The Future of Commercial Space Stations: Key Issues in Commercial LEO Development and Policy Recommendations

This paper is a product of the Commercial Space Station Working Group of the Beyond Earth Institute Leadership Council. While the paper represents a summary of Working Group discussions and interviews, the views and recommendations do not necessarily represent those of the members or their respective organizations.

Working Group Manager: **Elena Graham**
Writer: **Eammon Christian**
Managing Editor: **Elizabeth Sanchez Chang**
Technical Review: **Steve Hoeser**

Executive Summary

The Commercial Low Earth Orbit Destinations (CLD) initiative marks a pivotal shift in U.S. space strategy, from a government-operated International Space Station (ISS) to a competitive, commercially sustained orbital economy. NASA's three-phase CLD framework, supporting design, development, and service procurement, aims to preserve a continuous American presence in orbit while fostering market-driven innovation. However, this transition faces interlinked regulatory, technical, and institutional challenges that will determine whether the United States maintains leadership in low Earth orbit (LEO) amid intensifying global competition, particularly from China's Tiangong Station.

Regulatory uncertainty remains one of the program's greatest risks. The lack of a clear indemnification policy for on-orbit activities exposes firms to potential crippling liabilities beyond existing launch coverage. Without congressional action to modernize the Commercial Space Launch Act or extended indemnification authority, insurance limitations could threaten both investor confidence, CLD program continuity and U.S. space leadership in LEO. Similarly, the absence of a defined mission authorization regime undermines the ability of the U.S. to observe the spirit of the Outer Space Treaty and deters commercial investment. The 2025 White House executive order assigning licensing authority to the Department of Commerce offers a viable path forward, but interagency coordination between Commerce, NASA, the FCC, and the FAA will be essential to ensure predictable oversight and coherent qualification criteria and commercial market standards.

Operational continuity during the transition from the ISS to commercial orbital facility services is another central concern. Maintaining a permanent human presence in LEO is both a technical and strategic imperative. Continuous crewed operations will be vital to sustain research pipelines, ensure rapid on-orbit responsiveness, and maintain U.S. leadership. Yet NASA's current timeline leaves open the possibility of a "LEO station gap," especially if the ISS retires before CLDs achieve operational service readiness.

The Beyond Earth (BE) Commercial Space Station Working Group concludes that maintaining overlapping crewed operations, through coordinated NASA and private astronaut missions, remains critical to avoiding strategic and research disruptions. Bridging any potential CLD human services readiness gap may also require short-term buffering ISS operations or the contracting of commercial astronauts so that NASA can fulfill microgravity research commitments on deployed but not yet NASA astronaut-qualified interim commercial CLD free-flyer platforms.

Technically, NASA's multi-provider model represents both opportunity and risk. Awarding at least two, and preferably three or more, providers within six months of the Announcement for Proposals (AFP) introduces beneficial competition and CLD service diverse redundancy. However, it also requires clear articulation of NASA's expectations for interoperability, acceptable service capability thresholds, and utilization balanced among stations. The agency's new role as an "anchor services customer" will require changes in thinking and contracting.[1] This will require organizational adjustments in thinking and perspective as NASA moves from being a mission integrator and owner-operator to one among many customers. As a partner, NASA's CLD agreements will need performance-based contracting that incentivizes flexibility and innovation without holding to traditional development processes shown to cause program delays and cost increases. Establishing unified NASA qualification standards for crew capacity, laboratory function, and logistics compatibility will be crucial for sustaining scientific output, providing operational safety, and maintaining research continuity.

Emerging technologies, especially AI and autonomous systems, will likely play an increasing role in long-term commercial station sustainability. Experiments such as Booz Allen's 2025 ISS AI assistant, demonstrate[2] how autonomous systems can support crew, optimize maintenance, and reduce reliance on Earth-based control. Yet their deployment raises new concerns around cybersecurity, liability, and human-machine command hierarchies. Developing consistent human-AI protocols will be necessary to balance operational efficiency with safety and ethical responsibility for both commercial and government customers.

Ultimately, avoiding a LEO gap is both a national and global policy imperative. The Tiangong Station's growth and continuous international engagement have already positioned China as a competitive hub for orbital research. If the U.S. fails to foster sustained uninterrupted human and tended research access to microgravity environments, it risks both ceding leadership and losing partnership networks built over two decades of ISS operations. NASA's progress under the 2025 CLD Directive represents meaningful steps toward ensuring continuity. But maintaining the necessary orbital services momentum will depend on legislative clarity, sustained funding, and alignment between government oversight and commercial agility.

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1 Duffy, Sean. "Directive on Revised Commercial Low Earth Orbit (LEO) Destinations (CLD) Phase 2 Acquisition Strategy." NASA. August 2025. https://www.nasa.gov/wp-content/uploads/2025/08/nasa-cld-directive-aug-4-2025.pdf?emrc=35eca8.

2 Booz Allen Hamilton. "AI aids ability to make critical space station repairs." 2025. https://www.boozallen.com/menu/media-center/q1-2026/booz-allen-and-meta-space-llama.html

The 2025 BE working group focused on four key elements crucial to the advancement of CLDs and for sustaining free market space station capabilities:

1. Legislative modernization of indemnification and mission authorization frameworks.
2. Operational assurance through continuous human presence and research continuity measures.
3. Technical resilience via multi-provider service capability benchmarks and prudently measured integration of AI and autonomy.
4. Strategic foresight to prevent a CLD-ISS service capability gap and maintain international competitive leadership.

Introduction

As the International Space Station approaches retirement, the United States is entering a competitive transition toward CLDs. NASA's CLD program is structured as a three-phase effort to transition from the International Space Station to privately operated space stations.

Phase 1 commenced with a set of funded and unfunded agreements that supported early design and technology development for multiple commercial station concepts, enabling companies to demonstrate feasibility and advance critical systems.

Phase 2 builds on that foundation through new funded agreements that move concepts toward flight-ready hardware and eventual in-space demonstrations, marking the transition from design maturity to operational capability.

Phase 3 will transition from system development to service procurement, in which NASA intends to purchase access to and the services of qualified commercial stations for crew missions and research activities, using procurement approaches similar to how it currently buys commercial cargo and crew transport.[3]

This CLD phased structure aims to enable NASA to maintain its U.S. presence in low Earth orbit while stimulating new commercial activities and investment, reducing long-term government costs, plus ensuring the commercial sector is prepared to assume primary responsibility for orbital operations. The key objective of this program is to ensure a seamless handover of orbital space facilities operations to private industry.

As of the Working Group (WG) review, multiple firms, including Axoim Space, Blue Origin with Sierra Space, and Voyager Space with Airbus, are competing for contracts, while others, such as SpaceX, ThinkOrbital, and Vast, are working to develop and deploy independent commercial stations.[4]

Competing non-market economy state actors are also critical factors in the CLD race and global open market competition. China currently operates the Tiangong station, presenting a direct rival to US firms' future stations. With such an active LEO environment, staying competitive in the international market of LEO destinations is vital. Our foreign partners see a clear endpoint to the ISS and uncertainties in the American political commitment to NASA's CLD projects. This competing global market capability, along with what many foreign interests see as an apparent lack of clear and unified U.S. support, imposes additional pressures and risks to free enterprise development of commercial orbital space facilities.

[3] NASA. "FAQs: The International Space Station Transition Plan." NASA. 2024. https://www.nasa.gov/faqs-the-international-space-station-transition-plan/#q1

[4] Berger, Eric. "NASA's new chief has radically rewritten the rules for private space stations." Ars Technica. 2025. https://arstechnica.com/space/2025/08/as-the-end-of-the-iss-nears-nasa-shakes-up-program-for-commercial-replacements/

[5] SpaceNews. "Navigating the shift to commercial space stations." SpaceNews. 2025. https://spacenews.com/navigating-the-shift-to-commercial-space-stations/

A surge in launch capacity underscores the already existing momentum of U.S. commercial market growth. In 2024, Florida's Space Coast hosted a record 93 orbital launches, with 2025 expected to surpass 100 launches in a single year. SpaceX alone has projected up to 170 launches in 2025, averaging one every other day.[6] Along with this is the likely introduction of reusable medium lift launchers such as Rocket Lab's Neutron and Stokes rocket at alternative launch sites, further portending additional reductions in launch costs.[7,8] Such cost reductions and cadence capability provide the potential logistical backbone needed for assembling, supplying, and rotating crews on commercial stations. Still, this increasing launch cadence also increases pressure on regulators and industry to resolve critical gaps in space transport policy and infrastructure.

Despite notable progress, the Commercial Low Earth Orbit Development (CLD) program continues to encounter institutional and technical hurdles that may complicate both the transition from the ISS and the introduction of privately operated space stations. In August 2025, NASA issued a CLD Directive under the leadership of the new Associate Administrator for Space Operations, reaffirming its commitment to sustaining a continuous U.S. presence in low Earth orbit while clarifying expectations for industry partners. The directive introduced three key reforms: (1) establishing baseline capability thresholds for crewed operations and research payloads; (2) aligning Phase 2 and Phase 3 milestones with concrete flight-readiness targets to mitigate schedule uncertainty; and (3) adopting a risk-based oversight framework designed to streamline qualification processes for NASA use and reduce duplicative reviews across centers. Significantly, the directive redefines NASA's role from direct station operator to mission integrator for agency-sponsored payloads and anchor customer for commercial services. This repositioning is intended to foster commercial autonomy while upholding safety and interoperability standards. Collectively, these measures aim to enhance regulatory transparency, stabilize program timelines, and support the long-term viability of the commercial LEO ecosystem.

CLDs also face other regulatory and technical challenges that this paper seeks to address. Chief among these are the unresolved questions of liability and indemnification for on-orbit operations. Fragmented mission authorization regimes complicate compliance with treaty obligations, while timeline questions jeopardize continuous human presence in LEO. Furthermore, as multiple platforms prepare to operate simultaneously, issues of module capabilities, common interfaces and prudent implementation of AI/autonomous systems are emerging as new consideration factors in commercial operations. Collectively, these challenges will shape whether commercial stations can deliver on their promise of sustainable, innovative, and strategically competitive orbital platforms.

Regulatory Challenges

The Need for Indemnification

Indemnification revolves around liability protection for commercial space station developers and operators. Current U.S. law establishes such a government risk-sharing regime for launches under the Commercial Space Launch Act, wherein the government covers third-party claims exceeding required insurance up to a capped amount. However, this framework has never been tested and does not extend to on-orbit station operations.[9] NASA also possesses authority since 2004 to indemnify its contractors for "unusually hazardous" activities, but that authority has also never been exercised.[10]

Industry stakeholders in future orbital space facilities argue that without a government indemnification

[6] Berger, Eric. "NASA's new chief has radically rewritten the rules for private space stations." Ars Technica. 2025. https://arstechnica.com/space/2025/08/as-the-end-of-the-iss-nears-nasa-shakes-up-program-for-commercial-replacements/

[7] Foust, Jeff. "Short-duration space station missions not part of NASA's long-term plans." SpaceNews. 2025. https://spacenews.com/short-duration-space-station-missions-not-part-of-nasas-long-term-plans/

[8] Stoke Space. "Stoke Space Nova." 2025.https://www.stokespace.com/nova/

[9] GAO "Commercial Space Launch Insurance: FAA Needs to Fully Address Mandated Requirements. Washington, DC: U.S. Government Accountability Office", 2018. https://www.gao.gov/products/gao-18-57

[10] MacDonald, Alexander. "Commercial LEO Destinations Asset and Liability Insurance: Findings and Options". NASA. 2024. https://www.nasa.gov/wp-content/uploads/2024/09/cld-liability-september-ogc-somd-otps-cleared-with-cover-tagged.pdf

backstop, a catastrophic incident, such as a station failure causing loss of crew or ground damage, could expose companies to liabilities exceeding the capacity of insurance markets to cover, which is a risk that could deter investment altogether[11,12] . As a result, indemnification has become a central concern for commercial space station investors and insurers alike, since it underpins both financial stability and confidence in the long-term viability of CLDs.

Absent a clear indemnification framework for commercial stations, companies must rely on limited insurance markets and contractual waivers, which may prove inadequate to deal with catastrophic scenarios.[13] CLD providers conveyed to NASA Space Operations Mission Directorate that they were having difficulty obtaining insurance for their proposed destinations.[14] The U.S. Government Accountability Office (GAO) has previously warned that even for launches, the FAA's outdated insurance calculations might leave the government more exposed than intended.[15] Such a gap would only widen for coverage of long-term orbital operations. In the future, as CLDs host astronauts from global governments, firms, and private passengers, the financial stakes of an incident will rise considerably. A large liability claim with no government support may not only collapse one company but also devastate the entire commercial space industry.

Policy recommendations

Modernizing indemnification policy to cover the launch and on-orbit activities of CLDs. This can be accomplished by either extending the existing indemnification regime or by creating new risk-sharing provisions for CLDs.[16] Such coverage should explicitly address the extent to which on-orbit activities, ranging from crewed operations to hosted foreign payloads, fall within the indemnification framework.

One approach is for Congress to consider extending the FAA's commercial liability regime to CLDs. Implementing the GAO's recommendations, such as updating liability risk models and engaging insurers and stakeholders, could also aid in creating an indemnification framework.[17] In addition, NASA could potentially use its national defense Public Law 85-804 indemnification authority, which would allow NASA to indemnify CLDs under a national defense purview.[18]

Because of the global reach of the CLD market, it will be vital that liability coverage is consistent across both domestic and international operations. From a global perspective, as commercial stations anticipate carrying more foreign clients and payloads, clarification is needed on whether the United States will continue to rely on existing cross-waivers under current international mechanisms or develop a more explicit approach for mixed-nationality missions. Ultimately, legislation that balances industry growth with public risk will be needed to ensure that catastrophic liabilities are addressed without stifling innovation.

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[11] Kisiel, Edwin. "Indemnification for Commercial Space Services Vendors." Public Contract Law Journal 53, no. 3 (Spring 2024), American Bar Association, https://www.americanbar.org/groups/public_contract_law/resources/journal/2024-spring/indemnification-commercial-space-services-vendors/

[12] Tolliver, Clarence. "U.S. Commercial Launches of Space Nuclear Systems – Insurance and Indemnification Considerations." Pillsbury Law. 2025. https://www.pillsburylaw.com/a/web/eTQjCfYJZLjjisDujnvCQf/us-commercial-launches-of-space-nuclear-systems-insurance-and-indemnification-considerations-accepted-version_05may2025.pdf

[13] MacDonald, Alexander. Commercial LEO Destinations Asset and Liability Insurance: Findings and Options. NASA. 2024. https://www.nasa.gov/wp-content/uploads/2024/09/cld-liability-september-ogc-somd-otps-cleared-with-cover-tagged.pdf

[14] Ibid.

[15] GAO. "Commercial Space Launch Insurance: FAA Needs to Fully Address Mandated Requirements". Washington, DC: U.S. Government Accountability Office, 2018. https://www.gao.gov/products/gao-18-57

[16] Kisiel, Edwin. "Indemnification for Commercial Space Services Vendors." Public Contract Law Journal 53, no. 3 (Spring 2024), American Bar Association https://www.americanbar.org/groups/public_contract_law/resources/journal/2024-spring/indemnification-commercial-space-services-vendors/)

[17] GAO. "Commercial Space Launch Insurance: FAA Needs to Fully Address Mandated Requirements". Washington, DC: U.S. Government Accountability Office, 2018. https://www.gao.gov/products/gao-18-57)

[18] Acquisition.gov. "52.250-1 Indemnification Under Public Law 85-804." Acquisition.gov. 2025. https://www.acquisition.gov/far/52.250-1.

Maintaining Continuous Human Presence in LEO

Continuous human presence addresses the question of whether the United States should maintain an uninterrupted Government human presence in LEO, especially as the ISS era gives way to commercial stations. For over two decades, the ISS has hosted a continuous rotation of NASA astronauts, serving as a permanent human outpost in orbit.[19] As NASA transitions to CLDs, there is debate over NASA maintaining continuous crewed operations versus temporary operations. Some argue that next-generation stations might be intermittently uncrewed to reduce costs, while others insist on continuous occupancy as a cornerstone of U.S. space leadership.

There is little doubt that continuous NASA presence has enabled constant research, demonstrated global leadership, and maintained partnerships with allies. NASA's LEO strategy explicitly calls for a "continuous heartbeat in low Earth orbit" even after ISS retirement.[20] However, there seems to be variances in how this statement is interpreted..

NASA's recent CLD Directive stated a goal of a 4-person crew working for one month or longer, leaving flexibility for human presence in CLD. Past statements from NASA have emphasized "avoiding" a human presence gap in LEO, while more recent statements indicate they are focused on "minimizing" the gap, potentially showing a change in NASA's stance.

Others argue that continuous American heartbeats may come from U.S. commercial operators or private citizens, especially as NASA astronauts will no longer handle CLD stations operations and upkeep. Some estimates have suggested that up to 44% of the ISS U.S. segment's current total work hours are for maintenance and cargo operations.[21]

If continuous human presence on CLD stations is not maintained, there are both cost savings along with significant risks. While temporary operations could reduce life-support and logistics costs, NASA officials warn that lapses in presence could damage U.S. leadership and reduce responsiveness to on-orbit challenges.[22] Furthermore, a temporary presence could have downstream effects on the cost and complexity of micro-gravity research as well as the types of research that can be conducted in LEO. Human tending of long-duration microgravity is often essential for some biological and physical experiments, and interruptions may hinder important work in the overall research pipeline. Future risks include slower responses or worse yet, perhaps a complete inability to provide unforeseen and emergency responses to on-station issues likely resulting in erosion of public and international support for human spaceflight.

NASA's Commercial Crew Program currently supports NASA's long-duration crew rotation missions to the ISS under contract for their astronauts residing there for months at a time. In contrast, private astronaut missions to the ISS are shorter in duration and are brokered commercially. For example, Axiom's privately funded missions to the ISS have carried international payloads or private participants for brief stays.[23]

Because of such differences in mission duration, risk tolerance, and operational models, the scheduling and priority of future CLD missions to maintain continuous presence requires careful policy design.[24] If the goal is to keep at least one station continuously inhabited during the ISS-to-CLD handover and beyond, policymakers must determine whether to prioritize NASA's commercial crew rotations or permit and schedule private government-contracted astronaut missions accordingly.

Policy recommendations

U.S. strategy already identifies maintaining a continuous human presence as essential to sustaining American leadership in LEO.[25] As such the NASA needs to prioritize coordinated scheduling of NASA's future commercial crew astronaut missions to ensure at least one CLD station remains inhabited as the ISS-

[19] NASA. "FAQs: The International Space Station Transition Plan." NASA. 2024. https://www.nasa.gov/faqs-the-international-space-station-transition-plan/#q1.

[20] Wainscott, Anne. "NASA Calls for Continuous American 'Heartbeat' in LEO." AIAA. January 8, 2025. https://aiaa.org/2025/01/08/nasa-calls-for-continuous-american-heartbeat-in-leo/.

[21] Stack Exchange contributors. "How much time does the ISS require in 'non value adding activities'?" Space Stack Exchange. 2024. https://space.stackexchange.com/questions/65506/how-much-time-does-the-iss-require-in-non-value-adding-activities.)

[22] Lucas, Frank. "ISS and Beyond: The Present and Future of American Low-Earth Orbit Activities." Hearing Charter. House Committee on Science, Space, and Technology, Space and Aeronautics Subcommittee. 2024. https://democrats-science.house.gov/imo/media/doc/ISS%20and%20Beyond%20-%20Hearing%20Charter.pdf)

[23] Axiom. "Axiom Mission 4." Axiom Space. 2024. https://www.axiomspace.com/missions/ax4)

[24] NASA. "FAQs: The International Space Station Transition Plan." NASA. 2024. https://www.nasa.gov/faqs-the-international-space-station-transition-plan/#q1.

[25] White House. "National Space Policy: United States of America". White House Archives. December 2020. https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/12/National-Space-Policy.pdf

to-CLD handover occurs and beyond, while also investing in autonomy to help the U.S. CLD industry to effectively handle crew absences.[26-27] Investments in coordinated launches as well as autonomous systems, pursued through NASA-industry development partnerships, will enhance commercial industry's resilience, reduce operational risk, and ensure that research continuity and asset protection are not jeopardized by temporary gaps in human presence on CLD stations.

Mission Authorization

Mission authorization refers to the regulatory approval and supervision of private space activities. Today, regulatory authority is fragmented: the FAA licenses launches and reentries, the FCC manages the communications spectrum, and NOAA oversees remote sensing, but no agency has yet been designated or assigned the authority to oversee space station operations. This ambiguity conflicts with U.S. obligations under the Outer Space Treaty to authorize and supervise nongovernmental space activities.[28] The Biden Administration's Novel Space Activities framework (2023) acknowledged these gaps and outlined some interim steps for oversight. Currently, the Trump administration has continued the progress of CLD development; however, key points regarding mission authorization, notifications, and the issuance of operating licenses have not (as of this writing) been clarified. Congress continues to debate which agency, the Commerce Department, the FAA, or another agency, should hold mission operations authorization authority.[29]

Despite not filling the gap, the FCC's October 2025 Notice for Proposed Rule Making (NPRM) (SB Docket No. 25-306) signals movement towards a partial remedy in modernizing the space and Earth station licensing process through a new modular "Part 100" framework and a faster "licensing assembly line".[30] While it does not create comprehensive mission authorization, the 2025 NPRM begins to narrow the gap by modernizing part of the licensing ecosystem, including areas such as communications, orbital changes, and may include activities like in-space assembly or module reconfiguration.

However, remaining uncertainty in this regard creates financial and legal risks for CLD developers, potentially deterring further investments and complicating international compliance/cooperation. NASA's policy analysis highlights unresolved issues such as extending launch liability regimes to on-orbit operations and clarifying the FAA's role once the regulatory "learning period" ends.[31]

Policy recommendations

Implement the 2025 space executive order, which empowers the Department of Commerce to license commercial stations, with NASA providing interim guidance through contracting standards.[32] This early collaboration between Commerce and NASA will be an essential step to prepare government licensing and develop acceptable commercial standards for safe on-orbit operations and human activity. Clear mission authorization, authority, and procedures will give stabilizing industry predictability while ensuring compliance with treaty obligations and safety standards.

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[26] Wainscott, Anne. "NASA Calls for Continuous American 'Heartbeat' in LEO." AIAA. January 8, 2025. https://aiaa.org/2025/01/08/nasa-calls-for-continuous-american-heartbeat-in-leo/.

[27] NASA. 2025. "Commercial Low Earth Orbit Development Program (CLDP) Draft Announcement for Partnership Proposal (AFPP) Commercial Destinations - Development and Demonstration Objectives (C3DO)." https://www.nasa.gov/johnson/jsc-procurement/c3do/.

[28] WH.Gov. "FACT SHEET: U.S. Novel Space Activities Authorization and Supervision Framework." Biden White House Archives. December 20, 2023. https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2023/12/20/fact-sheet-u-s-novel-space-activities-authorization-and-supervision-framework/

[29] NASA. 2025. "Commercial Low Earth Orbit Development Program (CLDP) Draft Announcement for Partnership Proposal (AFPP) Commercial Destinations - Development and Demonstration Objectives (C3DO)." https://www.nasa.gov/johnson/jsc-procurement/c3do/.

[30] FCC. "October 7, 2025 FCC FACT SHEET: Space Modernization for the 21st Century Notice of Proposed Rulemaking – SB Docket No. 25-306." Federal Communications Commission. October 7, 2025. https://docs.fcc.gov/public/attachments/DOC-415048A1.pdf

[31] NASA. 2025. "Commercial Low Earth Orbit Development Program (CLDP) Draft Announcement for Partnership Proposal (AFPP) Commercial Destinations - Development and Demonstration Objectives (C3DO)." https://www.nasa.gov/johnson/jsc-procurement/c3do/.

[32] WH.Gov. "FACT SHEET: U.S. Novel Space Activities Authorization and Supervision Framework." Biden White House Archives. December 20, 2023. https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2023/12/20/fact-sheet-u-s-novel-space-activities-authorization-and-supervision-framework/

Continued Research During CLD Development

This topic questions how the research industry can avoid a scientific research gap as ISS retires and commercial stations come online. The ISS remains a prolific research platform, producing critical science in fields from biotechnology to human health. NASA's ISS Transition Plan emphasizes continuous access to microgravity R&D through CLDs, aiming to maintain the U.S. as "one of many customers" for commercial services.[33] However, uncertainty in CLD readiness and the 2030 ISS retirement plan creates the risk of a gap in access. Congressional hearings have also warned that without replacement stations, deep space missions may face delays due to a lack of ongoing testing in orbit.[34] If a gap occurs, critical experiments could be disrupted, causing delays in research progress and undermining international partnerships. The workforce trained for orbital science may shrink, and the U.S. risks ceding leadership to competitors, such as the rapidly developing capabilities of the Chinese Tiangong Station.[35] Additionally, unclear timelines could frustrate international partners that desire to have their own continuous LEO presence.

Policy recommendations:

Fully utilize the ISS while accelerating CLD development to prevent a gap in microgravity access. If NASA's CLD program or other contingencies cause delays, a limited extension of ISS operations or deployment of interim free-flyer platforms should be considered. Meanwhile, NASA and commercial partners should facilitate the seamless transfer of ISS experiments to commercial stations.[36] Ensuring funding continuity is essential: Congress needs to continue to provide sufficient resources to sustain ISS operations during the handover, while directing additional investment toward the CLD Phase II winner(s) and enhancing institutional research capacity to avoid brain-drain to other technical sectors or international competitors. To structure CLD support, NASA may consider adapting an ISS National Laboratory–style (ISSNL) framework for successor commercial platforms, a "sponsored program" or model that allows non-NASA users or institutions to contract for research and development access under an overarching governance and funding structure.[37]

Commercial Station Availability vs. NASA CLD-ISS Timelines

As termed in the press,[38] an ISS-CLD gap refers to the risk of a time lag between ISS deorbit and operational CLDs. As can be seen in the above figure NASA plans to retire ISS research operations in 2030, however CLD program development timelines may not align, potentially leaving no U.S. human and research orbital presence. To date Russia has only committed to the ISS through 2028, further heightening uncertainty.[39] Meanwhile, China's Tiangong station has been continuously crewed since 2022, raising the geopolitical stakes.[40]

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[33] NASA. "FAQs: The International Space Station Transition Plan." NASA. 2024. https://www.nasa.gov/faqs-the-international-space-station-transition-plan/#q1

[34] Lucas, Frank. "ISS and Beyond: The Present and Future of American Low-Earth Orbit Activities." Hearing Charter. House Committee on Science, Space, and Technology, Space and Aeronautics Subcommittee. 2024. https://democrats-science.house.gov/imo/media/doc/ISS%20and%20Beyond%20-%20Hearing%20Charter.pdf

[35] Space.com. "US space science could fall behind China if private successors to ISS are delayed, Congress warns." Space.com. 2024. https://www.space.com/international-space-station-replacement-china-congress

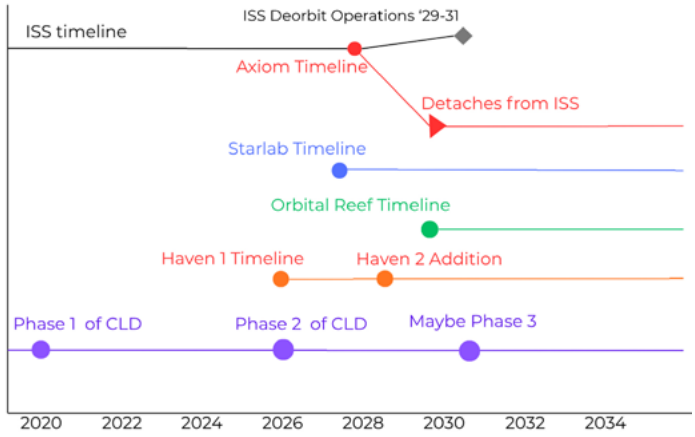
[36] Lucas, Frank. "ISS and Beyond: The Present and Future of American Low-Earth Orbit Activities." Hearing Charter. House Committee on Science, Space, and Technology, Space and Aeronautics Subcommittee. 2024. https://democrats-science.house.gov/imo/media/doc/ISS%20and%20Beyond%20-%20Hearing%20Charter.pdf

[37] CASS. "ISS History & Timeline." ISS National Lab. 2024. https://issnationallab.org/about/iss-national-lab-overview/iss-history-timeline/)

[38] Foust, Jeff. "Rocket Lab on 'green light' schedule to make first Neutron launch in 2025." SpaceNews. 2025. https://spacenews.com/rocket-lab-on-green-light-schedule-to-make-first-neutron-launch-in-2025/

[39] Lucas, Frank. "ISS and Beyond: The Present and Future of American Low-Earth Orbit Activities." Hearing Charter. House Committee on Science, Space, and Technology, Space and Aeronautics Subcommittee. 2024. https://democrats-science.house.gov/imo/media/doc/ISS%20and%20Beyond%20-%20Hearing%20Charter.pdf

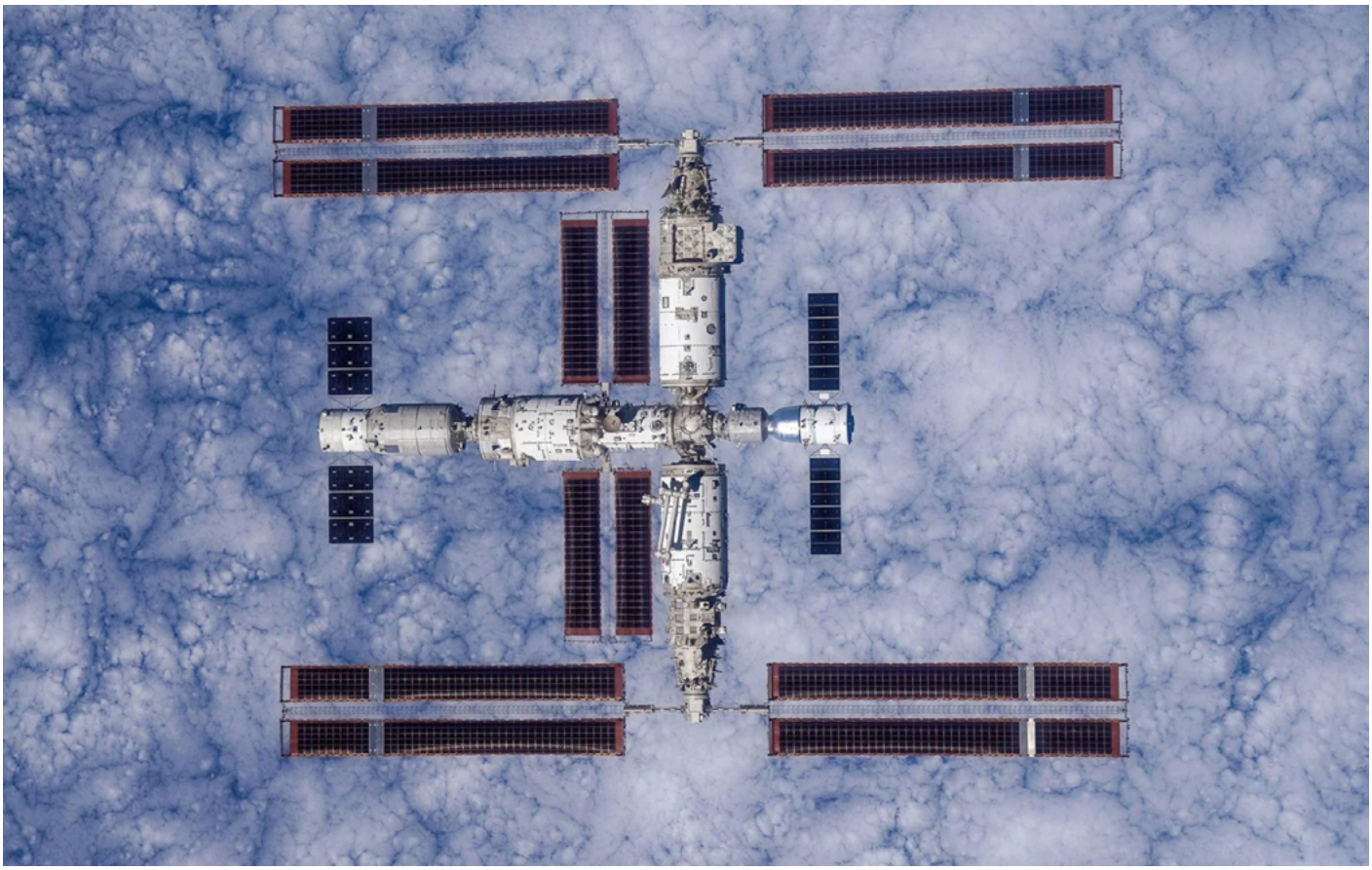
[40] Ibid.



(Christian, Created using Canva, 2025)

An ISS-CLD gap would not only disrupt research but also risk ceding symbolic and strategic leadership in LEO to competitors. Congress has strongly emphasized the importance of avoiding such a gap.[41] As shown in the graphic, initial stages of multiple stations will be starting as ISS deorbit operations unfold. Because commercial operations may not be fully ready by the completion of deorbit, this risks creating a human presence gap. If the gap materializes, ongoing microgravity experiments will be disrupted, NASA's exploration roadmap will be delayed, and the commercial LEO economy could be jeopardized. The NASA Inspector General has warned that losing ISS without a replacement ready would severely undermine research continuity and commercial viability.[42]

Tiangong's Implications



(Tiangong Station, image from Space.com 2023)

[41] Wainscott, Anne. "NASA Calls for Continuous American 'Heartbeat' in LEO." AIAA. January 8, 2025. https://aiaa.org/2025/01/08/nasa-calls-for-continuous-american-heartbeat-in-leo/

[42] NASA. 2025. "Commercial Low Earth Orbit Development Program (CLDP) Draft Announcement for Partnership Proposal (AFPP) Commercial Destinations - Development and Demonstration Objectives (C3DO)." https://www.nasa.gov/johnson/jsc-procurement/c3do/.

Ever since the Chinese successfully deployed the Tiangong Space Station in 2021, policymakers and industry have carefully watched this Chinese competitor. China's fast-paced operational tempo and continued stated dedication to space exploration have created the conditions for another space race, which is coming to a head in LEO. Contrary to the ISS, which was designed and deployed at the end of the 20th century, Tiangong is currently the newest and most sophisticated space station in orbit.

The Tiangong space station offers a large suite of experiment racks, 25 in pressurized modules plus external experiment platforms, supports modular growth, and has been continuously crewed by rotating three-person teams on roughly six-month rotations since mid-2022.[43-44] Additionally, China has engaged in a forward effort to entice foreign corporations and countries to contribute to research on Tiangong. Nations such as Russia, Japan, India, Mexico, Pakistan, Saudi Arabia, Switzerland, Poland, Germany, Italy, and others have already signed on to do micro-gravity research.[45] In the broader timeline, the Tiangong station provides consistent research access for international partners while ISS de-orbit timeline uncertainties remain.

Furthermore, China is expanding its influence through its research alignment. The International Lunar Research Station (ILRS) initiative, announced jointly with Russia in 2021, invites partner nations to collaborate on a long-term lunar base and research network under Chinese leadership.[46]

By contrast, the Artemis Accords, launched by the United States in 2020, promote transparency, interoperability, and peaceful exploration under a coalition of "like-minded" partners. The contrast between the two frameworks underscores China's strategy to pair rapid non-market economic domestic development, seen in Tiangong, with diplomatic outreach through ILRS. This creates an alternative network of international partners and shared research opportunities that rival U.S.-aligned initiatives. It is clear that if any real or perceived gap in research access or human presence occurs in U.S. space station availability, our state partners, and global private firms will have few options besides using the Tiangong alternative.

Policy recommendations

Accelerate the CLD downselect, focusing funding on capable partners to prevent any post-ISS-CLD gap while fostering further international partnerships and new research with CLD providers. While maintaining multiple projects hedges against delay, a quicker down-select allows NASA to concentrate resources on getting the remaining international and commercial partners to orbit. NASA must also avoid adding new requirements that increase costs or delays and instead prioritize launching commercial stations to demonstrate they meet NASA's research and habitation needs. To support this acceleration, NASA should adopt a parallel CLD facility qualification approach to facilitate the earlier, fast-track exploitation of CLD commercial facilities for hosting NASA-sponsored experiments. Taking advantage of commercial astronauts to tend these experiments as needed, this two-track approach accelerates experiment transition while supporting NASA human qualification. With proper crafting this approach leverages common qualification testing but decouples the completion of NASA personnel's human qualification activities from the requirements for experimental equipment.

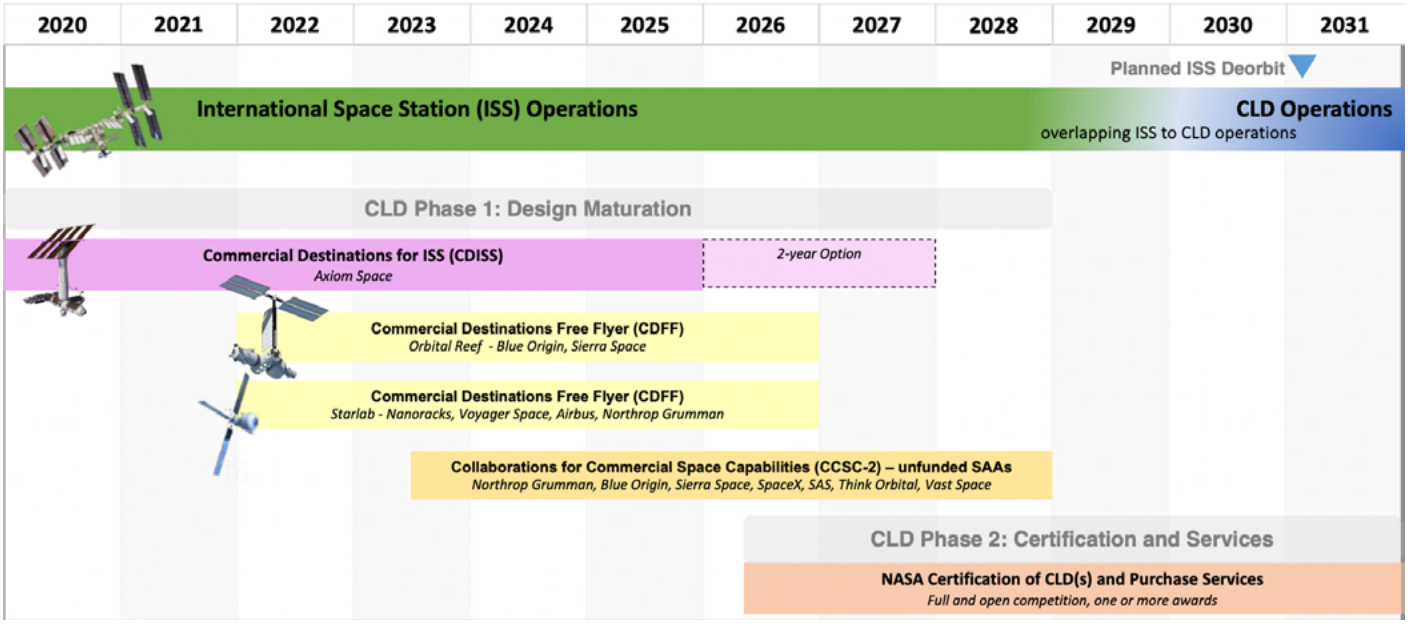
[43] Roll, Jonathan, and Oliver Du Bois. "Redshift: The Acceleration of China's Commercial and Civil Space Enterprise & The Challenge to America". Commercial Space Federation. 2025. https://commercialspace.org/wp-content/uploads/2025/09/CSF-Redshift-v6.pdf

[44] Tiangong | China Space Station. "Tiangong X Account." Twitter/X. February 14, 2022. https://x.com/TiangongStation/status/1493333813832736769

[45] Roll, Jonathan, and Oliver Du Bois. "Redshift: The Acceleration of China's Commercial and Civil Space Enterprise & The Challenge to America." Commercial Space Federation. 2025. https://commercialspace.org/wp-content/uploads/2025/09/CSF-Redshift-v6.pdf

[46] CLEP. "International Lunar Research Station (ILRS)." United Nations Office for Outer Space Affairs (UNOOSA). 2021. https://www.unoosa.org/documents/pdf/copuos/2023/TPs/ILRS_presentation20230529_.pdf

Capabilities of CLDs



(Commercial Space Division Programs, 2023)

NASA's recent policy, which allows for the award of at least two, and preferably three or more, CLD providers within six months of the final Announcement for Proposals (AFP), represents a major development in shaping that ecosystem. Expanding the field of providers enhances competition, diversifies supply chains, and reduces the risk of dependency on a single station service provider. However, it is also important that NASA clearly articulate how it intends to use such a multi-provider system-of-systems.

NASA's CLD program is structured to preserve a continuous U.S. human presence in orbit while transitioning from the single-platform model of the ISS to a diversified, commercially driven ecosystem. Initiated through a series of Phase 1-funded and unfunded agreements beginning in 2021, the program enabled multiple companies to mature early station designs and critical technologies. The first phase focused on defining the essential functions required for long-term orbital operations, crew habitation, logistics support, and research capabilities, while laying the groundwork for eventual government service procurement under Phase 3. As outlined in NASA's 2025 CLD Directive, the goal is to maintain these capabilities without replicating the ISS. Instead of one main hub this would distribute them across several independent yet interoperable stations that collectively sustain U.S. and partner research in low Earth orbit beyond the ISS's planned deorbit in 2030.

The early contract winners each illustrated different strategies for achieving CLD capabilities. Axiom Station plans a modular architecture that initially attaches to the ISS before detaching as an independent platform, offering a phased transition for NASA operations. Starlab, led by Voyager Space and Airbus, pursues a single-launch free-flying station with an integrated habitat and dedicated research park to enable continuous scientific work. Orbital Reef, developed by Blue Origin and Sierra Space with industry partners, envisions a larger, mixed-use complex supporting commercial, research, and governmental tenants simultaneously. Each of these concepts represents a unique approach to modularity, scalability, and logistics cadence, but all are expected to demonstrate the four "capability pillars" identified in NASA's 2023 HEO NAC Briefing: reliable crew capacity, robust laboratory functionality, resilient life-support and power systems, and integration with commercial cargo and crew vehicles.[47] These shared metrics ensure that future platforms maintain NASA's scientific throughput and human-rating reliability necessary to continue the ISS's research legacy.

[47] NASA. "Commercial Space Division Programs." NASA. 2023. https://www.nasa.gov/wp-content/uploads/2023/11/csd-heo-nac-briefing-may-2023-2023-11-14-16-4.pdf

As the CLD program moves into Phase 2, NASA has shifted its focus from concept definition to capability validation. The 2025 CLD Directive and subsequent HEO NAC guidance call for the establishment of baseline capability thresholds across all providers, covering crew duration, research volume, data management, and interoperability, to create a unified performance framework while allowing commercial flexibility in achieving those goals.[48] Under this framework, NASA intends to conduct an open competition and award contracts to at least two, and preferably three or more, CLD providers within six months of the final Announcement for Proposals (AFP). This multi-provider model is designed to expand competition, enhance redundancy, and reduce supply-chain risk while enabling NASA to act as a mission integrator coordinating its research access across multiple platforms. Collectively, these capability benchmarks and procurement mechanisms represent the core of NASA's post-ISS strategy: a diverse, commercially sustained orbital infrastructure capable of supporting both government missions and private-sector innovation well into the 2030s.

Policy recommendations

Strengthen the long-term sustainability of the CLD program. NASA can achieve this by clearly defining the core capabilities it expects while avoiding overly prescriptive design or operational requirements. Establishing transparent capability thresholds, covering crew capacity, laboratory functions, logistics compatibility, and interoperability, will give providers clear performance targets while preserving flexibility in how they achieve them. The agency's role should focus on setting measurable outcomes tied to mission and research needs, allowing commercial partners to pursue innovative architectures, designs, qualification and business models that meet selected market goals. This aligns with the evolving shift outlined in the 2025 CLD Directive, which emphasizes NASA's position as an anchor customer and mission integrator for its activities rather than a direct station operator and maintainer. By prioritizing performance-based benchmarks over technical mandates, NASA can ensure that future CLD capabilities remain adaptable to both agency and market demands.

Future policy guidance should clarify the agency's long-term vision for balancing roles, funding, and utilization across multiple stations, ensuring that resources are aligned with usage priorities and operational readiness. One practical framework would be an "anticipated" seven-year renewable lease, in which NASA commits to recurring service access while maintaining annual flexibility tied to performance and evolving mission needs. This hybrid model would provide stability for industry partners while protecting NASA's agility as an institutional customer and congressional funding authority. By combining clear capability-needs , competition among multiple providers, and flexible contracting, NASA can enable a resilient commercial LEO marketplace capable of sustaining U.S. presence well beyond the ISS era.

Autonomy

Autonomous systems are anticipated to play a key role in the future by improving the efficiency of CLD operations. As adopted by virtually all mega-LEO commercial communication constellation applications, well-understood housekeeping tasks such as station-keeping, environmental monitoring, data management, and robotic maintenance have been highly automated. Such tools hold the promise to reduce dependence on crew and ground support, thus lowering costs, enhancing safety and increasing resilience. For example, Booz Allen demonstrated an AI assistant on ISS in 2025 that could support astronauts in real time with procedures and troubleshooting, reducing the need for constant Earth-based intervention.[49] Such experiments highlight the potential of AI to serve as a digital partner in station operations and enable greater autonomy of operational systems such as the ECLSS. Fully integrated, autonomous systems promise improved safety and efficiency, enabling leaner on-board crew requirements as well as continuous systems monitoring of selected station operations during temporarily uncrewed operations.

However, such advantages will need to be balanced against potential implementation risks, including

[48] Ibid.

[49] Booz Allen Hamilton. "AI aids ability to make critical space station repairs." 2025. https://www.boozallen.com/menu/media-center/q1-2026/booz-allen-and-meta-space-llama.html

software reliability, human oversight authority and cybersecurity vulnerabilities. There are also unresolved questions of liability in case of autonomous mishaps and traditional ITAR/EAR ambiguities when adopting new software. The same issues plaguing terrestrial use of autonomous systems could follow their integration into CLDs if AI-assisted systems lessons-learned and designs do not work effectively with crew and mission control. While these systems will be bespoke in their capabilities, commercial suppliers will need to determine and ensure appropriate levels of operational interoperability of interfacing systems across vehicles and CLDs to ensure correct data collection, use, and efficient dissemination while vehicles are both manned and unmanned.

Policy recommendations

It is vital that NASA continue funding autonomy experiments that support commercial space facility needs and work with industry to establish greater protocols for space missions using autonomous or AI-assisted systems plus ensure that humans remain fully informed and retain the ultimate authority over critical decisions.

Conclusion

The transition to commercial low Earth orbit marks a defining moment for U.S. space leadership. The CLD program is more than a handover from the ISS, it is a test of whether the United States can modernize its laws, sustain human presence, and coordinate effectively with industry to preserve its orbital advantage. Legislative clarity on indemnification and mission authorization remains the foundation for commercial confidence, requiring close alignment between NASA, Commerce, and the FAA to ensure predictable oversight.

Operationally, avoiding a "LEO gap" is a strategic necessity. Continuous crewed operations, whether through NASA astronauts, commercial crews, or hybrid missions, must be prioritized to sustain research pipelines and global credibility. Interim measures such as extended ISS operations or free-flyer platforms can help preserve research access until commercial stations achieve full readiness.

Technically, NASA's role as an anchor customer in a multi-provider ecosystem offers resilience if managed through clear capability benchmarks and performance-based contracting. This balance of flexibility and accountability will allow companies like Axiom, Starlab, and Orbital Reef to innovate while meeting safety and interoperability standards. Emerging AI and autonomous systems further promise cost savings and operational efficiency, but they must be guided by clear human oversight and cybersecurity safeguards.

Finally, as China's Tiangong station expands global partnerships, sustaining U.S. presence in orbit carries geopolitical weight. The success of CLD will depend on legislative modernization, consistent funding, and coherent coordination that together ensure continuity, competition, and credibility. Ultimately, the CLD initiative must be viewed not as an endpoint but as the starting architecture for a sustainable, market-driven orbital economy. Through a unified national strategy that balances oversight with opportunity, the United States can turn today's regulatory uncertainty into a blueprint for global leadership. If executed with foresight and coordination, CLDs will serve as both a technological proving ground and a geopolitical statement: that American innovation and commercial partnership remain the defining forces in the next chapter of human spaceflight.

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Commercial Space Stations Working Group Membership Includes:
Elena Graham - Working Group Manager, Beyond Earth Institute
Eamonn Christian - Writer
Olivia Gamez Holzhaus - Chief Executive Officer, Rhodium Scientific
Richard Leshner - Vice President, Policy and Government Relations, Vast Space
Brad Powell - Deputy General Counsel, Vast Space
Ramzi Masri-Elyafaoui - Senior Policy Advisor, Axiom Space
Alicia Brown - Executive Director at Commercial Space Foundation
Eric Stallmer - EVP, Government Affairs & Public Policy, Voyager Technologies
Melodie Yashar- Founder, AENARA
Nancy Hoeser - Principal Line Editor, Beyond Earth Institute

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