



# NATIONAL CISELUNAR SCIENCE & TECHNOLOGY STRATEGY

*A Product of the*  
CISELUNAR TECHNOLOGY STRATEGY  
INTERAGENCY WORKING GROUP

*of the*  
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

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The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976 to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of the economy, national security, homeland security, health, foreign relations, the environment, and the technological recovery and use of resources, among other topics. OSTP leads interagency science and technology policy coordination efforts, assists the Office of Management and Budget with an annual review and analysis of Federal research and development in budgets, and serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government. More information is available at <http://www.whitehouse.gov/ostp>.

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The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is to ensure science and technology policy decisions and programs are consistent with the President's stated goals. The NSTC prepares research and development strategies that are coordinated across Federal agencies aimed at accomplishing multiple national goals. The work of the NSTC is organized under committees that oversee subcommittees and working groups focused on different aspects of science and technology. More information is available at <http://www.whitehouse.gov/ostp/nstc>.

## **About the Subcommittee on Cislunar Science & Technology and the Cislunar Technology Strategy Interagency Working Group**

The NSTC established the Subcommittee on Cislunar Science & Technology to support new interagency collaboration on Cislunar priorities identified in this strategy. Further, the Cislunar Technology Strategy Interagency Working Group was organized within the Subcommittee to coordinate science and technology policy, strategy, and Federal research and development (R&D) pertaining to Cislunar space. This group aims to coordinate activities, address emerging challenges and opportunities, and advance U.S. leadership and cooperation in Cislunar space.

## **About this Document**

This document provides a first interagency strategy to guide the actions of the U.S. government in advancing scientific, exploration, and economic development activities in Cislunar space. This Cislunar Science & Technology Strategy directly supports the United States Space Priorities Framework, which states that the United States will “advance a robust Cislunar ecosystem.” Further, this strategy is consistent with interagency and international efforts including the Artemis Accords, the U.S. government’s Interagency Roadmap to Support Space Related STEM-Education and Workforce, work of the United Nations Committee on Peaceful Uses of Outer Space (COPUOS), the ITU Radio Regulations, and other ongoing multilateral discussions, and supports the Outer Space Treaty of 1967, the Rescue Agreement, and other international treaties. This strategy also complements the 2022 National Strategy on In-Space Servicing, Assembly, and Manufacturing (ISAM), which advances capabilities and technologies for U.S. civil and private sector applications in space.

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## EXECUTIVE SUMMARY

The United States will lead the world in responsible, peaceful, and sustainable exploration and utilization of Cislunar space, including the Moon, consistent with the U.S. Space Priorities Framework. Cislunar space, the three-dimensional region of space beyond Earth's geosynchronous orbit but still within the gravitational influence of the Earth and/or the Moon, is a new sphere of human activity with diverse endeavors accelerating in the decade ahead.

Cislunar space offers tremendous promise for advancing science, technology, and exploration. Humanity's activities on the Moon remain uniquely inspiring for people around the world. Cislunar space provides opportunities for answering many of the highest priority questions in planetary science, opportunities to explore the history of our Solar System and Sun, a radio-quiet environment that can catalyze a new generation of radio astronomy, the potential for economic growth in space, and a valuable region for testing human exploration technologies and operations to enable crewed exploration to Mars and beyond.

U.S. science and technology leadership in Cislunar space will support the responsible, peaceful, and sustainable exploration and use of Cislunar space, including the Moon, by all space-faring nations and entities.

The *National Cislunar Science & Technology Strategy* provides a vision and the first science and technology objectives for realizing U.S. leadership in Cislunar space, including the Moon. Fostering scientific discovery, economic development, and international cooperation are essential to sustaining this leadership. The key objectives of the strategy are:

**Objective 1: Support research and development to enable long-term growth in Cislunar space.** American technological endeavors begin with a positive, expansive vision of the future, led by a highly diverse science and engineering workforce. The Moon is a driver of scientific advances and potential economic growth. Research and development opportunities in Cislunar space range from novel discoveries in space science to the development of new Cislunar technologies to new breakthroughs in understanding the effects of the space environment on humans.

**Objective 2: Expand international S&T cooperation in Cislunar space.** International S&T cooperation can foster peace, develop responsible practices, and create the foundations for new institutions to enable enduring human and robotic presence in Cislunar space. New international cooperation can also amplify U.S. objectives being achieved with the Artemis Accords by demonstrating how activities can be carried out for the benefit of and in the interests of all nations, including developing countries, while enhancing transparency and building confidence and cooperation among Moon-faring entities during this important decade for Cislunar development.

**Objective 3: Extend U.S. space situational awareness capabilities into Cislunar space.** Space situational awareness is the necessary foundation to enable transparency and safe operations for all entities operating in Cislunar space. As activities in Cislunar space increase, the U.S. government will define requirements for new space situational awareness capabilities, including associated reference systems and data-sharing approaches. The United States will pursue new cost-effective capabilities while improving existing capabilities as necessary. This objective has synergies with efforts to provide early warning for potentially hazardous asteroids.

**Objective 4: Implement Cislunar communications and positioning, navigation, and timing capabilities with scalable and interoperable approaches.** Communications and positioning, navigation, and timing (PNT) are the common information infrastructure needed for all activities in Cislunar space, including in Lunar orbit and on the Lunar surface. This objective will ensure that infrastructure deployed for NASA's Artemis program can also help enable a cooperative and

sustainable ecosystem in Cislunar space. Implementing needed Cislunar communications and PNT capabilities with scalable and interoperable approaches can foster new commercial development and lower barriers to entry while advancing responsible and safe spaceflight practices. U.S. Departments and government agencies will leverage and promote the use of commercial services in Cislunar space.

This strategy will guide the policymaking process and provide an early common vision for agencies and collaborators to coordinate on Cislunar activities. Any commitment of Federal resources or budget to support this strategy will be determined through the budget process.

## DEFINITIONS

**Cislunar Space:** For the purposes of this document, Cislunar space is the three-dimensional volume of space beyond Earth’s geosynchronous orbit that is mainly under the gravitational influence of the Earth and/or the Moon. Cislunar space includes the Earth-Moon Lagrange point regions (defined below), trajectories utilizing those regions, and the Lunar surface.

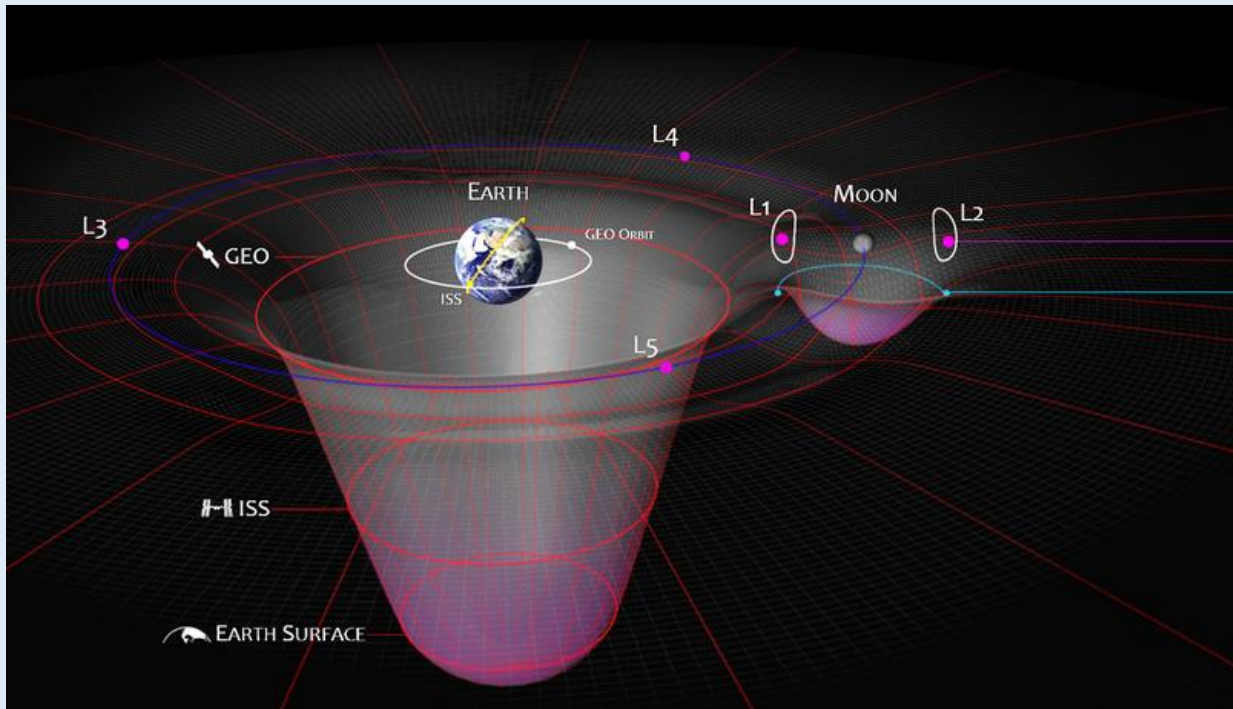


Figure 1: Three-dimensional depiction of Cislunar space. As the Moon revolves around the Earth, the Lagrange points keep the same orientation with respect to the Earth and the Moon. Not drawn to scale. (Image courtesy of NASA.)

**Lagrange Point Regions:** Lagrange points are places in space where an object will keep the same position relative to the Earth and the Moon. The Earth-Moon system contains five Lagrange points (L1-L5). Spacecraft placed in the regions around Lagrange points will require little to no propulsion to maintain their position.

**Shielded Zone of the Moon (SZM):** The Shielded Zone of the Moon is the portion of the Moon’s surface and the adjacent volume of space that is shielded from radio frequency interference coming from Earth.<sup>1</sup> This area may enable radio astronomy observations that are not possible anywhere else.

<sup>1</sup> See article 22, ITU-R Radio Regulations No. 22.22 – 22.25

## INTRODUCTION

### ***Purpose***

The United States will lead the world in responsible, peaceful, and sustainable exploration, development, and utilization of Cislunar space, including the Moon, consistent with the 2021 U.S. Space Priorities Framework.

Cislunar space offers tremendous promise for advancing science, technology, and exploration.<sup>2</sup> Humanity's activities on the Moon remain uniquely inspiring for people around the world. Cislunar space provides unique vantage points across and outward from the Earth-Moon system, opportunities to explore the history of our Solar System and Sun, a radio-quiet environment that can catalyze a new generation of radio astronomy, and new opportunities that are critical for crewed exploration and potential economic growth in space, among other possibilities.

U.S. science and technology leadership in Cislunar space will support the responsible, peaceful, and sustainable exploration and use of Cislunar space, including the Moon, by all spacefaring nations and entities. As we begin our next steps into space, the United States will work collaboratively with allies, international partners, and private entities to set the pace and direction of growing Cislunar activities—to foster scientific discovery, economic development, and international cooperation that reflects our shared values.

This document provides a vision and the early science and technology objectives for realizing U.S. leadership in responsible and sustainable exploration, development, and utilization of Cislunar space, including the Moon.

### ***The U.S. S&T approach to Cislunar space***

The decade ahead is critically important for exploration of Cislunar space, including the Lunar surface. The U.S. government, other countries, and private entities are all planning to send spacecraft into and through Cislunar space in the coming years. NASA estimates that over the next ten years human activity in Cislunar space will be equal to or exceed all that has occurred in this region since the Space Age began in 1957.

The growth of current and planned activities in Cislunar space is driven by decreasing launch costs, advanced and increasingly commodified space technologies, growing commercial interest in space activities, new missions by national space programs that are motivated by national and geopolitical ambitions, and the utility of Cislunar activities as a programmatic step toward some future missions into the solar system. These trends have opened Cislunar space as a new domain of diverse human activities, and spacefaring actors will begin to set important new precedents across the next decade.

Leadership by the United States and its international partners will support the responsible, peaceful, and sustainable exploration and use of Cislunar space, including the Moon. Fostering scientific discovery, economic development, and international cooperation are essential to sustaining this

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<sup>2</sup> *The 2022 National Academies of Science, Engineering, and Medicine's Decadal Survey on Planetary Science and Astrobiology, "Origins, Worlds and Life, 2023-2032", identified studies of the Moon as relevant to all three planetary science themes, and strongly relevant to six of twelve priority science questions.*

leadership. With this framework, the Cislunar S&T Strategy provides four objectives for the early years of Cislunar growth:

- (1) Support research and development (R&D) to enable long-term growth in Cislunar space.
- (2) Expand international S&T cooperation in Cislunar space.
- (3) Extend U.S. space situational awareness capabilities into Cislunar space.
- (4) Implement Cislunar communications and PNT capabilities with scalable and interoperable approaches.

All four S&T objectives support the U.S. vision of responsible, peaceful, and sustainable exploration and use of Cislunar space, including the Moon. Visionary R&D can foster world-leading scientific discovery; new approaches created in R&D enable responsible and sustainable space activities, enable economic development, and promote peaceful uses of space to the benefit of all. International S&T cooperation can foster peace, develop responsible practices, and create collaborations to enable enduring human presence in Cislunar space, including at the Moon. Extending space situational awareness (SSA) into Cislunar space creates a necessary foundation to promote and sustain responsible spaceflight practices, and enables transparency to promote peaceful and cooperative uses of Cislunar space. Finally, implementing needed Cislunar communications and PNT capabilities with scalable and interoperable approaches, analogous to development of early internet technologies, can foster commercial development necessary for sustainable activities, build early technology ecosystems based on cooperation around shared values, and advance responsible and safe spaceflight practices.

These objectives build on enduring strengths of the United States, including a global network of allies and international partners, the ability to draw the world's best talent and recombine it with the benefits of diversity, world-leading universities and higher education, private sector innovation ecosystems built on competition and self-correction, the rule of law and open science, and a culture of new beginnings.

### ***Near-term Cislunar trends***

Soon, the United States will achieve a key milestone with the NASA Artemis program, which will send the first human-rated spacecraft to Cislunar space since 1972. Robotic exploration of Cislunar space is also growing more robust, with many orbital cubesats and the first U.S. robotic Lunar landers since the Apollo era joining a host of other global probes and missions<sup>3</sup> operating in Cislunar space. This increase in activity spans a range of applications for science (including Lunar mapping and surveying from orbit, surface geophysical investigations, and radio astronomy observations), in-situ resource utilization (ISRU), and other exploration and development activities. To support these planned and future Cislunar activities, basic infrastructure is needed, including communications, PNT, transportation, and radio frequency spectrum management.

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<sup>3</sup> As one example, NASA is working with several U.S. companies to deliver science and technology to the Lunar surface through the [Commercial Lunar Payload Services \(CLPS\)](#) initiative. Under Artemis, commercial deliveries beginning in 2022 will perform science experiments, test technologies, and demonstrate capabilities to help NASA explore the Moon and prepare for human missions.



Near-term Cislunar enabling capabilities will need to be transparent, open, interoperable,<sup>4</sup> and scalable to advance a Cislunar ecosystem that is sustainable for years to come. Further, these activities must be supported by a diverse science and technology workforce equipped to tackle challenges associated with this still largely unexplored domain.

***The longer term: a new sphere of human activity***

Cislunar space is vast. Its volume of space is more than 2,000 times larger than the entire region of space within geosynchronous orbit, and the furthest region of Cislunar space is more than twelve times the distance of geosynchronous orbit from Earth. Spacecraft can operate in a variety of trajectories in Cislunar space including Lunar orbit, trans-lunar trajectories, and in families of orbits in the large regions around Earth-Moon Lagrange points.

A critical region of Cislunar space is the surface of the Moon itself. The Moon is tidally-locked, meaning one hemisphere (the “near side”) always faces the Earth, while the “far side” cannot be seen from Earth. This allows direct communication from Earth to the near side, but keeps the far side in the Shielded Zone of the Moon. The polar regions of the Moon are especially resource rich. Special locations include topographic peaks that are in near-continuous sunlight, and extremely cold, permanently shadowed regions that may preserve substantial deposits of ancient ice and other useful chemical compounds only found in trace amounts in other parts of the Moon.

In addition to government space programs, many other kinds of entities (spanning commercial, non-profit, and academic actors) are also expected to be operating in Cislunar space in the years ahead. The vision articulated in this document is designed to engage and be relevant to all space-faring entities as part of advancing a sustainable “Cislunar ecosystem.” To implement this vision, it will be necessary for the U.S. government to collaborate with other entities in the Cislunar ecosystem on a broad range of capabilities, standards, and infrastructure.

The United States continues to engage the international community to uphold and strengthen a rules-based international order for space, including in Cislunar space. Multiple international agreements already govern Cislunar space, including activities on the Lunar surface. This strategy is designed to be fully consistent with those agreements as well as other non-legally binding instruments that are applicable to Cislunar space. Particularly relevant to this strategy are the Outer Space Treaty of 1967,<sup>5</sup> the Rescue Agreement of 1968,<sup>6</sup> the Registration Convention,<sup>7</sup> the Liability Convention,<sup>8</sup> the ITU Radio Regulations,<sup>9</sup> the Artemis Accords,<sup>10</sup> additional efforts of the United Nations Committee

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<sup>4</sup> For information systems, interoperability is the capability of different systems or networks to communicate and exchange information with each other.

<sup>5</sup> [Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and other Celestial Bodies](#), United Nations Office for Outer Space Affairs

<sup>6</sup> [Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space](#), United Nations (UN) Office for Outer Space Affairs

<sup>7</sup> [Convention on Registration of Objects Launched into Outer Space](#), UN Office for Outer Space Affairs

<sup>8</sup> [Convention on International Liability for Damage Caused by Space Objects](#), UN Office for Outer Space Affairs

<sup>9</sup> [ITU Radio Regulations](#), World Radiocommunication Conferences

<sup>10</sup> [The Artemis Accords](#), Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes, NASA

on Peaceful Uses of Outer Space (COPUOS),<sup>11</sup> and other ongoing multilateral discussions and international treaties.

***Existing and future challenges that this strategy addresses***

The acceleration of activity in Cislunar space necessitates a cohesive and coordinated strategy to overcome early challenges associated with safe and sustainable operations in this complex spaceflight region. Achieving the U.S. government’s goal of responsible, peaceful, and sustainable activities in Cislunar space will require coordination among U.S. government and external entities (e.g. commercial, nonprofit, academic, and international actors). This strategy addresses key early scientific and technological challenges associated with spaceflight in this region of space.

**OBJECTIVES**

U.S. science and technology leadership in Cislunar space will continue to support the responsible, peaceful, and sustainable exploration and use of Cislunar space, including the Moon, by all space-faring nations and entities. Fostering scientific discovery, economic development, and international cooperation are essential to sustaining this leadership. To realize this vision, the U.S. government has adopted the following four high-level S&T objectives.

***Objective 1: Support research and development to enable long-term growth in Cislunar space***

Cislunar space is the gateway to the rest of the Solar System. It is a valuable place for us to test our systems and operations in preparation for future robotic and human missions to destinations in deep space. The Moon also has the potential to be a source of new scientific advances and resources to drive economic growth. To unlock these benefits and set the stage for humanity’s future in space, this objective includes the following clusters of sub-objectives: (1) R&D to enable enduring human presence, (2) R&D to best utilize Cislunar space for science, and (3) programs needed to ensure availability and readiness of a skilled workforce to support all efforts outlined in this strategy and beyond:

*Enable Enduring Human Presence*

**Develop and demonstrate capabilities and emerging technologies that enable an enduring human presence in Cislunar space and inform crewed missions to Mars and beyond.** The technologies that may be used for crewed missions into the Solar System—to Mars and beyond—have not yet been fully defined, leaving room for innovative concepts to be matured. Cislunar space should be used to experiment and innovate, while developing reliable and cost-effective technologies to support long-duration crewed missions beyond the Moon. The U.S. government will support the development of orbital and Lunar surface technologies and other scalable capabilities that support an enduring human presence on planetary surfaces. These include refuellable Lunar landers, environmental control and life support, lunar surface power systems, mobile and dust-resistant spacesuits, surface mobility in extreme environments, and sustainable habitats on

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<sup>11</sup> [Committee on the Peaceful Uses of Outer Space](#), *United Nations Office for Outer Space Affairs*

planetary bodies. The United States will identify and support engineering research on systems critical for these capabilities.

Further, the United States government will support Lunar resource assessments, as well as the advancement of research, development, and demonstration of capabilities for using materials sourced from the Moon and other celestial bodies. Such capabilities include resource characterization and surveys, manufacturing of components from in-situ materials, autonomous assembly of structures, construction of structures that maximize the use of in-situ materials, and processing of useful molecules such as water and oxygen.

The U.S. government, in collaboration with private entities, will demonstrate the ability to use the products created by these capabilities to enable an enduring human or robotic presence on the Lunar surface. U.S. government organizations will leverage collaborations with private entities to enable capabilities for large-scale ISRU and advanced manufacturing at the Moon, consistent with the U.S. National Strategy for In-space Servicing, Assembly, and Manufacturing. Use of Lunar materials should be included in the trade space for Lunar surface elements and operations.

**Conduct research to better understand and mitigate the negative effects on humans caused by the space environment.** There are limited data on the health effects of long-duration human spaceflight, leading to large uncertainty in the design of architectures for crewed exploration of deep space. The United States will use the Moon and Cislunar space to conduct research and gather data on radiation effects on crew performance and health, the effects of microgravity and partial gravity, psychological effects caused by isolation and confinement in a space environment, and the effects caused by simultaneous exposure to these aspects of the extreme space environment. Potential countermeasures, such as artificial gravity or metabolic stasis, should also be investigated and demonstrated. Long-duration Lunar exploration missions should be designed to provide insight on these factors that would clarify requirements and mitigation techniques for missions to Mars and other destinations across the Solar System, as well as enable enduring human presence on the Moon.

**Support social science research related to crewed exploration and permanent habitation of deep space to support enduring human presence in space.** Though microgravity and radiation are hallmarks of the space environment, there are additional challenges associated with long-duration human space exploration that must be further investigated. Many unresolved issues regarding space exploration cannot be solved through engineering alone, such as the guiding ethics of human expansion into space, long-term cooperative models for space development, and equitable governance structures for space communities. The United States will enable and support research in the social sciences to advance our understanding of these issues. This research will also encourage the scientific community and broader public to think more deeply about humanity's long-term future in space.

#### *Advance Cislunar Science*

**Maintain a Cislunar-focused science objectives summary to comprehensively identify the highest-priority scientific opportunities in Cislunar space.** The U.S. science community identifies scientific goals, questions, and recommended missions for the U.S. government for each traditional space scientific field by a Decadal Survey of that field. Further, NASA's Lunar Exploration Analysis

Group (LEAG) provides analysis of the scientific, commercial, technical, and operational issues to further Lunar exploration objectives. These collective efforts support the prioritization of U.S. scientific objectives in Cislunar space. The U.S. government will, in consultation with international collaborators, continue to build and maintain a Cislunar-focused science objectives summary, to include priorities identified in the Decadal Survey and analyses of LEAG as well as broader space science interests. This summary will identify the most compelling scientific studies to be accomplished in Cislunar space. The summary will be a primary factor in guiding planned Cislunar research and technology developments of the U.S. government.

**Develop and enhance technologies to enable near-side, far-side, and polar Lunar science.** Following the identification and prioritization of science opportunities in Cislunar space, the U.S. government will advance technologies as well as develop additional practices and guidelines to enable and protect Lunar science. This may include development of technology for Lunar far-side radio astronomy, advancement of space science instrumentation, research of the Lunar surface environment to investigate its impact on equipment, and enhancement of communication technologies for enabling these Lunar science activities, especially in the Shielded Zone of the Moon. These practices should be developed in a coordinated, balanced approach and should consider the unique environment of Cislunar space. New technologies are also required to explore the polar regions that may contain significant amounts of volatile compounds that are especially important for resource utilization.

*Support Our Workforce*

**Develop and support programs to train and retain diverse future generations of the space workforce.** The successful execution of the bold yet critical objectives in Cislunar space requires an expanded and advanced technical workforce. The United States Space STEM Task Force Roadmap will identify gaps and priority areas for encouraging early preparation at the K-12 level and entrance into the STEM educational and early-career pathways for space-related employment at the undergraduate, graduate, and postdoctoral levels, including broadening participation and opportunities. Institutions of higher education are critical in space exploration, especially in their education of the scientists and engineers who will carry out the research envisioned, make new discoveries, and take the next steps. In particular, the training of graduate students to work in interdisciplinary teams is critical. The United States will support a diverse set of institutions, including minority serving institutions, and encourage space-related careers by groups underrepresented in STEM to prepare the technicians, scientists, engineers, geodesists<sup>12</sup> and critical non-STEM occupations responsible for executing Cislunar space exploration and development. For the future technical workforce within the U.S. government, agencies will especially leverage programs to develop an advanced technical workforce, such as scholarship-for-service programs. The academic community has played an essential role in space exploration in past decades, and U.S. government investment in university laboratories and academic relationships will ensure

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<sup>12</sup> Several groups have discussed the ongoing need for geodesists, including through the reports [Evolving the Geodetic Infrastructure to Meet Scientific Needs](#), National Academies; [America's loss of capacity and international competitiveness in geodesy, the economic and military implications, and some modes of corrective action](#). The American Association for Geodetic Surveying

continuation of that role. In addition, a STEM-literate citizenry is needed to support space-related work: the great power of space exploration to excite people of all ages should be leveraged in both formal and informal learning environments.

***Objective 2: Expand international S&T cooperation in Cislunar space***

Achieving a peaceful, sustainable Cislunar ecosystem will require international cooperation. New Cislunar space operations and capabilities should invite expanded international engagement. For example, the Artemis Accords reinforce a practical set of principles to guide space exploration beyond Earth orbit. A number of international partners are actively contributing enduring Lunar infrastructure to NASA missions, while multiple nations have their own Lunar exploration plans.

Existing standards and organizational bodies, including those in the United Nations system of committees and specialized agencies, already impact the use of Cislunar space. The U.S. government will continue to work through these bodies, maintaining and promoting with international partners the availability of resources in Cislunar space for the full range of scientific activities.

To advance Lunar science and provide a basis for cooperative growth in Cislunar space, the United States will pursue specific areas in new S&T engagement with other nations, including:

**Develop and lead on a proposal for an International Lunar Year.** Science is an international enterprise, and scientists have long demonstrated the ability to work across boundaries for the common good. A United States-led initiative to establish an International Lunar Year (ILY) can build upon the historical examples of past International Polar Years (IPY), the International Geophysical Year (IGY), and the International Space Year (ISY). The ILY can amplify U.S. objectives being achieved with the Artemis Accords by fostering developments such as the coordinated use of Lunar data centers, coordinated Moon-based research (such as Lunar geophysical networks, solar science, and far side radio astronomy), and similar joint “leave behind” capabilities. The ILY can also demonstrate how these activities can be carried out responsibly for the benefit and in the interests of all nations, including developing countries, while enhancing transparency and building confidence and cooperation among Moon-faring entities.

**Develop technical foundations of best practices for safe Cislunar spaceflight operations.** With rapidly increasing spaceflight activities in Cislunar space, the U.S. government will lead development of best practices for safe and predictable operations in Cislunar space and Lunar orbit. In coordination with standard developing organizations, the U.S. government will support development of best practices related to debris mitigation, minimizing the hazard of Lunar landing ejecta, end-of-life operations, mishap reporting, collision avoidance, astronaut search and rescue, radio frequency interference, and other events associated with safety of flight. The U.S. government will also ensure Cislunar activities are supported by existing and future communication capabilities that manage spaceflight safety issues or emergencies. The U.S. government’s role in the development and use of standards will be guided by the National Technology Transfer and Advancement Act, OMB Circular A-119, and other Federal laws, regulations, and international agreements.

***Objective 3: Extend U.S. space situational awareness capabilities into Cislunar space***

SSA is essential to safe and successful spacecraft operations in all orbits, including in Cislunar space. SSA data, for example, help satellite operators avoid collisions with other satellites or debris, support rendezvous and proximity operations, and enable the identification of anomalous, irresponsible, or potentially dangerous spacecraft operations and space weather phenomena of significance. Expanded SSA capabilities will also provide benefits to, and benefit from, future missions to detect and warn of incoming potentially hazardous asteroids. The U.S. government will aim to understand the long-term effects of growing human activities on the Cislunar environment, and to preserve a safe and sustainable environment in Cislunar space—such as limiting debris in Lunar orbit. The following sub-objectives will advance this objective:

**Evaluate SSA needs, priorities, and existing gaps for extending current SSA capabilities into Cislunar space.** Though there are designs for preliminary program architectures, a comprehensive framework for the SSA R&D needs for Cislunar space remains undeveloped. The United States will support R&D to advance technology useful for Cislunar SSA, including improved monitoring methods and better understanding of Cislunar orbit families and spacecraft dynamics. In pursuing this work, the United States will leverage work undertaken across the Federal government, the private sector, and relevant standards developing organizations. The United States should pursue cooperation with all entities operating in Cislunar space to identify and track emerging requirements, and make recommendations for SSA and transparency improvements.

**Develop or improve current ground-based sensors, and demonstrate cost-effective space-based and Lunar surface sensors, as needed.** The United States should advance Cislunar SSA by initially identifying an architecture that optimizes terrestrial, Lunar-based, and space-based sensors, then leveraging existing ground-based sensors and developing new ground-based sensors as needed. Existing sensors should be investigated to determine if upgrades and/or modification to sensor software and hardware can improve detection of objects in Cislunar space. The U.S. government will support demonstrations of new, cost-effective terrestrial sensing capabilities optimized for Cislunar space, as well as continue developing and testing cost-effective space-based sensors for Cislunar SSA. These in-space tests should leverage orbits available in Cislunar space that can potentially enhance SSA capabilities. U.S. government organizations will leverage partnerships with the private sector to reduce the cost of Cislunar SSA capabilities.

**Increase cooperation and data-exchanges with other users of Cislunar space.** The scale and geometry of Cislunar space makes global networks of diverse sensors valuable to robust SSA, highlighting the value of international and private sector collaboration. The United States will pursue Cislunar SSA sharing with international collaborators, private sector actors, and academic institutions operating in Cislunar space. This could include joint research and development efforts, joint efforts on standards, and other areas. Due to the global importance of Cislunar SSA, the U.S. government will explore opportunities to increase the volume and speed of science and avoid duplication while coordinating critical overall efforts.

**Develop an integrated Cislunar object catalog.** Data formatting and standards between the U.S. government and private and international space missions will need to be coordinated to ensure compatibility. The U.S. government will develop and maintain an integrated catalog of Cislunar

objects, both natural and human-made, utilizing data from all available sources and in collaboration with private entities. The catalog should include human-made objects on the Lunar surface. The catalog should also include information about objects that can aid in assuring compatible coexistence with spacecraft and scientific investigations, including those from the Shielded Zone of the Moon. If possible, satellite operators should periodically provide their planned maneuvers and trajectories to the catalog.

**Develop procedures for publicly sharing Cislunar space situational awareness data, as well as navigation and spaceflight safety support in Cislunar space.** Consistent with national policy, including Space Policy Directive-3, the U.S. government will continue to share SSA information and provide basic spaceflight safety services to all space operators. A civilian open data platform will be used to leverage Cislunar SSA data and services provided from a variety of government, commercial, academic, and international sources. Additional discovery and characterization of potentially hazardous objects may leverage the International Astronomical Union’s (IAU) Minor Planet Center, the longstanding U.S. contribution via NASA’s Office of Planetary Defense.

***Objective 4: Implement Cislunar communications and positioning, navigation, and timing capabilities with scalable and interoperable approaches***

Communications and PNT are the common information infrastructure for all activities in Cislunar space, including in Lunar orbit and on the Lunar surface. The United States government will use scalable, interoperable, and secure approaches for information infrastructure to enable a cooperative and sustainable ecosystem in Cislunar space.

The NASA Artemis program, with its near-term mission to return humans to the Moon, provides the foundational elements for this objective. Through the Artemis program, NASA and its international partners will use innovative technologies to explore more of the Lunar surface than ever before, for the benefit of all.<sup>13</sup> The U.S. government, in collaboration with allies, international partners, and private actors, will work to establish the first long-term presence on the Moon. Lessons learned on and around the Moon will be used to take the next giant leap: sending the first humans to Mars.

This objective will ensure that the systems and infrastructure deployed for the Artemis program enable a cooperative and sustainable ecosystem in Cislunar space. U.S. Cislunar communications and PNT capabilities, if implemented with scalable and interoperable approaches, can meet requirements for NASA’s Artemis program, foster new commercial space activities and lower barriers to entry, and provide an early technological foundation for advancing responsible and sustainable activities in Cislunar space. To implement this objective, the potential future needs of

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<sup>13</sup> *Artemis I will fly an uncrewed flight test that will be the first in a series of increasingly complex missions to the Moon in preparation for human missions to Mars. Artemis II will perform a crewed Lunar flyby mission. Many other robotic missions will be conducted to Lunar orbit and the Lunar surface, including an uncrewed human lander demonstration mission. Subsequent Artemis missions will see the first woman and first person of color land on the Moon. This program will be supported by smaller-scale pathfinder missions, such as the Tipping Point Technology Demonstrations and larger programs such as the Lunar Gateway. These missions will include early tests of the establishment of PNT and communications networks.*

all stakeholders planning activities in Cislunar space should be considered. The following sub-objectives support this objective:

**Establish foundational capabilities in a timely fashion to enable a flexible Cislunar architecture.** The U.S. government and private actors are planning new Cislunar activities, but there is insufficient information regarding the capabilities needed to support these activities. Beyond network communications and PNT, capabilities of interest include mapping, in-space and Lunar surface transportation, radio frequency spectrum management, in-situ mobility, Lunar surface power generation and storage, use of Lunar resources, search and rescue, and space situational awareness. The United States government will define the needed capabilities, to include consideration of the cybersecurity, scalability, and interoperability of associated systems. The level of needed capability will inform updates to this strategy and subsequent implementation plans.

**Ensure that capabilities for U.S. government Cislunar operations are scalable and interoperable with systems operated by private and international actors.** Architectures deployed for Cislunar operations should be designed to anticipate the emergence of innovative and unexpected future user requirements that cannot be predicted at present. Architectures with this kind of flexibility likely require the use of broadly adopted technical standards. The United States will lead in developing capabilities and technical standards that support maximally interoperable and scalable infrastructure, while ensuring cybersecurity, especially for Cislunar communications and PNT. Standards of particular interest include: those for PNT in Cislunar space, radio and optical communications, a Lunar reference frame tied to the celestial and terrestrial reference frames, spacecraft safety and rescue, and orbit message formats and propagation models in Cislunar space. Infrastructure adaptation should include modernization and expansion of numerous sensing, ranging, and timing technologies and techniques to enable integration of new space-based operations with existing infrastructure. Such standards efforts should leverage bottom-up approaches that build upon existing<sup>14</sup> and emerging standards for space systems, including input from non-government experts. U.S. government agencies will leverage and promote the use of interoperable and scalable commercial services in Cislunar space.

**Coordinate new Cislunar activities with existing in-space operations.** Ongoing space activities like planetary defense, space weather research and monitoring, orbital debris mitigation, and space- and ground-based astronomy could begin to extend coordination to include consideration of new Cislunar development activities. The NSTC Subcommittee on Cislunar Science & Technology can help facilitate new U.S. government collaboration to advance Cislunar space priorities.

## CONCLUSION

Cislunar space is a new sphere of human activity, which offers opportunities to advance scientific understanding, exploration, and economic growth. This strategy provides a vision and the first science and technology objectives to advance the U.S. government's goal of responsible, peaceful, and sustainable exploration and utilization of Cislunar space.

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<sup>14</sup> [International Deep Space Interoperability Standards](#), *A partnership between International Space Station Agencies*