STATE OF THE SPACE INDUSTRIAL BASE 2024

Forging the Future of Space: Advancing Prosperity, Security, and Global Leadership

Summary Report by:

NewSpace Nexus

In collaboration with Key Partners to support NewSpace Nexus in developing topic areas for the SSIB Conference

U.S. Space Force | spaceforce.mil

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Cover: Starship Re-entry (Credit: SpaceX via Howell E. (2024). Relive SpaceX's epic Starship launch (and rocket catch) in these jawdropping photos and video. Space.com)

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ABOUT THE KEY GOVERNMENT PARTNERS

Key Partners support NewSpace Nexus in developing topic areas for the SSIB Conference

U.S. Space Force | spaceforce.mil

The U.S. Space Force (USSF) is a military service that organizes, trains, and equips space forces in order to protect U.S. and allied interests in space and to provide space capabilities to the joint force. The mission of the USSF is to secure our nation's interests in, from, and to space. USSF responsibilities include developing military space professionals, acquiring military space systems, maturing the military doctrine for space power, and organizing space forces to present to our Combatant Commands.

Air Force Research Laboratory | afrl.af.mil

The Air Force Research Laboratory's mission is leading the discovery, development, and integration of warfighting technologies for our air, space and cyberspace forces. AFRL is headquartered at Wright-Patterson Air Force Base, Ohio with locations in 10 States: California, Florida, Hawaii, Nevada, New Mexico, New York, Ohio, Tennessee, Texas, Virginia, and Washington, D.C. The lab supports external customers and partners with industry while investing in basic research, applied research and advanced technology development. As one integrated lab, AFRL seamlessly supports the Science & Technology needs of two services: the Air Force and the Space Force.

Defense Innovation Unit | diu.mil

The Defense Innovation Unit's (DIU) mission is to accelerate the adoption of commercial technology at speed and scale. It does so by focusing on those solutions that result in the most strategic impact for the joint force, allied and partner forces. DIU's Space Portfolio facilitates the Department of Defense's ability to access and leverage the growing commercial investment in new space to address existing capability gaps, improve decision making, enable a shared common operating picture with allies, and help preserve the United States' superiority in space.

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EXECUTIVE SUMMARY

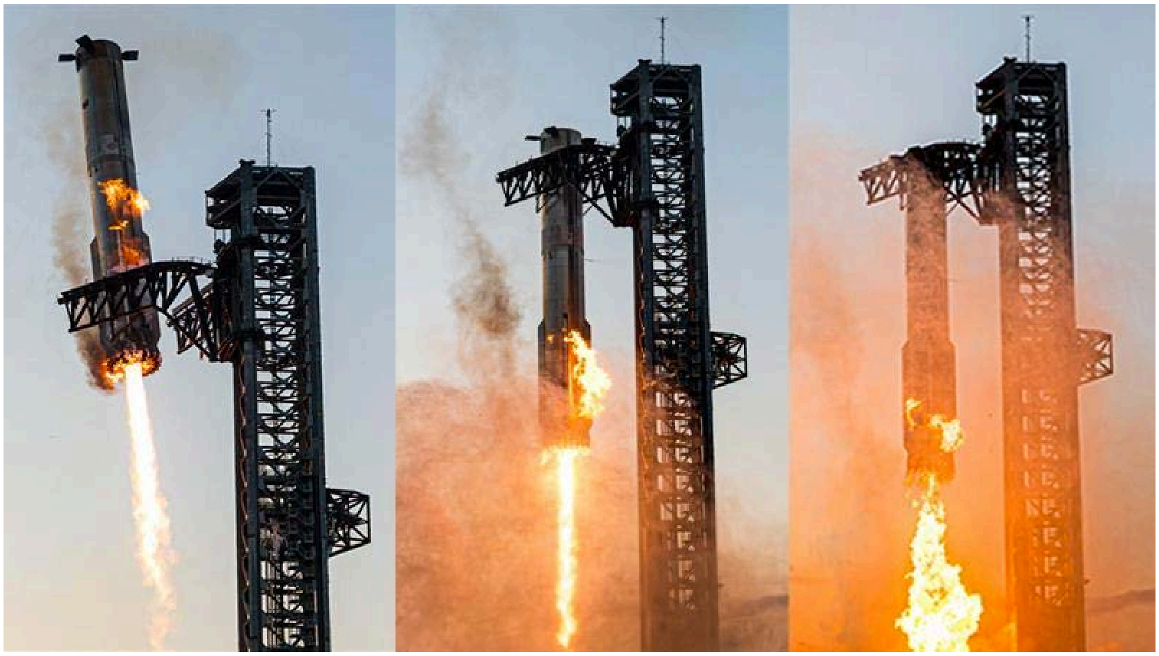

Figure 1. Starship Booster returns to be captured by the 'Chopstick Arms' (Credit: SpaceX[1])

"I couldn't say this on air but HOLY S–T"

- KATE TICE, SpaceX Employee[2]

GENERAL OBSERVATIONS

The *State of the Space Industrial Base 2024* report underscores the urgency of defining a national strategy for space amid growing global competition. The United States has made critical progress in space policy and industrial development, yet it still lacks a unifying "North Star Vision" to guide its long-term objectives in economic development, human settlement, and leadership in space. Strategic competition with China and other state actors continues to shape the space domain, driving the need for accelerated action, investment, and interagency coordination.

KEY OBSERVATIONS

- **A Grand Vision is Missing:** There is broad consensus that the U.S. needs a strategic vision to build a safe, stable, and sustainable space domain in alignment with democratic values and global leadership goals.

[1] Irene Klotz, I. (2024). SpaceX Steps Toward 'Aircraft-Like Ops' With Starship Booster Catch. Aviation Week.

[2] Nesi, C. (2024). Elon Musk jubilant as SpaceX Starship makes flawless flight, splash-down — and a first-ever 'Mechazilla' booster recovery. New York Post.

- **Licensing Novel Activities is Stalled:** Despite White House and congressional proposals, there is still no formal regulatory pathway for licensing novel in-space activities. This regulatory uncertainty hinders commercial innovation and growth.
- **Space Mobility & Logistics is Underfunded:** SML remains largely aspirational due to insufficient investment, despite being vital to the in-space economy and operational flexibility for defense and commercial systems.

STRATEGIC CONTEXT & COMPETITIVE LANDSCAPE

The 2024 workshop reaffirmed that space is now a central arena for geopolitical and economic competition. The *Joint Concept for Competing* reinforces that strategic success involves shaping the environment with allies, not just preparing for war. The U.S. must integrate civil, commercial, and military space strategies to maintain freedom of action, deny adversaries strategic goals, and ensure national prosperity.

CHINA'S STRATEGIC ADVANCES

China continues to expand its space capability rapidly, including reusable launch systems, Cislunar plans, sample return missions, and commercial space activity. Its integration of commercial, civil, and military assets positions it to challenge U.S. leadership across orbital regimes. China is aggressively pursuing space resource extraction, space-based solar power, and counterspace capabilities.

U.S. PROGRESS AND CHALLENGES

The U.S. has made meaningful policy strides, including new DoD and USSF commercial space integration strategies, growth in commercial launch volume (led by SpaceX), and successful technology demonstrations like Varda's in-space manufacturing and Intuitive Machines' Lunar landing. However, progress is uneven. Programs like OSAM-1 were canceled, ISAM remains underfunded, and debates continue over roles in GEOINT and TacRST. The U.S. risks falling behind in areas like sample return, Cislunar domain awareness, and orbital maneuver.

The greatest risk is not technological failure but institutional incoherence. While innovation flourishes, agency efforts remain siloed, and the absence of coherent demand signals in key areas like propulsion, sensing, and Cislunar operations is stalling progress where it matters most. No single body owns emerging domains like space-based solar power, advanced propulsion, or the Outernet, leaving critical capabilities adrift. Regulatory bottlenecks—from ITAR and EAR to launch licensing and energy policy—are mismatched to the speed of the sector, and technical interoperability remains elusive across architectures. Physical infrastructure—from LNG pipelines to payload processing—lags the cadence of commercial launch. And while the private sector shows growing strength, it often lacks federal backing to de-risk new technologies. The dominance of a few key players, particularly in launch, highlights the risk of fragility and market distortion.

At the same time, America's long-standing edge in human capital is slipping, threatened by STEM educator shortages, rising education costs, and declining global rankings. Workforce shortages, declining STEM performance, educator attrition create persistent gaps that are choking the space talent pipeline. Public-private coordination remains fragmented, and no national framework exists to harmonize STEM mentoring, workforce tracking, or training standards. At the same time, U.S. agencies are publishing strategic documents without follow-through, further weakening confidence and dampening momentum. As China executes a comprehensive, state-directed strategy across Cislunar, Lunar, and orbital domains, the U.S. finds itself with world-class innovations—but no integrated roadmap for turning them into enduring advantage.

KEY RECOMMENDATIONS

1. **Define and Promote a North Star Vision for Space.** Articulate a shared national vision centered on the peaceful economic development and human settlement of space, to inspire investment, attract allies, and unify public and private sector efforts.

2. **Finalize Novel Space Activity Licensing.** Congress and the Administration must establish a clear, streamlined process to license and regulate new in-space commercial activities.

3. **Invest in Space Mobility & Logistics.** Fully fund R&D and programs for in-space maneuver, servicing, and infrastructure. Prioritize dynamic operations that reduce operational surprise and enhance resilience.

CONCLUSION

Winning the new space race means more than outpacing competitors—it means securing a future of prosperity, liberty, and leadership beyond Earth. The SSIB 2024 workshop affirms the need for immediate action to align national vision, regulatory frameworks, and investment strategies. The U.S. must act with urgency to lead the next space age, shape the rules of the domain, and ensure that the largest geographic zone of human activity reflects American values and interests. Integration, clarity of purpose, and a decisive investment in human and industrial capacity will determine whether the U.S. continues to lead—not just in innovation, but in shaping the future of space civilization.

INTRODUCTION

Figure 2. Artist rendering of the X-37B conducting an aerobraking maneuver using the drag of Earth's atmosphere (Credit: Boeing Space[3])

"The United States should not stand by and allow China to assume leadership over the global space economy. Rather, the United States should make strategic investments today to secure its global leadership and economic prosperity in space tomorrow."

- Capt TYLER BATES, The Hill, Jan 2023

PURPOSE

The State of the Space Industrial Base (SSIB) conference is an annual meeting to assess progress and *provide input and recommendations* for the U.S. on its journey *to secure the space future that honors commitments made in our Constitution to provide for the common defense, promote the general welfare, and secure the blessings of liberty to ourselves and our posterity*. It solicits direct feedback from the U.S. space industrial base, investors, analysts, thought leaders and other stakeholders to assess our progress, suggest paths of synergy to build enduring national advantage, sustain and expand the space industrial base and the broader national security innovation base. It is meant to provide *actionable recommendations* to actors in the space ecosystem enabled by leaders across the entirety of U.S. society as well as those of our closest allies and partners.

[3] USSF (2024). X-37B begins novel space maneuver.

WORKSHOP OBJECTIVES

Winning the New Space Race. This workshop continues to assess the United States' progress toward preferred futures identified in *The Future of Space 2060 and Implications for U.S. Strategy*[4] which cautioned, "The U.S. must recognize that in 2060, space will be a major engine of national political, economic, and military power for whichever nations best organize and operate to exploit that potential."[5] The *Future of Space 2060* report defined the preferred future as one of *thriving off-Earth human communities, a vastly expanded and self-sustaining economic sphere, with a balance of power that favors U.S. leadership in shaping a free and open system*. As noted in the previous year, "*what's at stake is no less than whether the largest geographic zone of human activity is one of democratic freedom and fair trade, or an autocratic exclusion zone*."[6]

To sustainably *win* the new space race is to determine the conditions for which future generations may inherit not just the technological achievements of our day, but the preservation of our values, a free and open society, a free market economy, and the right of self-determination free from tyranny and oppression. This is an enduring and worthy pursuit.

Strategic Competition. The State of the Space Industrial Base Report series has been approached through the lens of Strategic Competition. In late 2023, the Joint Staff introduced *The Joint Concept for Competing* which for the first time provided rigorous definitions, explanations, central concepts and methodologies for successful strategic competition. It defined 'strategic competition' as a persistent and long-term struggle that occurs between two or more adversaries seeking to pursue incompatible interests without necessarily engaging in armed conflict with each other, and asserts that Strategic competition is thus an enduring condition to be managed, not a problem to be solved. Thus, 'succeeding' means *retaining freedom of action* to *pursue national interests at an acceptable risk and sustainable cost and avoiding armed conflict* with adversaries. *The Joint Concept for Competing* recognizes the inherently multi-dimensional nature of strategic competition, and the Joint Force will routinely play a mutually supporting role with other USG departments and agencies, allies and partners, and other interorganizational partners, and that the Joint Force is normally a *supporting* actor in strategic competition. Shaping the competitive space depends on the U.S. network of allies, partners, proxies, and surrogates. To achieve unity of effort, the Joint Force must seek opportunities to integrate its operations and activities in time, space, and purpose with the activities of interorganizational partners, *proxies*, and *surrogates*.

Never Off the Clock. *The Joint Concept for Competing* asserts the Joint Force is not just in the "warfighting business"--it is in the "national security business" and that the Joint Force is never "off the

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[4] Mozer, J. (2019). The Future Of Space 2060 & Implications For U.S. Strategy. DTIC.
[5] Air Force Space Command (2016). The Future of Space 2060 & Implications for U.S. Strategy.
[6] DIU (2021). State of the Space Industrial Base 2021 Infrastructure & Services for Economic Growth & National Security.

clock." It does, however emphasize the ability of the Joint Force to provide area security, logistics, communications, engineering, and other support to partners that do not have the resources or the ability to operate effectively in remote, austere, and contested environments, as well as information, intelligence and logistic support to augment or supply capabilities when operational requirements exceed their capabilities, such as via strategic lift for humanitarian and foreign disaster relief efforts or conduct noncombatant evacuation operations in crisis situations in response to natural disasters, domestic disturbances, or adversary attempts to impede access. It cautioned that the United States risks ceding strategic influence, advantage, and leverage while preparing for a war that may never occur, and that while the United States must remain fully prepared and poised for war, this alone will be insufficient to secure its strategic objectives and protect its freedoms. Thus, if the United States does not compete effectively against adversaries, it could "lose without fighting." The concept asserted that the Joint Force may lack concepts and capabilities critical to succeeding strategically in the current competitive environment and that the Joint Force must ask itself whether it is appropriately and adequately prepared and postured to help defend the United States from threats that do not require the Joint Force to engage in warfighting. The concept seeks to advance integrated campaigning employing combinations of military and non-military power to achieve our nation's strategic objectives as well as counter adversaries' competitive strategies and deny their strategic objectives indefinitely. The concept directs the Joint Force to focus on pursuing and promoting U.S. national interests and strategic objectives in addition to focusing on denying adversaries' incompatible interests.

Building a Competitive Strategy. Toward that end, *The Joint Concept for Competing* states a competitive strategy to tilt the competitive balance and shape to competitive space must be developed. A competitive strategy differs from conventional military strategies because its purpose is to integrate activities across the instruments of national power to succeed in enduring strategic competition, *not just warfighting*, and that these competitive strategies *require a different logic trail because they do not focus on military victory* and do not locate interagency partners or 'Commercial-Industrial' in a supporting role. This document helps advance progress towards a competitive strategy and integrated campaign through articulation of national interests, strategic objectives, analysis and net assessment of adversary competitive strategies, and best military and industrial advice regarding actionable components of an integrated campaign plan.

The North Star Vision Provides Unity. The path toward unity of effort begins with a shared vision of our national interests and strategic objectives. As championed by the participants of the previous three workshops and reports, The North Star Vision is one of economic development and human settlement, a vastly expanded and self-sustaining space economy, with a thriving off-Earth human presence and a balance of power that favors U.S. and allied leadership in shaping a free and open system. As observed in last year's Global Partnership workshop, this call for a grand strategy in space is shared by our closest allies and partners who recognize the necessity and wish to participate in the journey.

CURRENT STATE

PROGRESS TOWARD A NORTH STAR VISION

Advances in National Policy. Recognizing the importance of being able to compete across a number of novel in-space applications, the White House attempted to create a framework for authorization of novel space activities[7] and submitted companion legislation.[8] The Congress also introduced its own legislative proposal, H.R. 6131 for regulation and authorization of space activities.[9] Consensus was not reached and the debate on authorization and supervision continues. In late 2024, the White House charged the DoD[10] to "identify and prioritize research and development needed to support extension of U.S. SSA capabilities into Cislunar space, to include aiding planetary defense, improved debris population modeling, and detection, tracking, and characterization of satellites in the Cislunar volume," develop Cislunar monitoring tech, including for planetary defense.[11]

Advances in DoD Policy. OSD Space Policy released a revision of *DoD Instruction 3100.10*[12] which incorporated significant and previously not captured White House-level guidance, as well as a *Space Policy Review and Strategy on Protection of Satellites*,[13] and its 2024 *DoD Commercial Space Integration Strategy*.[14] The DoD also released its first National Defense Industrial Strategy.[15] The Joint Staff also released a revision of *JP3-14 Space Operations* which reflected a broader astrographic conception of the Space Area of Operations.[16] The Space Force also released its first *Commercial Space Strategy*.[17] The USSF also released Space Doctrine Publication (SDP), *SDP 3-100, Space Domain Awareness*.[18]

USSPACEFOR-JPN. Two years after the establishment of U.S. Space Force Indo-Pacific,[19] on December 4, 2024, the Space Force activated a new component field command in Japan (USSPACEFOR-JPN) at Yokota Air Base.[20]

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[7] White House (2023). United States Novel Space Activities Authorization And Supervision Framework; White House (2023). Fact Sheet: U.S. Novel Space Activities Authorization and Supervision Framework.
[8] White House (2023). Authorization and Supervision of Novel Private Sector Space Activities Act.
[9] U.S. House of Representatives (2023). H.R.6131: Commercial Space Act of 2023.
[10] Hitchens, T. (2024). White House charges Pentagon to develop cislunar monitoring tech, including for 'planetary defense'. Breaking Defense; White House (2024). National Cislunar Science & Technology Action Plan.
[11] White House (2024). National Cislunar Science & Technology Action Plan.
[12] DoD (2024). DOD Directive 3100.10 Space Policy.
[13] DoD (2023). Space Policy Review and Strategy on Protection of Satellites.
[14] DoD (2024). DoDCommercial Space Integration Strategy 2024.
[15] DoD (2024). National Defense Industrial Strategy.
[16] Hitchens, T. (2023). EXCLUSIVE: New Joint Force space doctrine clarifies Space Command's 'offensive', 'defensive' ops Breaking Defense.
[17] USSF (2024). U.S. Space Force Commercial Space Strategy.
[18] USSF (2023). SDP 3-100, Space Domain Awareness.
[19] Space Force (2024). US Space Forces Indo-Pacific marks two years of accomplishments, growth.
[20] PACOM (2024. Space Force activates component field command in Japan.

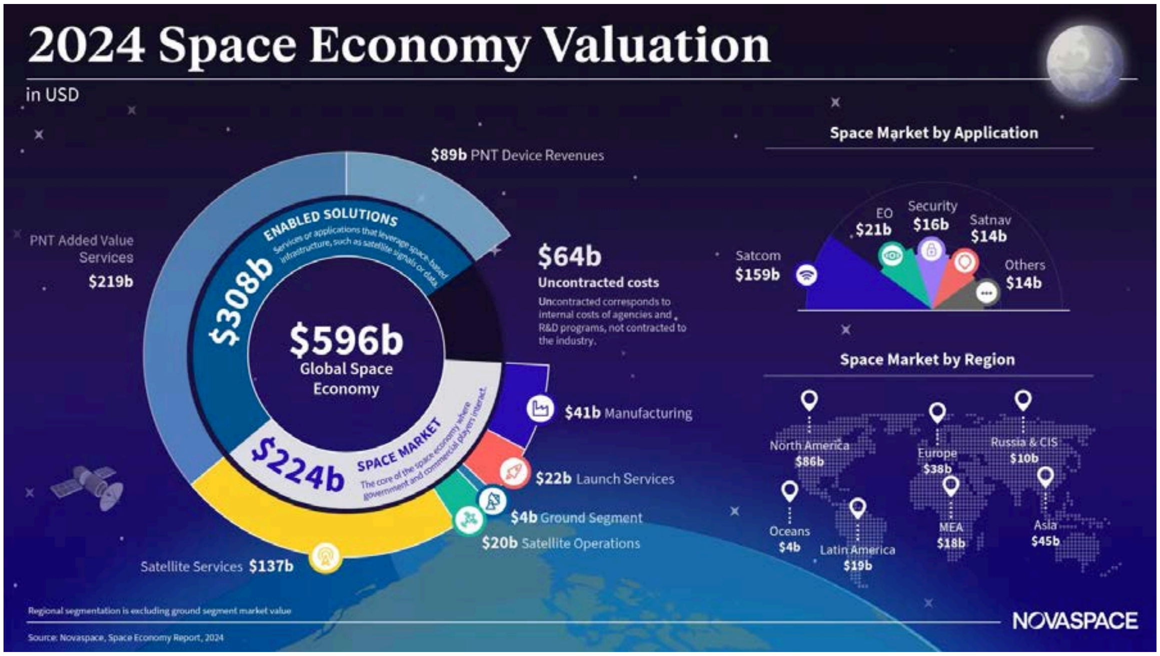

Figure 3. Space Economy Valuation (Credit: NovaSpacee)

Global Growth. NovaSpace reported the 2024 Space Economy as valued at $596 Billion, with government investments in space rising from $117 billion in 2023 to $135 billion in 2024, while private investment declined for the third consecutive year.[21] ESA reported a 7% growth rate for the space economy in 2024[22] while the World Economic Forum reported 9% growth and projected a valuation of 1.8 billion by 2035.[23]

The world experienced a record number of space launches–263 orbital launch attempts.[24] Over 2,700 satellites were launched in 2024 (slightly fewer than 2023), but the mass-to-orbit grew by nearly a quarter, to over 2,000,000 kg for the first time (it was just 1,500,000 kg in 2023)[25]--equivalent to launching 10 diesel locomotives worth of mass. At the end of 2024, there were over 14,000 satellites in orbit, with more than 10,400 actively functioning.[26] ABI research expects that by 2032, these numbers will rise to 480 orbital launches (nearly double today), to support 43,000 active satellites (over a four-fold increase).[27]

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[21] NovaSpace (2025). Highlights of the 2024 Space Economy.
[22] Wall, R. (2024). ESA Sees 7% Space Economy Growth In 2024. Aviation Week.
[23] WEF (2024). Space is booming. Here's how to embrace the $1.8 trillion opportunity.
[24] By Jack Kuhr, J. (2025). 2024 Orbital Launch Attempts by Country. Payload Space.
[25] Harrison, T. (2025). Space Trends in 2024. AEI.
[26] ABI Research (2024). Over 480 Orbital Launches and 43,000 Active Satellites Expected by 2032.
[27] ABI Research (2024). Over 480 Orbital Launches and 43,000 Active Satellites Expected by 2032.

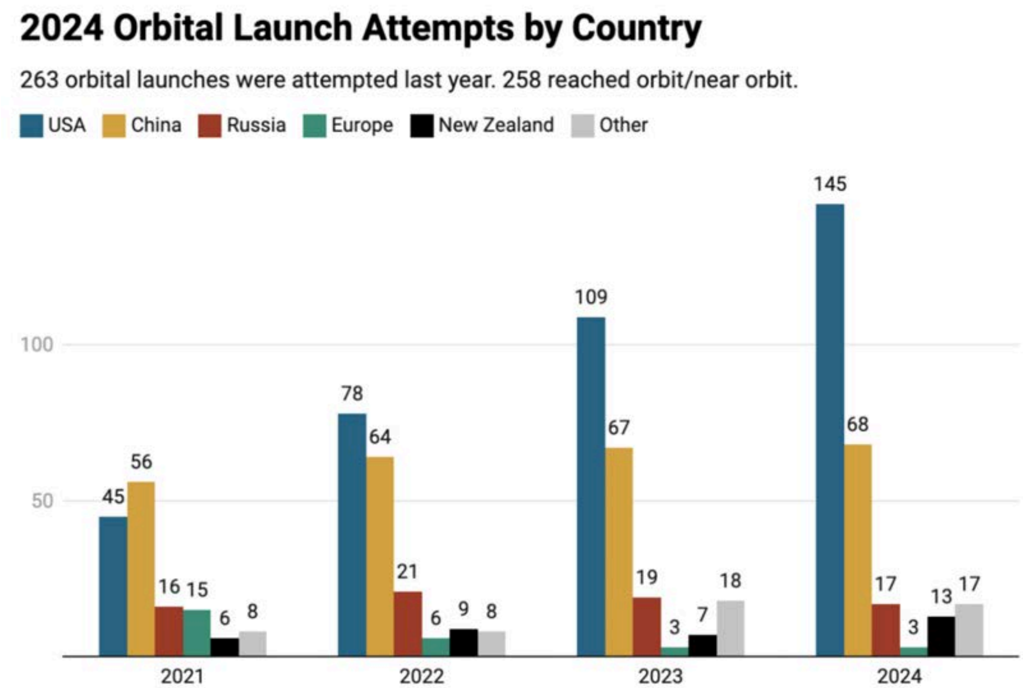

Figure 4. Space Launch Attempts by Country (Credit: Payload Space[28])

U.S. Leading Space Access & Mobility. The U.S. had an exceptional year,[29] accomplishing a record number of space launches,.[30] U.S. launches grew from 109 in 2023 to 145 in 2024–a 33% increase; moreover the U.S. accounted for 55% of all 263 total global launch attempts, with SpaceX accounting for 95% of all U.S. launches.[31] SpaceX's Starship conducted several test launches, including its first successful capture of the Superheavy Booster on the "Mechazilla" 'chopsticks' tower on the return of its 5th test flight, October 13, 2024–a milestone crucial for enhancing reusability and cost efficiency of the Starship system.

ULA Vulcan successfully launched for the first time.[32] Blue Origin's New Glenn was stacked for the first time ahead of its first launch.[33] The USSF X-37B conducted its first maneuver using aerodynamic lift and braking from a highly elliptical orbit.[34] The AFRL Rocket Cargo Program–which is exploring the potential of commercial rockets for rapid global logistics–awarded $4.5 million to Stoke Space via DIU to develop and demonstrate technologies for rapid, responsive, and cost-effective space-based cargo delivery.[35]

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[28] Kuhr, J. (2025). 2024 Orbital Launch Attempts by Country. Payload Space.
[29] Goswami, N. (2024). Taking stock of the US space program. The Space Review.
[30] Foust, J. (2025). SpaceX launch surge helps set new global launch record in 2024. SpaceNews.
[31] Kuhr, J. (2025). 2024 Orbital Launch Attempts by Country. Payload Space.
[32] ULA (2024). United Launch Alliance Successfully Launches First Next Generation Vulcan Rocket.
[33] Tingley, B. (2024). Blue Origin stacks huge New Glenn rocket ahead of 1st launch. Space.com.
[34] USSF (2024). X-37B begins novel space maneuver.
[35] Kuhr, J. (2024). DoD's Big Bet on 1 Hour Space Cargo Delivery. Payload Space.

"Our nation's commercial space industry continues to demonstrate innovation, excellence, and a commitment to ensuring American preeminence in space. Over the past several years, this industry has undergone exciting growth, particularly for launches and reentries ... But this growth - and our national security along with it - are at risk unless the Department of Transportation (DOT) and the Federal Aviation Administration (FAA) initiate immediate changes to their implementation of the launch and reentry regulatory framework (Part 450)."

- U.S. SENATOR JERRY MORAN, Letter to FAA Administrator Michael G. Whitaker

Varda, in its first attempt, successfully demonstrated in-space manufacturing and return of a finished pharmaceutical product, producing crystals for its? drug ritonavir, and received the first commercial FAA reentry license on February 14, 2024 for its return via capsule.[36]

Figure 5. Varda Space Industries completed its first mission by landing its capsule in Utah Feb. 21, 2024 (Source: VARDA[37])

[36] Foust, J. (2024). Varda capsule lands in Utah. SpaceNews.
[37] India Today (2024). IM-1 enters lunar orbit, sends first picture; private mission eyes Moon landing; See also: PBS (2024). Private U.S. lunar lander to cease operations Tuesday after landing sideways.

The commercial Polaris Dawn mission, led by Jared Isaacman put private astronauts into the highest orbit since Apollo aboard SpaceX's Crew Dragon Capsule, tested a new Space Suit[38] and Isaacman, along with mission specialists Sarah Gillis and Anna Menon ventured outside in the newly developed SpaceX spacesuits on September 12, 2024, performing the first private spacewalk on, a significant milestone in private space exploration.[39]

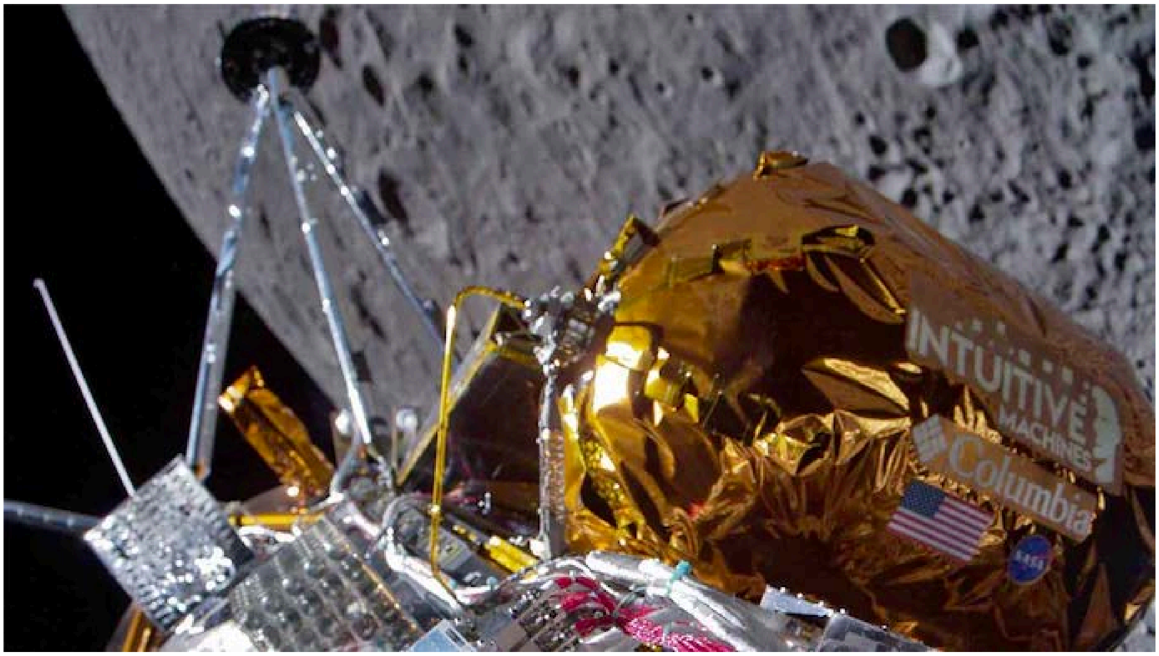

Figure 6. America's First Commercial Lunar Lander IM-1 in Lunar Orbit (Source: Intuitive Machines[40])

Intuitive Machines' Odysseus achieved an historic milestone, conducting the first successful private Lunar Landing–and the first U.S. Lunar landing since Apollo 17 (in 1972).[41] KMI launched its REACCH (Responsive Engaging Arms for Captive Care and Handling) to ISS which aims to demo safe capture and release a variety of objects of nearly any shape, size, or surface condition, providing a potential commercial solution for orbital debris removal.[42]

[38] Tingley, B. (2024). SpaceX Polaris Dawn astronauts perform historic 1st private spacewalk in orbit. Space.com.
[39] Rannard, G. (2024). Billionaire completes first private spacewalk. BBC.
[40] India Today (2024). IM-1 enters lunar orbit, sends first picture; private mission eyes Moon landing; See also: PBS (2024). Private U.S. lunar lander to cease operations Tuesday after landing sideways.
[41] Greshko, M. (2024). First Commercial Moon Landing Returns U.S. to Lunar Surface. Scientific American.
[42] Gorman, D. (2024). Kall Morris Inc. Begins ISS Residency. Payload Space.

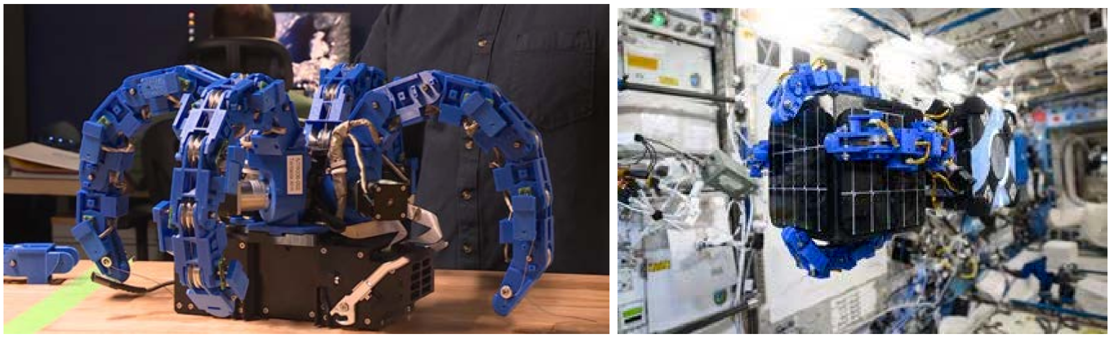

Figure 7. KMI REACCH (Credit: KMI)

Booming Foreign Military Sales Demand. Space Systems command reported a 500% increase in demand for space systems,[43] leading to think tank exploration of potential options for the Proliferated Warfighter Space Architecture as foreign military sales (FMS), excess defense articles, or commercial sales.[44]

Starlink for Hurricanes. Commercial space proved its utility with Starlink's support for disaster Relief. During Hurricane Helene in September 2024, Starlink helped restore communication services to western North Carolina, with FEME initially distributing 40 Starlink systems followed by another 140 units which enabled the broadcast of emergency alerts to cell phones on all networks in North Carolina.[45]

BENCHMARKING AGAINST THE PACING COMPETITOR: CHINA

China Tactically Responsive Space - In September, China launched 10 satellites on 2 rockets less than 6 hours apart, including its Kuaizhou 1A solid rocket.[46] The debut of the enhanced Kuaizhou-1A "is part of a wider proliferation of Chinese launch vehicles" which includes a range of active solid rockets for light-lift, including the Long March 11, CASC Jielong-1 and Jielong-3, the Ispace Hyperbola-1, Galactic Energy's Ceres-1, CAS Space Kinetica-1, and Orienspace's Gravity-1, all of which "suggests China's desire to acquire quick response launch capabilities. China has a range of active solid rockets."[47] The latest DoD report assesses the "PRC has developed quick-response SLVs to increase its attractiveness as a commercial small satellite launch provider and rapidly reconstitute LEO space capabilities, which could support PRC military operations during a conflict or civilian response to disasters. Compared with medium and heavy-lift SLVs, these quick-response SLVs can expedite launch campaigns because they are transportable via road or rail and can be stored launch-ready with solid fuel for longer periods than liquid-fueled SLVs. Because their size is limited, quick-response SLVs, such as

[43] Albon, C. (2024). US Space Force sees surge in foreign military sales demand. Defense News.
[44] Peter Garretson, Natalie Sturza, and Ashton Walter. Orbiting Partnerships: A Constellation's Second Life in Space Defense. AFPC.
[45] Singh, K. (2024). Dozens of Starlink systems deployed for Hurricane Helene by Biden administration. Reuters.
[46] Jones, A. (2024). China launches 10 satellites on 2 rockets less than 6 hours apart. Space.com
[47] Jones, A. (2024). China debuts modified solid rocket with remote sensing satellite launch. SpaceNews.

the Kuaizhou-1 (KZ-1), LM-6, and LM-11 can launch relatively small payloads of only up to approximately two metric tons into LEO.[48]

"While the PRC's space budget is significantly less than NASA's, its estimated budget was $14.14 billion in 2023. In 2022, the PRC conducted over 60 successful space launches, a three-fold increase compared to 5 years ago. One of these launches was a technology testing mission of a reusable space plane, which was in orbit from August 2022 until May 2023. These 2022 launches carried over 180 satellites into orbit, which is a five-fold increase in satellites deployed compared to 5 years ago. Last year, the PRC completed construction of the three-module PRC space station."

– Military and Security Developments Involving the People's Republic of China[49]

The People's Republic of China - In 2024 attempted 68 orbital launches, barely surpassing its 2023 (67 launches) and 2022 (64 launches) totals, but failing in its announced goal of 100 launches in 2024.[50] As of 2024, Beijing officially included commercial spaceflight in its list of priority emerging industries, and commercial rockets accounted for 70% of China's launches in 2024–a 65% increase compared to 2023 and a 55% increase compared to 2022.[51] Presently China is reported to have 77 NewSpace startups, of which 47 are backed by the government and 21 receiving A+ funding (capital investment from private investors).[52]

"The PLA has rapidly advanced in space in a way that few people can appreciate"

– MAJOR GENERAL GREG GAGNON, deputy chief of space operations for intelligence[53]

China's Orbital Ambitions - In September of 2024, China also for the first time surpassed 1,000 satellites on orbit[54] (China had only 129 satellites in 2015[55]) with over 200 specifically for military/intelligence, and over 220 for commercial remote sensing.[56] In August[57] and October[58] of

[48] DoD (2024). Military and Security Developments Involving the People's Republic of China.
[49] DoD (2024). Military and Security Developments Involving the People's Republic of China.
[50] Jones, A. (2024). China's 2024 space plans include 100 launches and moon sample return mission. SpaceNews.
[51] Kazinform (2025). The battle for the Moon & spy satellites: What U.S. and China are competing for in space.
[52] Kazinform (2025). The battle for the Moon & spy satellites: What U.S. and China are competing for in space.
[53] Decker, A. (2024). Chinese satellites are breaking the US 'monopoly' on long-range targeting. Defense One.
[54] Hadley, G. (2024). USSF Intel Boss: China Now Has 1,000 Satellites on Orbit. Air & Space Forces.
[55] By Todd Harrison, T. (2024). Unleash the Space Force. Military Times.
[56] Harrison, T. (2025). Space Trends in 2024. AEI.
[57] Kuhr, J. (2024). China Kicks Off its First Mega Constellation. Payload Space
[58] CGTN (2024). China launches a group of 18 satellites for internet constellation project.

2024, China launched the first and second batch of 18 satellites of its "Thousand Sails" constellation.[59] China has announced three satcom mega-constellations: 14,000 for Shanghai Spacecom Satellite Technology (SSST)'s *Spacesail/Thousand Sails/G60*, 13,000 for China Satellite Network Group Ltd.'s *Guowang*, and 10,000 Shanghai Lanjian Hongqing Technology's[60] *Honghu-3*. China's entry into the global broadband (and expected $6B direct-to-device (D2D) market[61]) has significant national security implications.[62] China is "building a massive architecture of remote-sensing satellites to help target U.S. forces if they move to defend Taiwan" and "Chinese satellites are breaking the US 'monopoly' on long-range targeting."[63]

China Space Recovery - China is also looking to compete in the LEO bio-tech, pharmaceutical and untended laboratory sub-sector. Toward that end, China launched and recovered Shinjian 19, its first reusable and recoverable satellite, which carried plant and microbial breeding payloads in hopes that the microgravity environment would accelerate genetic mutations that may enhance crop resilience and productivity; its 500 to 600 kilograms of payload included payloads from five countries, including Thailand and Pakistan. By making its recoverable satellites reusable, China hopes to reduce cost and improve efficiency.[64]

China's Lunar Ambitions - In 2024, China outlined its position on space resources. China considers space resource utilization as permissible stating, the "Working Group in scoping space resources should refer to the major projects of States members on exploring deep space planned for the near future and focus its discussion on physical resources such as water-ice in Lunar regolith and Lunar rocks" and "The Working Group should look into how to enforce the above-mentioned international responsibility with respect to space resource activities carried out by non-governmental entities."[65] In April, China published, The Geologic Atlas of the Lunar Globe, the first high-definition Lunar geological map, and the most detailed Lunar atlas to date with double the resolution of Apollo-era maps to "support the ambitions of China and other countries."[66] China continued to sign on new members to its international Lunar Research Station, including Serbia, Nicaragua, and Thailand.[67]

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[59] Page, M. (2024). 'China may be putting the Great Firewall into orbit'. ASPI; Feldstein, S. (2024). Why Catching Up to Starlink Is a Priority for Beijing. Carnegie Endowment.
[60] ABI Research (2024). Over 480 Orbital Launches and 43,000 Active Satellites Expected by 2032.
[61] NovaSpace (2025). Highlights of the 2024 Space Economy.
[62] Garretson, P. Nystrom, S. and Zou, D. (2025). Thousand Sails: Why Low Earth Orbit is the Next Frontier for Great Power Competition between the U.S. and China. AFPC.
[63] Decker, A. (2024). Chinese satellites are breaking the US 'monopoly' on long-range targeting. Defense One.
[64] Jones, A. (2024). Shijian-19 reusable satellite lands after 2 weeks in space. SpaceNews.
[65] Jones, A. (2024). China outlines position on use of space resources. Space News; PRC (2024). Submission by the Delegation of China to the Working Group on Legal Aspects of Space Resource Activities of the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space. COPUOS.
[66] Zhang, W. (2024). China releases world's first high-precision geological map of moon. Global Times; Chen, N. (2024). China Publishes World's First High-definition Lunar Geologic Atlas. Chinese Academy of Sciences; Ling Xin, L. (2024). China's Moon Atlas Is the Most Detailed Ever Made. SCIAM.
[67] Jones, A. (2024). Serbia becomes latest country to join China's ILRS moon base project. SpaceNews.

"The PRC has devoted considerable economic and technological resources to growing all aspects of its space industry, improving military space applications, developing human spaceflight, and conducting Lunar and Martian exploration missions….Furthermore, the PRC has launched a robotic lander and rover to the far side of the Moon; a lander and sample return mission to the Moon; and an orbiter, lander, and rover in one mission to Mars."

– Military and Security Developments Involving the People's Republic of China[68]

China's Cislunar Ambitions - In 2024, China articulated a Cislunar infrastructure plan,[69] and toward that end launched its second China's Queqiao-2 relay satellite into Lunar orbit.[70] China's interest in Cislunar drew significant interest from America's intelligentsia.[71]

China launched Chang'e 6 in May to the Lunar far side to collect samples[72] began its return in June[73] successfully delivering the first-ever far-side samples.[74] In August of 2024 China reported results from the previous Chang'e 5 sample return mission of an unknown Lunar Material, a "prismatic, plate-like transparent crystal" roughly the width of a human hair they call ULM-1.[75] Chang'e 7, which consists of a relay satellite, an orbiter as large as a rover and a mini hopper which will fly into a permanently shadowed crater to look for water at the Lunar South Pole is expected to launch in 2026.[76] In 2024, China formally announced plans for a human Lunar landing by 2030 (and that they have the spacesuit to do it)[77] calling into question whether NASA accomplished its Presidential-level order to land the next human on the Moon.

Its ambitions for the Lunar surface continue to advance, with a "Proposal to Develop China's Lunar Orbital Space Station and Moon" presented at the 3rd Annual Space Science Conference," showcasing the automated construction of a human tended habitat. China's ILRS is expected to be nuclear powered, and China has articulated a desire for nuclear shuttles which can enable asteroid mining at

[68] DoD (2024). Military and Security Developments Involving the People's Republic of China.
[69] Jones, A. (2024). Chinese scientists outline major cislunar space infrastructure project. SpaceNews.
[70] Jones, A. (2024). China's Queqiao-2 relay satellite enters lunar orbit. SpaceNews.
[71] Aerospace Corporation (2024). High Ground Or High Fantasy: Defense Utility Of Cislunar Space; AFPC (2024). Reacting To Major Space Events On The Moon And In Cislunar Space; Galbreath, C. (2024). Securing Cislunar Space and the First Island Off the Coast of Earth. Mitchell Institute; Garretson, P. (2024). Congress Must Demand Stronger Leadership from OSD Space Policy. Global Security Review; Swope, C and Gleason, L. (2024). Salmon Swimming Upstream: charting a course in Cislunar space. CSIS.
[72] Jemma Crew, J. (2024). China rocket blasts off for far side of Moon. BBC.
[73] Frances Mao, F. (2024). China's far-side Moon mission begins journey back. BBC.
[74] Jones, A. (2024). Chang'e-6 delivers first lunar far side samples to Earth after 53-day mission. SpaceNews.
[75] Yeung, J. (2024). China moon samples reveal water molecules in groundbreaking discovery, scientists say. CNN.
[76] NASA (2024). CHANG-E-7.
[77] McCarthy, S. (2024). China's astronauts are aiming to land on the moon by 2030. CNN.

scale[78] as part of a solar-system wide resource utilization plan.[79] Toward that end, in 2024, China continued to develop their designs for a 1.5 megawatt space reactor.[80] Chinese scholars are now publishing designs for a rotational Lunar massdriver (catapult).[81] China has previously linked Lunar industrialization efforts with its Solar Power Satellite plans.[82]

Despite NASA doubling-down on its pessimistic assessment,[83] China continued to make progress in 2024, with its research team presenting design and technology details for space solar-powered satellite[84] and creating concerns by a former NASA Deputy Associate Administrator for Technology, Policy and Strategy and as the agency's Deputy Chief Technologist that America must win the race for space solar power — or buy it from China.[85] In 2024, China also sought to ban materials necessary to develop Space Solar Power and high efficiency photovoltaics.[86]

China's Military Reorganization - In April of 2024, China reorganized its military space forces, separating it from cyber forces[87] and stating the new 'Aerospace Force' was "of great significance to strengthening the capacity to safely enter, exit and openly use space, enhancing crisis management and the efficacy of comprehensive governance in space and promoting peaceful utilization of space."[88]

China has previously sought to develop transatmospheric vehicles, sub-orbital and orbital spaceplanes[89] and fractional orbital bombardment systems.[90] In late November 2023, China also added a "hypersonic 'near-space command' to its military for 'precise and merciless' attacks."[91] This is amidst DoD estimates that China has over 600 operational nuclear warheads (100 more than the previous year), and that it will have over 1,000 nuclear warheads by 2030 and will continue to expand its nuclear force beyond that.[92]

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[78] Chen, S. (2017). China's nuclear spaceships will be 'mining asteroids and flying tourists' as it aims to overtake US in space race. SCMP.
[79] Jones, A. (2023). Chinese scientist proposes solar system-wide resource utilization roadmap. SpaceNews.
[80] Houser, K. (2024). China is one step closer to having a nuclear-powered spacecraft. FreeThink; Wu, Y. et al. (2024). Design and R&D of megawatt lithium-cooled space nuclear reactor. SciEngine.
[81] Williams, M. (2024). China proposes magnetic launch system for sending resources back to Earth. Phys.org; Xin, L. (2024). Chinese scientists planning rotating launch system on the moon. SCMP.
[82] Xinhua (2016). Exploiting earth-moon space: China's ambition after space station. China Daily.
[83] Foust, J. (2024). NASA report offers pessimistic take on space-based solar power. SpaceNews.
[84] TechXplore (2024). Research team presents design and technology details for space solar-powered satellite; NCSTI (2024). China looks set to build space solar power station.
[85] Steitz, D. (2024). NASA that America must win the race for space solar power — or buy it from China. SpaceNews.
[86] Fernholz, T. (2024). China's Materials Bans Could Transform Space Solar. Payload Space.
[87] Goswami, N. (2024). The Reorganization of China's Space Force: Strategic and Organizational Implications. The Diplomat.
[88] Sachs, D. (2024). Six Takeaways From the Pentagon's Report on China's Military. CFR.
[89] Goswami, N. and Garretson, P. (2024). The Strategic Implications of China's 'Divine Dragon' Spaceplane. The Diplomat.
[90] Hitchens, T. (2021). It's a FOBS, Space Force's Saltzman confirms amid Chinese weapons test confusion. Breaking Defense; Gupta, R. (2023). Orbital hypersonic delivery systems threaten strategic stability. The Bulletin.
[91] Chen, S. (2024). Fifth force: is China adding hypersonic 'near-space command'to its military for 'precise and merciless' attacks?. SCMP.
[92] DoD (2024). Senior Defense Official Briefs on 2024 China Military Power Report.

"The People's Republic of China is moving at breathtaking speed in space, and they are rapidly developing a range of counter-space weapons to hold at risk our space capabilities. They're also using space to make their terrestrial forces, their army, their navy, the marine corps, their air force, more precise, more lethal and more far ranging...And so that obviously is a cause for concern and something that we are watching very, very closely."

– GEN. STEPHEN WHITING, COMMANDER, U.S. SPACE COMMAND[93]

China's Counterspace - In 2024 RAND released a report noting China's growing appetite for a space fight with U.S., noting that the PLA changed its approach to space operations in 2013, focusing on military competition and controlled escalation to achieve political objectives, and highlighting China's increasingly aggressive space strategy, "a potent mix of coercion and deterrence aimed at the US."[94] The DoD's assessed that the "PRC's goal is to become a world space power" and that the "PRC considers space-based capabilities essential in enabling joint operations and force projection capability by providing communications, intelligence, surveillance, early warning, and navigation during peacetime and war" and that the "PLA views space superiority, the ability to control the space-enabled information sphere and to deny adversaries their own space-based information gathering and communication capabilities, as a critical component to conduct modern 'informatized warfare." As a result, the "PRC continues to develop counterspace capabilities—including direct-ascent anti-satellite missiles, co-orbital satellites, EW [Electronic Warfare], and directed-energy systems—to contest or deny another nation's access to and operations in the space domain"[95] elaborating that the "PRC has launched multiple ground-based anti-satellite (ASAT) missiles that can destroy satellites and developed mobile jammers to deny SATCOM and Global Positioning System (GPS)" including in "2013, the PRC launched an object into space on a ballistic trajectory with a peak orbital radius above 30,000 km, near GEO altitudes." The DoD report assesses that the "PRC has an operational ASAT missile intended to target LEO satellites. The PRC probably intends to pursue additional ASAT weapons capable of destroying satellites up to geosynchronous Earth orbit." They note that the "PRC is developing other sophisticated space-based capabilities, such as satellite inspection and repair. At least some of these capabilities could function as a weapon...Over the past two years, the PRC has launched multiple satellites to conduct scientific experiments and to verify new technologies. In January 2022, Shijian-21 moved a derelict BeiDou navigation satellite to a high graveyard orbit above GEO. The Shijian-17 is a PRC satellite with a robotic arm. Space-based robotic arm technology could be used in a future system for grappling other satellites." Moreover, the PRC's counterspace development efforts

[93]Choi, S.H. (2024). Cause for concern: US watching China's 'breathtakingly fast' space development 'very, very closely', top commander says. South China Morning Post.
[94] Honrada, G. (2024). China's growing appetite for a space fight with US. Asia Times.
[95] DoD (2024). Military and Security Developments Involving the People's Republic of China.

include orbital counterspace systems with EW and directed-energy weapons systems" and "The PRC has multiple ground-based laser weapons of varying power levels to disrupt, degrade, or damage satellites, including a limited capability to employ laser systems against satellite sensors. By the mid- to late-2020s, the PRC may field higher power systems to extend the threat to the structures of non-optical satellites." As a result, the "PRC continues to strengthen its military space capabilities despite its public stance against the weaponization of space. The PLA continues to invest in improving its capabilities in space-based ISR, satellite communication, satellite navigation, and meteorology as well as human spaceflight and robotic space exploration. The PRC has built an expansive ground support infrastructure to support its growing on-orbit fleet and related functions, including spacecraft and SLV manufacture, launch, C2, and data downlink. The PRC continues to develop counterspace capabilities—including direct ascent, co-orbital, EW, and directed-energy capabilities—that can contest or deny an adversary's access to and operations in the space domain during a crisis or conflict."[96]

> *"The PRC has launched multiple ASAT missiles, which can destroy satellites, and developed mobile jammers to deny SATCOM and GPS. The PLA continues to acquire and develop a range of counterspace capabilities and related technologies, including kinetic-kill missiles, ground-based lasers, and orbiting space robots as well as expanding space surveillance capabilities, which can monitor objects in space in their field of view and enable counterspace actions."*
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> – Military and Security Developments Involving the People's Republic of China[97]

In their annual 2024 *Global Counterspace Capabilities* report, Secure World Foundation concluded, "China appears to be highly motivated to develop counterspace capabilities to bolster its national security...China has conducted multiple tests of technologies for close approach and rendezvous in both low-earth orbit (LEO) and geostationary earth orbit (GEO) that could lead to a co-orbital ASAT capability. "[98] The CSIS *Space Threat Assessment 2024* provided details, "Over the course of 2023 and into early 2024, SJ-23 and other Chinese spacecraft exhibited unusual behaviors in GEO, particularly in proximity to certain U.S. government and commercial satellites...Elsewhere, in late 2023, a pair of Chinese satellites—Shiyan (SY) 12-01 and 12-02—appeared to move in synchronized yet opposite direction...These RPOs continue to enable China to mature operational concepts and technical skills necessary for orbital ASAT weapons."[99]

[96] DoD (2024). Military and Security Developments Involving the People's Republic of China.
[97] DoD (2024). Military and Security Developments Involving the People's Republic of China.
[98] Weeden, B. and Samson, V. (2024). Global Counterspace Capabilities. SWF.
[99] Swope, C. Bingen, K, Young, M. Chang, M. Songer, S., Tammelleo, J. (2024). Space Threat Assessment 2024. CSIS.

China Planetary Defense - In July, China announced the target for its dual-spacecraft observation and impact mission, asteroid 2015 XF261, a roughly 30-meter-diameter near-Earth asteroid similar to DART,[100] with the launch expected in 2027 (a two-year slip).[101] China is also studying concepts for a space-based observatory to search for near-Earth asteroids which might include "novel orbits" for the observatory, such as sun-Earth L1 Lagrange point, positions leading or trailing Earth in its orbit, and possibly a constellation of spacecraft in a distant retrograde orbit around the Moon.[102]

Space Mining. In 2024 China for the first time outlined its position on space resources to the United Nations, stating that space resource utilization is permissible.[103] Scientists from the China Academy of Sciences also articulated a pressing need for China to amplify its asteroid research, tapping into the vast untapped potential for discovery and innovation.[104] China's Tianwen 2 probe is expected to launch in May 2025 to return samples from a near-Earth asteroid 469219 (also known as Kamo'oalew) and then explore main-belt comet 311P/PANSTARRS.[105] The PRC unveiled plans for a Lunar Electromagnetic launcher.[106]

Eyes on China's Ambitions. China's strides in space attracted several think tanks to examine potential scenarios.[107] The scale of China's ambitions led some to state that they dwarf U.S. ambitions[108] and others to note that should asteroid mining become reality, it is essential for the future of U.S. National Security "given the announcement in July 2023 that China would restrict exports of gallium and germanium for reasons of national security, the United States needs to aggressively explore new mineral supply chains decoupled from China."[109]

DOMESTIC CONCERNS

Losing national focus? Despite a statutory requirement to hold a National Space Council Meeting, vice president Harris did not convene NSpC meeting in the final quarter. Moreover, the future of the National Space Council is in doubt.

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[100] Andrew Jones, A. (2024). China targets its first planetary defense test mission. Planetary Society.
[101] Foust, J. (2024). China reschedules planetary defense mission for 2027 launch. SpaceNews.
[102] tlpnetwork.com (2024). China Delays Asteroid Deflection Mission to 2027, Changes Target.
[103] Jones, A. (2024). China outlines position on use of space resources. SpaceNews; PRC (2024). Submission by the Delegation of China to the Working Group on Legal Aspects of Space Resource Activities Of the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space. UNOOSA.
[104] Jones, A. (2024). Chinese scientists call for focus on asteroid missions. SpaceNews.
[105] Mansfield, S. (2024). China's Tianwen 2 Probe to Undertake Ambitious Asteroid and Comet Mission. Space Daily
[106] Williams, M. (2024). China proposes magnetic launch system for sending resources back to Earth. Phys.org; Xin, L. (2024). Chinese scientists planning rotating launch system on the moon. SCMP.
[107] AFPC (2024). Reacting To Major Space Events At Or Below Geostationary Orbit; AFPC (2024). Reacting To Major Space Events On The Moon And In Cislunar Space; AFPC (2024). Reacting To Future Major Space Events;
Galbreath, C. (2024). Securing Cislunar Space and the First Island Off the Coast of Earth. Mitchell Institute.
[108] Aedan Yohannan, A. (2024). China's Space Strategy Dwarfs U.S. Ambitions. National Interest.
[109] Blue, A. (2024). A Sci-Fi Concept That Should Become Reality: Asteroid Mining Is Essential for the Future of U.S. National Security. CNAS.

Continuing Resolutions. The likelihood of a continuing resolution will continue to differentially harm national efforts to begin new programs to maintain national advantage. This combined with concerns over tariffs which could raise the cost of aerospace materials, potential hiring freeze and culling of bureaucracy which might slow licensing could be counterproductive to the goals of the incoming administration to advance U.S. spacepower.

Resourcing. Various actors have called for the Space Force to grow. HASC Chairman Mike Rogers asserted that the Space Force should grow in both people and budget.[110] The NSSA called for increasing the Space Force budget to $45-$50 billion.[111] CNAS discussed the USSF's need for 'Space to Grow.'[112] Yet the Space force budget is going down. After a large increase from $26.3B in FY23 to $30B in FY24, the Space Force saw a modest decrease to $29.4B for 2025.

GEOINT and Tactical Surveillance and Reconnaissance and Targeting (TacRST) Turf Wars. Turf wars continued over space roles and responsibilities with regard to geospatial intelligence (GEOINT) and tactical reconnaissance and surveillance –who has the authority and who should be allowed to own collection and dissemination of timely information critical to warfighting kill chains.

ISAM in Jeopardy. Despite the priority given by the White House, and the creation of the Consortium for Space Mobility and ISAM Capabilities (COSMIC),[113] we learned that NASA had cancelled both OSAM-1[114] and OSAM 2.[115]

Getting Behind In Prospecting & Sample Return. Despite China's experience with Lunar sample return, and the priority that China has placed on their own Mars sample return,[116] NASA's Mars sample return appears in jeopardy or cancelled.[117]

"We want a maneuvering capability that allows us to maneuver through multiple orbital regimes," he said. "We think that will help limit the opportunity for operational surprise. So it is a mission-by-mission, orbit-by-orbit determination, but absolutely we see certain missions, certain orbits where Dynamic Space Operations, sustained space maneuver makes great sense for the nation."

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110 Mike Rogers (2024). Rogers Gives Speech on Space Force and its Future. Armed Services.
111 NSSA (2024). Moorman Center for Space Studies Releases Second Tranche of Presidential Transition Issue Papers.
112 Dennis, H. (2024). Space to Grow Foundational Opportunities and Challenges for the U.S. Space Force. CNAS.
113 COSMIC (2024). COSMIC.
114 Foust, J. (2024). NASA reaffirms decision to cancel OSAM-1.
115 Katalyst Space (2024). In-Space Servicing, Assembly, and Manufacturing (ISAM).
116 Kuthunur, S. (2024). China moves Mars sample-return launch up 2 years, to 2028. Space.com
117 Friedman, L. (2024). NASA's no to Mars. SpaceNews.

– GENERAL STEPHEN N. WHITING USSPACECOM Commander[118]

SML in Jeopardy. The Space Force announced space mobility and logistics as one of its core competencies in 2020. In 2024, despite the significant buzz over 'dynamic space operations,' 'sustained maneuver,'[119] a second Space Mobility Conference,[120] the creation of the Consortium for space mobility and ISAM capabilities (COSMIC)[121] and urging by the White House to to provide "real" resources and funding to developing space mobility and logistics,[122] such investments have yet to materialize, and in fact, the Space Force zeroed out funding for in-space mobility in its FY26 budget request.[123]

"What is the Space Force going to look like 50 years out? Well, we're going to need to preserve all of the routes between here and the Moon. We're going to need to preserve all the Cislunar insertion orbits. We're going to need to protect a lot of the asteroids that are near Earth that we need to be mining for critical minerals, critical resources that are going to power our infrastructure here on Earth, but also as we expand out into space."

– PALMER LUCKEY, founder of Anduril Industries[124]

Sufficient Attention to Looking Out. In 2024 the debate raged about the importance of Cislunar / xGEO or 'looking out' spacepower[125] with one paper "a bluewater USSF, pegged to 3.2% of U.S. Space GDP, growing rapidly to eclipse the warfighting budget in 2035, achieving a total budget nearly nine times the size of the base budget in 2070"[126] and a separate paper by the Mitchell Institute's Charles Galbreath providing a concrete suggestion that "Congress must fund additive growth of about $250M

[118] Hadley, G. (2024). SPACECOM Boss Wants Satellites That Can Maneuver to and from New Orbits. Air & Space Forces; USSPACECOM (2024).
[119] Hadley, G. (2024). SPACECOM Boss Wants Satellites That Can Maneuver to and from New Orbits. Air & Space Forces; USSPACECOM (2024). 'Extending the Advantage:' USSPACECOM outlines elements of victory; Stone, C. (2024). The US needs to get real about maneuver warfare in space. Breaking Defense; Chris Williams, C. (2024). Dynamic Space Operations: An Overview and Assessment. NSSA; Hendrick, S. (2024). Sustained maneuver: Why the time is now for in-space refueling. GovExec; SpaceWerx (2024). Sustained Space Maneuver (SSM) Challenge; Staats, B. (2024). The USSF Should Prioritize Sustained Space Maneuver as a Central Space Warfighting Principle. Aerospace.
[120] Tribou, R. (2024). Space Coast's new general spearheads more cooperation with private space companies. Stars and Stripes.
[121] COSMIC (2024). About COSMIC.
[122] Hitchens, T. (2024). White House official urges more 'real' Pentagon investment in space mobility. Breaking Defense.
[123] Hitchens, T. (2025). Space Force zeroed out funding for in-space mobility in FY26 budget request. Breaking Defense.
[124] Lucky, P. (2025). Fox News Sunday (Feb 16, 2025). Cited in NSNX Sadler Report.
[125] Aerospace Corporation (2024). High Ground Or High Fantasy: Defense Utility Of Cislunar Space; AFPC (2024). Reacting To Major Space Events On The Moon And In Cislunar Space; Garretson, P. (2024). Congress Must Demand Stronger Leadership from OSD Space Policy. Global Security Review; Swope, C and Gleason, L. (2024). Salmon Swimming Upstream: charting a course in Cislunar space. CSIS.
[126] Garretson, P. (2023). Bluewater and Brownwater Space Strategies and Their Budgetary Profiles. NPEC.

a year to the Space Force budget and increase end strength by approximately 200 personnel for the new responsibilities associated with emerging national interests on the Moon and the Cislunar region."[127]

"Think about the type of space domain awareness that we're gonna have to do out to ex-GEO, Cislunar. How are we going to do that? As we start to collect data on moving target indications, what's the battle management process that your Space Force will use to make sure that the data from the sensor gets to the shooter on operationally relevant time? This is the kind of thought process that's going to go through this Concepts and Technology Center."

– GENERAL CHANCE SALTZMAN, Chief of Space Operations[128]

NOVEL SPACE ACTIVITY LICENSING

Background - In 2024, the U.S. government advanced two significant legislative efforts to regulate commercial space activities: the Commercial Space Act of 2023 (H.R. 6131) and the proposal developed by the National Space Council.

Commercial Space Act of 2023 (H.R. 6131) - Introduced in November 2023, H.R. 6131 aims to amend Title 51 of the United States Code to update government oversight of commercial space activities. The bill seeks to enhance the regulatory framework governing commercial space operations, ensuring safety, sustainability, and competitiveness in the U.S. space industry. As of September 12, 2024, the Congressional Budget Office (CBO) released a cost estimate for the bill, indicating ongoing legislative evaluation.[129]

National Space Council Proposal - In parallel, the National Space Council has been developing a comprehensive proposal to regulate commercial space activities. This initiative focuses on establishing a new commercial space transportation administration, creating a commercial spaceflight research alliance, and developing a national spaceport network. The proposal aims to strengthen the nation's position in space by supporting the licensing and operation of commercial space transportation systems and spaceports.[130]

The Commercial Space Act of 2023 (H.R. 6131) and the proposal from the National Space Council both reflect a concerted push to modernize and streamline the regulatory environment for commercial

[127] Galbreath, C. (2024). Securing Cislunar Space and the First Island Off the Coast of Earth. Mitchell Institute.
[128] Saltzman, C. (2024). Remarks by Chief of Space Operations General Chance Saltzman during the AFA Air Warfare Symposium's Great Power Competition Senior Leader Panel. SpaceForce.mil.
[129] CBO (2023). H.R. 6131, Commercial Space Act of 2023.
[130] NSS (2024). Proposed Commercial Spaceflight Operations Act of 2024.

space activities, balancing the need for innovation with the imperative of safety and national security. Both aim to regulate and support the growth of the commercial space sector, but they differ in their focus, scope, and specific policy approaches. The National Space Council proposal is more ambitious in terms of infrastructure and national strategy, while H.R. 6131 is more regulatory and focused on operational clarity.

Scope and Regulatory Focus - The Commercial Space Act of 2023 (H.R. 6131) focuses primarily on refining and improving existing regulations to enhance the safety, operational standards, and competitiveness of commercial space activities. It aims to provide clearer guidelines on space operations, including licensing and safety standards for launch and re-entry activities, to ensure U.S. leadership in the global space sector. The bill is designed to streamline regulatory processes, helping private companies remain competitive internationally while ensuring the sector operates safely. In contrast, the National Space Council's proposal takes a more comprehensive approach, focusing not only on regulation but also on establishing a broader strategic framework for the U.S. space industry. It emphasizes creating new infrastructures, such as a national spaceport network and partnerships with the private sector, to drive growth and long-term success in the space domain.

Infrastructure and Development - The Commercial Space Act (H.R. 6131) does not directly address infrastructure development. Its primary focus is on improving the regulatory framework for space activities, ensuring that existing systems operate efficiently and that the regulatory environment supports private sector growth. By streamlining licensing processes and clarifying safety standards, the bill aims to reduce bureaucratic hurdles for space companies. On the other hand, the National Space Council's proposal is heavily focused on infrastructure, including the establishment of a national spaceport network and the creation of a commercial spaceflight research alliance. These initiatives aim to foster technological innovation and provide the necessary physical infrastructure to support a growing commercial space industry.

Government vs. Private Sector Focus - The Commercial Space Act (H.R. 6131) is centered on creating a balance between government oversight and private sector freedom. It seeks to modernize existing regulations and provide a predictable environment for private companies to thrive without introducing overly burdensome regulations. The goal is to foster competition and innovation while maintaining essential safety and operational standards. In contrast, the National Space Council's proposal positions the government as an active partner in driving the growth of the commercial space sector. It emphasizes the need for public-private partnerships and infrastructure investments, with a focus on long-term collaboration between the government and private industry to ensure that the U.S. remains a global space leader.

Long-Term Strategic Goals - The Commercial Space Act (H.R. 6131) primarily addresses immediate needs by refining regulatory processes to improve the efficiency, safety, and global competitiveness of commercial space activities. It focuses on enhancing clarity in the regulatory framework, helping space companies navigate current challenges and thrive in a growing market. In contrast, the National Space Council's proposal is forward-looking, focusing on building a sustainable, competitive space ecosystem over the long term. It aims to position the U.S. as a leader in the space economy by investing in infrastructure, fostering collaboration, and ensuring the country's space capabilities remain robust for decades to come. The proposal envisions a more integrated approach, bringing together both government and industry to drive space policy, innovation, and development.

GENERAL OBSERVATIONS

At present, there are four key observations requiring immediate attention to fuel our collective industrial base, retain its pace of innovation, and flourish in terms of new capabilities, jobs and contribution to our gross domestic product.

A UNIFYING VISION IS STILL REQUIRED

The United States Continues to Lack a Grand Unifying Vision for Space Development - Since 2020, the SSIB has consistently advocated for a North Star Vision for the U.S. and its Global Partners. The US must create a safe, stable, secure, and sustainable space domain which builds and advances an enduring competitive advantage for the United States and its global partners for economic prosperity and collective security in pursuit of national goals that embrace the peaceful economic development and human settlement of space in a manner that is consistent with our shared values, democratic principles and appreciation for both human rights and the environment. More than ever, America needs a unifying vision for this second space age with its unparalleled potential for breakthroughs in manufacturing, biotechnology, mining, and new sources of energy – to build a thriving space economy and become a true spacefaring civilization.

LICENSING NOVEL SPACE ACTIVITIES REMAINS UNRESOLVED

Licensing Novel Space Activities Must Be Resolved - Despite proposals by both the House and the White House, the nation remains without a stable, well understood, and legislatively authorized process for licensing novel in-space activities. This must be resolved to allow for a vibrant in-space economy.

SPACE MOBILITY AND LOGISTICS IS UNDER RESOURCED

Space Mobility and Logistics (SML) Must Receive Real Resources - Despite significant policy push from the White House, the broader vision of building the underpinnings–SML–of a vibrant in-space economy and new mode of transportation remain largely aspirational.

"Vision Without Execution Is Hallucination."

- SIMON SINEK[131]

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[131] Sinek, S. (2016). Simon Sinek: 'Vision Without Execution Is Hallucination'. Inc.

KEY ACTIONS & RECOMMENDATIONS

From the above observations and additional inputs from the working groups, participants advocated for or expressed interest in these overarching recommendations for action:

1. **Articulate an Enduring U.S. North Star Vision for Space.** America needs a unifying vision for this second space age with its unparalleled potential for breakthroughs in manufacturing, biotechnology, mining, and new sources of energy – to build a thriving space economy and become a true spacefaring civilization. The vision must motivate America to invest in creating and protecting this bright future, and attract allies and partners interested in economic prosperity and collective security in the grand project of economic development and human settlement of space.
2. **Finalize a Process to License Novel Space Activities**. The Administration and Congress need to finalize a process that can enable rapid licensing to keep the U.S. in a dominant position in space innovation and allow the maximum contribution from the U.S. commercial sector to our prosperity and security.
3. **Make the Necessary investments in Space Mobility and Logistics.** Space Mobility and Logistics, including in-space servicing, assembly and manufacturing constitute a new avenue for prosperity and national advantage, but demand serious and sustained investment.

WORKING GROUP BREAKOUTS

The State of the Space Industrial Base 2024 conference was held in Albuquerque, NM with a Partner Workshop Seattle, WA. The conference workshops were organized with specific breakout sessions enabling dialogue between stakeholders from industry, academia and government to address the challenges above and answer the most important question, "Are we making the progress we should be, and if not why not?" Chatham House Rules were observed within the breakout sessions to facilitate a more comprehensive discussion. Specific working group breakouts for SSIB'24 included:

- Novel Space Activities
- Outernet
- Space Policy & Regulation
- Next Generation Power & Propulsion
- Space Sensing

We also ran "Co-innovation Sessions" on topics of interest to the larger group

- Space Workforce, STEM & Education
- Commercial Space Launch International Partnerships
- Regulatory Environment for Novel Space Technologies
- Supply Chain Challenges

NOVEL SPACE ACTIVITIES

Working Group Co-Lead: Gabe Mounce, AFRL
Working Group Co-Lead: Rob Antypas, AFRL
Working Group Co-Lead: Scott Maethner, NewSpace Nexus

Figure 8. Testing new SpaceSuit on Polaris Dawn mission (Source: SpaceX[132])

"...there is increasing recognition that a space program that focuses only on government needs without regard to a healthy commercial sector is not complete, nor will it be competitive in the international marketplace."

- The Future of the U.S. Space Industrial Base: A Task Group Report, Vice President's Space Policy Advisory Board, November 1992[133]

BACKGROUND

Novel space activities refer to innovative and previously unexplored or currently unregulated applications and operations conducted in outer space. They represent a transformative shift in how humanity utilizes space, including promising advancements that can significantly benefit both

[132] Lele, A. (2024). Framing the success of the Polaris Dawn mission. The Space Review.
[133] Vice President's Space Policy Advisory Board (1992). The Future of the U.S. Space Industrial Base: A Task Group Report.

Earth and space economies. This includes capabilities like in-space manufacturing and assembly, satellite servicing, on-orbit refueling, debris removal, space tourism, energy collection and transmission, and in-situ resource extraction from celestial bodies like the Moon and asteroids. Unlike traditional space missions that focus on exploration, data collection or signals propagation, novel space activities aim to establish sustainable and economically viable operations that can support long-term human presence, robotic activities and commercial endeavors in space with tangible benefits for Earth.

Figure 9. America's First Commercial Lunar Lander IM-1 on its way to the Moon (Source: Intuitive Machines[134])

Novel Space Activities Elevate National Pand Prestige. They project a nation's pioneering spirit and drive to open new economic frontiers. Investments and resulting accomplishments can inspire generations of new students, promote public enthusiasm, national pride and geopolitical influence. These activities signal technological leadership on a global stage and attract international partners.

Novel Space Activities Drive Technological Advancements, increasing efficiencies, and furthering ever more activities in space. For example, in-space manufacturing enables the production of stronger, lighter and more complex structures that are built in space which are not possible or cost effective on Earth due to the constraints of gravity. The benefits are transformative with respect to efficiency, flexibility, and sustainability of space missions. In-situ resource utilization accompanied by space

[134] Foust, J. (2024). IM-1 mission on course for the moon after engine test. SpaceNews.

manufacturing and assembly reduces dependence on Earth-based supply chains and enhances mission flexibility, particularly for long-duration missions to the Moon or Mars where resupply opportunities are limited. In-space manufacturing has the potential to lower the costs of space missions by reducing the mass and volume of payloads launched from Earth. Over time, this could make space missions more economically viable and sustainable.

Novel Space Activities Have the Potential to Create New Markets and Industries. In-space manufacturing and assembly, exemplified by recent Northrop Grumman and ESA 3D printing experiments onboard the ISS, will reduce operating/mission costs and enable on-demand production of customized parts, creating new commercial opportunities in space construction and repair services, and increasing the longevity and sustainability of our orbiting labs. Space tourism, driven by companies like SpaceX, Virgin Galactic, and Blue Origin, offer luxury experiences and broad market potential, leading to the development of training programs and spaceport operations. Asteroid mining, pursued by firms like Planetary Resources and Cislunar industries, promises high-value materials and supports long-duration missions by providing resources for in-space manufacturing, life support systems, and propellant. Satellite servicing and on-orbit refueling, demonstrated by Northrop Grumman's Mission Extension Vehicle (MEV), extends the lifespan of satellites and fosters a new market for maintenance and refueling services.

Novel Space Activities Contribute to the Sustainable Use of Space Resources. They promote resource efficiency and reduce waste and the environmental impact on and around Earth. In-space recycling of inoperable satellites and rocket bodies for raw materials and parts can mitigate debris hazards. Extracting materials from asteroids or the Moon can reduce the dependency on Earth-based resources and support the development of a space-based economy. In-space manufacturing and assembly help create a sustainable space economy by reducing the need for frequent launches from Earth, thereby lowering the carbon footprint associated with space missions.

"...there are interests clearly within the Earth Moon system that we need to be thinking about as we go forward."

- JOHN E. SHAW, Space Strategy Podcast 18 May 2022

CURRENT STATE

In recent years, the space industry has witnessed significant advancements in In-Space Servicing, Assembly, and Manufacturing (ISAM) as well as the introduction of National Policy, new legislation, and strategic initiatives aimed at fostering innovation and sustainability. Despite these achievements, several challenges remain that hinder the full realization of novel space activities. These include regulatory and bureaucratic hurdles, a lack of long-term roadmaps, uncertainty in the value proposition and business case for new technologies, and the difficulty many companies face in transitioning from early development stages to full-scale commercialization. Addressing these challenges is crucial for ensuring that the commercial space sector can thrive and contribute effectively to national and global space objectives.

Several ISAM Demonstration Missions Have Been Planned and/or Executed –Northrop Grumman's MEV-2 successfully docked with Intelsat 10-02, extending its operational life by several years and demonstrating the ability to provide life-extension services to existing satellites. Astroscale's ELSA-d mission demonstrated space debris removal capabilities and completed end-of-life operations in Oct 2022. NASA's Restore-L mission (now OSAM-1) which aims to refuel and service a satellite in low Earth orbit was formally canceled but contributed greatly to the national knowledge base.

DARPA/NRLs RSGS, in partnership with Northrop Grumman, has finished testing and is preparing for integration and launch. The Space Infrastructure Dexterous Robot (SIDR) project, which is designed to assemble large structures in space, completed successful ground-based testing of its robotic arm and autonomous operations systems. Additionally, Made In Space's Archinaut One project, which aims to 3D print and assemble parts in space, achieved milestones for ground testing, robotic arm development, integrations and systems testing and pre-launch preparations. ESA has achieved critical design review milestones for Space Rider, an uncrewed robotic laboratory that will be able to service satellites, perform repairs, and conduct in-space manufacturing. Sierra Nevada Corporation's Dream Chaser Cargo spacecraft completed thermal vacuum testing, flight software testing and launch vehicle integration. Dream Chaser is designed to transport cargo to the ISS and includes capabilities for on-orbit servicing and assembly tasks. Finally, the SpaceWERX Orbital Prime program has pipelined 28 companies toward in-space demonstrations via matching of Small Business Administration funding with US Space Force and private investment to include three Strategic Funding Increases (STRATFI) and nine Tactical Funding Increases (TACFI) valued at approximately $55M, one Space Systems Command (SSC) Other Transaction valued at $26M (under the Space Enterprise Consortium), establishment of several Work Programs with IN-Q-Tel and SSC's Commercial Solutions Office (CSO).

Considerable Progress Has Been Made with Respect to the Introduction of Legislation, Policy, Strategy, and the Creation of Organizations – The Orbital Sustainability Act of 2023 or the ORBITS Act has been introduced to create a regulatory environment that supports the long-term sustainability of space activities. Policy development is underway for the regulation of Novel Space Activities with key tensions remaining in the areas of regulatory or market-driven innovation, the scope of the frameworks (national or international) and short-term flexibility vs. long term stability. The DoD introduced its Commercial Space Integration Strategy which outlines its approach to leveraging commercial space capabilities through space innovation and collaboration while enhancing resilience and capability of defense operations. The USSF introduced its Commercial Space Strategy to enhance integration of commercial space capabilities into military operations emphasizing rapid acquisition and deployment, enhanced resilience, interoperability, integration, promoting innovation and security.

Finally, the creation of organizations like CONFERS and COSMIC , which are international or industry-led collaborative initiatives focused on advancing technologies and best practices related to novel space activities such as space mobility and in-space servicing assembly, and manufacturing, have enhanced dialogue and improved coordination.

Space Sustainability and Reusability of Satellites are Becoming Recognized Needs – Government officials, including those from NASA, the Department of Commerce, and the Space Force, have repeatedly emphasized the importance of space sustainability in public statements and testimonies before Congress. For example, Gen Stephen Whiting, Commander United State Space Command said, "Sustained space maneuver will change how we operate, opening up new tactics, techniques, procedures and operating concepts, and allowing operations until the mission is complete, not until the fuel we launched with runs out." These statements often cite the need for reusability in satellite design as a key factor in maintaining a sustainable space environment. Governments worldwide have implemented several measures to address orbital debris mitigation. The U.S. Federal Communications Commission (FCC) introduced a rule in 2022 reducing the time for deorbiting satellites from 25 to 5 years for U.S.-licensed objects. NASA, ESA, and other agencies have adopted stricter guidelines, such as the 25-year rule for deorbiting spacecraft and second-stage rocket bodies. International organizations like the United Nations' Office for Outer Space Affairs (UNOOSA) and the Inter-Agency Space Debris Coordination Committee (IADC) provide frameworks for member nations to follow best practices in debris mitigation. Additionally, the European Space Agency (ESA) is funding active debris removal missions, such as the ClearSpace-1 mission, to remove defunct rocket stages from orbit. Industry is following suit. For example, Magdrive, a UK-based space tech startup is pursuing the use of recycled or recyclable metal propellant which opens up the opportunity to reduce costs and the environmental impact of space exploration by enabling spacecraft to generate their own propellant for long missions. In addition, the U.S. firm CisLunar Industries is working on innovative approaches to recycle metal debris in space to create metallic fuel for propulsion systems and recycled metals for building large structures in space.

Regulatory and Bureaucratic Hurdles are Barriers to Innovation and Speed – Regulatory and bureaucratic hurdles are often cited as significant barriers to innovation and speed, particularly in the space industry. For example, the lengthy and complex process of obtaining licenses and approvals from multiple government agencies can delay the development and deployment of new technologies, as seen in the case of commercial satellite launches and on-orbit servicing missions. Companies have also reported that unclear or outdated regulations make it difficult to innovate, particularly when developing novel technologies like in-space manufacturing or debris removal. Additionally, the time-consuming nature of navigating existing and emerging regulatory frameworks can lead to increased costs and reduced competitiveness, particularly when compared to countries with more streamlined processes. The ambiguity of ownership for defunct or "disposed" of space assets and convoluted international policy make rendezvous and proximity operations for servicing, reuse or disposal difficult to coordinate. These challenges highlight the need for more adaptive and responsive regulatory environments to foster innovation.

Lack of Long-Term Roadmaps for Novel Space Activities – Constantly shifting directions of technical innovation in novel space activities make long term planning unreliable. There is a recognized dearth of long-term roadmaps for novel space activities, which hinders the strategic development and investment in emerging technologies like in-space manufacturing, asteroid mining, and on-orbit servicing. While agencies like NASA and the Department of Defense have initiated programs to explore these areas, comprehensive and coordinated long-term plans that outline clear goals, timelines, and pathways for commercial and governmental collaboration are often lacking. This lack of strategic foresight leads to uncertainty in the industry, making it difficult for companies (especially startups, small and early growth companies) to plan investments and align their innovations with future government needs. Furthermore, the absence of detailed road maps can result in fragmented efforts and missed opportunities to collaborate or fully capitalize on the potential of these new space domains.

Uncertainty in Value Proposition and Business Case for Novel Space Activities: Uncertainty in the value proposition and business case for novel space activities is a significant challenge, as evidenced by the hesitation of commercial companies to fully invest in emerging sectors like in-space manufacturing and satellite servicing. Many companies cite the lack of clear government demand signals as a barrier to scaling up their capabilities, fearing that without predictable contracts or government partnerships, the return on investment might not justify the risks. For instance, the fluctuating priorities, budgets, and unclear long-term plans from agencies like NASA and the Department of Defense leave companies unsure about the future market for these advanced technologies. It is becoming clear that the Department of Defense and commercial space markets have different priorities in emerging ISAM fields. Commercial space companies see business cases closing around high efficiency longer duration timelines that do not close military use cases. This is driving a wedge in between emerging commercial and government driven markets. This uncertainty stifles innovation and slows the growth of the commercial space sector, underscoring the need for more explicit and consistent government demand signals to drive commercial participation and investment. NASA's Moon to Mars Architecture and the commercial space strategies issued by the DoD and USSF are important first steps, but more dialogue and studies are needed to quantify demand signals.

"But if we want to have robust capabilities, we really need to make sure that we're investing properly in research and development, to include prototyping activities that we do with commercial companies that are doing really interesting things to give the U.S. a competitive advantage in space."

- BRIG GEN STEVE "BUCKY" BUTOW - SpaceNews 11 Jan 2023

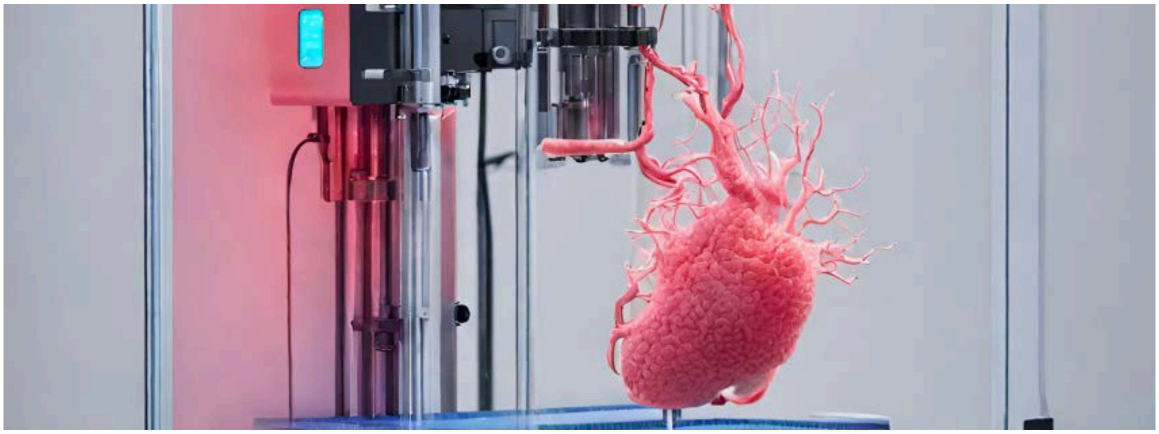

Figure 10. AI Vision of Organ Bioprinting (Source: Ilak Manoharan with AI[135])

Too Many Space Companies are Stuck in the Valley of Death - Many space companies find themselves stuck in the "Valley of Death," where they struggle to transition from early-stage development to full-scale commercialization. According to the U.S. Bureau of Labor Statistics 49.4% of startups fail within the first five years, often due to a lack of funding and market traction. This number is likely higher for space startups given the additional challenges they face like longer time to market, regulatory hurdles and high operational costs. This situation is particularly challenging because companies have typically exhausted initial funding sources but have not yet secured the larger, sustained investments needed to scale their operations. For example, numerous small satellite and space technology firms have completed successful prototypes and proof-of-concept missions but face difficulties in securing follow-on contracts or investment to move to large-scale production or deployment. The lack of clear government contracts or commercial customers exacerbates this issue, leaving many promising technologies at risk of stalling before they can achieve commercial viability. This gap highlights the need for more robust support mechanisms, such as government procurement programs or public-private partnerships, to help companies bridge this critical phase.

ASPIRATIONAL GOALS

- **Expand Human Presence Beyond Earth:** Establish sustainable human habitats on the Moon and Mars, using Lunar bases as stepping stones for deeper space exploration, and aiming for permanent settlements on Mars to ensure humanity's long-term survival.
- **Leverage In-Space Resources, Manufacturing, and Energy**: Develop advanced in-space manufacturing and resource utilization technologies, including 3D printing, asteroid mining, and space-based solar power stations, to reduce reliance on Earth, generate abundant clean energy, and enable long-duration space exploration.
- **Promote Space Sustainability and Environmental Protection**: Implement strategies to

[135] Manoharan, I. (2024). Bioprinting in Space: Revolutionizing Regenerative Medicine in Microgravity. Medium.

mitigate space debris, develop technologies for debris removal, and enhance space-based Earth observation systems to monitor and protect Earth's environment from climate change and disasters.

- **Foster Commercial Space Ventures and International Cooperation**: Encourage space tourism, private space stations, and international collaborations, while establishing regulatory frameworks to govern the peaceful and sustainable use of space resources and activities.

KEY ISSUES & CHALLENGES

The rapidly evolving space industry is currently facing a range of critical challenges and opportunities that will shape the future of novel space activities. Among the most pressing issues is the need for sustainable and reusable space technologies. While the focus on developing these technologies represents a promising shift, significant hurdles remain, particularly in establishing viable business models for in-space activities like refueling and recycling, alongside addressing the growing concerns of space debris and orbital traffic congestion. Compounding these challenges is the lack of a clear and coordinated government strategy and support system. Uncertainty around demand signals, bureaucratic obstacles, and unclear agency responsibilities have made it difficult to secure consistent backing for innovative technologies such as in-space manufacturing and space-based solar power. The development of effective public-private partnerships is crucial for fostering innovation and bridging the gap between government expectations and commercial realities. Finally, while there is a burgeoning interest in ISAM, the absence of a coherent strategy and the dynamic demand signals for its development is hindering both investment and innovation. To fully realize the potential of these novel space activities, a unified, strategic approach from both government and industry is essential.

Need for Sustainable and Reusable Space Technologies – The growing focus on developing sustainable and reusable technologies for satellites and other space assets marks a significant and promising shift in the industry. However, significant challenges remain, particularly in establishing a clear business case for in-space activities such as refueling and recycling. These challenges are compounded by the need to address space debris and traffic congestion, which are critical to ensuring the long-term sustainability and safety of space operations. As the industry progresses, it will be essential to demonstrate the economic viability of these technologies while also implementing strategies to manage and mitigate the risks associated with an increasingly crowded orbital environment.

Lack of Clear Government Strategy and Support – Uncertainty surrounding government demand signals and the absence of coordinated long-term strategies have created significant challenges for the development of novel space activities. Bureaucratic hurdles and ambiguous ownership of responsibilities across various agencies further complicate efforts to support these emerging sectors. As a result, it has been difficult to secure consistent government backing for cutting-edge technologies such as in-space manufacturing and space-based solar power. To drive innovation and ensure progress, a more unified and transparent government approach is essential, with clear roles, responsibilities, and strategies that provide the necessary support and guidance to the commercial space sector.

Commercialization and Public-Private Partnerships – Clearer and more effective public-private partnerships are essential for advancing novel space ventures and fostering innovation. Currently, there are significant gaps between government expectations and the realities faced by commercial entities, which can hinder the success of these partnerships. One of the main challenges is the transition from government being the primary or initial customer to expanding into broader commercial markets. To bridge this gap, it is crucial to align government policies and incentives with the needs of the private sector, ensuring that both sides can collaborate effectively and sustainably to support the growth of emerging space industries

Innovation and Development of ISAM Capabilities – A growing number of companies are actively pursuing innovations in ISAM, yet they face significant challenges in securing both funding and government support. Demonstrating these capabilities is essential not only for driving market development but also for shaping the future landscape of space activities. However, the absence of a coherent and unified government strategy (national security and civil space sectors) for the development and funding of ISAM infrastructure is a major obstacle, stifling commercial investment and slowing the pace of innovation. For example, the military wants to embrace commercial ISAM offerings but is realizing that those offerings are not approaching the high impulse and high thrust technologies needed to provide military utility. Commercial solutions business cases are largely focused on high efficiency low thrust capabilities. To unlock the full potential of ISAM, a strategic, well-coordinated approach is needed from government stakeholders, ensuring that the necessary resources and support are in place to foster growth in this critical area.

Shifting Economics of Space Infrastructure and Services - The rapid evolution of the space market, driven by the proliferation of LEO constellations, lower-cost rideshare launches, and the potential impact of Starship, is reshaping the economics of space activities. While the demand for LEO refueling infrastructures is declining, the need for satellite disposal, orbital transfer, and repositioning services is rising. This shift creates uncertainty around the profitability of long-term infrastructure investments, posing a challenge for businesses to adapt to an environment where affordable mass-to-orbit options are changing the calculus of sustainable space operations.

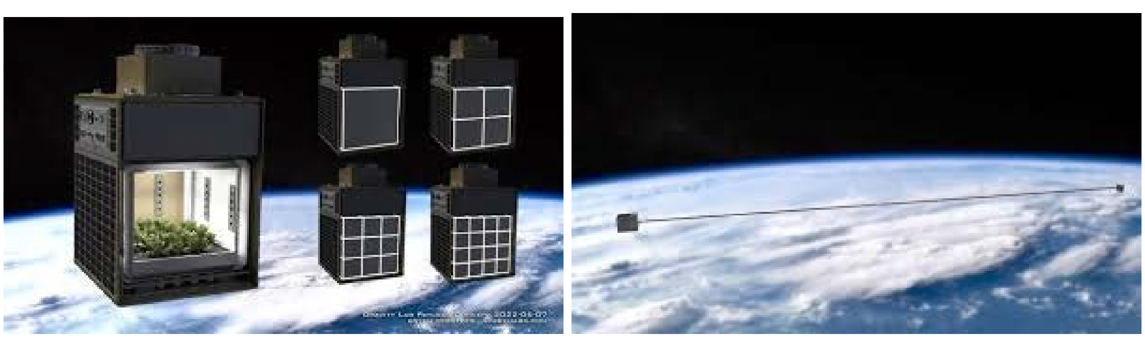

Figure 11. Gravity Lab Mark 1 (Source: Gravity Lab[136])

[136] Gravity Lab (2024). Gravity Lab.

KEY INFLECTION POINTS

- Starship/New Glen has the potential to revolutionize space access by significantly reducing launch costs and lowering the barriers for novel space activities and missions.
- In-Space infrastructure development is essential for progress in novel space activities and missions as is akin to how interstate highways and the internet spurred innovation.
- Clear government demand signals for ISAM/SAML can accelerate the development of novel space activity technologies. Inconsistent or weak signals may hinder commercial investment and innovation.
- Human spaceflight expansion and permanent Lunar presence can anchor future space activities. Sustained support & international cooperation are crucial for success in these areas.
- Collaborative efforts like COSMIC and CONFERS demonstrate the value of industry collaboration and standards development in advancing space technologies.
- Enabling technologies like AI, ML, and automation are key drivers for complex robotic space missions. Slow adoption or underinvestment in these technologies could limit the advancement of novel space activities.
- Down-mass capabilities and proliferated LEO constellations are crucial to improving public perception of the value of space, and to unlocking new opportunities and markets in space.
- Geopolitical conflicts and resource allocation will affect the ability to achieve space priorities and development milestones.
- China's megawatt-class power milestone could set a new standard for in-space power capabilities, induce regret within the U.S. and accelerate global competition and investment in space technologies.
- On-orbit structure demonstrations with high-definition videos of on-orbit structure assembly could inspire further innovation, proving the feasibility and potential of in-space manufacturing and assembly.

KEY ACTIONS & RECOMMENDATIONS

"The Space Force should pursue an investment strategy that rapidly develops and deploys commercially produced ISAM, SBSP and rocket cargo prototype systems. This strategy will allow commercial operators to take calculated risks and maximize innovation. The resulting prototype systems will provide the Space Force with initial demonstration capabilities to validate operational concepts and incrementally increase joint force resilience and flexibility in the short term. This investment strategy will yield ISAM, SBSP and rocket cargo capabilities that are economically viable in new civilian markets and ready to be procured as future programs of record for new Space Force missions."

- Capt Tyler Bates, The Hill, Jan 2023

SHORT-TERM PAYOFF

Studies and Dialogues on ISAM Capabilities: Conduct and present studies on ISAM capabilities from both government and industry perspectives, facilitating opportunities for comments and dialogues. (OPR: COSMIC/Aerospace)

Update and Review National ISAM Strategy: Review and potentially update the April 2022 National ISAM strategy, engaging industry for feedback to ensure it remains relevant. (OPR: NSpC)

Establish Standards Working Group: Create a working group to harmonize government and commercial standards for ISAM, facilitating a common understanding and implementation framework. (OPR: CONFERS)

Engage in Outreach Programs: Have space industry representatives engage with applicable adjacent industries to identify transferable technologies and solutions, bringing back insights on potential pain points. (OPR: Government group or non-profit)

Space Solar Power Roadmap: Develop a technology development roadmap for U.S. space solar power and space nuclear power programs, aiming for 1MW power output within the next decade. (OPR: Needs government support)

ISAM Platform Development: Develop a versatile ISAM platform, in-space and digital, to test multiple technologies, aiming to reduce technical risks and increase technology readiness levels (TRL). Collaborate with companies like SpaceX (Starship) for rapid & iterative testing & development. (OPR: DIU)

Design/Build/Test Competitions: Organize competitions under tight timelines to design, build, and test interface technologies, promoting innovation and practical solutions. Recommend the U.S. government specifically identify funding toward prize competitions, especially as might be applied toward international cooperation (example- via the X-Prize Foundation)

MID-TERM PAYOFF

Demonstrate Novel Space Activities: Focus on demonstrating novel space activities to showcase capabilities and drive market development. Include discussions on standardizing fuel types to streamline logistics.

Define Long-Term Space Strategy/Vision: Develop a comprehensive vision and plan for the long-term U.S. space strategy, focusing on managing strategic competition and ensuring sustained leadership in space. (OPR: DoD)

Public-Private Partnership Clarification: Foster a better understanding of public-private partnerships (PPPs), ensuring clear expectations and roles for both government and industry.

LONG-TERM PAYOFF

ISO Guidelines for ISAM: Work on developing International Organization for Standardization (ISO) guidelines for ISAM, recognizing the lengthy process but aiming for international standardization to facilitate global cooperation.

Sustainability Scoring System: Investigate and develop a sustainability scoring system for space activities, akin to LEED for construction, to encourage sustainable practices and economic viability.

Permanent Lunar Infrastructure: Establish an entire program office in DARPA for space industrial development, including a permanent infrastructure between Earth and the Moon, involving public-private partnerships and substantial government investment to motivate industry participation. (OPR: DARPA, DARPA-EXO)

Defense Production Act Title 3: Utilize the Defense Production Act Title 3 to issue a presidential determination for developing the in-space industrial base, covering mining, manufacturing, power generation, and servicing. (OPR: OSD Industrial Policy)

Prepare for Space Economy: Develop infrastructure and standards to support a thriving space economy, including fiducials for docking on all spacecraft and advancing ISAM technologies to build satellites in space.

Figure 12. Early Inversion Prototype (Source: Adam Amengual for The New York Times[137])

[137] Wakabayashi, D. (2022). Dreaming of Suitcases in Space. New York Times.

OUTERNET

Working Group Co-Lead: Steve Nixon, Outernet Council
Working Group Co-Lead: Michael Cheng, Outernet Council

Figure 13. The Space Development Agency will begin launching its Tranche 1 Transport Layer communications mesh network in 2024 (Source: Northrop Grumman[138])

"The outernet is the internet in space. The basic idea being that if I'm a sensor or a satellite in space, I shouldn't have to worry about how my data gets to where it needs to go...That's very important because it gives us real-time command and control and access to our data... which we don't always have today."[139]

- COLONEL ERIC FELT, director of architecture and integration, C4ISRNET April 26, 2023

BACKGROUND

Following developments in the last year, namely the creation of the Outernet Council, the Hybrid Space Communications working group was renamed to the Outernet working group. The Outernet

[138] Hitchens, T. (2025). SDA again postpones launch of first 'operational' data relay, missile warning satellites. Breaking Defense.

[139] U.S. Space Force Chief of Space Operations, General B. Chance Saltzman delivered this statement during his keynote address at the 38th Space Symposium on April 19, 2023, emphasizing the need for innovation in response to emerging space challenges.

Council[140] describes the Outernet as "a connected, secure, resilient, network of communications satellites." The same goal as 2023 was set forth: discuss challenges, opportunities, and risks associated with a diversified network of operators and intersatellite links.

The Outernet has the potential to completely uproot the way network traffic is handled around the world. Globally, almost a million miles of undersea cables keep opposite ends of the earth connected. However, each mile of cable represents a vulnerability to attack by an ever-increasing number of global actors. Even in its early stages, the Outernet can serve as a backup for important communications channels to remain open during times of crisis. As with other space-based technologies, much of its viability relies on the foreseen drop in launch costs over the coming decade; with reusable vehicles such as SpaceX's Starship, Stoke's Nova rocket, and claims of cheap kinetic launch on the horizon.

CURRENT STATE

In 2024 and the latter half of 2023 saw significant progress in the hybrid space communications realm, with commsat upmass increasing, proliferation of interconnected satellites, and increased global interest in space data. Multiple government agencies have shown significant interest in HSA, and most importantly have well-defined, funded programs to mature nascent technologies. Increased global conflict and incidents with terrestrial infrastructure have heightened global attention to the need for a non-terrestrial communications network.

Creation of the Outernet Council – Following the recommendations of the SSIB 2023 report, the Outernet Council was established to accelerate creation of the space internet. The Council aims to do so by development of standards and facilitation of partnerships among industry, government, and other organizations.

Proliferation of Walled Gardens – SpaceX Starlink, Amazon Kuiper, OneWeb, Telesat, and other companies continue development and deployment, adding significantly to the bandwidth provided from space. However, these systems also continue to be developed without the ability to interconnect with each other. Eventually, a widely adopted Outernet will require commercial players to communicate amongst each other. The earlier this is realized, and the faster hardware standards develop, the more beneficial the Outernet can be in the short term.

Developments in Laser Communications Technologies – Multiple in-space demonstrations of optical communications technologies such as Amazon Kuiper's on-orbit test,[141] NASA's deep space laser comm demo,[142] and SpaceX's continued use of intersatellite links on Starlink display the growing interest by industry and civil space. As well, multiple companies (Mynaric, KSAT, Safran) are commercializing optical ground station technology. The global space-based laser communications market is projected to grow from $10.72 billion by 2033, up from $3.04B in 2023. Although

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[140] Outernet Council (2024). Outernet Council.

[141] Amazon (2023). Amazon's Project Kuiper completes successful tests of optical mesh network in low Earth orbit; Boyle, A. (2024). Amazon reveals that its satellites are using lasers. Cosmic Log.

[142] NASA (2023). NASA's Deep Space Optical Comm Demo Sends, Receives First Data; ScienceBlog (2024). NASA's Laser Communication Breaks Distance Record, Paving Way for Future Space Exploration.

bandwidth of space-to-space communications is ever increasing, each exists in its own 'walled garden' where no companies can communicate with each other's hardware.

Space Development Agency Accelerating Pace of Transport Layer Buildout – SDA's rapid and steady growth of contract awards of its Transport Layer reflect the agency's commitment toward proving optical link technology. Since the last SSIB, another $1.5B has been awarded by the agency for 72 more satellites, all capable of intersatellite communication. DARPA and DIU are also increasing funding levels for HSA activities, with DIU completing an on-orbit test of intersatellite communication capabilities and DARPA awarding Phase 2 contracts for its Space-BACN program. The Space Force also released an RFI exploring USSF adoption of a space orchestration API, similar to the Outernet Council's Federation API. Moreover, a recent RAND report suggests overcoming fragmentation to do enterprise wide commercial satcom purchases.[143]

KEY ISSUES & CHALLENGES

The Outernet working group identified continuing and new challenges which generate barriers in developing technology to address the warfighters' needs and remain relevant. Workforce recruitment and retention, as well as effective communication between government and industry partners, were specifically highlighted. Many of these challenges parallel those observed during the creation of the terrestrial internet; like the lack of effective government oversight and creation of standards. At the moment, most companies or agencies are developing systems that are not interoperable with each other.

Lack of Standards for Optical Interfaces – Although SDA standards are being used, the bandwidth capabilities are too limiting for widespread and long-term use. The vast majority of commercial ISLs already operating in space are operating 50-100 times faster than the SDA standard. As it stands, multiple private entities are developing proprietary communications standards and hardware, which will make interconnection substantially more difficult down the road. Additionally, government dominance of the current market biases any potential standards toward government needs, leaving the nascent commercial developments behind.

Lack of Clear, Large-Scale Benefits to Outernet Architecture – The Outernet concept and its benefits are still just being realized, making it difficult to persuade significant government financial backing. Additionally, the few commercial entities developing Outernet infrastructure lack a larger, concerted advocacy group. The Outernet Council seeks to change this, but requires never-seen-before cooperation among industry and government partners.

Commercial and Other Entities are Each Developing Proprietary Interfaces – "pockets" of interconnection are created when standards don't exist, and companies aren't incentivized to adapt to or compromise with their competitors. Commercial entities are also disincentivized from making their networks interoperable due to proprietary terminal revenue. The use of non-proprietary hardware would significantly alter business models, both on the ground and in space. The longer these proprietary interfaces continue to be developed and proliferated, the harder it will be to integrate them

[143] Erwin, S. (2023). New report recommends Space Force change how it buys commercial satellite services. SpaceNews.

together. This challenge also extends internationally, where competitor nations may have wildly different norms and standards.

KEY INFLECTION POINTS

Satellite servicing becomes possible and widespread enabling lower operating costs and risks, installation/retrofitting of existing spacecraft with new hardware, and refueling/repairing of existing assets on orbit. Fitting older but still operational vehicles with optical terminals and greatly improved communications technology will allow for more, and smaller, actors to participate in the growth of the Outernet.

Kuiper or another constellation begins real competition with Starlink – Starlink's dominance of LEO, in addition to SpaceX's launch market share, make it difficult for competitors to emerge in this space. Although OneWeb, Kuiper, and other proposed constellations show promise, none have yet to pose serious competition to Starlink.[144]

Due to rising widespread global tension, the need for geospatial products is expected to rise. With regional conflicts and tensions building across the globe, the need for geospatially driven situational awareness also grows. The commercial sourcing of Earth-imaging has recently provided both the Government and the public with an unprecedented amount of up-to-date information that drives public opinion and Government decision making.

New technologies in intersatellite links may provide a future with lower latency in communications and control. The latency present in any satellite constellation due to bandwidth of RF communications has been a consistent design limitation since space communication's inception. With the rapid advent of optical communications, new satellite constellations will likely enjoy greater bandwidth with lower latency arranged as networks as opposed to static chains.

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

USG Should Aggressively Encourage Industry to Develop Outernet Standards: In the absence of a strong signal from major customers such as the USG, the space communications industry will continue its current technical fragmentation, reducing economic efficiency, resilience, and future commercial viability. The USG should encourage industry to develop Outernet Standards, and provide funding and government participation in an industry-led standards initiative.

Outernet Council to Provide Neutral Advocacy: The Council should survey its constituents to provide thought leadership and advocacy across the industry, following the Linux Foundation as an example.

[144] Roulette, J. (2024). SpaceX to sell satellite laser links that speed in-space communication to rivals. Reuters.

Industry Consortium to Define Procurement Language: Interoperability and standardized interfaces should be prioritized, and the government should give preference to hardware with these attributes.

Contracting Recommendations: RAND recommends enterprise contracting for comms to better achieve hybrid architecture.

MID-TERM PAYOFF

Encourage Operators to Data Share to Undesignated Government Agency: Real-time STM will become more necessary for collision avoidance, a central data authority can help resolve.

U.S. Government to Incentivize Interoperability and Develop Standards: Collaborate with industry to develop these standards. Award contracts preferentially to companies who opt into the Hybrid Space Architecture.

Industry to DevelopInteroperable and Non-Aggression Incentive Framework: Use the Open Innovation Network and LOT Network as examples.

LONG-TERM PAYOFF

Develop Ship-to-Ship Communications Protocols Between Human Vessels: Traffic management of human vessels takes priority over other unmanned spacecraft.

Encourage International Cooperation, Even with Adversaries: Problems on-orbit affect all nations. Collaborate with the international community by disincentivizing adversarial action against cooperative assets, tying in the Outernet to the Outer Space Treaty/Artemis Accords.

SPACE POLICY & FINANCE LANDSCAPE

Working Group Co-Lead: Ilsa Mroz, Aerospace Industries Assoc.
Working Group Co-Lead: Bruce Cahan, Urban Logic
Working Group Co-Lead: Nikolai Joseph, AFRL

"If you ask 'Should we be in space?,' you ask a nonsense question.
We are in space. We will be in space."

–FRANKLIN PATRICK HERBERT JR. author of "Dune"

BACKGROUND

The commercial and government sectors of space historically have been inseparable. Government has been, and remains, an anchor customer to the growing commercial space enterprise, and government policy and regulatory regimes continue to help shape public-private interdependence. Strategic planning for policy/finance considerations at private companies is often at the mercy of the market, the political climate, and the competition.

Private company stakeholders of the Policy and Finance Working Group identified a series of challenges and inflection points faced by industry, as well as successes that have benefited the public-private enterprise as a whole. They noted that collective growth of the commercial space sector depends on transparency, consistency, continuity, and harmony between the government and private sector, especially in clarity of communication and scope and timelines for funding.

New entrants to the commercial sector struggle to successfully close a business case alone (independent of government as customer, investor or grantmaker). Private company stakeholders noted that emerging companies look to the US government to bail them out of the Valleys of Death, but that the lack of a "pure" commercial space market demands the commercial sector, for as long as necessary, rely on the government for support. "Valleys of Death" arise from the risks of managing a new enterprise, in a technically challenging scientific area (space) while competing for initial and follow-on funding, and designing products and services that customers have yet to see and integrate into their own business models. Private company managers will succeed only by navigating and properly prioritizing a parallel sequence of readiness levels - technology, manufacturing, integration, business, systems and commoditization.[145]

It is difficult for new space companies to compete against the major established aerospace companies (primes) and existing programs of record, and they are faced with diverse and legacy embedded barriers to entry for procurement organizations in order to meet a layer cake of regulatory requirements.

[145] Cahan, B. (2023). Avoiding the Valleys of Death: A "System Readiness Level" metric could provide a baseline for lean product development. Optics & Photonics News.

As space capabilities continue to advance, so does the appetite for both risk taking and efficiency. The U.S. Government is increasingly interested in demonstrations of small/proliferated vs large/exquisite capabilities, and the DOD has grown more accepting of experimentation. This growth has also stimulated the economic and regulatory environment further, and we've seen somewhat streamlined regulatory approvals and contracting vehicles, such as OTAs, Strat Fis, and TacFis. The risk appetite of traditional banking and insurance is also warming up to commercial space, and stakeholders are encouraged by the increased USG visibility and support. However, equity investments in space are relatively unchanged year-on-year.[146]

CURRENT STATE

In 2023, the USG continued a forward leaning approach to adopt commercial space capabilities and increasingly focusing innovation on public private partnerships. This is a recognition of the role that commercial services can provide in reducing costs, increasing flexibility in offerings, and introducing more dynamism to the timelines of availability. The maturation of the Commercial Orbital Transportation Services and Commercial Lunar Payload Services programs within NASA are high profile examples for transportation services, but the USAF has been purchasing weather data for several years. In 2023, NASA is purchasing satellite-servicing and orbital debris mitigation capabilities from the commercial market with Starfish's SSPICY ("Small Spacecraft Propulsion and Inspection CapabilitY") Otter.

The space industry has expanded into a $630 billion enterprise, and it is estimated that the global space economy will be worth $1.8 trillion by 2035.[147] Others estimate that the global space economy is $595 billion and is projected to grow to $944 billion by 2033.[148] For more stats on startups/investments, see Space Capital's Space IQ report.[149]

Due to the space industry's dependence on government procurement and political priorities, various regional conflicts (Ukraine, Israel/Hamas) illustrate the value of space-based capabilities, while inherently adding business risk to supply chains and foreign currency flows. (For Ukraine, see Aerospace[150]; for Israel in Hamas War, see Quilette[151]; for Defense Industry, see Deloitte[152]).

In 2024, the run up to the US Presidential Election injected additional risks in predicting the form, function and nature of federal space policy, for civil space and national security space. Workshop Stakeholders were curious about how a new Administration would reconfigure Mission Authorization, Space Force Commercial Space Strategy, National Space Council and other converging commercial space coordinating bodies of domestic and international significance.

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[146] Space Capital (2024). Q1 2024 2024 SPACE IQ Space Investment Quarterly.
[147] Acket-Goemaere, A., Brukardt, R., Klempner, J., Andrew Sierra, A., Stokes, B. (2025). Space: The $1.8 trillion opportunity for global economic growth. McKinsey & Company.
[148] NovaSpace (2025). The Space Economy to Reach $944 Billion by 2033.
[149] Space Capital (2025). Space IQ: Space Investment Quarterly.
[150] Gleason, M. (2024). Russia's War In Ukraine: Key Observations About Space. Aerospace Corp.
[151] Fox, A. (2025). Lessons for Western Militaries from the Gaza War. Quillette.
[152] Berckman, L., Chavali, A., Hardin, K., Sloane, M., Dronamraju, T. (2024). 2025 Aerospace and Defense Industry Outlook. Deloitte.

KEY ISSUES & CHALLENGES

Regulatory processes and priorities: The increasing number of U.S. government agencies involved in space licensing processes impedes innovation and hinders the development of emerging technologies. The current space policy and regulatory framework suffers from fragmentation and lags behind technological advancements. Overlapping regulatory responsibilities and authorities contribute to significant risks and delays. Companies face challenges due to the incoherence of government priorities and processes, often necessitating the pursuit of parallel approval pathways with multiple, disparate agencies (for instance, the bureaucracy associated with re-entry). Furthermore, timelines are inconsistently synchronized across organizations and regulators, compounded by a lack of trust that obstructs the alignment of all stakeholders. Substantial resources are dedicated to navigating regulatory approvals, placing smaller companies at a disadvantage when competing with larger primes that possess greater capacity for regulatory, compliance, and legal expenditures. This proliferation of U.S. government agency involvement in space licensing continues to slow innovation and negatively impact nascent technology development, with overlapping regulatory responsibilities and authorities exacerbating risks and causing delays.

The unique nature of space, where activities are often scrutinized and disallowed in the absence of explicit permission due to treaty obligations, contrasts with a model of presumptive approval. Many regulatory processes require a single “no” to derail an application and the prevailing default is "no," or inaction that yields the same outcome. A shift towards an approach where space activity is permitted unless explicitly prohibited warrants consideration, as there are currently insufficient incentives for government entities to actively seek consensus. Moreover, interagency groups dealing with or requiring space capabilities often lack the clear authority or mandate to work effectively towards agreement. Indeed, bureaucratic inefficiencies result in no adverse consequences for delays or cost overruns stemming from a failure to achieve timely consensus, positioning the U.S. government as its own primary obstacle in this regard.

Acquisition and Procurement Reforms: Government officials' advocacy for improved acquisition and procurement processes is not adequately supported by necessary resources. The allocation of appropriations and the designation of funding by Congress, the White House, and the Department of Defense lack a cohesive, overarching "North Star Infrastructure Vision" to prioritize holistic financing approach that supports building and maintaining the nation's Space Industrial Base capabilities. Consequently, space government acquisition and procurement processes are protracted and tend to favor established legacy primes and emerging new primes, often at the expense of smaller businesses.

Defense budgets are often pre-allocated and fail to adapt or keep pace with the emergence of new technologies. Legacy programs, such as IRAD, frequently give a disproportionate advantage to, and against their historical record, rely on, prime contractors for innovations that could potentially evolve into products and services desired by the U.S. government.

The government needs to clearly articulate its intended role as both an "anchor customer" and as a national steward focused on fostering a competitive and sustainable market. Despite concerns regarding over-dependence on a limited number of suppliers, monopolistic tendencies persist in key segments of the space industry. The government should assume a more proactive role in supporting new companies to validate their markets and secure early-stage customers, thereby strengthening their technological maturity. A fundamental misalignment exists in the perceived roles, where government strategies often fail to acknowledge the necessity of being the anchor customer for early-stage approaches or bespoke, but necessary, space capabilities which the market alone does not support. Moreover, the allocation and designation of funding (limited tranches, constrained "colors" of use, token next stage funding) represent outdated paradigms that routinely undermine U.S. government efforts to effectively leverage and grow commercial space capabilities.

Financial markets: The commercial space market exhibits varying levels of maturity across different space activities. Currently, the development of space assets and services that generate terrestrial revenue streams attracts investment, which consequently delays investment in space assets and services of longer-term strategic significance. The U.S. Government continues to be a primary customer for both emerging and established segments of this market. From a financial perspective, Wall Street views the space industry as a long-term investment, often referencing timelines beyond 2040 and currently not classifying space as a core infrastructure asset class. Traditional banking and insurance sectors are showing increasing interest in commercial space, driven by the role of space capabilities in monitoring and mitigating terrestrial risks. However, a significant number of emerging companies are seeking U.S. government funding to overcome the "Valleys of Death" funding gaps, indicating a relative scarcity of purely commercial investment within the space sector. As with other critical infrastructure industries (healthcare, finance, energy), venture capital can get a new space company started, but that company will need different, larger and cheaper forms of debt and equity financing, along with risk-transfer derivative mechanisms, to grow along a 5 to 10 year timeframe to maturity.

KEY INFLECTION POINTS

Our Working Group identified four types of inflection points:

- 4 year Congressional & Presidential Administration cycles degrade long term planning and commitments.
- Congressional failure to observe a timely appropriations process, and resulting Continuing Resolutions (CRs) destabilize current programs.
- Bankruptcies and forced mergers of aerospace companies and their suppliers put intellectual property and teams at risk.
- Market forces of competition may prioritize profit and mergers/acquisitions, and distract from focusing on innovation.

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Accelerate Regulatory Approvals. The current approach lacks certainty of time and risk for completion, which risks absorbing, burning and wasting small to medium sized enterprise working capital and equity, burn out technical teams who would take their knowledge elsewhere, and delay delivery of critical novel innovations. Interagency approval processes need to be journey-mapped, aligned, coordinated and analyzed to see that they are "fit for purpose" in building space services. The current regulatory apparatus lags advances in technology and space business models. Pre-agency coordination using industry associations and innovations like a Space Commodities Exchange may forecast interdependencies, and thus synchronize government and private sector efforts, and find ways to identify bottlenecks.

Interagency Approval: Interagency approval processes need to be better aligned and coordinated. The current regulatory apparatus often lags behind advances in technology and new space business models. Pre-agency coordination, potentially utilizing industry associations with resources, could help synchronize government and private sector efforts and identify potential bottlenecks.

Space Activities and Investments Processes Journey Map: Develop a Space Activities and Investments Process map as a journey map benchmarked by data-driven statistics on specific space activities, procurement or investment commitments, Regulatory Approval Process and company / government changed conditions. Identify pain points aligned to incentives at each approval element. Parse Regulatory Approval Decision authority and intensity based on novelty / routineness of activity and its risks to other activities in space. Examine where risk of failure or interference resides, and deal with those risks holistically. Invert the accountability threshold of risk so that regulatory approval of commercial space activity presumptively would be "yes, approved" until a justification is given to decide "no, not approved because…." Consider speed and resiliency as overarching themes, tethering the speed of regulation to the speed of technology change. Think about framing points under path speed, asymmetric advantage path, align with commercial strategies recently released.

Support Nascent Space Companies via an Ombudsperson / Coach / Sherpa for procurement and regulatory navigation. There is also potential for helping private sector companies, based on their specific "Readiness Levels," to advance their business case's viability/credibility while growing the space capabilities that specific U. S. Government customers need and commit to buying. Form a "Good Lawyers Corps" to help government procurement, government operations and commercial parties navigate the FAR, DFAR and other regulations with creative speed and authenticity to overcome "lethargy" and "bureaucratic inertia" that stymies innovation or reasonable risk-taking. This Corps would be especially relevant to "level the playing field" as new space companies seek to compete with primes and other established vendors in winning and supplying USG customers.

Revise ITAR, MTCR – If industry can't hire foreign born individuals, some direction is good (e.g. list countries to avoid), but an alternative needs to be available. Preventing companies from gaining the top talent undermines commercial viability while empowering adversarial advantages.

Space Financing bill, e.g what is the financing for in-space. Consider creating Space Infrastructure Bonds (akin to the bonds that grow other Critical Infrastructures terrestrially) and the Space Commodities Exchange.

MID-TERM PAYOFF

Financial markets: Establish a Center for Space Finance, Insurance and Market Formation to do such research. Think of "space finance" as solving a Rubik's Cube where the parallel readiness levels of any given company or project (technology, manufacturing, business model) needs to authentically tell investors, customers and the government a coherent story of why it needs the next tranche of funding as a means to anticipate and overcome the obstacles in progressing over the next set of readiness level risks. Innovate ways to match appropriate finance mechanisms to the "story" of the readiness levels of a given company or project. Develop new, or better aligning, financing mechanisms that match the timing and budget for appropriate phases of development. Diversify supply chain/ensure resiliency: break up monopolies and prevent them (launch example given, early stage).

LONG-TERM PAYOFF

Funding Mechanisms: Mirroring other critical infrastructure industries, the government should establish funding mechanisms that support the maturation and resilience of space technology. Diversifying supply chains is also crucial to ensure the resilience of the U.S. Space Economy.

It is prudent to anticipate potential business failures (bankruptcies, reorganizations or forced mergers) among commercial space companies and to develop strategies for effectively and quickly keeping intact their talented personnel, innovative technologies and dependent customers to foster continued growth within the U.S., potentially under temporary or renewed business models, management, or capital structures. Collaboration with the private equity industry to establish one or more "Space Company Reorganization" Funds should be considered. This would aim to preserve the human capital and intellectual property of struggling space companies, preventing their fragmentation and acquisition by potential competitors or entities adverse to U.S. national security interests. National space industrial policy should anticipate and provide public / private financial structures for space companies to mature, pivot to add new revenue streams, sometimes fail, reorganize, recapitalize and ultimately succeed in the U.S., together with our foreign allies and their companies.

Finally, the development of a coordinated, interagency space policy and regulatory approach is necessary to support a unified "Moon to Mars"-like program and establish a cohesive "North Star Vision" for space.

NEXT GENERATION POWER & PROPULSION

Working Group Co-Lead: Peter Garretson, AFPC
Working Group Co-Lead: James Winter, AFRL

"the US can't be a space power if the US doesn't lead in space power"

-- SSIB2020

BACKGROUND

Space-based energy and power remain among the most important underpinnings of comprehensive spacepower, and a key area of great power competition. This year witnessed substantial new interest in advanced power and propulsion systems.

CURRENT STATE

Space Operational Energy is a Focus Area. There is now official interest in Space Operational Energy. In 2010, the Department of Defense (DoD) established its Operational Energy Office to explore energy research and development for non-static applications.. The 2023 DoD Operational Energy Strategy states, "Successful military capabilities are underwritten by assured access to sufficient and secure supplies of energy"[153] and the Operational Energy Capability Improvement Fund (OECIF) has buoyed innovation in space energy. Space Force doctrine publication 4.0 Logistics states, "Actions should be taken to order, receive, store, and issue all materiel needed for servicing and maintaining energy, power, resources, and capabilities, both in garrison and deployed, to supply the mission, forces, and infrastructure."[154] While the need is understood, there is a lack of institutional support elements to make meaningful progress. Since 2024, the Space Force has had its own operational energy office, but a Space Operational Energy Strategy is needed to guide future investments. The Department of the Air Force also has its own Operational Energy Strategy, and at present, the Deputy Assistant Secretary of the Air Force for Operational Energy (SAF/IEN) has an open PME topic for "Operational Energy in Space."[155]

Increasing Global and Allied Interest In SBSP - Since 2022 the world has seen a significant increase in international interest in Space-Based Solar Power (SBSP). ESA released both a plan and tender,[156]

[153] DoD (2023). Department of Defense Operational Energy Strategy.
[154] USSF (2022). Space Doctrine Publication 4-0, Sustainment.
[155] Air University (2025). Operational Energy in Space.
[156] ESA (2023). SOLARIS activity plan 2023-2025.; ESA (2023). Pre-phase a System Study of a Commercial-scale Space-based Solar Power System (SBSP) for Terrestrial Needs. DevelopmentAid.org; ESA (2023). Pre-Phase A System Study Of A Commercial-Scale Space-Based Solar Power System (SBSP) For Terrestrial Needs. ESA.

Japan planned a demo for 2025,[157] and the UK Space Energy Initiative is being supported by Saudi Arabia.[158] South Korea showcased its own design and RF power beaming. South Korea unveiled its own 2GW design,[159] and Korea's KERI is the longest distance.[160] ESA/UK jointly sponsored a Space Conference on Energy from Space. [161] The UK's Space Solar has partnered with Icelandic energy firm Reykjavík Energy[162] to advance their space-based solar power projects. ESA sponsored a visionary study by AstroStrom[163] of how to build solar power satellites at scale from a Lunar industrial base–providing a powerful rationale for Lunar development.

China Space Solar Power - China announced plans to conduct power beaming demos on its space station, in LEO and in GEO.[164] The potential impact of these respective demos was examined in wargames.[165] China's interest led a former NASA's Deputy Associate Administrator and Deputy Chief Technologist, David Steitz, to warn, "While America dithers, China is charging ahead, announcing plans to build a prototype SBSP system by 2030 that would become the largest human-made object in space. This isn't just about energy — it's about demonstrating space capabilities that could revolutionize military operations and industrial development in orbit."[166]

Domestic Progress on Space Solar Power - In some ways 2024 was a banner year for domestic space solar power progress. Northrop Grumman delivered its SBSP payload for AFRL's SSPIDR program.[167] DARPA began its POWER program[168], which profiles potential in-space applications.[169] DARPA's LUNA-10 supported innovative power beaming work and research by Powerlight, Blue Origin, Fibertek, and Redwire.[170] CALTECH succeeded in the first space-to-ground transmission of power.[171] After much anticipation, NASA delivered its updated SBSP study which ran a sensitivity analysis and concluded that using a favorable combination of factors,[172] a design similar to SPS-Alpha Mark-III

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[157] Gislam, S. (2023). Japan to demonstrate space solar power by 2025. Industry Europe.
[158] UK Government (2023). Business Secretary in talks with Saudi Arabia to advance commercial collaboration in UK space based solar. Gov.UK.
[159] Wang, B. (2024) South Korea Plan for Space Based Solar for More Than All US Nuclear Power. NextBigFuture.
[160] Pulse (2024). KARI successfully tests world's longest-distance wireless power transfer.
[161] ESA (2024). International Conference on Energy from Space 2024, 17-19 April 2024, London UK.
[162] Stojkovski. B. (2024). 30 MW space solar plant designed to send electricity to Earth by 2030. Interesting Engineering.
[163] Astrostrom / Greater Earth (2023). Greater Earth Energy Synergies ; Astrostrom (2023). Greater Earth Lunar Power Station (GE⊕-LPS). ESA.
[164] Jones, A. (2022). China to use space station to test space-based solar power. SpaceNews; Jones, A. (2022). China aims for space-based solar power test in LEO in 2028, GEO in 2030. SpaceNews.
[165] AFPC (2024). Reacting To Major Space Events At Or Below Geostationary Orbit; AFPC (2024). Reacting To Major Space Events On The Moon And In Cislunar Space.
[166] Steitz, D. (2024). America must win the race for space solar power — or buy it from China. SpaceNews.
[167] David, L. (2023). Space Solar Power: Progress Reported in Air Force Demo Program. Leornarddavid.com.
[168] DARPA (2022). POWER Aims to Create Revolutionary Power Distribution Network.
[169] Savage, N. (2024). Optical power transmission lights up remote possibilities .SPIE.
[170] DARPA (2024). LunA-10 LSIC Performer Binder. JHU. (p4,5, 39, 41, 82)
[171] Caltech (2023). In a First, Caltech's Space Solar Power Demonstrator Wirelessly Transmits Power in Space.
[172] These very reasonable assumptions "yields SBSP solutions that are cost competitive with terrestrial alternatives, with lower GHG emissions: • lower launch cost: $50M per launch, or $500/kg; $425/kg with 15% block discount • electric propulsion orbital transfer from LEO to GEO • extended hardware lifetimes: 15 years • cheaper servicer and debris removal vehicles: $100M and $50M, respectively • efficient manufacturing at scale: learning curves of 85% and below" (p. ix)

could achieve an LCOE to 0.03 $/kWh "competitive with terrestrial alternatives" and GHG emissions intensity of 3.78 gCO2eq./kWh, "values less than nuclear and wind-without-storage technologies."[173,174] For the first time, DOE's ARPA-E awarded its first grant on space solar power to Virtus Solis.[175] However, will all the progress, it is still disjointed, lacking a vision to orient along, and a strategy to account for advancement..

Multiple US Space Solar & Power Beaming Start-ups Exist. In the US, multiple start-ups are pursuing space solar power. Solaren[176] and SST[177] have been joined by Virtus Solis[178]–all are pursuing RF power beaming. Virtus Solis is partnered with ThinkOrbital for an orbital demonstration for 2027.[179] AetherFlux[180] and Overview Energy[181] are pursuing non-RF power beaming for Earth applications. Powerlight, StarCatcher and Volta are looking for space-to-space optical power beaming. Virtus Solis[182] and Volta[183] both conducted public power beaming tests. Space power beaming companies are also raising capital, with Overview Energy raising $18+M.[184], StarCatcher and Powerlight with $12+M[185][186] , and Reflect Orbital began a seed round for $6.5M.[187] Volta raised an undisclosed amount in seed funding.[188]

ARACHNE is ready to fly! - The first major flight experiment of AFRL's Space Solar Power Incremental Demonstrations and Research Project (SSPIDR), and the culmination of years of work by the AFRL and Northrop-Grumman teams, ARACHNE is nearly ready to fly.[189] This will require sufficient budget to enable it to perform its flight tests. Whether or not ARACHNE transitions to exciting follow-on scaling such as SCORPION will depend both on Congressional resourcing and USSF vision to POM for it.

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[173] NASA (2024). New Study Updates NASA on Space-Based Solar Power. (p. viii)
[174] Virtus Solis provided its own response white paper concluding that "SBSP can be an economically competitive contributor to the world's energy mix. The technical and safety viability of SBSP with low associated carbon emissions were established in multiple prior studies...Applications for SBSP include grid-connected customers and point loads such as data centers, green hydrogen generation, desalination, and other high-power customers" and suggested SSP could achieve an LCOE as low as $25/MWh. Virtus Solis (2024). Persistent, global, scalable energy from space.
[175] ARPA-E (2025). U.S. Department of Energy Announces $147 Million for Advancing Technologies to Strengthen U.S. Energy Leadership, to Enhance Grid Reliability, and Accelerate Carbon Utilization.
[176] Solaren (2024). Solaren Space Solar.
[177] SST (2024). SST Space Solar Technologies: Baseload Space Solar Power.
[178] Virtus Solis Technologies (2023). Persistent, global, scalable energy from space.
[179] Werner, D. (2024). Orbital Composites and Virtus Solis announce space-based solar power demonstration. SpaceNews.
[180] Alamalhodaei, A. (2024) Billionaire Robinhood co-founder launches Aetherflux, a space-based solar power startup. Tech Crunch.
[181] Overview Energy (2024). Overview Energy.
[182] Virtus Solis Technologies (2023). Virtus Solis Beaming Day 2023 Drone Demonstration. Youtube.
[183] Volta Space Technologies (2024). Volta Space First Outdoor Wireless Power Demonstration. Youtube.
[184] Pitchbook (2024). Overview Energy.
[185] Werner, D. Star Catcher banks $12.25 million for orbital energy grid. SpaceNews.
[186] Trackn. (2024). PowerLight funding & investors.
[187] Reflect Orbital (2024). Announcing Our $6.5m Seed Round.
[188] Foust, J. (2024). Volta Space Technologies unveils plans for lunar power satellite network. SpaceNews.
[189] David, L. (2023). Space Solar Power: Progress Reported in Air Force Demo Program. Leornarddavid.com.

AFRL JETSON - Hoping to encourage the USSF to develop competency in space nuclear *electric* power, Congress added money to AFRL's budget resulting in the AFRL's Joint Emergent Technology Supplying On-orbit Nuclear Power (JETSON) program, which awarded Intuitive Machines, Lockheed Martin and Westinghouse Government Services to advance technologies for nuclear powered space vehicles.[190] Lockheed received $33.7 million for the high power track, Westinghouse received $17 million under the same track, Intuitive Machines was awarded $9.5 million for the low power track, with all products due by December 29, 2025.[191] In 2024, Intuitive Machines selected Cobalt-60 as its heat source coupling it with a Stirling engine, the first time a non-plutonium heat source has been selected for an RTG.[192] Lockheed has stated its suite of nuclear capabilities (JETSON and DRACO) could reach initial operating capability by 2030.[193] Of note, these are the same three companies awarded by NASA for Lunar Surface Power in 2022 for 40-kilowatt class fission power system[194] (considered by the community to be underpowered for most ISRU applications or to keep pace with PRC objectives).

DRACO - The NASA / DARPA's Demonstration Rocket for Agile Cislunar Operations (DRACO) was originally expected to fly in 2026[195] and selected Lockheed[196] and began design and fabrication.[197] It slipped to 2027 but then appears to have been put on an indefinite hold for nuclear reactor test requirements[198] despite an environmental assessment Finding of No Significant Impact (FONSI).[199]

Megawatt Energy Requirements? The National Cislunar S&T Strategy states, "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."[200] Several US companies have ambitions for large-scale Lunar ISRU processing which may demand megawatt levels of power. These include Starpath,[201] Ethos

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[190] Erwin, S. (2023). Air Force Research Lab awards design contracts for nuclear powered spacecraft. SpaceNews.
[191] Hitchens, S. (2023). AFRL picks 3 contractors for JETSON effort to develop fission powered spacecraft. BreakingDefense.
[192] Intuitive Machines (2024). Intuitive Machines Advances Radioisotope Power System for AFRL Space Vehicles Directorate; Reim, G. (2024). Intuitive Machines Picks Ultra Safe's Cobalt-60 Heat Source For Jetson. Aviation Week.
[193] Easley, M. (2024). Lockheed Martin pitching nuclear propulsion portfolio for defense space mobility, logistics. DefenseScoop.
[194] NASA (2022). NASA Announces Artemis Concept Awards for Nuclear Power on Moon.
[195] Wall, M. (2023). NASA, DARPA to launch nuclear rocket to orbit by early 2026. Space.com.
[196] Hitchens, T. (2023). DARPA, NASA tap Lockheed Martin to design, build DRACO nuclear rocket for deep space missions. Breaking Defense.
[197] DARPA (2023). DARPA Kicks Off Design, Fabrication for DRACO Experimental NTR Vehicle.
[198] Machi, V. (2025). Nuclear Reactor Test Requirements Put DRACO Launch Plans On Hold. Aviation Week.
[199] NASA (2024). Finding Of No Significant Impact (FONSI) Environmental Assessment For The Demonstration Rocket For Agile Cislunar Operations (DRACO) Mission.
[200] White House (2022). National Cislunar Science & Technology Strategy.
[201] Payload (2024). Mega Scale Prop Production, with Saurav Shroff (CEO of Starpath). Youtube; Starpath (2024). Mega Scale Propellant Production in Space.

Space,[202] and Cislune.[203] As mentioned above, the ESA sponsored AstroStrom[204] a project to build Solar Power Satellites at scale from a Lunar industrial base would also require megawatt scale power. Many large-scale ISRU projects would also require megawatt-level energy generation to move commodities and products off the Lunar surface via Lunar electromagnetic catapults.

KEY ISSUES AND CHALLENGES

Although making considerable headway on multiple fronts, advanced power & propulsion (including space nuclear, space-based solar power, and other advanced propulsion) still face significant regulatory and technological hurdles. Participants expressed concerns about government projects being cancelled or failing to transition due to lack of funding, to private companies struggling to find testing infrastructure. A lack of a specific demand signal from the government also dissuades investment into 'risky' technologies. Participants assessed that the poor reception and lack of consensus between the broader community and the NASA space-solar power report was evidence of a clear lack of communication and understanding between current commercial developments and government leadership.

US Government providing insufficient funding to support pervasive power and propulsion sub-industry - While other countries, especially China, are making strides in industrial base advancement, the US lags behind. The US consistently shows greater interest in technology that can be ready in 1-3 years, while neglecting technologies with longer maturation times.

Effects of COVID and embargos still causing supply chain issues – Lead times on large amounts of space hardware remain long, even simple fasteners such as bolts. Chinese (and other) embargoes of materials such as Germanium are impacting specific sub-industries more than ever. On top of material supply chain issues, workforce for deep tech and space/nuclear especially remain challenging as more attractive options exist in other industries, or other areas within the space industry.

US Government remains opaque regarding contracting & feedback - Few government agencies seem willing to work with companies on how to improve funding processes. On top of this, NASA's Space Solar Power report seemed to have been published without industry consensus on current state and feasibility. Industry has little or no visibility into the USSF's demand signal, especially with specific requirements for power and deltaV.

Lack of Demand Signal for Advanced Power & Propulsion - The USSF's "Book of Needs" is not widely known about, and difficult for most start-ups to get access to. Recent technology goals such as reduction in optical signature, IR signature, and radar cross section can be reached with better power and propulsion.

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[202] Space Settlement Progress (2024). Ethos Space has ambitious plans for the Moon and beyond; Kuhr, J. (2024). Lunar Infrastructure Startup Ethos Emerges from Stealth. Payload Space; Ethos Space (2024). Critical Lunar Infrastructure: Space development with lunar resources.

[203] Berger, E. (2024). A Startup Will Try to Mine Helium-3 on the Moon. Wired; Cislune (2024). Cislune: Gateway to our Lunar Future.

[204] Astrostrom / Greater Earth (2023). Greater Earth Energy Synergies ; Astrostrom (2023). Greater Earth Lunar Power Station (GE⊕-LPS).

Existing Space Industrial Base Fragmented with Opposing Philosophies - Legacy space companies continue to build and market MEO/GEO while NewSpace is increasingly leaning toward LEO for most, if not all services. Little overlap exists in funding leadership, which hinders overall industry growth.

Lab work such as SSPIDR or DRACO may not transition - Although well funded, many programs go defunct with changing administrations and their priorities, as well as a rapidly changing commercial landscape.

A failure of requirements and vision. The primary risk to U.S. competitiveness in advanced space power and propulsion is the lack of stated ambition and requirements from NASA, USSF, and USSPACECOM to provide 'tech pull' and market demand. There is sufficient interest in industry and academia and the national lab structure–and even Congress has proven repeatedly willing to add budget for advanced power and propulsion–but no national level operational users (NASA, USSF, USSPACECOM) have authored sufficiently ambitious requirements documents and time-bound goals to keep apace with our pacing competitor. This is a failure of imagination, vision and leadership.

INFLECTION POINTS

The next five years hold great potential for advancements in power and propulsion technologies. Key missions such as Artemis, broader Moon to Mars, as well as greater on-orbit maneuvering needs will spur investment into advanced power and propulsion and associated companies. However, industry success still depends on successful government-to-industry communication, demo-mission successes, and engagement with international partners.

Key Milestones with New Launch Systems - Starship and/or New Glenn reaching orbit, Vulcan reaching a higher operational cadence, as well as a number of small launch companies (kinetic or traditional) reaching orbit and/or showing significant development will enable more ambitious power and in-space propulsion..

Long-Term Vision - A crisp 'North Star Vision' for the overall U.S. space effort (e.g., eventual settlement of the solar system) would build upon progress made during the past year at the national level.

Successful In-Space Demos of Nuclear Systems - Any commercial in-space demo of a fission or fusion reactor would serve to validate safety, regulatory, environmental, and technological concerns of such a novel activity.

ACTIONS AND RECOMMENDATIONS

SHORT-TERM PAYOFF

Space Futures Command To Fully Implement CSO Intent - The USSF should strive to be the home to, and advocate for, novel game-changing technologies including advanced power & propulsion. The USSF should also push for "non-requirements" leaving industry to develop solutions not restricted by specific requirements.

Establish Immediate Material Sources for Embargoed Materials - I.e. Germanium, a key component in space solar cells, nuclear fuels, and other materials with fragile supply chains. The US must identify the most critical to its future ambitions and secure alternate sources of these materials.

Create Vetted Presentation of Tech Needs for Power & Propulsion for Industry - The USSF should publish a requirements document with specifics regarding deltaV, total impulse, power, or other requirements that are currently vague or not defined at all.

Fly ARACHNE, DRACO and JETSON and POM for Operational Capabilities - Congress has generously funded these programs, and the DoD should take them to flight demo and provide a path for transition to funded operational capabilities.

MID-TERM PAYOFF

Publish a Process Guide to Navigate Technology Development and SIB - Government support such as SSC, AFRL, DIU, and others have opaque contracting and acquisition processes that require (often external) specialized talent to assist prospective companies. The industry is in need of an "idiot's guide" to working with these agencies.

DoD to Publish Clear Goals for Power and Propulsion Needs - The DoD should publish a "book of needs" with more specificity regarding on-orbit power and propulsion needs. The space industry lacks clear, defined demand signals from any agency which hinders new technology development and adoption. USSF should brief its "book of needs" tech needs for power and propulsion at SSIB.

Change Submission Forms to Web-Based Forms - While other agencies and entire industries have modernized contracting processes, space acquisition lags behind. Agencies requiring space capabilities should make efforts to streamline their processes, potentially utilizing AI for compliance checks, data input, and feedback.

Establish a Space-Industry Equivalent to the CHIPS Act - The Space Industrial Base is struggling with meaningful funding of new technologies, a congressional bill to support technology development would remedy this with other meaningful benefits such as workforce development.

LONG-TERM PAYOFF

Establish a vision for space energy dominance - The DoD should take leadership to create a vision for space energy dominance as part of its operational energy initiative.

COMMERCIAL SPACE LAUNCH

Co-Innovation Session Lead: Dale Ketcham, Space Florida

"I want resiliency in the different types of launch vehicles that we have, so, if you have a fleet running anomaly, you have other launch vehicles that you can look to other families and launch vehicles. I want resiliency across companies so, God forbid, if a company has a strike or a serious financial issue that would prevent them from continuing operations, I have other options. Resiliency across supply chains, because if something happens in another sector, we want to make sure that they continue to launch ... I see our ability to deter based on the launch capacity we have, our readiness, our resiliency, because ultimately, we have a deterrent effect when the adversary knows that."

- BRIG. GEN. KRISTIN L. PANZENHAGEN, BREAKING DEFENSE, 28 Jan 2025.[205]

BACKGROUND

Although the US continues to lead with innovation, the global competition remains capable of creating destabilizing advantages if we don't stay hungry.

CURRENT STATE

The United States has historically maintained a leading position in space innovation. However, the escalating global competition necessitates a proactive and adaptive strategy to preserve this leadership and prevent the emergence of destabilizing advantages by other nations. The current state of the commercial space sector reflects a period of adjustment, with private capital markets experiencing a decline in enthusiasm, mirroring broader trends in spatial markets. This shift necessitates a critical reassessment of investment strategies and market dynamics to ensure continued growth and innovation. Several key issues and challenges are impacting the sector's trajectory. Firstly, significant infrastructure deficiencies are hindering expansion. The required increase in launch capabilities, particularly at sites like Cape Canaveral, demands substantial public infrastructure investment beyond traditional real estate development. This includes upgrades to roads, bridges, power systems, wastewater management, LNG pipelines, and maritime facilities. Specifically, the necessity to increase launch cadence from 1000 to 5000 tons to orbit per year requires a massive public infrastructure project. Additionally, unmet private infrastructure needs, particularly in payload processing, remain a bottleneck. Secondly, the market dominance of companies like SpaceX poses potential destabilization risks to the broader commercial space market. Lastly, the Federal Aviation Administration's (FAA) regulatory framework

[205] Daehnick, C. et al. (2013). Space launch: Are we heading for oversupply or a shortfall?. McKinsey & Co.

has proven ill-suited for the rapid innovation and "fail-fast, break-things" approach essential for maintaining US space leadership.

Furthermore, the emergence of heavy-lift launch vehicles, such as Starship, Vulcan, and New Glenn, and their associated price points, presents a key inflection point that may significantly disrupt the existing marketplace. In response to these challenges, several strategic actions and recommendations are proposed. In the short term, aggressive deregulation and new governance models within the federal government is crucial to playing to the strengths of the American marketplace. Federal policies should prioritize leveraging the commercial space market as a National Security Space (NatSecSpace) asset. Ongoing evaluations of other US and overseas launch sites are also necessary to diversify launch and landing capabilities, enhancing NatSecSpace resilience. In the medium term, federal policies should focus on ensuring the vibrancy of the commercial space marketplace, enabling a reduction in federal oversight and liability. Finally, in the long term, the establishment of revenue-generating mechanisms, such as fees and taxes, within the commercial space industry is recommended to supplement or replace ongoing federal investment in shared space infrastructure, mirroring existing terrestrial industry models. The enthusiasm of the private capital markets has waned for commercial space as a reflection of the broader spatial markets. But for the long term, the concept of space infrastructure as part of a broader investment portfolio of the capital markets continues to establish itself for the future.

KEY ISSUES & CHALLENGES

Infrastructure, not Real Estate - Growing the launch cadence at the Cape well beyond its existing capacity is not real estate, but public infrastructure. Upgrades to the roads & bridges, electric power & wastewater systems, wetland mitigation, LNG pipelines, and maritime wharf space, would enable an increase from 1000 to 5000 tons to orbit per year. Unmet private infrastructure requirements remain payload processing.

The SpaceX domination is destabilizing – The marketplace at present reflects the reality of the success of SpaceX as the disrupter. But history repeats itself with competitive pressures from commercial and government customers likely bending the marketplace to a more level playing field. The challenge is daunting and the question is when. With new vehicles coming online now it may be soon.

FAA remains a chokepoint – Federal regulatory structures are woefully inadequate to the essential ‘fail-fast and break things’ approach which is so successful in assuring US leadership in space.

KEY INFLECTION POINTS

Will Heavy Lift Cripple Marketplace? - Starship, Vulcan and eventual New Glenn capabilities and price points may prove overly disruptive to the broader marketplace

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Aggressively pursue deregulatory regimes and governance models within the broader deregulatory efforts across the Federal government.

Leverage the private capital markets to provide funding for infrastructure at existing launch sites.

Federal policies to support continued development of the commercial space market as a NatSecSpace priority as that marketplace continues to mature.

Continue to evaluate other US and overseas launch sites to provide diversity of launch and landing sites for NatSecSpace resiliency.

MID-TERM PAYOFF

Federal policies geared toward assuring the self-sustainment of the commercial space marketplace, enabling gradual Federal disengagement

LONG-TERM PAYOFF

Establish revenue generating fees, taxes, etc. from the industry to supplement or replace ongoing federal investment in common infrastructure in space similar to existing terrestrial industries.

Figure 14. Second Stage Prototype Hop (Credit: Stoke)

SPACE SENSING

Working Group Co-Lead: Jaime Stern, AFRL
Working Group Co-Lead: Katie Corcoran, DIU
Working Group Co-Lead: James Frith, AFRL

"The Space Force will add over 100 satellites just in 2025. That is to add resilient capabilities for our winning capabilities, missile warning and missile track, secure communications for the force, and, of course, reconnaissance and sensing that allows us to close long-range fires on a scale that no other country can really do...Gaining cyber and space superiority over your adversaries is an early objective in ground campaigns, and I think that will play out as we move forward later into the 21st century with additional conflict."

-- MAJ. GEN. GREGORY GAGNON, deputy chief of space operations for intelligence, *Air and Space Forces Magazine 22 Mar 2025*

BACKGROUND

Figure 15. Weather Satellite Map APK (Source: Weather Satellite Map[206])

[206] Weather Satellite Map (2024). Weather Satellite Map APK.

The need for space sensing continues to grow in both military and civilian applications. As space traffic and threats in space continue to grow, so does the need for both government-owned and commercial-owned sensing and processing capabilities to serve the Space Traffic Coordination and Space Situational Awareness missions. Similarly, earth-imaging capabilities have had profound impacts on everyday life through such as via apps on mobile devices that provide satellite map overlays, weather and tracking data, as well as for military and intelligence purposes. A thriving private sector is a prerequisite to the continued capabilities in both these realms. The industry base and commercial sector in both earth-imaging and non-earth-imaging space sensing have faced similar forward leaps and setbacks in the last year, and workshop participants were eager to discuss the good and the bad. Several concrete recommendations were put forward to mitigate the troubling trends and capitalize on the opportunities at hand.

The More Things Change, The More They Stay The Same – Participants and track leads observed that many of the challenges and concerns from previous years are echoed in discussions at this year's meeting. This suggests that while there have been bold movements and conspicuous intent from the government in releasing strategy documents such as the National Cislunar S&T Strategy, the DoD and USSF Commercial Integration Strategies, there has yet to be the tactical follow-up implementation that turns these strategies into revenue- generating activities.

Hello Out There – A common theme throughout workshop discussion is the need for changing the communication pipeline between government and commercial partners. While government strategy documents are published, commercial partners still lack guidance in requirements. Conversely, commercial partners are developing technology, but are unsure if their Research and Development paths fit into the government acquisition strategy priorities.

CURRENT STATE

The government is beginning to open up space in actionable ways to the industrial base and commercial providers. The establishment of marketplaces and accelerator programs continues to encourage commercial involvement and investment, while broader strategic moves are setting the tone for continued integration of non-traditional entities. However, these positive movements are offset by a troubling trend in which companies of all sizes are reducing their workforce. With fewer talent resources, commercial partners have to tread lightly in where they focus their energies.

Strategic Movements for Integrating Commercial Capabilities – The release of the DoD and USSF Commercial Space Strategies suggest intent to truly integrate commercial sensing capabilities for both earth imaging and non-earth imaging. While these are being implemented, flexible contracting strategies such as Other Transaction Authorities, exemplified in Victus Haze, have successfully brought non-traditional entrants into the space enterprise.

Data Sharing Venues – More concrete steps impacting the industry and commercial were also taken this year, largely around the increased sharing of data and availability of non-traditional data into government processes. These include the Commercial Space Marketplace for Innovation, the opening of the Space Domain Awareness Tools, Applications, & Processing (TAP) Lab, and the successful use of public datasets in making the world aware of adversary activities. Another success story exemplified was the COMSO Industry Day wherein distinctions were communicated for what government tech will be done in-house, shared with commercial partners, or directed to be commercial only. Additionally, the loosening restrictions on Tier 3 remote sensing licensing has been an additional boon to the space sensing enterprise.

KEY ISSUES & CHALLENGES

The Space Sensing working group identified continuing and new challenges in developing technology to address the Warfighters' needs and our country's priority to remain relevant. Workforce recruitment and retention as well as effective communication between government and industry partners, were specifically highlighted.

Workforce recruitment and industry layoffs – Talent acquisition and retention in the space industrial base proves to be a significant challenge. SSIB conference attendees stated "Space may not be a romantic field anymore." Industrial partners are seeing recent graduates looking towards other industries that have more attractive cultures and/or better compensation. Similarly, the industrial base is seeing far more layoffs within the space industry. Workforce recruitment and retention challenges lead to lack of innovation and commercial partners who communicate in echo chambers. One identified cause of industrial layoffs is the uncertainty of "soft funds" from government partners year-to-year.

Lack of feedback from government partners – Industrial partners express the difficulties in developing relevant space sensing technologies due to the lack of communication and feedback with government partners. One such example is the lack of beneficial feedback in Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) proposal submissions. Specifically in the case of a proposal that has been rated "selected" and not "funded," small businesses do not receive any comments. The lack of feedback especially impacts small businesses, as they have limited monetary and labor resources. Such businesses prioritize these resources based on the government communicated tech needs, and without feedback, commercial partners misappropriate their resources while government partners do not receive solutions which satisfy the Warfighters' needs.

Lack of government communicated needs for Cislunar operations - Cislunar operations and technology development is a popular topic at Space Situational Awareness conferences and meetings. However, industrial partners cite the lack of communication from the government on technology needs, current ongoing research and development, data production, and Cislunar architecture requirements. The Cislunar regime is a significantly more difficult space to operate in, and technology development needs defined requirements to overcome the difficulties. Balancing budgets, responding to RFIs, and maintaining a workforce becomes difficult if there is a lack of demand signal. Industrial partners cite the current National Cislunar Strategy[207] as a starting point, but the lack of clear communication between government and industrial partners prevents any real industry investment. A further-developed, DoD-specific with Cislunar technology and operation requirements would benefit industrial partners.

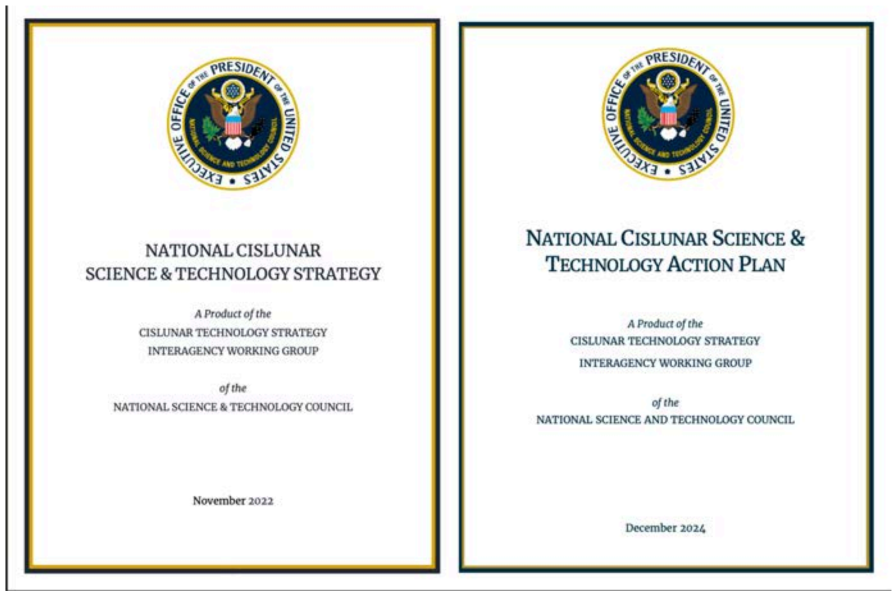


Figure 16. National Cislunar S&T Strategy & Implementation Plan (Source: White House[208])

KEY INFLECTION POINTS

- Competition between government and the commercial sector is noted to be slowing as the government responds to industry recommendations with recent policy changes. Past interactions and developments between commercial and government have been marked by misaligned and repeated efforts, ultimately hampering the development of the sensing community. With the NOAA reduction in restrictions on tier 3 sensing licenses, there is a noted shift in government support to the commercial sensing sector in response to recommendations.
- The proliferation of Low Earth Orbit (LEO) may encourage commercial activities in slightly different regimes. As LEO becomes increasingly populated with mega-constellations, the traffic and coordination within LEO is becoming more difficult to navigate. This may lead future commercial and government investments into higher LEO orbits, posing new sets of engineering and operations challenges.

[207] White House (2022). National Cislunar Science & Technology Strategy; White House (2024). National Cislunar Science & Technology Action Plan.
[208] White House (2022). National Cislunar Science & Technology Strategy; White House (2024). National Cislunar Science & Technology Action Plan.

- Due to rising widespread global tension, the need for geospatial products is expected to rise. With regional conflicts and tensions building across the globe, the need for geospatially driven situational awareness also grows. The commercial sourcing of Earth-imaging has recently provided both the Government and the public with an unprecedented amount of up- to-date information that drives public opinion and Government decision making.
- New technologies in inter-satellite links may provide a future with lower latency in communications and control. The latency present in any satellite constellation due to bandwidth of RF communications has been a consistent design limitation since space communication's inception. With the rapid advent of optical communications, new satellite constellations will likely enjoy greater bandwidth with lower latency arranged as networks as opposed to static chains.

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

SWAC to develop an unclassified force architecture for Earth and non-Earth sensing. The commercial sensing community needs better communicated demand signals from the USG, and specifically DoD, to help the industry develop future capabilities essential to support USG mission areas.

All agencies to improve the CRADA process and increase the USG workforce to offer more program support, in general. Understaffing and turnover in program offices handicap commercial programs, leading to delays in onboarding and poor program handoffs.

DoD to communicate a Cislunar strategy and define requirements for SSA-specific missions.[209] The National Cislunar S&T Strategy outlines a government-wide approach to US and allied leadership in Cislunar space. As part of the implementation of that strategy, the DoD needs to communicate to industry its plans to develop Cislunar SSA capabilities to enable meaningful private sector investment in technology and personnel.

CISA to designate space as a critical infrastructure sector. Space assets, systems, and networks are vital to US national security and require formal strategic planning to ensure ongoing resilience.

DoD and DoC to adopt a north star vision to build out space domain awareness (SDA) and space traffic coordination (STC) capabilities. These intertwined capabilities are critical to a sustainable space economy, but an overarching strategy that communicates current and future needs from the commercial sector and industry base is still lacking for both missions.

DICE to create a role or agency responsible for tracking and monitoring efforts of DoD, DoC, DoS, NASA, commercial space, etc. including operational and technical standards.

[209] Galbreath, C. (2024). Securing Cislunar Space and the First Island Off the Coast of Earth.

Community awareness of efforts and core standards that may be agency or operator agnostic will improve efficiency and minimize duplication of effort.

DoS and DoC to update, clarify, and eliminate no-longer relevant portions of ITAR and EAR. Rules around space sensing remain unclear and require modernization to account for the diversity of capabilities and operators represented in the commercial sector.

MID-TERM PAYOFF

Reassess classification levels of data, e.g., telemetry, IQ/sensor data. Improve communication between government and industry about classification levels, e.g., accelerate the implementation of the presidential reclassification directive.

All agencies to improve interagency communication regarding data, technical R&D efforts, and available funding; and improve communication between government and industry, in general. Agencies often don't have current, or any, data pertaining to other agency budgets, including unobligated and available funding.

Increase funding for the COMSO office to support Earth and non-Earth sensing capabilities, while accounting for reasonable costs associated with industry development efforts. COMSO has enabled communication lines which guide industry partners in their efforts to address government needs.

Continue to expand data collection, fusion, and analysis architecture towards a resilient, persistent network of cooperative capabilities.

LONG-TERM PAYOFF

SAF/IA to expand international collaborations - establish MOUs & better agreements between allied/partnered nations to reduce barriers created by ITAR/EAR specific to imagery/space sensing.

Optimize acquisition strategies to include COTS components/systems to enable faster and cheaper capabilities.

INTERNATIONAL LANDSCAPE

Co-Innovation Session Lead: Namrata Goswami
Co-Innovation Session Co-Lead: Scott Maethner, NewSpace Nexus

> *"Relationships matter, and space is a team sport. At U.S. Space Command, we are committed to building a coalition of teammates to achieve a collective advantage, and we're committed to being great teammates ourselves."*
>
> -STEPHEN N. WHITING, Commander, U.S. Space Command[210]

BACKGROUND

Space activities are rapidly expanding, reflecting the growing ambitions of nations and private organizations to explore and utilize space. What was once the domain of a few pioneering countries has evolved into a truly international endeavor. As emerging space powers recognize the strategic, economic, and scientific value of space, they are increasingly engaging in collaborative efforts to address challenges and seize opportunities beyond Earth's atmosphere. Established space powers also recognize the economic, scientific, strategic and security benefits of building and maintaining coalitions.

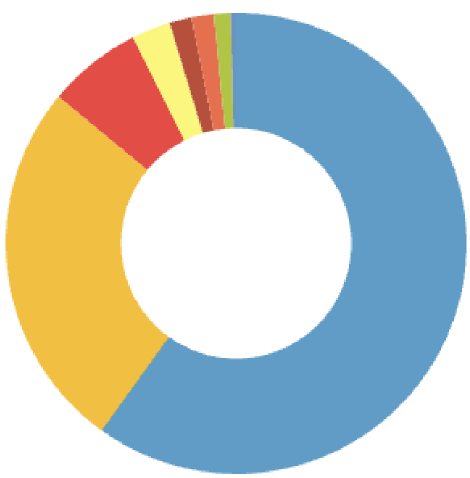
As space emerges as a critical domain for exploration, security, and economic growth, nations worldwide are ramping up their investments and collaborations, fueling a surge in international space activities that span satellite launches, Lunar missions, and ambitious space station projects, reflecting a shared commitment to expanding humanity's reach into space, exploiting space-derived services and utilizing the domain for economic benefits. Alongside Apollo-like missions aimed at technological demonstration, there is a growing focus on advancing ambitious goals such as establishing a permanent human presence in space, mining celestial resources, and developing space-based solar power generation and transmission. Many nations are adopting long-term strategic plans that prioritize space activities as central to their economic and security agendas. The private sector is playing a transformative role, driving down costs through innovations like reusable rockets and high-volume satellite deployments. Space is also becoming more integral to both civil and military operations, with increased discourse around the utilization of space resources and the development of ecosystems centered on affordable and sustainable launch infrastructure. These shifts highlight the dynamic, competitive and collaborative nature of the global space environment.

Today, eleven countries and one intergovernmental organization, the European Space Agency, maintain the capability to launch objects into orbit using their own launch vehicles. This group includes major space powers like the United States, Russia, and China, as well as emerging players like India, South

[210] US Space Command (2024). Whiting underscores growing partnerships, capabilities required for competition, conflict at Space Symposium 39.

Korea, and New Zealand. Beyond launching capabilities, over 100 countries have placed satellites into orbit, demonstrating the global reach of satellite technology. These satellites, launched either independently or through international collaborations, support diverse functions, from communications to Earth observation and scientific research. In terms of human spaceflight, citizens from 48 countries have traveled to space, primarily through international partnerships. While only three nations—the United States, Russia, and China—have independently launched humans into orbit, collaboration through platforms like the International Space Station (ISS) has enabled astronauts from 23 countries to live and work in space.

With over 7,500 active satellites currently orbiting Earth, the demand for space services continues to rise. The increasing number of orbital launches exemplifies the acceleration of space activities. As of December 30, 2024, the global space industry has achieved a record number of orbital launches, surpassing previous years. In 2023, there were 223 orbital launches, setting a new all-time high at that time. In 2024 there were 257, including the United States led with 154 launches, followed by China with 67, and Russia with 17. This increase reflects the growing capabilities and ambitions of space-faring nations, with private companies like SpaceX and Rocket Lab significantly contributing to the surge in launch activities.



United States	154
China	67
Russia	17
Japan	7
India	4
Iran	4
Europe	3
North Korea	1
Total	257

Figure 17. 2024 Orbital Launches by Country (Source: Gunter's Space Page)[211]

[211] Space Stats (2024). Orbital launches in 2024 | Space Stats

China's Grand Strategy in Space - China's grand strategy in space revolves around securing access to and utilizing space capabilities as a core element of its national development agenda. Viewing space as a critical domain for extending its influence and presence, China has integrated its civil and military efforts to maximize strategic and economic gains. Its ambitions include exploiting the economic potential of the Earth-Moon zone, with projections of generating $10 trillion annually by 2050. Additionally, China seeks to assert its power in shaping the rules of space commerce and influencing international legal frameworks to define access and usage, positioning itself as a dominant player in the global space economy.

China's Key Space Drivers - China views its space program as an avenue for economic growth, job creation, and the development of high-tech industries. It seeks to capitalize on the commercial aspects of space exploration and foster a competitive space sector. China has expressed interest in the exploration and utilization of extraterrestrial resources, particularly on the Moon. Helium-3, a potential fuel for fusion reactors, and other valuable resources could be found on the Lunar surface. China's space program aims to lay the groundwork for future resource extraction and establish space infrastructure for long-term exploration and exploitation. China recognizes the important contribution of space exploration for scientific discovery and technological innovation. China's space program has significant military implications. Satellites play a crucial role in modern warfare, providing capabilities such as communication, surveillance, reconnaissance, and navigation. China aims to develop a robust space-based infrastructure to enhance its national security, protect its interests, and potentially challenge the military dominance of other nations. China sees its space program as a symbol of national prestige and a way to enhance its global standing. Achievements allow China to showcase its technological capabilities and project itself as a major player on the world stage. And ignite the imaginations of the Chinese population and foster a sense of unity and purpose.

China's Key Space Objectives - China aims to expand the construction of the Tiangong space station and conduct extended-duration missions, fostering scientific research, technological development, and international cooperation. China has missions for establishing Lunar bases and enabling human settlement on the Moon, conducting long-term scientific research, resource utilization, and expanding human presence in Cislunar space. China plans to launch a Mars sample return mission, which would involve collecting samples from the Martian surface and bringing them back to Earth for detailed analysis. China aims to conduct close observation of a threatening asteroid and "implement an asteroid impact" to change its orbit. Finally, China is planning for asteroid belt and Jupiter missions which would include asteroid sample returns and exploration of the Jupiter system.

Figure 18. China views space exploitation & utilization as key to its national power & prestige (Source: ChatGPT)

Russia Space Updates - Russia's space program, led by the state corporation Roscosmos, remains focused on maintaining its role as a leading spacefaring nation, despite facing challenges such as budget constraints and international sanctions. Current goals include the continued operation and eventual replacement of the Soyuz spacecraft and the development of the Oryol spacecraft for crewed missions. Russia is also advancing plans for a new orbital station, known as the Russian Orbital Station (ROS), to replace its participation in the International Space Station (ISS) program. Additionally, the program prioritizes Lunar exploration, including the Luna-25 mission and broader ambitions for a Lunar base. Russia is also pursuing advancements in satellite technology for communication, Earth observation, and navigation, with a focus on military and commercial applications. Amid growing global competition, Roscosmos aims to modernize its launch infrastructure, increase partnerships with emerging space nations, and sustain its influence in the evolving international space landscape.

India Space Updates - India's space program, led by the Indian Space Research Organisation (ISRO), is advancing ambitious goals to establish the country as a major player in the global space industry. These objectives include expanding its satellite capabilities for communication, navigation, and Earth observation to support domestic development and strategic needs. ISRO is also focused on deep space exploration, with missions like Chandrayaan for Lunar exploration and Gaganyaan, India's first crewed mission to space. Beyond exploration, India aims to foster a thriving commercial space ecosystem by encouraging private sector participation under its NewSpace India Limited (NSIL) initiative. Additionally, India is investing in technologies for reusable launch systems and space-based solar power, while also strengthening its international partnerships to collaborate on scientific research and space applications. These efforts align with India's vision to enhance its space capabilities for economic growth, technological innovation, and national security.

India's International Partnerships - India made a clear signal of its strategic intent when it joined the U.S.-initiated Artemis Accords. The U.S. and India agreed to establish a working group for commercial space collaboration, develop a strategic framework for human spaceflight and advance planetary defense. India has advanced the idea of a BRICS satellite constellation and a BRICS space exploration consortium ensuring the long-term sustainability of outer space activities and prevention of an arms race in outer space (PAROS) and of its weaponization, including through negotiations to adopt a relevant legally binding multilateral instrument. India has advocated for a universally acceptable and multilaterally negotiated legally binding instrument on PAROS introducing a number of subjective elements, including responsible and irresponsible behavior, characterization and interpretation of behavior as well as perception of threats. India views commercial space as a major part of its diplomatic space outreach. The country had over 150 startups in the Space sector as of 2023.

India's Space Vision 2047 - India's Space Vision 2047 outlines an ambitious plan to position the nation as a global space leader by its centennial year of independence. Key milestones include establishing the Bharatiya Antariksha Station (BAS) by 2035, achieving a human Lunar mission by 2040, and advancing technologies like heavy-lift launch vehicles, human-rated spacecraft, docking systems, and high-capacity landers. The vision emphasizes expanding satellite-based services to deliver secure, high-speed broadband across India, supporting governance, education, and enterprise sectors. Additionally, India aims to grow its share in the global space economy by focusing on cost-effective small satellite production and space data services, leveraging its expertise in software and data analytics. This comprehensive strategy highlights India's commitment to innovation, sustainability, and collaboration in the global space arena.

Figure 19. Representative Image of Gaganyaan Astronaut (Source: LiveMint[212])

[212] PTI (202). Gaganyaan: Space suits for India's first manned space mission astronauts under production in Russia. Financial Express.

Europe Space Updates - Europe's space program, coordinated by the European Space Agency (ESA) and supported by national space agencies such as CNES (France) and DLR (Germany), focuses on fostering collaboration among member states to drive innovation, sustainability, and competitiveness in space. Current goals include advancing the Copernicus Earth observation program and the Galileo satellite navigation system to enhance Europe's autonomy in critical space infrastructure. ESA is also committed to Lunar exploration, including contributions to the Lunar Gateway and Artemis programs, as well as developing technologies for future Lunar and Martian missions. Europe is investing in next-generation launch systems like Ariane 6 and Vega-C to ensure independent access to space while reducing costs. Additionally, ESA emphasizes green technologies, such as space debris mitigation and reusable systems, and promotes the growth of its space economy by supporting private-sector initiatives and fostering entrepreneurship. Europe's space ambitions underscore its commitment to strengthening its position as a key player in the global space ecosystem.

CURRENT STATE

The landscape of international space activities has entered a dynamic era of collaboration and competition, with nations pushing the boundaries of exploration and innovation. China and India have emerged as major players, with China advancing its ambitious space station, Lunar exploration, and satellite constellation projects, while India achieved landmark successes, such as the Chandrayaan-3 Lunar mission. At the same time, global partnerships are strengthening under initiatives like NASA's Artemis Accords, which unite nations in Lunar exploration and sustainable space development, and the International Lunar Research Station Cooperation Organization (ILRSCO), led by China and Russia, fostering multilateral collaboration on Lunar research. These developments highlight a growing emphasis on shared goals and rivalries in the pursuit of space as the next frontier.

China: Reorganization of its PLA Space Forces – In April 2024, China reorganized its People's Liberation Army (PLA) space forces by dissolving the Strategic Support Force (SSF) and establishing four specialized entities: the Aerospace Force (ASF), Cyberspace Force (CSF), Information Support Force (ISF) and the Joint Logistics Support Force (JLSF). The ASF now oversees space missions, including satellite management and space-based command, control, communications, and intelligence systems. The CSF focuses on cyber operations, network security, and cyber warfare, while the ISF manages electronic warfare and information-centric operations. This restructuring reflects China's strategic emphasis on enhancing operational efficiency and bolstering its capabilities in space and cyber domains to address the demands of modern warfare.

China: Long March 9 Rocket Concept – In 2024, China made significant advancements in the development of its Long March 9 rocket, a super-heavy launch vehicle designed to enhance the nation's space exploration capabilities. Notably, China unveiled an updated concept for the Long March 9, featuring a fully reusable design reminiscent of SpaceX's Starship. This new configuration aims to support China's Lunar exploration and deep-space missions, reflecting a strategic shift towards reusability to increase cost-effectiveness and operational efficiency.[213]

China: Satellite Constellations - In 2024, China achieved significant milestones in satellite constellation development and deployment, solidifying its position as a key player in the global space race. The nation launched the second batch of 18 satellites for the Thousand Sails (Qianfan) mega constellation, advancing its plan for a 14,000-satellite network aimed at global internet coverage.[214] Additionally, China initiated the Guowang broadband constellation with the launch of 10 satellites as part of a broader 13,000-satellite network to enhance global broadband services.[215] The Spacesail Constellation also completed deployment, providing connectivity to international markets, including Brazil.[216] These efforts underscore China's strategic focus on low Earth orbit dominance and its commitment to leveraging satellite networks for economic and technological influence on a global scale.

China: Key Space Objectives - Expansion of the space station and long-duration missions: China aims to expand the construction of the Tiangong space station and conduct extended-duration missions, fostering scientific research, technological development, and international cooperation. Lunar bases and human settlement goals: China has missions for establishing Lunar bases and enabling human settlement on the Moon, conducting long-term scientific research, resource utilization, and expanding human presence in Cis Lunar space. Mars sample return mission: China plans to launch a Mars sample return mission, which would involve collecting samples from the Martian surface and bringing them back to Earth for detailed analysis. Planetary Defense: China aims to conduct close observation of a threatening asteroid and "implement an asteroid impact" to change its orbit. Asteroid Belt and Jupiter Missions: These would include asteroid sample returns and exploration of the Jupiter system

India: New Space Policy – India's new space policy focuses on developing a thriving commercial space ecosystem by fostering private-sector participation and innovation. The Department of Space, under the Prime Minister's Office, serves as the central policymaking and implementation body, overseeing directives and the distribution of responsibilities. The Indian Space Research Organization (ISRO) will concentrate on research and development of advanced space technologies and applications, while New Space India Ltd (NSIL) is responsible for commercializing technologies developed through public expenditure and providing manufacturing and service support for space systems. Meanwhile, the Indian National Space Promotion and Authorization Center (IN-SPACe) will act as a single-window authorization center to facilitate activities by both public and private sectors, ensuring streamlined and efficient collaboration within India's growing space industry.

India: Air and Space Forces – The Indian Air Force (IAF) has submitted a proposal to rename the IAF as the "Indian Air and Space Forces"(IASF) in a shift in strategic thinking on Space security. The

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[213] Jones, A. (2024). China unveils fully reusable Starship-like rocket concept. SpaceNews.
[214] Jones, A. (2024). China launches second batch of 18 satellites for Thousand Sails megaconstellation. SpaceNews.
[215] Wall, M. (2024). China launches 1st set of spacecraft for planned 13,000-satellite broadband constellation. Space.com.
[216] Xinhua (2025). Chinese commercial satellite constellation completes network connection test. China Daily.

IAF aims to develop space-based precision, navigation, timing (PNT) and intelligence, surveillance, reconnaissance (ISR). The IAF will include civilian space stakeholders to develop capacities for space traffic management, space situational awareness, and space weather prediction. The IAF Air Force Doctrine identifies space as vital for both tactics and strategy including ISR, PNT, military communication, nuclear command and control, missile tracking, electronic warfare, battle management and training and strategic guidance informed by deterrence, compellence, offense and defense.

India: Defense Space Agencies – In 2019, India set up the Defense Space Agency (India's version of a space force). The Defense Space Agency will develop a strategy to integrate space assets from the army, navy, and air force. The Defense Space Research Organization will develop space-warfare systems and technologies for the Defense Space Agency. India's ability to utilize space for both economic and national security will boost the entire gamut of space technologies.

India: Private Sector Engagement – Launched in October 2022, **Mission DefSpace** engages private sector space companies to apply for 75 defense space challenges for indigenous development, covering the entire range of products and services in the space industry including Launch System, Satellite System, Communication & Payload System, Ground System, and Software System. India's Chief of Defense Staff (CDS) has called for developing dual-use platforms with special focus towards incorporating cutting-edge technology, expanding NAVIC constellation, providing agile space-based intelligence, surveillance and reconnaissance (ISR) and ensuring secure satellite-assisted communications.

India: Space Capabilities and Missions - ISRO is developing key technologies for a fully reusable launch vehicle aimed at reducing the cost of space access. The Space Docking Experiment (SPADEX) is a twin spacecraft mission designed to advance technologies related to orbital rendezvous, docking, formation flying, and other proximity operations, with applications in human spaceflight, in-space satellite servicing, and beyond. The Chandrayaan-4 mission will be India's Lunar sample return project, incorporating multiple launch vehicles, including the Transfer, Lander, Ascender, and Reentry modules. The NASA-ISRO SAR (NISAR) mission will provide detailed measurements of Earth's ecosystems, dynamic surfaces, and ice masses, offering insights into biomass, natural hazards, sea level rise, and groundwater, among other applications. ISRO is also progressing with plans to deploy the first module of its space station, aiming for completion around 2040. The Gaganyaan human spaceflight program will demonstrate the ability to launch a crew of three on a 400 km orbit for a three-day mission, with a safe return to Earth via a sea landing. India's Mars Orbiter Mission (MOM) serves as a technology demonstrator for interplanetary missions and the scientific exploration of Mars. The Lunar Polar Exploration Mission (LUPEX), a collaboration between ISRO and JAXA, will send a rover and lander to explore the Moon's south pole. ISRO's Shukrayaan-1 Venus orbiter will study the surface and atmosphere of Venus. Mars Orbiter Mission 2 will feature a rover, sky crane, helicopter, and communications satellite to study the Martian atmosphere, including experiments like Mars Orbit

Dust Experiment (MODEX) and others. The Martian Boundary Layer Explorer (Marble) will conduct aerial exploration of up to 100 meters above the surface.

France and Japan Strengthen Partnerships with the U.S. - In 2024, France and Japan took significant steps to strengthen their space partnerships with the United States. France reaffirmed its commitment to space cooperation through the Combined Space Operations (CSpO) Initiative, which focuses on coordinating national security space activities[217], and through the U.S.-France Comprehensive Dialogue on Space, where the two countries discussed opportunities for collaboration in space exploration, satellite technology, and space situational awareness.[218] Japan, similarly, advanced its space ties with the U.S. by engaging in the U.S.-Japan Comprehensive Dialogue on Space, which focused on commercial space collaboration, spaceflight safety, and space sustainability.[219] Both nations also participated in CSpO, underlining their shared commitment to responsible space operations. These efforts highlight the strengthening of bilateral and multilateral partnerships between the U.S., France, and Japan, with a focus on space security, exploration, and commercial opportunities.

Artemis Accords – 52 counties have signed the Artemis Accords, a set of non-binding principles based on the Outer Space Treaty of 1967 and the 1979 Moon Agreement that guide civil space exploration and use. Led by the U.S. Department of State and NASA, the goals of the accords include avoiding conflict in outer space, increasing the predictability, transparency, safety, and sustainability of human space exploration, and ensuring space exploration benefits all countries and all humankind. Signatories include 26 counties from Europe, 9 from Asia, 7 from South America, 3 from Africa and 2 from Oceania.

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[217] DoD (2024). Joint Statement From the Combined Space Operations Initiative.
[218] DoS (2024). Joint Statement of the Second Meeting of the U.S.-France Comprehensive Dialogue on Space.
[219] Office of Space Commerce (2024). U.S., Japan Hold Ninth Comprehensive Dialogue on Space.

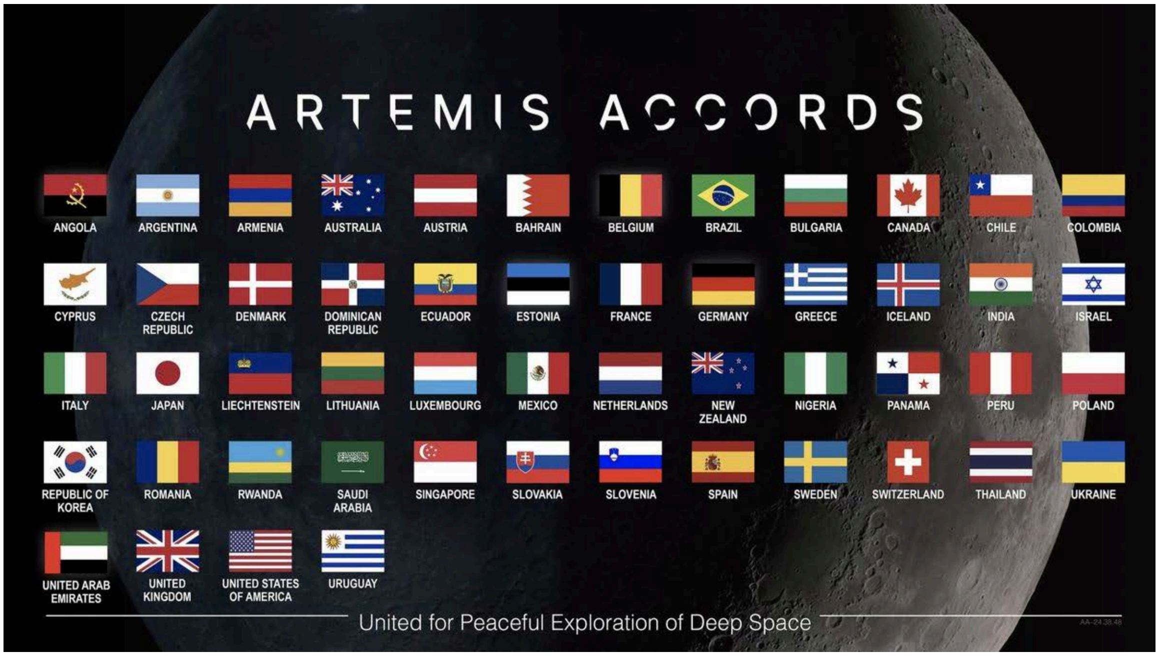

Figure 20. Counties that have signed the Artemis Accords (Source: Space.com)[220]

ILRSCO – The International Lunar Research Station Cooperation Organization (ILRSCO) is an alternative and competing international cooperative initiative led by China and Russia that is focused on the development and construction of the International Lunar Research Station (ILRS), a proposed scientific base on the Moon. This project, currently involving partnerships between 7 counties and space agencies, aims to facilitate scientific research and exploration of the Moon, as well as to support sustainable Lunar exploration. The ILRS is envisioned as a long-term Lunar outpost for scientific research, resource utilization, and technology demonstration and was established to manage and coordinate efforts of participating countries and organizations. It is expected to serve as a hub for international collaboration on space exploration, offering opportunities for research in fields such as astronomy, geology, life sciences, and space technology. Key goals of ILRSCO include: Developing infrastructure for a sustainable human presence on the Moon; Facilitating scientific cooperation and sharing of research among space agencies; Promoting technology development for future missions to the Moon, Mars, and beyond; and Ensuring that Lunar exploration benefits all of humanity through peaceful, transparent, and cooperative efforts.

[220] Lea, R. (2025). Artemis Accords: What are they & which countries are involved?. Space.com.

	Artemis	ILRSCO
Leadership	led by the U.S. with a broader international coalition	led by China and Russia
Goals	focuses on returning humans to the Moon and using it as a stepping stone for Mars exploration	focuses on establishing a permanent Lunar research station
International Collaboration	Artemis promotes a more inclusive, open approach to global cooperation	more centered on cooperation between China, Russia, and select nations
Geopolitical Focus	aligned with U.S. leadership and NATO allies	counter to Western-led initiatives, particularly in space exploration

TABLE 1. Key differences between the Artemis Accords and ILRSCO

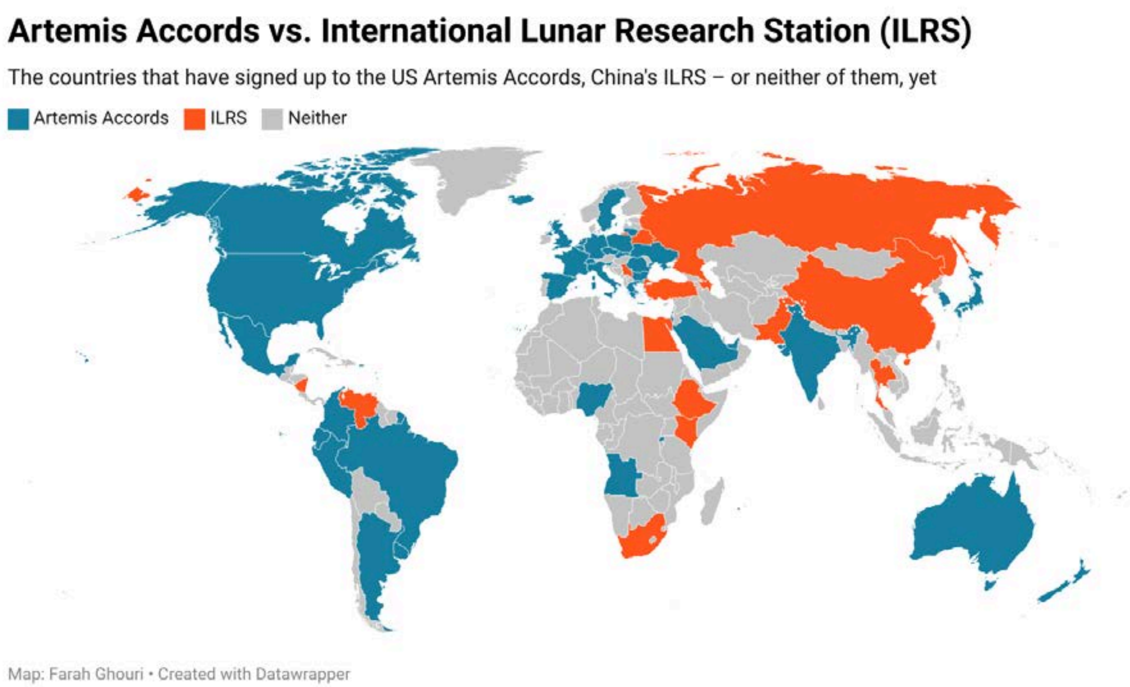

Figure 21. Counties that have signed the Artemis Accords and ILRSCO (Source: XXX)[221]

KEY ISSUES & CHALLENGES

International cooperation in space exploration and utilization faces several significant issues and challenges, including geopolitical tensions, diverging national priorities, and complex legal frameworks. Disparities in funding, technological capabilities, and space infrastructure can hinder collaboration, while concerns about space debris, security risks, and ethical issues related to resource extraction add

[221] Ghouri, F. (2024). Picking sides in space: China's ILRS Moon base or the US Artemis Accords?. Seradata.

further complexity. Additionally, cultural and institutional differences between countries can affect decision-making and project execution. Overcoming these challenges requires building trust, aligning priorities, and creating standardized agreements to ensure successful and sustainable international partnerships in space

Geopolitical Tensions: Space activities are often influenced by geopolitical dynamics, with competition between space-faring nations and regions. Tensions, such as those between the U.S. and China or Russia, can impact collaborative projects and lead to mistrust or reluctance to share technologies and data.

Diverging National Priorities: Different countries have varying space objectives, ranging from scientific research and exploration to commercial opportunities and national security interests. Aligning these priorities for successful partnerships can be challenging.

Legal and Regulatory Frameworks: The space environment is governed by international treaties, such as the Outer Space Treaty (1967), but enforcement of these laws can be unclear or inconsistent. Disagreements about resource utilization, space debris management, or military uses of space add complexity to partnerships. ITAR (International Traffic in Arms Regulation) export control laws makes it challenging for countries to partner with the U.S. for space-related projects.

Funding and Resource Allocation: Space missions require significant financial investments, and countries involved in international partnerships often face budgetary constraints. Disparities in funding capabilities can affect the implementation of shared projects, leading to unequal contributions or delays.

Technological and Standards Gaps: Countries and organizations may have different technological capabilities, making interoperability of spacecraft, satellites, and other systems a key challenge. Standardizing technologies and data formats is critical for seamless collaboration.

Space Debris: The increasing accumulation of space debris poses risks to satellites and space exploration missions, and countries often have different approaches to addressing debris management. Cooperation is needed to develop sustainable policies for debris mitigation.

Access to Space: Not all countries have equal access to space infrastructure, such as launch vehicles and ground stations. Ensuring equitable access and sharing of resources is vital for international collaboration.

Security Concerns: As space becomes more integrated into national security infrastructure, concerns about the protection of sensitive technologies, cyber-attacks, and the militarization of space can strain partnerships.

Ethical and Environmental Issues: The extraction of resources from celestial bodies, like mining asteroids, raises ethical questions about ownership, environmental impact, and the long-term sustainability of space activities. Collaborations must address these concerns to avoid conflicts.

Cultural and Institutional Differences: Collaboration across nations involves navigating diverse cultural and organizational structures. Differing attitudes toward risk, decision-making, and project management can complicate effective cooperation.

KEY INFLECTION POINTS

There has:

- **Competition or collaboration between Artemis and ILRSCO**: A clear winner may emerge between U.S.-led Artemis and China-Russia-led ILRSCO in attracting global partners, shaping space governance norms, and controlling Lunar and Mars exploration efforts. A competitive rivalry could lead to polarization in space alliances, akin to a "space race," while collaboration could establish a unified global framework for space exploration
- **Successful Lunar resource utilization**: A nation or private company successfully mines and uses Lunar resources (e.g., water ice for fuel or oxygen) at scale. This could drive national policies to prioritize Lunar resource claims and infrastructure, prompting revisions in international space treaties like the Outer Space Treaty (OST). It may also accelerate competition for Lunar territory and resources.
- **Establishment of Lunar and Martian habitats**: The establishment of the first permanent research stations or colonies on the Moon or Mars. This milestone would shift the focus of space policies from exploration to governance of extraterrestrial settlements. Questions about sovereignty, resource sharing, and governance structures for human settlements will require new international agreements.
- **Space traffic management and orbital debris mitigation**: An increase in satellite constellations (e.g., Starlink, OneWeb) leads to a catastrophic collision or "Kessler Syndrome" scenario, threatening access to Earth's orbit. National and international policies would prioritize orbital debris mitigation, space traffic management, and stricter licensing for satellite operators, potentially creating a global regulatory body for space traffic.
- **Breakthroughs in space propulsion and exploration technologies**: New technologies, such as nuclear propulsion or reusable interplanetary spacecraft, significantly reduce the cost and duration of deep space missions. Cheaper, faster missions could enable smaller nations and private companies to participate in interplanetary exploration, democratizing access to space and necessitating more inclusive international collaboration frameworks.
- **Militarization or weaponization of space**: Deployment of space-based weapons or anti-satellite (ASAT) tests sparks geopolitical tensions. National policies may focus on space defense, leading to the militarization of space and the establishment of military space branches, while international treaties might seek to limit space-based weapons and ensure space remains peaceful.
- **Private sector leadership in space exploration**: Companies like SpaceX, Blue Origin, and others achieve key milestones (e.g., private Lunar landings, Mars colonization) ahead of government space agencies. National policies may shift toward incentivizing public-private

partnerships, redefining the role of government agencies as regulators or collaborators rather than leaders in space exploration.

- **Broadening participation from emerging space nations**: Emerging nations (e.g., UAE, India, South Korea) play key roles in international missions or develop independent capabilities. Space activities could become more globally distributed, leading to more diverse international partnerships and increasing the need for an equitable framework for technology sharing and governance.
- **Technological advancements in space-based energy**: Space-based solar power becomes viable as a large-scale energy solution for Earth. Policies could shift to prioritize investment in orbital solar arrays, and nations may develop partnerships or compete for access to key orbital slots and technology.
- **Updates to international space governance**: Revisions or replacements to the Outer Space Treaty (1967) and related agreements to address new challenges like resource extraction, human settlement, and private sector activities. This could unify or fracture global space governance, depending on how inclusive and balanced the new frameworks are between spacefaring and non-spacefaring nations.
- **Civilian space flight milestones**: Commercial space tourism and private missions become more accessible to the general public. National policies would need to address regulations for safety, liability, and environmental impacts of commercial spaceflight, while international partnerships could emerge to standardize global protocols.

"We know the gains of cooperation. We know the losses of the failure to cooperate. If we fail now to apply the lessons we have learned, or even if we delay their application, we know that the advances into space may only mean adding a new dimension to warfare. If, however, we proceed along the orderly course of full cooperation we shall, by the very fact of cooperation, make the most substantial contribution toward perfecting peace."

- PRESIDENT LYNDON B. JOHNSON, Special Message to the Senate on Transmitting the Treaty on Outer Space, 7 Feb 1967[222]

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Strengthen Existing Alliances. Deepen collaboration with established partners like ESA, Japan (JAXA), and Canada (CSA) on ongoing missions such as Lunar exploration and the International

[222] UCSB (n.d.). Johnson, L.B. (1967). Special Message to the Senate on Transmitting the Treaty on Outer Space. The American Presidency Project.

Space Station. Focus on seeking mutual benefits and alignment of interests such as joint training programs for astronauts and mission-critical systems integration to enhance operational efficiency.

Leverage Private Sector Expertise. Facilitate public-private partnerships that allow U.S. companies to partner internationally. For example, enabling U.S. firms like SpaceX and Blue Origin to launch satellites for allied nations fosters economic and diplomatic goodwill.

Promote Standardization Efforts. Advocate for international standards in launch vehicle integration, satellite communication, orbital debris mitigation, and space traffic management to ensure safer, resilient, and more efficient operations.

Advocate for U.S. Companies in International Markets. The U.S. Government should take steps to advocate for U.S. space Companies in international markets including establishing trade partnerships and bilateral agreements, leveraging diplomatic channels to open markets, create export incentives for space technologies, promoting U.S. space capabilities through global advocacy, and investing in infrastructure to support international collaboration. (OPRs: National Space Council)

MID-TERM PAYOFF

Pursue Joint Missions to the Moon and Mars. Co-lead missions under programs like Artemis to ensure U.S. leadership while encouraging significant contributions from partners, both in funding and technology. Integrate international partners into Lunar gateway development, enabling shared infrastructure for future exploration.

Expand Collaborative Research. Develop joint research initiatives focused on Earth observation (e.g., climate change monitoring) and advanced propulsion technologies. Share scientific data from space missions, creating opportunities for global innovation and goodwill.

Increase Support for Emerging Space Nations. Provide technical and financial assistance to developing countries with emerging space programs, creating new allies and expanding the U.S.'s influence in the global space ecosystem.

Comprehensive Regulatory Review. A legislative review of regulations such as ITAR should focus on making the regulations more adaptable to the fast-evolving global and technological landscape while still ensuring national security. Legislative reform could help balance the need for control with the realities of international cooperation, technological innovation, and economic growth. Consider using NATO as a vehicle for streamlining processes.

LONG-TERM PAYOFF

Build a Permanent Multinational Space Presence. Establish international partnerships for a long-term human presence on Mars or other celestial bodies, leveraging resources, expertise, and shared goals for humanity's expansion into the solar system.

Lead in Space Governance. Take a leadership role in creating and enforcing new international treaties for space resource utilization, planetary protection, and orbital debris management to maintain a sustainable space environment.

Foster Global Space Economy Development. Promote policies and partnerships that enable equitable access to space resources, ensuring economic opportunities for all nations and reinforcing the U.S.'s position as a leader in a thriving global space economy.

KEY ISSUES & CHALLENGES

ITAR Still Poses Real Barriers to Growth – The burden of complying with the ITAR and related Export Administrations Regulations (EAR) poses a major barrier to companies developing novel space technologies. Ironically, many of these new technologies are not specifically named in export controls, but companies are not willing to take the risk of potential legal backlash, and agencies aren't willing to spend money re-evaluating old standards and creating new ones to match the current tech landscape.

Lack of Federal Government Space Development Roadmap – Praise is widely shared by industry toward the Space Development Agency's approach to rapidly building out their communications constellation. However, this rapid acquisition and contracting strategy has not been adopted by any other agencies, and a unified whole-of-government strategy detailing broadly what the future of space entails for regulations and public-private partnerships.

KEY ACTIONS & RECOMMENDATIONS

Review Space-Based Sustainability Requirements with Growth in Mind: The National Environmental Policy Act (NEPA) doesn't apply to space, however with continued increase in in-space activities, the need for environmental and sustainability regulations is inescapable. These regulations must be compatible with other nations' interests, including our adversaries.

Look to Far future Space Activities: Approaching the future of all in-space activities with a forward-thinking mindset is a necessity to keep developing the industry as well as prepare for the inevitable global expansion into the stars. Striking a balance of properly regulating nascent technologies is difficult and will require input from all sectors (government, industry, academia).

Space-Based Solar Power Needs an Owner: Specifically mentioned numerous times was the regulatory landscape (or lack thereof) behind proposed SBSP programs. Because no agency will take ownership of the controversial technology, regulations that will enable its development from current stage to widespread adoption don't exist. This topic requires collaboration across energy, environment, defense, diplomatic, and space stakeholders to map the regulatory world that SBSP will exist in.

SPACE WORKFORCE, STEM & EDUCATION

Co-Innovation Session Co-Lead: Scott Erwin, AFRL
Co-Innovation Session Co-Lead: Casey Anglada DeRaad

"Workforce development is crucial as we explore farther than ever before. Investing in the next generation of scientists, engineers, and explorers ensures that NASA and the United States will remain at the forefront of space exploration and discovery."

- BILL NELSON, NASA Administrator[223]

"That's why building readiness is a central obligation of our service...It is based on the straightforward observation that day-to-day space operations do not prepare Guardians for the challenges they will face in a high-intensity combat environment."

- - GENERAL B. CHANCE SALTZMAN, Chief of Space Operations, USSF[224]

BACKGROUND

The U.S. stands at a pivotal moment in ensuring its leadership in the space domain by prioritizing workforce development. The space workforce bridges public and private sectors and is the engine of scientific and technological progress, driving breakthroughs that secure our nation's future both on Earth and beyond. The demand for skilled professionals in the space industry is surging, fueled by initiatives from both public agencies and rapid growth in the private sector. As global competitors like China, India, and the European Space Agency rapidly expand their space capabilities, the U.S. must rise to meet this occasion by strengthening STEM education, fostering public-private collaboration, and building robust, diverse, and inclusive talent pathways. To lead the world in space technology, exploration, resource utilization and commercialization, the U.S. must take decisive action to prepare, inspire, and retain a workforce equipped to tackle the complexities of tomorrow's space missions and technologies. Now is the time to invest in our people and reaffirm America's role as the global leader in space innovation.

Space Workforce Trends - The space workforce is undergoing significant transformation, driven by rapid technological advancements, increased commercial activity, and evolving national security priorities. One notable trend is the growing demand for professionals skilled in artificial intelligence,

[223] NASA (2021). "NASA's Artemis Generation: Preparing the Future Workforce," NASA Workforce Development Press Release.

[224] Gordon, C. (2024). Saltzman: New Space Force Readiness Model Will Be 'Drastic Change'. Air and Space Forces Magazine.

robotics, and cybersecurity, reflecting the integration of these technologies into space operations. The rise of private-sector players has also shifted workforce needs, emphasizing agility and innovation in spacecraft design, launch services, and satellite technologies. Additionally, the space industry is seeing a diversification of roles, with emerging fields like space law, sustainability, and space tourism creating opportunities beyond traditional engineering and science disciplines. Internationally, competition and collaboration are reshaping workforce dynamics, as countries invest in space programs to secure economic and strategic advantages. To meet these demands, there is a heightened need for the U.S. to focus on and provide resources for space-related training, education, reskilling, and fostering a workforce that is not only technically proficient but also adaptable to the rapidly changing space landscape.

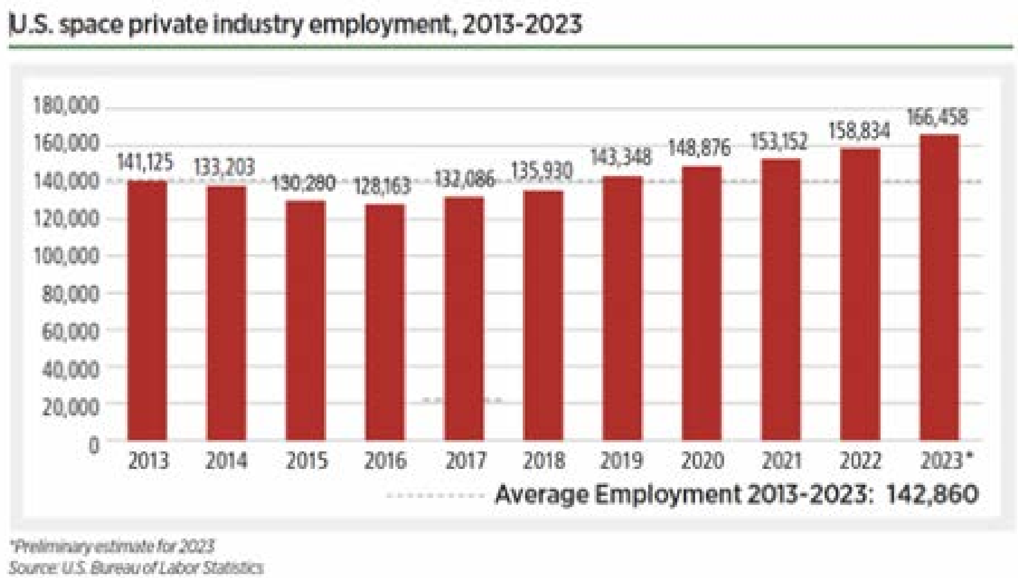

Figure 22. U.S. Space Private Industry Employment, 2013-2023 (Source: Source)[225]

Progress against 2023 Key Actions & Recommendations - The 2023 SSIB Report identified several short-term, mid-term and far-term actions and recommendations to ensure the U.S. bolsters a steady pipeline of human talent and does not fall behind its adversaries. See Table 2 below for a summary and the following paragraphs for an update on the short-term goals for space workforce and STEM.

[225] Gorman, D. (2024).New Data Shows a Rapidly Expanding Space Workforce. Payload Space.

Short Term	Mid Term	Far Term
Implement Pathways to the Stars	Aligned Space-STEM North Star Vision: Interagency Roadmap to Support Space-Related STEM Education and Workforce	Salaries / Recruitment / Retention of STEM Workforce
Establish strategic messaging and marketing.	Assess and address funding gaps/engagement models as a coordinated nationwide effort.	Scale Pathways to the Stars Program

Table 2. Summary of key actions and recommendations from 2023 SSIB Report.

Pathways to the Stars - NewSpace Nexus launched the Pathways to the Stars program leveraging a partnership with RocketLab for their CHIPS (Creating Helpful Incentives to Produce Semiconductors) and Science Act of 2022 grant award. Pathways to the Stars aims to grow the space industry talent pipeline inclusively with programming, mentoring, experiential learning, and career connection services spanning K-12 to early career, with industry involvement and special attention given to reaching minority populations to connect students to jobs and careers. Early accomplishments include evaluating the pathways for students to gain access to space (STEM) careers to include identifying gaps in programming support, evaluating current and future labor market trends, and understanding employer workforce challenges.

Strategic Messaging and Marketing - Currently there is no orchestrated, national campaign to attract students into space careers. The Interagency Roadmap to Support Space-Related STEM Education and Workforce (September 2022) was a response to the Vice President's space priorities framework which included building STEM workforce and describes associated Federal interagency goals and implementation activities.[226] This document lists several objectives and actions related to strategic messaging and marketing. For example, Objective 1.1. Increase awareness of the breadth of space-related careers (actions include creating a compendium of space careers and launching an awareness campaign including materials for departments and agencies to use in their outreach and engagement activities). Objective 2.1 Increase awareness of pathways to careers in the space workforce (with an action to create a coordinated campaign to increase awareness of space-related pathways and learning opportunities for the space workforce).

While Federal government efforts to build a STEM workforce strategy take shape, disparate efforts to promote space-related careers in the United States exist and involve a combination of government initiatives, industry-led programs, and educational outreach, all orchestrated by various organizations. Government Initiatives include NASA's Office of STEM Engagement which offers a range of programs aimed at inspiring and preparing the next generation of explorers. Initiatives include internships,

[226] White House (2022). Interagency Roadmap to Support Space-Related TEM Education and Workforce.

fellowships, and educational resources designed to engage students and the public in space exploration. The United States Space Force (USSF) has implemented several initiatives to enhance its recruiting efforts and attract top talent. These initiatives are primarily orchestrated by the Air Force Recruiting Service (AFRS), which oversees recruitment for both the Air Force and the Space Force. The National Space Grant College and Fellowship Program supports a network of universities across the U.S. to promote aerospace education and research. It encourages collaboration among universities, the aerospace industry, and government agencies to enhance STEM education and workforce development.

Industry-Led Programs actively engage in marketing and outreach to attract talent, offering internships, scholarships, and use career fairs to connect with potential candidates. Platforms like SpaceCrew.com list marketing job opportunities within the space industry, reflecting the sector's commitment to workforce development.[227]

Notable educational outreach initiatives include NASA's L'SPACE Program.[228] This free, online, interactive experience is open to undergraduate and graduate STEM students interested in pursuing a career with NASA. It provides participants with hands-on experience in mission design and project management. Additionally, Jet Propulsion Laboratory (JPL) Education Office offers a variety of educational programs, including internships and fellowships, to engage students and educators in space science and technology. These programs aim to inspire interest in STEM careers and provide practical experience in the field.

CURRENT STATE

The U.S. space STEM workforce is at a critical juncture, facing challenges that threaten its ability to sustain leadership in space innovation and exploration. Declining STEM education outcomes, educator shortages, and unequal access to resources have created a talent pipeline that struggles to meet growing demands in the space industry. Compounded by rising education costs and global competition, the U.S. risks losing its edge as nations like China and India ramp up investments in STEM programs and workforce development. Efforts like the Space Force's SPAFORGEN model and federal STEM strategic plans aim to address these issues, but significant gaps remain. Without a unified national strategy and renewed investments in education, training, and professional development, the U.S. could jeopardize its ability to lead in a rapidly evolving space domain.

The U.S. Is Falling Behind in Hi-Tech/STEM Education - The United States is facing a growing challenge in maintaining its leadership in high-tech and STEM education, with significant implications for its competitiveness in the global economy. While countries like China, India, and several European nations are making substantial investments in STEM programs, infrastructure, and workforce development, the U.S. has struggled to keep pace. According to the National Science Board, the U.S. share of the global STEM workforce has declined as other nations produce a larger volume of graduates

[227] Space Crew (n.d). The solar system's biggest space jobs site.
[228] ASU (2024). NASA L'SPACE Program.

in science, technology, engineering, and mathematics.[229] Chronic underinvestment in K-12 STEM education, unequal access to resources, and declining interest among students in pursuing STEM careers are exacerbating the problem. Additionally, the rising cost of higher education limits opportunities for students to enter critical high-tech fields. If unaddressed, these trends could weaken the U.S. innovation ecosystem, undermine its ability to lead in industries like aerospace, artificial intelligence, and biotechnology, and erode its position as a global technology powerhouse.

"Without a steady pipeline of space workforce professionals, our ability to innovate and compete globally is threatened."

- MELANIE STRICKLAN, Executive Director of Space Workforce for Tomorrow

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The U.S. is Facing STEM Educator Shortages - The United States is grappling with a significant shortage of STEM educators, a critical issue that threatens the nation's ability to prepare the next generation for careers in science, technology, engineering, and mathematics. According to the U.S. Department of Education, many school districts across the country report unfilled teaching positions in STEM subjects, particularly in underserved and rural communities.[230] Low salaries, limited professional development opportunities, and high turnover rates have contributed to a dwindling pipeline of qualified educators in these fields. Additionally, competition from the private sector, where STEM professionals can often earn significantly higher wages, makes it challenging to attract and retain talent in education. Without sustained investments in teacher training programs, scholarships for aspiring STEM educators, and incentives to keep skilled teachers in the classroom, the U.S. risks falling further behind in equipping students with the skills needed to compete in a rapidly evolving global economy.

USSF Implements SPAFORGEN to Prepare Guardians - The Space Force Generation (SPAFORGEN) model is designed to transform and prepare the U.S. Space Force Guardians and coalition partners to meet the challenges of an evolving space domain by ensuring a highly skilled, ready, and adaptable force. Introduced in the summer of 2024, SPAFORGEN provides a structured framework for training, equipping, and developing Guardians in alignment with mission requirements and technological advancements. By focusing on deliberate preparation cycles, the model emphasizes continuous skill development, hands-on experience with cutting-edge space systems, and adaptability to emerging threats in the contested space environment. SPAFORGEN also supports workforce readiness by prioritizing professional development, operational training, and leadership growth, ensuring Guardians are equipped to drive innovation, execute space missions, and maintain U.S. leadership in space. This systematic approach not only strengthens the Space Force's operational effectiveness but

[229] NSF (2024). The State of U.S. Science and Engineering 2024 Key Insights.
[230] Teachers of Tomorrow (2024). Teacher Shortages in the U.S: Challenges, Solutions & Initiatives in 2025.

also cultivates a highly capable workforce to sustain the United States' strategic advantage in the space domain.

White House Issues STEM Education Strategic Plan - In April 2024, the White House issued a 2023 Progress Report on the Implementation of the Federal Science, Technology, Engineering, and Mathematics (STEM) Education Strategic Plan.[231] It served to update Congress and the broader STEM education community on federal activities from Spring 2022 to Spring 2023 and provided a summary of the Committee on STEM Education's (CoSTEM) progress in implementing the current five-year STEM education strategic plan, details on interagency collaborations addressing common challenges, and an inventory of federal STEM education programs. The report also includes actual investments for Fiscal Year 2022, estimated investments for Fiscal Year 2023, and requested funding levels for Fiscal Year 2024.

KEY ISSUES & CHALLENGES

The space industry is experiencing unprecedented growth and innovation, but its workforce and STEM talent pipeline face significant challenges that threaten its long-term sustainability. From a lack of a national framework for STEM mentoring to falling behind global competitors in education, the U.S. struggles with systemic issues that hinder the development of a robust talent pool. High costs of higher education and a shortage of STEM graduates exacerbate these challenges, while rapid technological advancements create a widening gap between workforce skills and industry needs. Compounding these issues are workforce retention struggles, security clearance bottlenecks, and strategies that open opportunities to the full scope of talent. Without better coordination between public and private training initiatives, enhanced focus on soft skills, and meaningful investment in workforce development, the U.S. risks falling behind in preparing a space-ready workforce equipped to meet the demands of this rapidly evolving sector.

National Framework for Mentoring: STEM outreach tends to be grassroots, regional efforts and there is no existing national framework through which to share data, audiences, lessons learned, etc. The U.S. lacks a "whole of government" approach to the challenge, including unreliable or highly disaggregated funding for STEM programs.

Falling Behind in Education: U.S. students are still largely behind their global peers in STEM education. Students take fewer STEM classes, perform at lower levels, and graduate less prepared for college than elsewhere in the world.

[231] White House (2024). CoSTEM Progress Report.

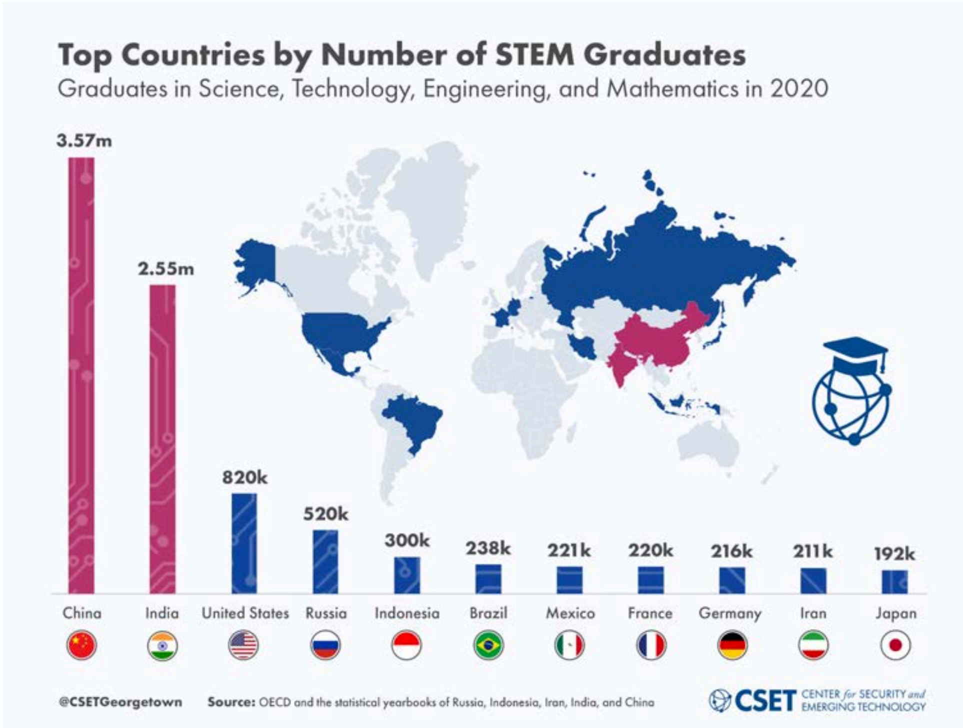

Figure 23. Top Countries by Number os STEM Graduates (Source:CSET[232])

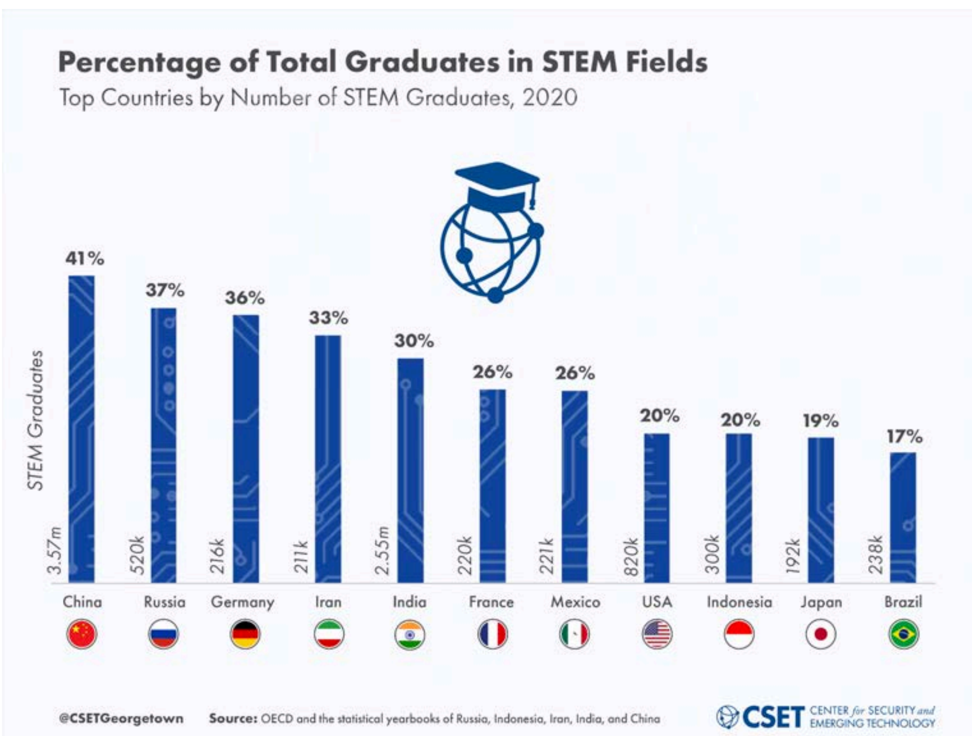

Figure 24. Percentage of Total Graduates in STEM Fields (Source:CSET[233])

[232] Oliss, B. McFaul, C. and Riddick, J. (2023). The Global Distribution of STEM Graduates: Which Countries Lead the Way?. CSET.
[233] Oliss, B. McFaul, C. and Riddick, J. (2023). The Global Distribution of STEM Graduates: Which Countries Lead the Way?. CSET.

Lack of Meaningful Funding: The cost of getting a four-year degree is the highest it's ever been. Attaining and maintaining a scholarship through a four-year degree is prohibitively difficult for many students.

STEM Education Pipeline Issues: The U.S. struggles to produce enough graduates in science, technology, engineering, and mathematics (STEM) to meet the growing demands of the space industry and government. Insufficient exposure to STEM in K-12 education, combined with teacher shortages and declining interest in these subjects, limits the talent pipeline. As a result, the industry faces a shortage of workers qualified to fill critical technical and engineering roles.

Rapid Technological Change: The pace of innovation in space systems, AI, robotics, and advanced manufacturing often outpaces the ability to train workers with updated knowledge, skills, and abilities. Emerging technologies evolve faster than traditional workforce development systems can adapt, leading to a mismatch between the current workforce's skills and the demands of next-generation space operations.

Workforce Retention and Competition: Retaining skilled workers in the space sector is challenging as they are lured away by other high-tech industries, such as AI and cybersecurity, offering higher salaries and opportunities. Private sector competition and international demand for talent make it difficult for space organizations to retain experienced professionals, particularly in critical, specialized roles.

Security Clearance and Workforce Bottlenecks: Many government space roles require security clearances, which can create bottlenecks in onboarding qualified professionals. Lengthy vetting processes and restrictions on hiring non-U.S. citizens reduce the available talent pool, slowing the ability of organizations like NASA and the Space Force to fill high-priority roles efficiently. However, there is an opportunity here for unclassified skills development through onboarding programs dedicated to training and apprenticeship programs.

Diversity and Inclusion Gaps: The space workforce remains underrepresented by women, minorities, and underserved populations, limiting opportunities for innovation through diverse perspectives. Systemic barriers, lack of mentorship, and unequal access to STEM education contribute to this gap, narrowing the overall talent pool and missing opportunities to attract new talent.

Public-Private Training Gaps: Workforce training programs often lack coordination between government, academia, and private industry, resulting in inconsistent preparation for space professionals. Fragmented training systems and a lack of standardized requirements for knowledge, skills, and abilities hinder the development of a cohesive, space-ready workforce.

Addressing Soft Skills for Space Missions: In addition to technical expertise, space missions require strong soft skills, including communication, teamwork, leadership, and problem-solving under pressure. Many training programs neglect these critical skills, leading to challenges in executing complex, multi-partner missions that require seamless collaboration and adaptability.

Economic and Resource Constraints: Workforce development programs are often subject to funding shortfalls or deprioritization during economic downturns. Competing policy priorities and limited resources hinder long-term investments in workforce development, impacting the future readiness and competitiveness of the U.S. space workforce.

KEY INFLECTION POINTS

There are several key inflection points that could affect progress, either positively or negatively in creating a space-ready workforce. By identifying and addressing these potential inflection points, policymakers, educators, and industry leaders can create strategies to strengthen and future-proof the space-ready workforce.

- **Federal and Private Investment Levels in STEM Education** - Greater funding for K-12 STEM programs, workforce development initiatives, and scholarships could produce a stronger talent pipeline for the space industry
- **Rapid Adoption of Emerging Technologies** - Incorporation of AI, robotics, and virtual training tools (e.g., VR/AR simulations) can accelerate workforce readiness, enabling faster and more effective training for complex space operations.
- **Public-Private Workforce Partnerships** - Collaboration between the government, academia, and private industry to design targeted training and internship programs can bridge skills gaps and prepare workers for evolving space-related roles.
- **High-Profile Missions and Innovations** - Major successes like Lunar landings, Mars missions, or breakthroughs in commercial space tourism could inspire more students and professionals to pursue careers in space-related fields.
- **Economic Downturn or Budget Cuts** - Reductions in federal funding for space programs, research, or STEM education could weaken workforce development efforts and slow progress in preparing skilled professionals.
- **STEM Educator Shortages** - A persistent shortage of STEM teachers and educators could hinder the talent pipeline, especially in underserved or rural communities where opportunities are already limited
- **Competition from Other High-Tech Industries** - Fields like AI, cybersecurity, and biotech often attract top talent with higher salaries, potentially drawing professionals away from space-related careers
- **Technological Disruption Outpacing Training** - The rapid evolution of space systems and technologies without corresponding upskilling or reskilling programs could leave the workforce unprepared for new operational demands.

"Tell me and I forget, teach me and I may remember, involve me and I learn."

- Xun Kuang, Chinese Confucian Philosopher (312-230 BC)

KEY ACTIONS & RECOMMENDATIONS

SHORT-TERM PAYOFF

Advance NewSpace Nexus' Pathways to the Stars Program – Document K-Grad workforce exploration and readiness programs to include creating an ecosystem map of current New Mexico programs supporting students in pathways to space careers. Conduct a labor market analysis to compile and evaluate data trends in aerospace careers and job-ready technical skill, identifying skills gaps and talent pipeline projections. Document industry workforce challenges via responses to a survey of employers and economic development community members to understand workforce pipeline challenges and identify technical skills and competencies.

Interagency Alignment and Coordinated Initiatives - Develop a unified national framework for space workforce development that involves establishing a Space Workforce Task Force to align efforts between federal agencies, academia, and industry. Create a national space workforce database to track talent pipelines, skill needs, and workforce trends. Incentivize public-private partnerships for workforce training programs with standardized certifications.

Launch a National Space Awareness Campaign - Promote public awareness and inspiration while generating excitement about learning about space and working in the space industry. Promote space careers through documentaries, advertising campaigns, and social media outreach. Highlight the real-world impacts of space exploration, such as economic growth and technological innovation. Encourage storytelling around successful space professionals to inspire the next generation.

MID-TERM PAYOFF

Include a Requirement for Internships as part of the SBIR/STTR Program. Mandate that all SBIR/STTR awardees incorporate internships into their project proposals. Develop clear guidelines for SBIR/STTR recipients on how to structure internships. Reduce administrative burdens for small businesses implementing internships by offering toolkits and templates for onboarding interns, tracking progress, and reporting outcomes. Allow businesses to apply for supplemental funding under SBIR/STTR to support the cost of internship programs, including stipends and mentorship resources. ale internship requirements as companies progress through SBIR/STTR phases

Streamline Security Clearance Processes - Improve the process for obtaining security clearances. Reduce processing times for security clearances by modernizing systems and expanding personnel dedicated to vetting. Develop pathways for non-U.S. citizens with critical expertise to contribute to unclassified projects.

LONG-TERM PAYOFF

Investigate ways to reduce the cost of higher-education for STEM - Address affordability and accessibility for higher education by reducing barriers to pursuing STEM degrees. Expand funding for Pell Grants and space-focused scholarships to make education more accessible. Create loan forgiveness programs for graduates entering space-related careers in government or industry. Subsidize internships and co-op programs to ensure students from underserved backgrounds can participate.

Provide Tax Incentives for STEM professionals. Implement tax deductions for STEM professionals who remain employed in critical roles for a specified period (e.g., 5+ years). Provide tax credits for relocation expenses for STEM professionals moving to areas with workforce shortages. Offer higher tax deductions for educators teaching in STEM fields. Offer partial tax exemptions for retired STEM professionals returning to the workforce as mentors, instructors, or consultants.

The U.S. is behind both China and India in producing STEM[234] graduates,[235] and that China is outpacing the U.S. in PhD growth.[236] While the U.S. led for years, and India had the most graduates of any country worldwide with 78.0 million, China was right behind India with 77 million compared to the U.S.' 67.4 million graduates, with China seeing the fastest increase in graduates with a growth rate of 300%.[237] China is also building the most universities at the equivalent of one university a week.[238]

The U.S. is also no longer unchallenged in competition for global talent and U.S.-trained talent, meaning that the DoD and Defense Industrial Base face stiff competition to compete for STEM talent.[239] According to the Programme for International Student Assessment (PISA), the USA is only 38th of 71 countries in Math and 24th in Science, and the gap is widening for middle school students (ages 11 to 13), with the US ranked eleventh among the forty-six participating education systems., with the top leaders being Singapore, China, South Korea, Japan, and Russia.[240] Worse still, the U.S. faces a shortage of STEM teachers, making it difficult to increase production[241] or to develop emerging STEM education trends in AI, Remote, Online, and Hybrid Learning, Vocational preparation, Virtual and Augmented Reality, and Soft Skills and STEM,[242] and with artificial intelligence quickly becoming a focal point in K-12.[243] The projections are dim for the U.S. on its present course, with expectations that "by 2030, China and India will lead in a big way. They could account for more than 60% of the STEM graduates. This is compared to only 8% in Europe and 4% in the United States."[244]

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[234] Britannica (n.d.). STEM Education.
[235] Oliss, B., McFaul, C. and Riddick, J. (2023). The Global Distribution of STEM Graduates: Which Countries Lead the Way?. CSET.
[236] Zwetsloot, R. Corrigan, J. Weinstein, E. Peterson, D. Gehlhaus, D. and Fedasiuk, R. (2021). China is Fast Outpacing U.S. STEM PhD Growth. CSET.
[237] Jones, A. (2023). Why there's a special education and STEM teacher shortage and what can be done: Experts say obstacles include recruitment, funding and institutional support. ABC News.
[238] Jones, A. (2023). Why there's a special education and STEM teacher shortage and what can be done: Experts say obstacles include recruitment, funding and institutional support.. ABC News.
[239] Gehlhaus, D., Ryseff, J. and Corrigan, J. (2023). The Race for U.S. Technical Talent: Can the DOD and DIB Compete?. CSET; CSET (2023). How other countries are luring workers trained in U.S. universities.
[240] Krystal DeVille, K. (2024). STEM Education Statistics in 2024. STEM education Guide.
[241] Jones, A. (2023). Why there's a special education and STEM teacher shortage and what can be done: Experts say obstacles include recruitment, funding and institutional support.. ABC News.
[242] Marr, B. (2023). The Top 5 Education Trends In 2023. Forbes; See also, Labster (2023). The Top 4 Innovations in STEM Education You'll See in 2023.
[243] Crawford, A and Wu, C. (2024). Riding the AI Wave: What's Happening in K-12 Education?. CSET.
[244] Krystal DeVille, K. (2024). STEM Education Statistics in 2024. STEM education Guide.

EPILOGUE

Figure 25. Still from an animation showing a SpaceX Starship Super Heavy booster being caught by the "chopstick" arms of its launch tower after a liftoff (Source: SpaceX[245])

"...but military we're going to reach and it's my plan. I'll talk to Elon: Elon get those rocket ships going because we want to reach Mars before the end of my term–we want to do it. We will lead the world in space. Remember, I did Space Force–I did that–I rebuilt the military, I did a lot. But we have Space Force, first time in 79 years since Air Force first time think of it Space Force and now we're leading in Space over Russia and China. They were killing us when I took over and now we're leading but the military we're going to reach and–and it's my plan. I'll talk to Elon: Elon get those rocket ships going because we want to reach Mars before the end of my term we want to do it–and we want to have also great military protection in space cuz that's where it's going to be at... and unleash safety prosperity and peace for Americans of of every race religion color and creed"

- DONALD J. TRUMP, Wilmington, NC, September 23, 2024[246]

[245] Wall, M. (2024). Watch SpaceX catch Starship Super Heavy booster with 'chopsticks' in this animation. Space.com.
[246] Trump, Donald J. (2024). 'Elon, Get Those Rockets Going': Trump eyes Mars by end of his term'. The Economic Times, Youtube.

As the year 2024 ended, Donald J. Trump was elected. President Trump's first term featured a vibrant space council, clear direction for Artemis, including goals and deadlines, and the creation of the Space Force. Trump 2.0 is likely to continue its focus on space dominance and peace through strength, with a focus on the Space Force. The proximity of Elon Musk to President Trump suggests a renewal of interest in Mars. The Trump 1.0 goals were to return humans to Mars by 2024 and sustain a Lunar presence by 2028. A new Trump administration is likely to expect a renewed urgency. President Trump has also signaled an interest in using tariffs which in the short term could negatively affect space supply chains, but in the long-term might help create and protect domestic supply chains. Trump has nominated entrepreneur and private spaceflight participant Jared Isaacman to be the NASA Administrator, whose acceptance tweet echoed past themes of SSIB recommendations.

"I am honored to receive President Trump's @realDonaldTrump nomination to serve as the next Administrator of NASA. Having been fortunate to see our amazing planet from space, I am passionate about America leading the most incredible adventure in human history.

On my last mission to space, my crew and I traveled farther from Earth than anyone in over half a century. I can confidently say ***this second space age has only just begun****. Space holds unparalleled potential for* ***breakthroughs in manufacturing, biotechnology, mining, and perhaps even pathways to new sources of energy****. There will inevitably be a thriving space economy—one that will create* ***opportunities for countless people to live and work in space.*** *At NASA, we will passionately pursue these possibilities and usher in an era where* ***humanity becomes a true spacefaring civilization****.*

I was born after the Moon landings; my children were born after the final space shuttle launch. With the support of President Trump, I can promise you this: We will never again lose our ability to journey to the stars and ***never settle for second place****. We will inspire children, yours and mine, to look up and dream of what is possible. Americans will walk on the Moon and Mars and in doing so, we* ***will make life better here on Earth****.*

It is the honor of a lifetime to serve in this role and to work alongside NASA's extraordinary team to realize our shared dreams of exploration and discovery.

Grateful to serve, Jared"

- JARED ISAACMAN, December 4, 2024[247]

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[247] Isaacman, J. (2024). Acceptance Tweet. X.

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APPENDIX A

WORKSHOP PARTICIPANTS

Main Conference - Albuquerque

In-Person:

Aguilar, Ricardo, Proof Labs
Alvarez, Michael, Ecliptic Enterprises Corp
am Ende, Barbara, The Aerospace Corporation
Anderson, Robert, Retired UNM
Anglada DeRaad, Casey, NewSpace Nexus
Antypas, Rob, Air Force Research Lab (AFRL)
Asselin, Randy, Hoonify Technologies, Inc.
Aurand, Joshua, Verus Research
Austin, Emmanuel, Northrop Grumman
Ayala, Miguel, Aphelion
Baker, Julie, Ursa Space Systems
Baldwin, Morgan, Kuiper Government Solutions
Balster, Pace, Katalyst Space Technologies
Banks, Darwyn, National Reconnaissance Office
Bargiel, Jeff, Hyperspace Challenge
Barnes, Michael, Digantara U.S.
Barnett, Brian, Solstar Space
Beam, Jon, Rogue Space Systems Corporation
Beck, David, Space Force
Bellito, Justin, New Mexico Partnership
Benitez, Salma, Rhea Space
Berglund, Andrew, Aerospace Corporation
Bisio, Todd, Redwire
Blenkush, Severin, Space Advisory Group
Boyer, Tom, Katalyst Space Technologies
Breckenridge, Carter, NewSpace Nexus
Brown, Kevin, All Points Logistics, LLC
Buck, Lt Gen David, BRPH
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Cheng, Michael, Outernet Council
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Damphousse, Paul, Volta Space Technologies
Davis, Luke, BST North America
DeHerrera, Arial, NewSpace Nexus
Dendiu, Rachel, Moonbeam Exchange
DeRaad, Jordan, NewSpace Nexus
DeRaad, Dylan, BlueSpace
Deshpande, Jayram, Aadi Space Inc
Deuitch, Alex, Propel Space
Dinelli, Chris, Rhea Space
Doyle, Mike, Space Northwest
Enoch, Michael, Lockheed Martin Space
Erwin, Dr. Scott, Air Force Research Lab (AFRL)
Esfahani, Mona, Relativity Space
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Frank, Donald, Vantage Systems
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Frisco, Eric, ExoAnalytic Solutions
Frith, James, Air Force Research Lab (AFRL)
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Garcia, Nico, Cheshir
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Garretson, Peter, NewSpace Nexus
Germain, Andew, NewSpace Nexus
Gigeue, Jamie,
Gill, David, AWE (UK)
Goel, Aneesh, TRL11
Good, Michael, Lockheed Martin
Goodman, Bill, Goodman Technologies

Goodrum, Jennifer, Rocket Lab
Goswami, Namrata, Professor and Author
Greason, Jeffrey, Electric Sky
Greer, Monty, The Aerospace Corporation/COSMIC
Hahn, Victoria, City of Albuquerque
Handler, Jordan, Magma Space
Hankamer, Dane, Amazon/Kuiper Government Solutions
Harroun, Alexis, Juno Propulsion Inc.
Hastings, Elliott, Rhea Space
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Hwang, Sabrina, Verus Research
Irby, Rhonda, Volta Space Technologies
Jaeger, Theodore, Northrop Grumman
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Jordan-Tomaszewski, Steve, Aerospace Industry Association
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Kater, Dennis, Freedom Space Technologies
Katz, Robert, World Innovation Network
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Kennedy, Bryce, ACSP
Ketcham, Dale, Space Florida
Keuchkerian, Martin, Voyager Space
Kfir, Sagi, SpaceFund
Kha, Yen, Urban Logic
Kief, Craig, University of New Mexico
Knight, Valerie, Air Force Research Lab
Knighten, Patricia, Arrowhead Center
Kodeboyina, Sri, BlueSpace
Kozuki, Toyotaka, GITAI USA
Kreisel, Joerg, iBOSS
Krukin, Jeff, Orbital Transports
Kvale, Jay, Infinity Systems Engineering
Lacy, Seth, Air Force Research Lab (AFRL)
Lai, Winnie, Auriga Space
Lam, Eric, Air Force Research Laboratory
Lavender, Harold, CNM Ingenuity
Lazich, Jason, Virgin Galactic
Leader, Jeremy, USSF, Commercial Space Office
Lebar, Jr., Gerard, Northrop Grumman
Lee, Ghonhee, Katalyst Space Technologies
Lee, Nate, Bank of America
Linnaea Wise, Julia, Los Alamos National Laboratory
Lippay, Zachary, Verus Research
Lo, Eric, Booz Allen Hamilton
Loughlin, Jim, Vantage Systems Inc.
Lozada, Laura, Sierra Lobo Inc.: TEST3 @ White Sands
Luick, Landon, LEAP
MacKenzie, Andrew, NewSpace Nexus
Maethner, Scott, NewSpace Nexus
Mahoney, Sean, Space Frontier Foundation
Mai, Max, AxientCorp
Mallare, Jason, Umbra
Marlow, Mike
Martin, Josh
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APPENDIX B

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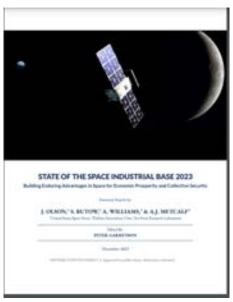

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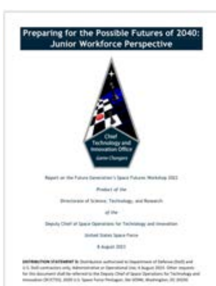

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APPENDIX C

KEY ACTIONS &
RECOMMENDATIONS
FROM SSIB'23
REVISITED

ASSESSING 2023 KEY ACTIONS & RECOMMENDATIONS

What progress has been made toward last year's SSIB recommendations?

1. Embrace a Collective North Star Vision for the U.S. and its Global Partners. The US must create a safe, stable, secure, and sustainable space domain which builds and advances an enduring competitive advantage for the United States and its global partners for economic prosperity and collective security in pursuit of national goals that embrace the peaceful economic development and human settlement of space in a manner that is consistent with our shared values, democratic principles and appreciation for both human rights and the environment.

UPDATE: Still no broad collective vision.

2. Accelerate Transition to Dynamic Space Operations. The U.S. must create capabilities for the conduct of operations which can respond to challenges in the space operating environment in a rapid and agile manner at scale. This includes responsive spacecraft and payload development and integration, responsive space access not only to orbit but to all areas of U.S. interest, sustained maneuver, and the ability to resiliently re-allocate within and across constellations.

UPDATE: Significant focus by USSPACECOM and USSF

3. A Shift toward Agile Policy Making and Execution. We are immersed in a Fourth Industrial Revolution highlighted by accelerated change in the advancement of new technologies. Policy and precedent must maintain pace so that the U.S. and its global partners remain leaders in establishing global standards, norms, and practices consistent with U.S. National Policy, strategy, and objectives outlined in the Space Framework. Policy must outpace innovation, or else the U.S. will concede its competitive advantage for the sake of bureaucratic convenience.

UPDATE: No agreement between the White House and Congress on licensing novel space technologies.

4. Development and Production at Speed and Scale. Fast following commercial technology to achieve strategic outcomes requires timely, effective, streamlined, flexible, and enabling contracts, procurement approaches, architectures, digital systems engineering practices, funding paradigms, collaborative development efforts, rapid prototyping, concurrent engineering, and active technology demand pull to fully harness and leverage commercial speed, scope, scale, and production capacity to compete economically while contributing to integrated deterrence.

UPDATE: No clear evidence of highly scaled space systems at present.

5. Address Bureaucratic Delay. The U.S. needs to incentivize private investment in the space economy so that the USG doesn't have to carry the full burden, but bureaucratic delay (including delays in launch and re-entry licenses per FAA Part 450) destroys or drives away private investment and U.S. competitive advantage. Bureaucratic delays in licensing and permitting are the single most self-defeating--and addressable problem across the space enterprise.

UPDATE: Licensing delays remain a concern. Varda had a significant delay in re-entry.

6. Sustained Funding for Programs that Leverage Commercial Solutions. Examples include the Space Development Agency Proliferated Warfighting Space Architecture, Artemis, Hybrid Space Architecture, Tactically Responsive Space (TacRS), xGEO and Cislunar Space Domain Awareness partnerships, and many others.

UPDATE: PWSA, CLPS, TacRS efforts continued.

7. Protection of Space Commerce. A continuum of conflict from competitive, through crisis, and conflict, exists today where space systems, networks, ground stations and infrastructure are all experiencing cyber attacks or are at risk of physical damage through the actions of peer competitors and criminal enterprises. Peacetime is 'all the time' which requires protection of commercial capabilities that contribute to the growing space economy. Integrated deterrence begins with the protection of our national interests across all domains including space.

UPDATE: OSD Policy did release its Congressionally mandated "Space Policy Review and Strategy on Protection of Satellites"

8. Supply Chain Trust and Resiliency. A dynamic, robust, diverse, resilient, innovation-driven, and scalable supply chain, industrial base, and entrepreneurial ecosystem are essential to achieve and sustain our national goals and objectives in space.

UPDATE: Supply chain remains a concern and a focus in 2024

9. In order to save the planet, we must get off-planet. Advancements in space power production, manufacturing, connectivity, and Lunar resource extraction will be foundational to creating and powering the future multi-trillion-dollar space economy. In order to lead, enabling new and evolved strategy, policy, and law, perhaps even treaties, are required. Activities and human presence in space should be driven by an international rules-based order and systems that uphold liberty and prosperity for all humankind.

UPDATE: The US has yet to refocus its narrative about Artemis to focus on industrial development and strategic competition. The US has yet to establish a strategy for in-space power production or space solar power.

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APPENDIX E

ACRONYMS & ABBREVIATIONS

AFA –Air & Space Forces Association
AFRL – Air Force Research Lab
AFRL/RV – Air Force Research Lab Space Vehicles Directorate
AI – Artificial Intelligence
AI/ML – Artificial Intelligence/Machine Learning
AMC –Air Mobility Command
CASR – Commercial Augmented Space Reserves
CISA – Cybersecurity and Infrastructure Security Agency
CLPS – Commercial Lunar Payload Services (NASA)
COMSO – Commercial Services Office (under USSF/SSC)
COVID – Coronavirus Disease
COSMIC– COnsortium for Space Mobility and ISAM Capabilities
COTS – Commercial Orbital Transportation Services
CR – Continuing Resolution
CSO – Commercial Solutions Openings [DIU]
CSO – Chief of Space Operations [USSF]
CSET – Center for Security and Emerging Technology
CSPO –Commercial Systems Program Office (NRO)
CRADA - Cooperative Research and Development Agreement
DARPA – Defense Advanced Research Projects Agency [DoD]
DIU – Defense Innovation Unit [DoD]
DoC – Department of Commerce
DoD – Department of Defense
DoE – Department of Energy
DoS – Department of State
DoT – Department of Transportation
DPA – Defense Production Act
DRACO – Demonstration Rocket for Agile Cislunar Operations (DARPA)
DSO – Dynamic Space Operations
EO – Electro Optical
EO – Executive Order [White House]
EOP – Executive Office of the President
FAA – Federal Aviation Administration [DoT]
FCC – Federal Communication Commission
FMS – Foreign Military Sales
FY – Fiscal Year
GAO – General Accounting Office
GEO – Geostationary Earth Orbit
HSA – Hybrid Space Architecture
IA – International Affairs Offices
IC – Intelligence Community
ISAM – In-Space Servicing Assembly and Manufacturing
ISRU – In-Situ Resource Utilization
ISS – International Space Station
ITAR – International Trafficking in Arms Regulation
ITAR/EAR – International Trafficking in Arms Regulation or Export Administration Regulations
JETSON – Joint Energy Technology Supplying On-Orbit Nuclear
kWe – Kilowatt-electric
LEO – Low Earth Orbit
MEO – Middle Earth Orbit
MEV – Mission Extension Vehicle
MW – Megawatt
NASA – National Aeronautics and Space Agency
NATO – North Atlantic Treaty Organization
NDAA – National Defense Authorization Act
NOAA – National Oceanic and Atmospheric Agency [DoC]

NRO – National Reconnaissance Organization [DoD]
NRO/CSPO – National Reconnaissance Organization Commercial Systems Program Office [DoD]
NSA – National Security Agency
NSC – National Security Council [EOP]
NSF – National Science Foundation
NSIC – National Security Innovation Capital [DoD]
NSpC – National Space Council [EOP]
ODNI – Office of the Director of National Intelligence
OIG – Office of Inspector General [NASA]
OMB – Office of Management and Budget [EOP]
OPR – Office of Primary Responsibility
OSAM – On-Orbit Servicing Assembly and Manufacturing
OSC – Office of Strategic Capital [DoD]
OSC – Office of Space Commerce [DoC]
OSD – Office of the Secretary of Defense [DoD]
OSTP – Office of Science and Technology Policy [EOP]
OTA – Other Transaction Authority
OUSD R&E – Office of the Undersecretary of Defense for Research and Engineering
PNT – Precision Navigation & Timing
PRC – People's Republic of China
PWSA – Proliferated Warfighter Space Architecture
R&D – Research and Development
RDT&E – Research Development Test and Evaluation
RF – Radio Frequency
RTG – Radioisotope Thermoelectric Generators
SAF/IA – Office of the Assistant Secretary of the Air Force for International Affairs
S&T – Science and Technology
SA – Situational Awareness
SAF/IA – Assistant Secretary of the Air Force for International Affairs
SAF/SQ – Office of the Assistant Secretary for Space Acquisition and Integration
SAR – Synthetic Aperture Radar
SATCOM – Satellite Communications
SBIR – Small Business Innovative Research
SBSP – Space Based Solar Power (renewable energy source)
SDA – Space Development Agency
SDA – Space Domain Awareness
SpaceX – Space Exploration Technologies (company)
SSA – Space Situational Awareness
SSC – Space Systems Command [USSF]
SSC/CSCO – Space Systems Command Commercial Satellite Communications Office[USSF]
SSIB – State of the Space Industrial Base (report)
STEM – Science Technology Engineering and Math
STM – Space Traffic Management
STTR – Small Business Technology Transfer
U.S. – United States
UK – United Kingdom
UKR – Ukraine
USA – United States of America
USAF – United States Air Force
USCG – United States Coast Guard
USG – United States Government
USML – United States Munitions List
USSF – United States Space Force [DoD]
USSPACECOM – United States Space Command [DoD]
USSOCOM – United States Special Operations Command
VICTUS HAZE – Victus Haze is a tactically responsive space mission that includes the design, build, launch, own spacecraft
xGEO – Beyond Geostationary Orbit
Yr – Year

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