique environment to address global challenges in science, medicine, manufacturing, communications, agriculture, and national security. The U.S. Government will build partnerships and share findings from space-based R&D across U.S. Government and non-government research communities. Federal departments and agencies will explore new,



accelerated and potentially disruptive programs for LEO research. These programs will enable interagency, international, non-government user groups, and commercial partnerships and collaborations through open communication, and clear cost-sharing mechanisms. Activities to realize this strategic objective include:

**2.1 Encourage new entrants in LEO R&D through a LEO National Laboratory.** NASA is studying the establishment of a LEO National Laboratory model represented and supported by government-sponsored LEO research. It has the potential to provide a diverse suite of R&D capabilities and technical support for the LEO research community through a merit-based access model. As part of this model, the U.S. Government will explore establishing collaborative frameworks, such as institutes and consortia, which would be responsible for enabling engagement and collaboration across government, academia, industry, and international partners. These frameworks would ensure data, resources, standards, and requirements are widely shared. A future LEO National Laboratory would encompass orbital and suborbital platforms as well as existing and new terrestrial facilities, including DOE's national laboratories, NASA's space flight and research centers, DOD's service research laboratories, U.S. universities, and private-sector partners. To make strides in standards for future space situational awareness (SSA) technologies and in cybersecurity for satellites, the Laboratory would continue to collaborate on cutting-edge research with DOC. The Laboratory would educate the public on the use and importance of space-based research. (Lead: NASA; Support: HHS, USDA, DOE, DOD, DOC, DOS, DOT, NSF)

**2.2 Promote data sharing.** The 2022 OSTP Public Access Memorandum outlines expectations for Federal departments and agencies to increase free, immediate, and equitable access to federally funded research, building on U.S. efforts to advance policy that benefits all of America. The guidance establishes researcher responsibilities on how scientific data will be managed and shared. The U.S. Government supports making scientific data underlying peer-reviewed scholarly publications resulting from federally-funded research freely available and publicly accessible by default at the time of publication, unless subject to limitations, such as legal, privacy, ethical, technical, intellectual property (IP), or security limitations. The U.S. Government is developing approaches and timelines for sharing other federally-funded scientific data that are not associated with peer-reviewed scholarly publications. To the extent possible, data from government funded basic, use-inspired, and applied science research should be shared through open databases. Instruments on new LEO platforms, like those currently on the ISS, could potentially collect climate data, and make observations in support of natural-resource management and disaster response. When possible, researchers who conduct space-based science should openly share data on the successes and failures of their investigations to promote openness, maximize research investments, and promote transparency. Departments and agencies should consider giving private entities conducting research in LEO incentives to share non-competitive data through databases in order to accelerate discovery and the development of new technologies. (Lead: NASA; Support: USDA, DOC, NSF, DOE, DOD, DOT, HHS, ED)

**2.3 Prioritize sustainable access to LEO for scientific research.** In cooperation with international partners and consistent with U.S. policies, the U.S. Government will continue to support the exploration and use of space for peaceful purposes, including the use of LEO for R&D. As such, the U.S. Government promotes best practices, guidelines, and other rules of the road, as well as technological improvements that enable the enduring use of the LEO ecosystem. The U.S. Government will continue scientific and technological research and development to prevent and address orbital debris as well as to develop novel technologies to increase spacecraft endurance. In accordance with applicable law, the U.S. Government will conduct basic and applied research in LEO to aid U.S. national security interests. (Lead: DOD and DOS; Support: DOC, NASA, NSF)

### **3. Promote Market Opportunities, Innovation, and Sustainability**

The U.S. Government will continue to strengthen cooperation with the commercial sector in order to understand and implement solutions that support commercial LEO access providers in building a scalable, revenue-based economy on orbit. This will be accomplished, in part, by ensuring high-quality research facilities are continuously available to support a timely transition from the ISS before it is decommissioned. The U.S. Government will encourage the development of LEO platforms outfitted with the infrastructure to support space-based research for a rapidly diversifying user base, including research institutions, for-profit companies, foreign governments (and their user bases), and the U.S. Government. Activities to realize this strategic objective include:

**3.1 Support non-traditional use cases of human spaceflight.** The U.S. Government will support transportation to and from commercial platforms by enabling new users to demonstrate new applications in LEO. The U.S. Government will seek to connect the unique properties of space with core interests of new users, who are solving real-world challenges such as seeking more effective treatments for cancer. The U.S. Government will also set priorities, develop processes, and engage parties so that infrastructure can be easily adapted to shape offerings by service providers, and to meet user demands. It will seek to prioritize activities, provide flexibility for users to access needed capabilities where platforms are located, account for scalability, and enable diverse and simultaneous activities in LEO. An increase in awareness for emerging and promising use cases for space-based R&D, coupled with increased collaboration within and between research communities, should result in increased interest in flight opportunities, driving the field forward and encouraging growth in the market. (Lead: NASA; Support: NSF, DOC, DOD, DOE)

**3.2 Enable equitable access to equipment and instrumentation on future commercial platforms.** To encourage the development and growth of small businesses in exploring opportunities in space-based research, especially in non-space disciplines, the U.S. Government, where appropriate, will create opportunities for small companies interested in conducting space-based R&D through flight opportunities and collaboration with private entities. These opportunities may include open-source resources (e.g., webpages)

that list private entities seeking partnerships in LEO research, and the use of Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs for participating Federal departments and agencies to solicit small business space-based research proposals that align with U.S. Government missions. The U.S. Government will provide competitive opportunities for government grants to support commercial space startup companies to establish the feasibility of promising scientific and technological capabilities and applications. (Lead: DOC; Support: USDA, NASA, DOE, DOD, DOT, HHS, ED, DOS, NSF)

**3.3 Address economic and regulatory barriers to market space-based R&D.** The U.S. Government will work with commercial providers to reduce technical and economic barriers to commercial platforms, while maintaining safety. For example, successful commercial LEO SSA pilots could be enhanced by infrastructure to support satellite owners and operators, and SSA providers. The purpose of these activities is to encourage market growth, foster innovation, enable a streamlined regulatory process, advance scientific discovery, maximize positive user experiences and access, and mitigate risks to return on investment for platform providers. To accomplish these goals, the U.S. Government will:

- Encourage commercial companies to incorporate space-based R&D into their terrestrial R&D strategies;
- Promote voluntary technology transfer on mutually-agreed terms and patent procurement between the U.S. Government and the commercial sectors for commercial, academic, and public benefit;
- Ensure regulatory processes enable the commercial sector to operate both efficiently and safely, and, as appropriate, create consistent guidance regarding the ownership, protection, and use of IP;
- Evaluate existing export control policies to ensure a balance between promoting and protecting space technologies. (Lead: DOC; Support: DOT, DOD, NASA, DOS)

#### **4. Expand International Cooperation**

The United States supports scientific research that answers fundamental questions about humanity, how our world works, and our place in the universe. From human exploration to scientific research, the progress the United States has made in space has influenced the actions of other nations. Future technological progress in space will be propelled by the U.S. Government empowering the free market, while working with allies and partners to protect IP. The United States, through its participation in relevant international bodies, including the United Nations Committee on the Peaceful Uses of Outer Space, will leverage its experience and expertise to promote a stable and responsible trajectory of R&D in LEO. Activities to realize this strategic objective include:

**4.1 Deepen and expand opportunities for international cooperation.** The United States will continue to leverage established relationships and coordinate with allies and partners on future space-based research priorities to remain the partner of choice in LEO. Using the

entrepreneurial nature, creativity, and innovative capabilities of commercial enterprise, coupled with diplomatic engagements, the United States will conduct regular outreach to international stakeholders, comply with our international obligations, and champion norms of responsible behaviors in LEO. The United States will seek to fulfill its LEO research needs by leveraging an emerging marketplace run by commercial and private enterprises engaged in LEO. It will collaborate with the growing number of emerging spacefaring nations. The U.S. Government will also continue to encourage transparency, data sharing, interoperability, and related norms that facilitate international cooperation in space-based fundamental research. (Lead: NASA; Support: DOS, DOC, DOD)

**4.2 Encourage the establishment and implementation of human spaceflight safety coordination.** In the post-ISS LEO environment, the United States will lead in the development and implementation of open, transparent, and credible international policies and practices for human spaceflight safety. The United States will promote the use of common, internationally recognized standards when sharing orbital information on human spaceflight missions and potential hazards to the life or health of astronauts. The United States will also support capacity building in developing countries with emerging space capabilities to support their participation in human spaceflight safety coordination. (Lead: DOT, NASA, and DOS; Support: DOC, DOD)

## **5. Stimulate STEM Education and Workforce Development**

The U.S. Government will prioritize regular, reliable, and affordable access to space-based research for a diverse community of researchers from academia, the Federal government, and private industry. The U.S. Government will build technical capacity in R&D pertaining to space by ensuring a diverse, growing workforce to support continued research, technology development, and manufacturing in space. These efforts align with the Interagency Roadmap to Support Space-Related STEM Education and Workforce<sup>1</sup> that focuses on the breadth of the space sector. Activities to stimulate STEM education and workforce development in direct support of R&D in LEO include:

**5.1 Support STEM education and workforce efforts.** The U.S. Government will work to increase outreach and engagement of pre-Kindergarten to 12<sup>th</sup> grade students interested in space, particularly for students from backgrounds historically underrepresented in STEM fields. The U.S. Government will provide professional support for educators so they may increase their up-to-date content knowledge and encourage student involvement in ongoing programs through experiential learning. The U.S. Government will provide educators with training and curriculum development, including specialized activities where experiments performed on-orbit are live-streamed to classrooms and activities where students design and conduct experiments on orbit remotely. The U.S. Government will leverage existing STEM education

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<sup>1</sup> OSTP. Interagency Roadmap to Support Space-Related STEM Education and Workforce. <https://www.whitehouse.gov/wp-content/uploads/2022/09/09-2022-Interagency-Roadmap-to-Support-Space-Related-STEM-Education-and-Workforce.pdf> Released September 2022

efforts and continue to provide training for teachers. (Lead: ED; Support: NASA, NSF, USDA, DOD, DOE)

**5.2 Increase opportunities for people from backgrounds underrepresented in STEM fields to engage in space-based R&D.**

The U.S. Government will identify and prioritize opportunities for people from backgrounds underrepresented in STEM fields and organizations to access opportunities for space flights to conduct R&D in space. It will create and regularly update a landing page with flight opportunities, and encourage the specific allocation of resources for underrepresented groups and organizations. It will establish formal opportunities to support partnerships between large, established space-based R&D organizations and institutions underrepresented in this community to support workforce development and capacity building in R&D. The U.S. Government will socialize opportunities and provide guidance for new entrants and connect institutions with grant mechanisms and other existing resources. It will encourage these non-career aspiring space researchers to socialize their experiences and science with the general public further messaging that space is for all humankind. (Lead: NASA; Support: NSF, USDA, DOC, DOD, DOT, DOE, HHS, ED)

**5.3 Build capacity in U.S. post-secondary learning institutions for space science and technology.**

The U.S. Government will continue to support research initiatives that build capacity in U.S. colleges and universities to include opportunities such as equipment grants; collaborative research grants to connect across institutions, government research efforts, and industry; student and postdoctoral fellowships; collaborative research centers; Reserve Officer Training School space programs; and opportunities for visiting scientists. The U.S. Government will engage in building capacity in post-secondary two-year learning institutions and trade schools for these often-underserved learning communities. (Lead: DOD; Support: ED, NASA, NSF, DOE).

**Conclusion**

The U.S. Government is committed to meeting the objectives outlined in this Strategy through the following efforts:

- Helping to provide predictable, long-term demand for commercial LEO platforms and services by coalescing efforts through a LEO National Laboratory as one of many customers of commercial space products and services;
- Continuing to assist in the planning and preparation of diverse commercial platforms to sustain a U.S. presence in LEO in advance of the retirement of the ISS;
- Implementing safety protocols and standards to ensure timely access and flight safety to, within, and through LEO, to ensure the efficient use of these resources for R&D;
- Working closely with industry partners, international organizations, and other government agencies to develop innovative solutions that can enhance SSA, reduce operational risks, and enable faster emergency response;

- Reducing barriers to private sector participation in the development of LEO by providing regulatory clarity, IP protections, and greater opportunities for LEO R&D, while seeking to provide more open-source data from LEO research;
- Providing opportunities for R&D on novel concepts, encouraging the participation of previously uninvolved sectors of industry, and expanding opportunities for academia through sub-orbital platforms and other means of access to space-based environments; and
- Remaining the global leader and partner of choice for orbital platforms and other space research facilities.

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