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FOR STRATEGY AND SECURITY

Harnessing Allied Space Capabilities

A series of papers assessing commercial, exploration, and security space objectives

ROB MURRAY, TIFFANY VORA, PHD, and NICHOLAS EFTIMIADES

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Cover: Space shuttle Endeavour lights up the night sky as it lifts off from Launch Pad 39A at NASA's Kennedy Space Center in Florida. The primary payload for the STS-130 mission to the International Space Station is the Tranquility node, a pressurized module that will provide additional room for crew members and many of the station's life support and environmental control systems. Attached to one end of Tranquility is a cupola, a unique work area with six windows on its sides and one on top. The cupola resembles a circular bay window and will provide a vastly improved view of the station's exterior. The multi-directional view will allow the crew to monitor spacewalks and docking operations, as well as provide a spectacular view of Earth and other celestial objects. The module was built in Turin, Italy, by Thales Alenia Space for the European Space Agency. Image Credit: NASA/Jim Grossmann

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Introduction

Harnessing allied space capabilities

The United States' vast network of alliances and partnerships offers a competitive advantage—this is especially evident in outer space. Often characterized as a global commons, space holds value for all humankind across commercial, exploration, and security vectors. As technological advancements trigger a proliferation in spacefaring nations, the United States and its allies and partners are confronted with new challenges to and opportunities for collective action.

This series examines how US space strategy can recognize the comparative advantages of allies and partners in space and best harness allied capabilities:

- **Robert Murray** examines the state of the commercial space market and key drivers, considering how government investments in enabling activities can support broader national imperatives.
- **Tiffany Vora** analyzes current US space exploration goals and the capabilities that will be critical to achieving them, highlighting arenas where US allies and partners are strongly positioned for integration.
- **Nicholas Eftimiades** assesses the potential benefits to US national security offered by allied integration, identifying pathways for cooperating with allies and partners on their space capabilities.

The way forward for US and allied coordination in space

Several common themes emerge across this series. First, outer space is characterized by a transforming landscape and market. Commercial tech advancements—including the introduction of small satellites, advancements in Earth observation and asteroid mining, and the rise of space tourism—drive the development of what Murray terms the "NewSpace" market. The way in which the United States and its allies do business in space is changing, with the private sector leading in capability development and the government becoming the consumer. The burgeoning space sector, totaling $464 billion in 2022, is attracting allies and adversaries alike to invest in and expand their space operations. Strategic competitors recognize they can now target US and allied commercial and national security imperatives from space.

Second, this increasingly competitive environment further accentuates the value of alliances and partnerships in space. As Vora highlights, US and allied cooperation in space today rests on the Artemis Accords, which advances shared principles for space activity, and is a key mechanism for the international transfer of expertise, technology, and funding. The US Department of Defense also houses the Combined Space Operations Vision 2031, which offers a framework to guide collective efforts with several allies, and a host of collaborative exercises and wargames. Eftimiades describes the cross-cutting benefits of this collaboration: it alters the decision calculus for hostile actors, threatening a response from a coalition of nations; offers the ability to share capabilities, responsibilities, and geostrategic locations; and creates consensus in setting the norms for responsible space behavior. Current collective efforts in the space domain are limited, albeit expanding, considering the benefit allies and partners bring to the table.

Third, in order to promote stronger collaboration among the United States and its key allies and partners, it is necessary to address and overcome the barriers that stand in the way. Vora identifies protectionist policies and regulations that act as hurdles to the transfer of key technologies and information. Murray explains that lengthy government contract timelines, coupled with insufficient investment in technologies critical to NewSpace, hinder US and allied commercial advancement. Eftimiades argues that the United States has yet to articulate a strategy for space coordination, highlighting a lack in transparency with allies and partners on capability and data gaps.

The authors put forth ideas to pave the way forward for US and allied space development. Recommendations for the United States and its allies and partners include conducting gap analysis on where allied investments can complement existing US capabilities, establishing a "space bank" to support NewSpace actors, and formulating a US and allied strategy for space development, building upon the Artemis Accords. To maintain its competitive advantage in space, the United States cannot go at it alone.

The NewSpace Market: Capital, Control, and Commercialization

by ROBERT MURRAY

Commercial opportunities in space-based technologies are expanding rapidly. From satellite communications and Earth observation to space tourism and asteroid mining, the potential for businesses to capitalize on these emerging technologies is vast and known as "NewSpace."[1]

The NewSpace model is important for governments to understand because the dual-use nature of space, specifically its growing commercialization, will influence the types of space-based technologies that nations may leverage, and consequently, impact their national security paradigms. By capitalizing on the private sector's agility and combining it with the essential research efforts and customer role played by the public sector, the NewSpace industry can play a critical function in addressing current and future national security challenges through public-private codevelopment.

As the NewSpace industry expands, the role of government is evolving from being the primary developer and operator of space assets to facilitating their commercialization, while still prioritizing key advancements. US and allied governments can capitalize on this competitive landscape by strategically investing in areas that align with their national security objectives. However, it is crucial for them to first understand and adapt to their changing roles within this dynamic environment.

Indeed, the benefits of the burgeoning NewSpace industry extend beyond the United States. International collaboration and competition in this area can lead to faster technological advancements and economic gains. The global NewSpace landscape is driving down costs, increasing access to space, and fostering innovation that can improve not only economic well-being, but also impact national security models.

To that end, this paper will examine the broad state of the space market, discuss the industry drivers, and propose recommendations for US and allied policymakers as they consider future government investments in those enabling space-based activities that support wider national security ambitions.

The Commercial Context

In recent years, the space industry has undergone significant commercialization (NewSpace) in which governments have partnered with private companies and invested more into the commercial space sector. NewSpace companies often carry many of the characteristics listed above in Figure 1.[2]

NewSpace contrasts with the historical approach to space-based technologies, which typically involved a focus on standardization to ensure the reliability and quality of space components. This standardization was (and still is) essential for the safety of manned space flight, the longevity of systems, and the overall success of missions. Despite the increased collaboration between the public and private sectors, the failed January 2023 Virgin Galactic launch in the United Kingdom, the failed March 2023 Mitsubishi H3 launch in Japan, and the failed June 2022 Astra launch in the United States serve as clear reminders of the challenges associated with NewSpace technology.[3]

Today, when considering who is spending what on space-based technology research, US and allied governments can be viewed more as customers than as creators. This is in stark contrast to former US President John F. Kennedy's famous 1962 speech launching the Apollo program, which put NASA at the forefront of driving the necessary technology and engineering needs.[4] Indeed, the capital flows of research and development (R&D) from the US government relative to the private sector have shifted significantly since the era of

1 Ken Davidian, "Definition of NewSpace," *New Space: The Journal of Space Entrepreneurship and Innovation* 8, no. 2 (2020), https://www.liebertpub.com/doi/10.1089/space.2020.29027.kda.

2 Roger Handberg, "Building the New Economy: 'NewSpace' and State Spaceports," *Technology in Society* 39 (2014): 117–128, https://www-sciencedirect-com.iclibezp1.cc.ic.ac.uk/science/article/pii/S0160791X14000505.

3 Peggy Hollinger, "Virgin Orbit Pledges to Return for New UK Satellite Launch," *Financial Times*, January 12, 2023, https://www.ft.com/content/250b6742-a0a6-4a96-bca6-d7a61883a975; Tariq Malik, "Astra Rocket Suffers Major Failure during Launch, 2 NASA Satellites Lost," *Space.com*, June 12, 2022, https://www.space.com/astra-rocket-launch-failure-nasa-hurricane-satellites-lost; "Mitsubishi/Rockets: Launch Failure Points to Drain on Resources," *Financial Times*, March 7, 2023, https://www.ft.com/content/30386ff6-eaea-442d-b285-82c19dbb1b19.

4 President John F. Kennedy, "Address at Rice University on the Nation's Space Effort," John F. Kennedy Presidential Library and Museum, September 12, 1962, https://www.jfklibrary.org/learn/about-jfk/historic-speeches/address-at-rice-university-on-the-nations-space-effort.

Figure 1: Characteristics of NewSpace Companies

KEY CHARACTERISTIC	DESCRIPTION
Low-cost focus	Aim to minimize the cost of space hardware or services, and target high-usage markets like space tourism to achieve lower costs through economies of scale.
Lower prices, bigger payoffs	Believe that lower prices will lead to bigger markets and thus bigger payoffs in the long run, while mainstream aerospace companies believe lower costs will reduce their revenues.
Incremental development	Follow a step-by-step approach to space development, starting with limited capabilities and gradually improving over time through profit-generating markets.
Consumer markets	Aim to pursue commercial and consumer markets such as space tourism to achieve lower costs.
Operational focus	Prioritize operational costs over system performance, and might sacrifice performance for improvements in reliability, reusability, and maintenance.
Innovation	Might use innovative technologies or combine existing technologies in a new manner to achieve low-cost, robust space systems.
Small teams	Have a tight structure with minimal bureaucracy and overhead.
Fixed-price contracts	Prefer fixed-price contracts instead of cost-plus contracts that contribute to high space-hardware costs.
Humans in space	Most see their technology as helping to lay the foundation for enabling large-scale human settlements in space.

Sputnik (1957), a pattern that also is evident across many allied nations (see Figure 2).[5]

For US space technology, this financial shift from public sector to private sector is arguably no surprise given the findings of a 2004 presidential commission on US space exploration, which recommended that:

> NASA recognize and implement a far larger presence of private industry in space operations with the specific goal of allowing private industry to assume the primary role of providing services to NASA. NASA's role must be limited to only those areas where there is irrefutable demonstration that government can perform the proposed activity.[6]

As a result of the commission's findings, Congress created the Commercial Orbital Transportation Services Program, which sought to create new incentives to support the privatization of both upstream and downstream space activities.[7] In short, the aim of this legislation was to create market forces that would enhance innovation while driving down costs through competition.

To do this, a new approach was developed to shape the relationship between NASA and its private contractors. Instead of being a supervisor, NASA became a partner and customer of these companies. This shift was reflected in the change of contract type, replacing cost-plus procurement with fixed-price payments for generic capabilities such as cargo delivery, disposal, or return, and crew transportation to low-Earth orbit (LEO).[8] As a result, the risk was transferred from NASA to private firms, leading to less intensive government monitoring of cost-plus contracts and more encouragement of innovation.

Ripple Effects

In recent years, the European Space Agency (ESA) has also prioritized commercialization activities. This, too, was

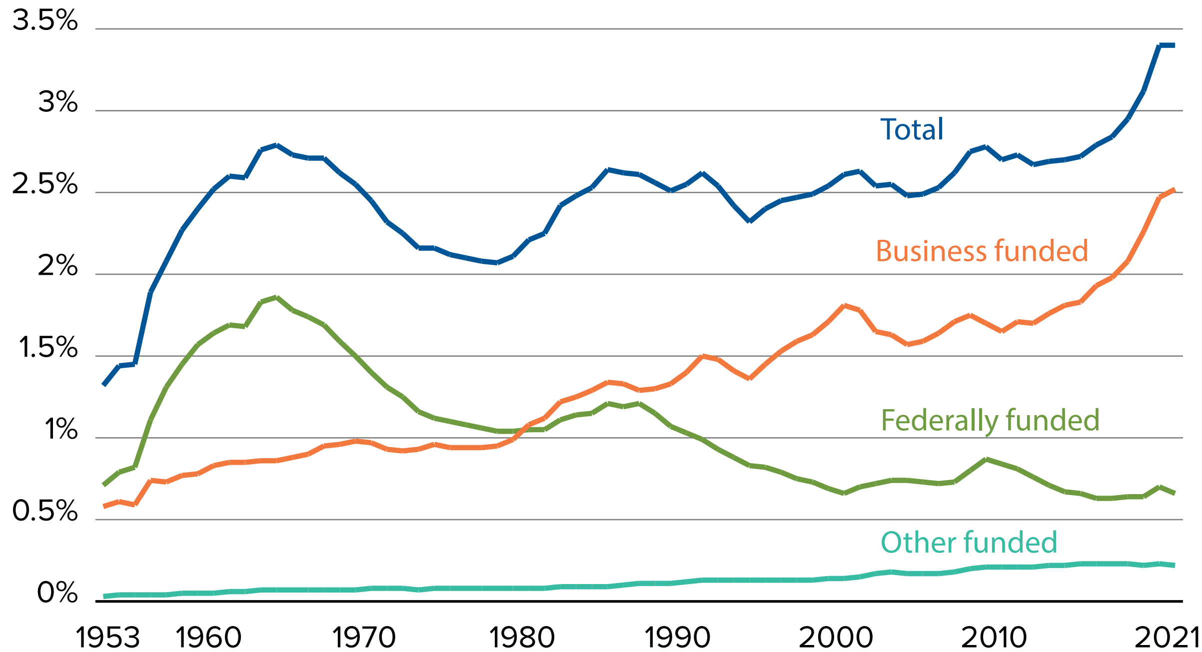
5 Gary Anderson, John Jankowski, and Mark Boroush, "U.S. R&D Increased by $51 Billion in 2020 to $717 Billion; Estimate for 2021 Indicates Further Increase to $792 billion," National Center for Science and Engineering Statistics, January 4, 2023, https://ncses.nsf.gov/pubs/nsf23320 and https://eda.europa.eu/docs/default-source/brochures/eda---defence-data-2021---web---final.pdf

6 *A Journey to Inspire, Innovate, and Discover*, Report of the President's Commission on the Implementation of United States Space Exploration Policy, June 2004, https://www.nasa.gov/pdf/60736main_M2M_report_small.pdf.

7 The upstream market can be thought of as: satellite manufacturing; launch capabilities; and ground control stations. The downstream market can be thought of as: space-based operations and services provided, such as satellites and sensors.

8 Matthew Weinzierl, "Space, the Final Economic Frontier," *Journal of Economic Perspectives* 32, no. 2 (Spring 2018): 173–192, https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.32.2.173.

Figure 2: US gross domestic product, R&D, and ratio of R&D to gross domestic product (and components): 1953–2021



Source: United States National Science Foundation, https://ncses.nsf.gov/pubs/nsf23321.

an outcome of political and economic pressure to rethink European space policy to provide products and services for consumers, with a specific focus on downstream space activities. This policy shift toward greater commercialization was driven, in part, by those structural changes (i.e., competition) emerging from the United States (NASA).[9]

Likewise, in India—following a 2020 change in Indian space policy—private firms are no longer only suppliers to the government, but the government is now supporting and investing in them, similar to the NASA model.[10] These and other shifts in public policy have shaped much of the market we have today.[11]

However, this market arguably represents a challenge to government control over NewSpace firms and their technologies. NewSpace companies operate with more agility and flexibility than traditional government-led programs.[12] This rapid pace of innovation and commercial competition can make it difficult for governments to keep up with regulatory frameworks and oversight. Additionally, the increasing role of the private sector in space activities is arguably leading to a diffusion of state control, making it more challenging for governments to ensure the responsible use of space and manage potential security risks associated with dual-use technologies. Therefore, governments should look to partner, co-develop, and invest in NewSpace firms as alternative ways to influence the sector. Such an approach carries impacts not only on public-sector capital flows but also on national security paradigms.

The Global Space Market

The space industry is a rapidly growing market that can bring about both commercial and national security benefits: the total sector was valued at $464 billion in 2022 and is expected to reach around $1.1 trillion by 2040, with a projected compound annual growth rate (CAGR) of around 7

9 Douglas K. R. Robinson and Mariana Mazzucato, "The Evolution of Mission-oriented Policies: Exploring Changing Market Creating Policies in the US and European Space Sector," *Research Policy* 48, no. 4 (2019): 936-948, https://doi.org/10.1016/j.respol.2018.10.005.

10 "Indian Startups Join the Space Race," *Economist*, November 24 2022, https://www.economist.com/business/2022/11/24/indian-startups-join-the-space-race.

11 Robinson and Mazzucato, "The Evolution of Mission-oriented Policies."

12 Amritha Jayanti, "Starlink and the Russia-Ukraine War: A Case of Commercial Technology and Public Purpose," Belfer Center for Science and International Affairs, Harvard Kennedy School, March 9, 2023, https://www.belfercenter.org/publication/starlink-and-russia-ukraine-war-case-commercial-technology-and-public-purpose.

This image from April 24, 2021, shows the SpaceX Crew Dragon Endeavour as it approached the International Space Station less than one day after launching from Kennedy Space Center in Florida. Source: NASA, https://www.flickr.com/photos/iip-photo-archive/51149622563/.

percent.[13] Of today's total market, the commercial sector accounts for around 75 percent.[14] To put this in perspective, the 2021 global aerospace industry saw the top ten earning companies generate a combined revenue of $417.15 billion.[15] Breaking this down further, the United States is currently the largest market for both public and private space activity, holding a 32 percent market share, while Europe and the United Kingdom hold a combined 23 percent.[16]

However, Asia has experienced the most significant growth in this market over the last five years and now holds 25 percent of the market share.[17] In terms of satellite launches, China has been the most active country in the region, with a total of sixty-four launches in 2022, placing it behind only the United States, which launched eighty-seven times that year.[18] Trailing China is India, which deployed over fifty satellites across four separate launches in 2022. [19]

In China and India alike, commercial firms are supported by both government R&D and public programs designed for national needs (including requisite contracts), as well as mature commercial markets that demand advanced satellite systems.

13 "Space Foundation Releases the Space Report 2022 Q2 Showing Growth of Global Space Economy," Space Foundation News, July 27, 2022, https://www.spacefoundation.org/2022/07/27/the-space-report-2022-q2/; and "Space: Investing in the Final Frontier," Morgan Stanley, July 24, 2020, https://www.morganstanley.com/ideas/investing-in-space.

14 "Space Economy Report 2022," Ninth Edition, Euroconsult, January 2023, https://digital-platform.euroconsult-ec.com/wp-content/uploads/2023/01/Space-Economy-2022_extract.pdf?t=63b47c80afdfe.

15 Erick Burgueño Salas, "Leading Aerospace and Defense Manufacturers Worldwide in 2021, Based on Revenue," Statista, November 27, 2022, https://www.statista.com/statistics/257381/global-leading-aerospace-and-defense-manufacturers/.

16 "Space Economy Report 2022," Ninth Edition, Euroconsult, January 2023, https://digital-platform.euroconsult-ec.com/wp-content/uploads/2023/01/Space-Economy-2022_extract.pdf?t=63b47c80afdfe.

17 "Space Economy Report 2022."

18 Andrew Jones, "China Wants to Launch Over 200 Spacecraft in 2023," *Space.com*, January 27, 2023, https://www.space.com/china-launch-200-spacecraft-2023.

19 2022: A Year of Many Firsts for Indian Space Sector," World Is One News (WION), updated December 30, 2022, https://www.wionews.com/science/2022-a-year-of-many-firsts-for-indian-space-sector-heres-a-recap-548099; and "List of Satish Dhawan Space Centre Launches," Wikipedia, accessed April 12, 2023, https://en.wikipedia.org/wiki/List_of_Satish_Dhawan_Space_Centre_launches.

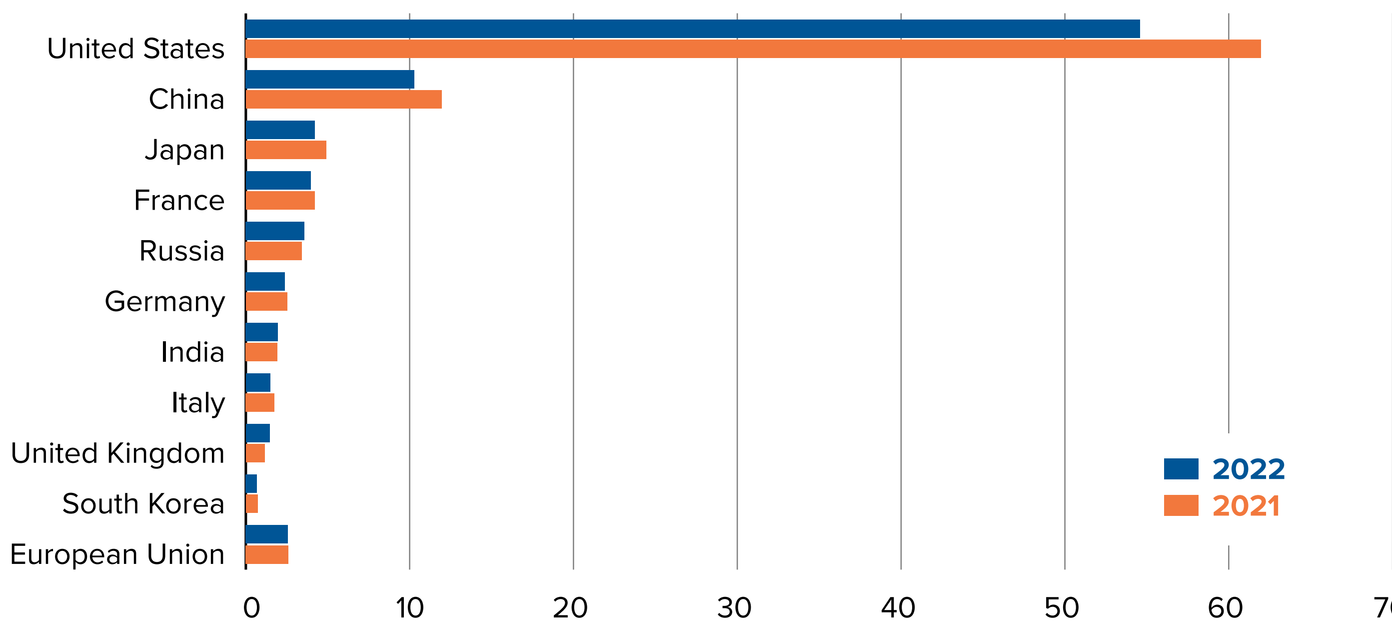
What this translates to is an upstream market that relies on government funding to thrive, while the downstream market is more evenly distributed and does not require significant upfront investment or government contracts to sustain itself. This downstream market is currently driven by NewSpace demand for connectivity and location-based services, and its growth is influenced by demographic and regional economic trends, as well as government efforts to close the digital divide as governments finance satellite connectivity.[20]

Challenges to and Opportunities for NewSpace Industry Growth

The key challenges to NewSpace industry growth are the regulatory landscape and access to financing. This is evidenced by the European NewSpace ecosystem where, at a structural level, regulatory frameworks do not facilitate the scaling of the financial resources (public and/or private) necessary to match the political and commercial intent (demand) espoused by European political and business leaders. This mismatch between demand and financial firepower results in slower development and uptake of NewSpace opportunities despite significant engineering and entrepreneurial talent residing within Europe.[21] Figure 3 shows the breakdown of global government investment in space technologies between 2020 and 2022 in real terms, and figure 4 shows how such expenditure relates to GDP, while figure 5 shows the global private sector space investment breakdown, which highlights a significant role for venture capital (VC) firms.[22]

Noting that the United States accounts for almost half of the world's available VC funds, while Europe only accounts for around 13 percent, it is evident that the sheer scale of investment from the United States enables NewSpace to flourish within the US market, while many allies and partners struggle to access private funding.[23] For Europe to embrace the NewSpace model, conditions must foster timely connections between both public and private finance and NewSpace

Figure 3: Government Expenditure on Space Programs in 2020 and 2022, by Major Company (in billions of dollars)



Source: Statista, https://www.statista.com/statistics/666095/value-of-investments-in-space-ventures/, accessed through author's Imperial College London account.

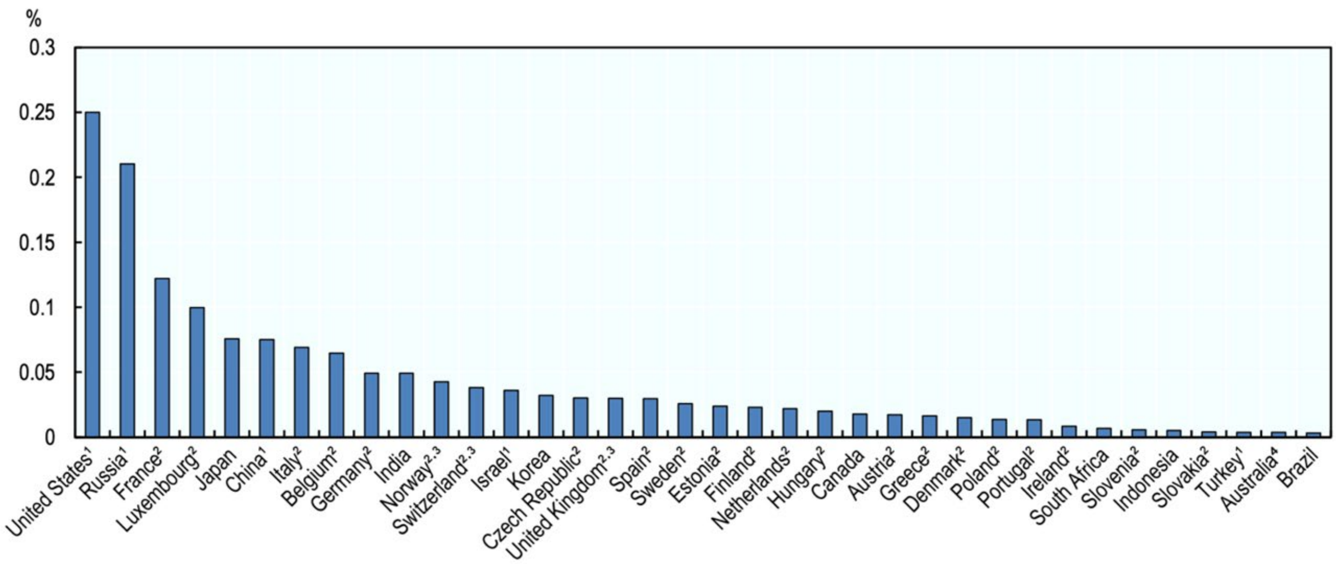
20 "Space Economy Report 2022."

21 OECD Space Forum, *Measuring the Economic Impact of the Space Sector,* Organisation for Economic Co-operation and Development, October 7, 2020, https://www.oecd.org/sti/inno/space-forum/measuring-economic-impact-space-sector.pdf.

22 "Space Industry Worldwide," Statista, 2020, https://www.statista.com/study/59030/space-exploration/; and *OECD Handbook on Measuring the Space Economy*, Second Edition, OECD, July 12, 2022, https://www.oecd-ilibrary.org/docserver/8bfef437-en.pdf?expires=1678223695&id=id&accname=guest&checksum=34A62A18C888485A89F58BE6E5841B30.

23 "Value of Venture Capital Financing Worldwide in 2020 by Region," Statista, April 13, 2022, https://www.statista.com/statistics/1095957/global-venture-capita-funding-value-by-region/.

Figure 4: Government Space Budget Allocations for Selected Countries and Economies (measured as a share of GDP in 2020)



Source: The Organization for Economic Cooperation and Development, https://www.oecd-ilibrary.org/sites/8bfef437-en/1/3/3/index.html?itemId=/content/publication/8bfef437-en&_csp_=960b4892f748598a5607cbccfc369a41&itemIGO=oecd&itemContentType=book#figure-d1e8930

opportunities.[24] That said, given the deep technology nature of NewSpace, and the long time horizons for venture capitalists to see a return, financing this sector writ large remains a challenge.

In addition to attracting financing, the business models of NewSpace companies rely on foundational technologies—often resourced by governments—to be in place. Such technologies include: access to low-cost launch capabilities; conditions for in-space manufacturing and resource extraction for space-based production; foundational research to support space-based energy collection, combined with reliable radiation shielding; and debris mitigation efforts in an increasingly busy orbital environment. This indicates that there is a persistent role for governments to actively invest in deep technologies to help foster the commercial markets that NewSpace can bring about. Only governments have the financial risk tolerance (a tolerance that takes one beyond risk and into uncertainty) to undertake such endeavors.

While each of these foundational technologies has limited profitability, together they form a self-sustaining system with enormous potential for profit when subsequently exploited through relatively cheap NewSpace technologies. Indeed, the economics of human space activities often mean that the whole is greater than the sum of its parts. To that end, one might envisage how a potential self-reinforcing development cycle would support the space economy, with cheaper and more frequent rocket launches enabling short-term tourism and industrial and scientific experimentation, leading to demand for commercial space habitats, which would then create demand for resources in space. However, it is doubtful that this path will be easily achieved without government support.[25]

In addition to traditional space-based areas of monitoring, observation, and communications, the sectors listed above offer further commercial opportunities NewSpace is likely to exploit.[26]

Allied Advancements in NewSpace

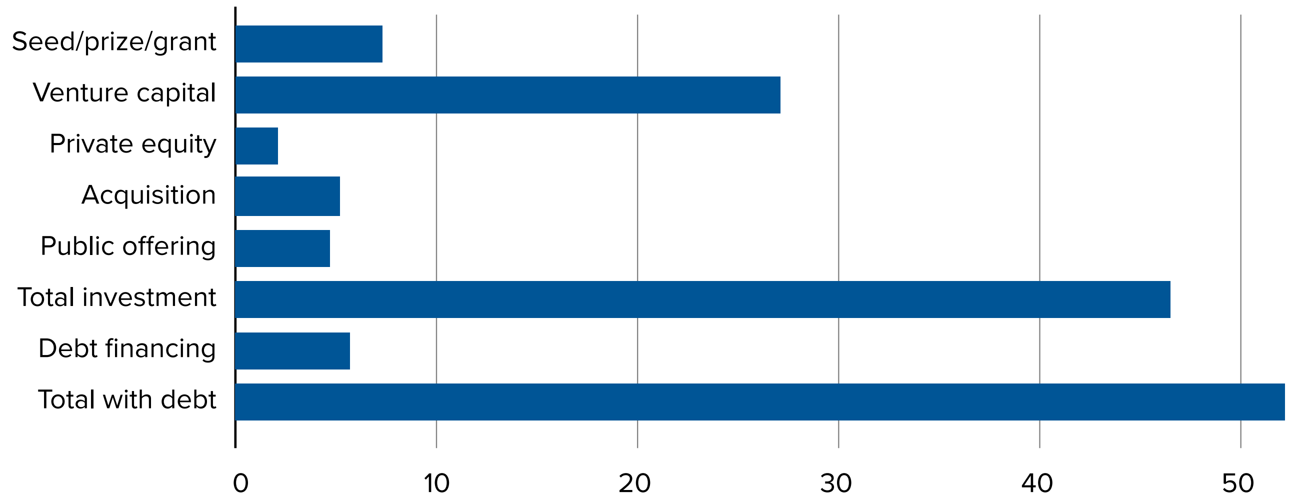
While the above table represents a broad perspective, many US allies and partners are already at the leading edge of aggregating NewSpace technologies to take advantage of growing markets.

24 Matteo Tugnoli, Martin Sarret, and Marco Aliberti, *European Access to Space: Business and Policy Perspectives on Micro Launchers* (New York: Springer Cham, 2019), https://doi.org/10.1007/978-3-319-78960-6.

25 Weinzierl, "Space, the Final Economic Frontier."

26 James Black, Linda Slapakova, and Kevin Martin, *Future Uses of Space Out to 2050*, RAND Corporation, March 2, 2022, https://www.rand.org/pubs/research_reports/RRA609-1.html.

Figure 5: Value of investments in space ventures worldwide from 2000 to 2021, by type (in billion U.S. dollars)



Source: Statista, March 23, 2023, https://www.statista.com/statistics/666095/value-of-investments-in-space-ventures/, accessed through author's Imperial College London account.

In **Denmark**, the government and private commercial actors are working on project BIFROST, with plans to launch in early 2024. BIFROST is a satellite-based system for advanced on-orbit image and signal analysis that aims to demonstrate artificial intelligence-based surveillance from space. The satellite will have versatile payloads on board to provide information on applied AI in space for Earth-observation missions—detecting ships, oil spills, and more. The main purpose of the mission is to establish: "a platform in space for gaining further experience in AI-based surveillance and sensor fusion using multiple on-board sensors. The satellite will also test means of communication between different satellites to achieve real-time access to intelligence data and demonstrate the feasibility of tactical Earth observation."[27] Additionally, the mission will evaluate the capability of changing AI models during its lifespan to improve the surveillance system.[28]

In **Sweden** and **Germany**, OHB (a German-based European technology company) is working with **Swiss** start-up ClearSpace SA for its space debris removal mission, ClearSpace-1. OHB will provide the propulsion subsystem and be responsible for the complete satellite assembly, integration, and testing. The mission is aimed at demonstrating the ability to remove space debris and establishing a new market for future in-orbit servicing. The mission will target a small satellite-sized object in space and be launched in 2025. Carrying a capture system payload—"Space Robot," developed by the ESA and European industry—it will use AI to autonomously assess the target and match its motion, with capture taking place through robotic arms under ESA supervision. After capture, the combined object will be safely deorbited, reentering the atmosphere at the optimum angle to burn up.[29]

In **Belgium**, entities such as Interuniversity Microelectronics Centre, known as imec, are at the leading edge of developing nanotechnology that is being commercialized for space. Imec's Lens Free Imaging system is a new type of microscopic system that is not dependent on traditional optical technologies and fragile mechanical parts. Instead, it operates through the principle of digital holography, which allows images to be reconstructed afterward in software at any focal depth. This eliminates the need for mechanical focusing and the stage drift that occurs during time-lapse image acquisition, making it a more robust and compact system suitable for use in space.[30] Imec is also perfecting manufacturing in space leveraging microgravity, which minimizes "gravitational forces and enables the production of goods that either could not be produced on Earth or that can be made with superior quality. This is particularly relevant for applications such as drug compound production; target receptor discovery; the growth of larger, higher-quality crystals in solution; and the fabrication of silicon

27 "BIFROST: Danish Project with International Collaboration to Explore AI-based Surveillance Applications from Space," Gatehouse Satcom (website), August 22, 2022, https://gatehousesatcom.com/bifrost-danish-project-with-international-collaboration-to-explore-ai-based-surveillance-applications-from-space/.

28 "Terma Delivers AI Model for Danish Surveillance Satellite Project," Defence Industry Europe, January 28, 2023, https://defence-industry.eu/terma-delivers-ai-model-for-danish-surveillance-satellite-project/.

29 "OHB Sweden Contributes to ClearSpace-1 Mission," December 8, 2020, OHB, https://www.ohb.de/en/news/2020/ohb-sweden-contributes-to-clearspace-1-mission.

30 "Imec Technology Taking Off to Space," Imec (website), January 25, 2021, https://www.imec-int.com/en/articles/imec-technology-taking-space.

Figure 6: Commercial Opportunities for NewSpace Companies

SECTOR	OVERVIEW OF USE CASE
Agriculture	Space agriculture and space-based support for terrestrial farming.
Climate protection	Space applications for environmental conservation and combating climate change.
Energy	Space energy creation and use for both terrestrial and space-based activities.
Manufacturing, servicing, and debris removal	Building, repairing, and maintaining space-based structures, as well as manufacturing in space and monitoring terrestrial infrastructure.
Mining	Space-based mining and monitoring of terrestrial mining.
Tourism	Space-based tourism.
Communications	Space-based secure communications.

wafers or retinal implants using a layer-by-layer deposition processes,"[31] all of which are enhanced in microgravity.

In the **United Kingdom**, collaboration between the agricultural and space sectors seeks to enhance societal resilience through more efficient and self-sustaining crop production. Research entities such as the Lincoln Institute for Agri-Food Technology is commercializing technologies on LEO satellites to improve the spatial positioning of robots in agriculture to enhance their precision weeding, nutrient deployment, and high-resolution soil sampling capabilities.[32] Furthermore, UK start-ups such as Horizon Technologies have developed novel ways of creating signals intelligence focusing on specific parts of the electromagnetic spectrum, allowing the company to leverage meta data for both commercial and government clients. An important component to Horizon's success is the reduction in productions costs combined with accessibility to space launches.

Across **Europe**, the ESA is conducting R&D to harness the sun's solar power in space and distribute that energy to Earth. Under Project Solaris, space-based solar power is harvesting sunlight from solar-power satellites in geostationary orbit, which is then converted into microwaves, and beamed down to Earth to generate electricity. For this to be successful, the satellites would need to be large (around several kilometers), and Earth-surface rectennas[33] would also need to be on a similar scale. Achieving such a feat would enhance Earth's energy resilience, but would first require advancements in in-space manufacturing, photovoltaics, electronics, and beam forming.[34]

The **United States** also partners with **allied firms** on foundational research to support upstream and downstream NewSpace technologies. The Defense Advanced Research Projects Agency (DARPA) Space-Based Adaptive Communications Node (BACN) is a laser-enabled military internet that will orbit Earth. The Space-BACN will create a network that piggybacks on multiple private and public satellites that would have been launched regardless, using laser transceivers that are able to communicate with counterparts within 5,000 km. The satellite network will be able to offer high data rates and automatic rerouting of a message if a node is disabled, and it will be almost impossible to intercept transmissions. DARPA is working with Mynaric, a German firm, which designs heads for Space-BACN, and MBryonics, an Irish contractor, which uses electronic signals to alter light's phase, with the aim of having a working prototype in space in 2025.[35]

While US allies and partners offer a plethora of specific space-based commercial opportunities, the criteria for successful development remains constant: the combination of multiple technologies, reduction in production and maintenance costs, and safe access to operate in space. With that in mind, the US government can play two roles to help further expand this market:

31 "Imec Technology Taking Off."

32 "Lincoln Institute for Agri-Food Technology," homepage accessed February 2023, https://www.lincoln.ac.uk/liat/.

33 A rectenna (rectifying antenna) is a special type of receiving antenna that is used for converting electromagnetic energy into direct current (DC) electricity.

34 "Wireless Power from Space," European Space Agency, September 11, 2022, https://www.esa.int/ESA_Multimedia/Images/2022/11/Wireless_power_from_space.

35 "DARPA, Lasers and an Internet in Orbit," *Economist*, February 8, 2023, https://www.economist.com/science-and-technology/2023/02/08/darpa-lasers-and-an-internet-in-orbit.

The SpaceX Falcon 9 rocket carrying the Dragon capsule lifts off from Launch Complex 39A at NASA's Kennedy Space Center in Florida on July 14, 2022. Source: SpaceX, https://commons.wikimedia.org/wiki/File:NASA-SpaceX_CRS-25_Liftoff_(KLS01-0007).jpg.

- Act as a reliable, adroit customer who can issue contracts quickly (noting that many NewSpace firms do not carry large amounts of working capital and therefore cannot wait months for contractual confirmation).

- Continue to invest in deep technologies and develop those foundational upstream building blocks that NewSpace will seek to leverage.

Notably, however, some US executives are deliberately registering firms in allied jurisdictions and conducting all research and patenting there, too, to avoid the bureaucratic challenges of dealing with US International Traffic in Arms Regulations (ITAR) and, specifically, the tight controls associated with exporting NewSpace dual-use products for commercial use. This suggests two things: The first is that, while allies may lack financial firepower, they have jurisdictional strengths that can attract NewSpace firms to their shores; and the second is that US ITAR controls impacting dual-use technologies need to be updated to enable NewSpace firms to thrive. If such companies are blocked from selling to allied and partner markets, then the very model of dual-use becomes diminished and governments will be unable to benefit from the competition and iterative technology development that spill over from such commercial settings into the public sector. As Figure 2 shows, the US government does not currently invest enough in technologies relative to the private sector to enable such a stringent export controls program in the context of NewSpace. The two policies are incongruous: limited government R&D spending and excessive export controls.

Recommendations for US and Allied Policymakers

Taking all the above into account, US and allied policymakers should focus on enhancing regulations and financial resources. Governments need to continue to create the conditions for the NewSpace market to prosper by playing the roles of a *nimble customer* and *deep technology investor*, enabling NewSpace companies to quickly access government contracts, while also helping mature next-generation space-based technologies. This helps such companies grow, become competitive, and enhance the sector. Specifically, US and allied governments should consider the following:

Recommendation #1: US and allied governments must continue to provide a stable and progressive regulatory environment for the NewSpace industry. This includes providing a clear and predictable legal framework for commercial space

An increasing number of nations are launching an increasing number of space missions. United Launch Alliance Atlas V rocket carries Cygnus cargo vessel OA-6 for commercial resupply services supporting the International Space Station. Credit: United States Air Force Flickr, https://www.flickr.com/photos/usairforce/25422547293/.

activities, as well as ensuring that regulations are flexible and adaptable to the rapidly changing technology and business models of the industry. ITAR is one area that needs urgent reform, given the dual-use nature of many new space technologies. This problem is exemplified by US talent establishing next-generation space companies in Europe to avoid overly controlling and outdated ITAR constraints, according to interviews with industry participants.[36] Given the cross-cutting nature of ITAR, the US National Security Council should examine ITAR rules and their utility for dual-use technologies impacting NewSpace, assessing such rules from a holistic perspective covering defense, trade, and economics.

Recommendation #2: US and allied governments should maximize coinvestment with industry in R&D to support the codevelopment of new technologies and capabilities for both the public and private sectors. This includes funding for research into new propulsion systems, as well as materials and nanotechnologies that will enable more cost-effective and reliable access to space. To support such funding—and noting the challenge of private investment finding its way to allied entrepreneurs and engineers—the US government should consider establishing with allies and partners a new multilateral lending institution (MLI) focused on space technology to provide funding and other forms of support to companies in the commercial space industry. The MLI or "space bank" could provide loans, grants, loan guarantees, insurance, and other forms of financial assistance to companies engaged in commercial space activities, helping to mitigate the high costs and risks associated with space ventures. This could be modeled after any of the MLIs of which the United States is already a member.[37]

Recommendation #3: Furthermore, the US government could provide tax credits and grants to NewSpace firms (US and allied) based on certain provisions that support wider government objectives—such as manufacturing locations, supply network participants, and expected labor market impacts.

Any such credits and grants should be complemented by leveraging a suitable financial vehicle to conduct direct

36 Author's video interview with multiple American NewSpace executives, December 2022.

37 Rebecca Nelson, *Multilateral Development Banks: U.S. Contributions FY2000-FY2020*, Congressional Research Service, January 23, 2020, https://sgp.fas.org/crs/misc/RS20792.pdf.

investment to take equity in NewSpace firms both at home and abroad. Crucially, this should be conducted without the government owning any of the intellectual property, as this impacts export opportunities and thus undermines the dual-use model. Such an effort would go some way in minimizing the socialization of risk and the privatization of rewards, and could be a role for either In-Q-Tel and/or the Department of Defense's new Office of Strategic Capital.[38]

Recommendation #4: To further support such an approach, the US government might create a national space co-R&D center of excellence for government and industry to work hand in glove to drive the codevelopment of breakthrough technologies, taking inspiration from a conceptually similar UK model of designing government contracts to address specific problems and awarding them to capable small companies.[39]

Conclusion

NewSpace is making significant strides in developing cost-effective and innovative technologies for both public- and private-sector customers. This is important because it drives economic growth and can enhance national security through the delivery of new, cost-effective, and resilient technologies. Indeed, the NewSpace market is unquestionably growing, and governments, including the United States and its allies, have a critical role to play in shaping this market by acting as both customers and codevelopers with NewSpace firms. Such an approach allows governments to exert a degree of influence in the sector without constraining its creativity. However, this way of working may carry wider implications for national security paradigms in terms of dual-use technologies and public/private partnerships.

While use cases for NewSpace are almost limitless, multiple US allies and partners are already forging niche NewSpace areas of excellence that can bring about a degree of comparative advantage. To make best use of such opportunities, the United States should:

1. Keep its market as open as possible to encourage competition and thus drive innovation.

2. Provide specific programs and locations for codevelopment between allied academia, government, and industry without taking any intellectual property.

3. Act as a nimble customer.

4. Ensure there is a pragmatic balance between regulations that protect US space interests (i.e., ITAR) and those that unleash innovative dual-use endeavors.

5. Create new financial instruments with allies through an MLI bank to support the financial investment needed to help the private sector commercialize the next generation of breakthrough space-based technologies.

About the Author

Rob Murray is a senior lecturer at Johns Hopkins University. During his twenty-five-year career, he has focused on the convergence of technology, finance, and national security. Prior to Johns Hopkins, Murray worked for almost a decade on the secretary general's political staff at NATO headquarters, Brussels. At NATO, Murray held multiple policy roles including head of intelligence, surveillance, and reconnaissance, and most recently he was the Alliance's head of innovation. In the innovation role, Murray conceived and led the successful negotiations among allies for the creation of a NATO Defense Advanced Research Projects Agency (known as the Defence Innovation Accelerator for the North Atlantic, or DIANA), and a multisovereign venture capital fund to invest in deep technologies. He also wrote and negotiated the world's first multilateral artificial intelligence strategy that includes principles of responsible use for all NATO nations. Before NATO, Murray was a British Army Officer for twelve years specializing in surveillance and reconnaissance. He deployed on operations all over the world leading multiple teams in various environments. Academically, Murray holds a master of international relations from Staffordshire University, a master of science in intelligence management from the University of Lincoln, and a master of business administration from the University of Chicago's Booth School of Business. He is an Honorary Practice Fellow of Imperial College London, and sits on several advisory boards.

38 In-Q-Tel is an independent, nonprofit strategic investor for the US intelligence community, created in 1999, https://www.iqt.org; The US Secretary of Defense created the Office of Strategic Capital (announced December 2022), https://www.cto.mil/osc/.

39 "Niteworks," UK Ministry of Defence, March 28, 2018, https://www.gov.uk/government/collections/niteworks; and "UK MOD Front Line Commands Set to Benefit from New Decision Support Capability That Replaces Former Niteworks Service," Qinetiq, June 4, 2021, https://www.qinetiq.com/en/news/futures-lab.

Beyond Launch: Harnessing Allied Space Capabilities for Exploration Purposes

by TIFFANY VORA, PHD

The "United States Space Priorities Framework," released in December 2021, confirmed the White House's commitment to American leadership in space.[1] Space activities deliver immense benefits to humankind. For example, satellite imaging alone is crucial for improvements in daily life such as weather monitoring as well as for grand challenges like the fight against climate change. Such breakthrough discoveries in space pave the way for innovation and new economies on Earth. Exploration is at the cutting edge of this process: it expands humankind's knowledge of the universe, transforming the unknown into the supremely challenging, expensive, risky, and promising. US allies and partners accelerate this transformation *via* scientific and technical achievements as well as processes, relationships, and a shared vision for space exploration. By integrating these allied capabilities, the United States and its allies and partners set the stage for safe and prosperous space geopolitics and economy in the decades to come.

However, harnessing the capabilities of US allies and partners for space exploration is complex, requiring the balance of relatively short-term progress with far-horizon strategy. Space exploration has changed since the US-Soviet space race of the 1960s. In today's rapidly evolving technological and geopolitical environment, it is unclear whether the processes, relationships, and vision that previously enabled allied cooperation in space, epitomized by the International Space Station (ISS), will keep pace. Here, China is viewed as the preeminent competitor for exploration goals and capabilities—as well as the major competitor for long-term leadership in space.[2] This development drives fears of space militarization and weaponization, prompting protectionist legislation, investment screening, and industrial policies that can disrupt collaboration among the United States and its key allies and partners.[3] Further complication stems from the rise of commercial space, with opportunities and challenges due to the decentralization, democratization, and demonetization of technologies for robotic and crewed space exploration.

This paper serves as a primer for current US space exploration goals and capabilities that will be critical to achieving them. It highlights arenas where US allies and partners are strongly positioned to jointly accelerate space exploration while also benefitting life on Earth. This paper concludes with recommended actions—gleaned from interviews with international experts in space exploration—for the US government as well as allied and partner governments to increase the number and impact of global stakeholders in space exploration, to remove friction in collaboration, and to guide the future of space toward democratic values.

Current Space Exploration Efforts

Over the next few decades, US and allied space exploration will integrate uncrewed (robotic) and crewed missions to achieve scientific discovery, technological advancement, economic benefits, national prestige, and planetary defense.

Uncrewed space exploration missions generally focus on expanding fundamental scientific knowledge and laying the foundation for future activities such as resource extraction. Collaborators include the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) and member space agencies, and the space agencies of India, Japan, South Korea, Israel, and the United Arab Emirates (UAE), with public-private partnerships delivering additional capabilities.[4] Several missions to Mars will study the planet's geology, atmosphere, and possible past or current life, with sample-return missions currently scheduled by

1 "United States Space Priorities Framework," White House, December 2021, https://www.whitehouse.gov/wp-content/uploads/2021/12/united-states-space-priorities-framework-_-december-1-2021.pdf.

2 "China's Space Program: A 2021 Perspective," State Council Information Office of the People's Republic of China, January 28, 2022, http://www.china.org.cn/china/2022-01/28/content_78016843.htm.

3 "Rethinking Export Controls: Unintended Consequences and the New Technological Landscape," Commentary series on expert controls, Center for a New American Security, accessed March 23, 2023, https://www.cnas.org/publications/reports/rethinking-export-controls-unintended-consequences-and-the-new-technological-landscape.

4 "Our Missions," European Space Agency, accessed February 14, 2023, https://www.esa.int/ESA/Our_Missions; and Gary Daines, "Solar System Missions," National Aeronautics and Space Administration, March 11, 2015, http://www.nasa.gov/content/solar-missions-list.

To project leadership in space exploration, the United States and its allies and partners ought to be first in returning humans to the Moon. Source: US Navy, https://www.dvidshub.net/image/6159909/moon.

NASA and the ESA for the early 2030s.[5] The search for conditions suitable to life will be extended to other locations in the solar system, such as the moons of Jupiter and Saturn. Robotic missions will continue to increase understanding of the Sun, Mercury, Venus, the Moon, asteroids, Jupiter and its moons, and deep space. Observational studies of planets outside our solar system, black holes, comets, stars, and galaxies will be enabled by space telescopes and other imaging modalities. Uncrewed exploration goals are also being pursued by the China National Space Administration, with particular attention to its planned International Lunar Research Station.[6] Note that important technological gaps in robotic space exploration—such as dust mitigation[7] and space situational awareness[8]—are being tackled by critical research and development by US partners and allies.

Crewed space exploration objectives for the United States and its allies and partners are encapsulated by the Moon to Mars roadmap,[9] an integrated strategy that, over the next several decades, will synergize exploration goals in low-Earth orbit (LEO), cislunar space, and Mars. Within this roadmap, for which all timelines may shift, the Artemis program will return humans (including the first woman and person of color) to the Moon no earlier than 2025, with the long-term goal of establishing a sustainable human presence on the lunar surface.[10] The Artemis program will use the heavy-lifter Space Launch System (SLS) and the Orion spacecraft to send astronauts and payloads to a space station in lunar orbit called the Gateway. From there, the Human Landing System will transport them to and from the Artemis Base Camp on the lunar surface (note that mission details are still

5 Timothy Haltigin et al., "Rationale and Proposed Design for a Mars Sample Return (MSR) Science Program," *Astrobiology* 22, no. S1, June 2022, https://doi.org/10.1089/ast.2021.0122.

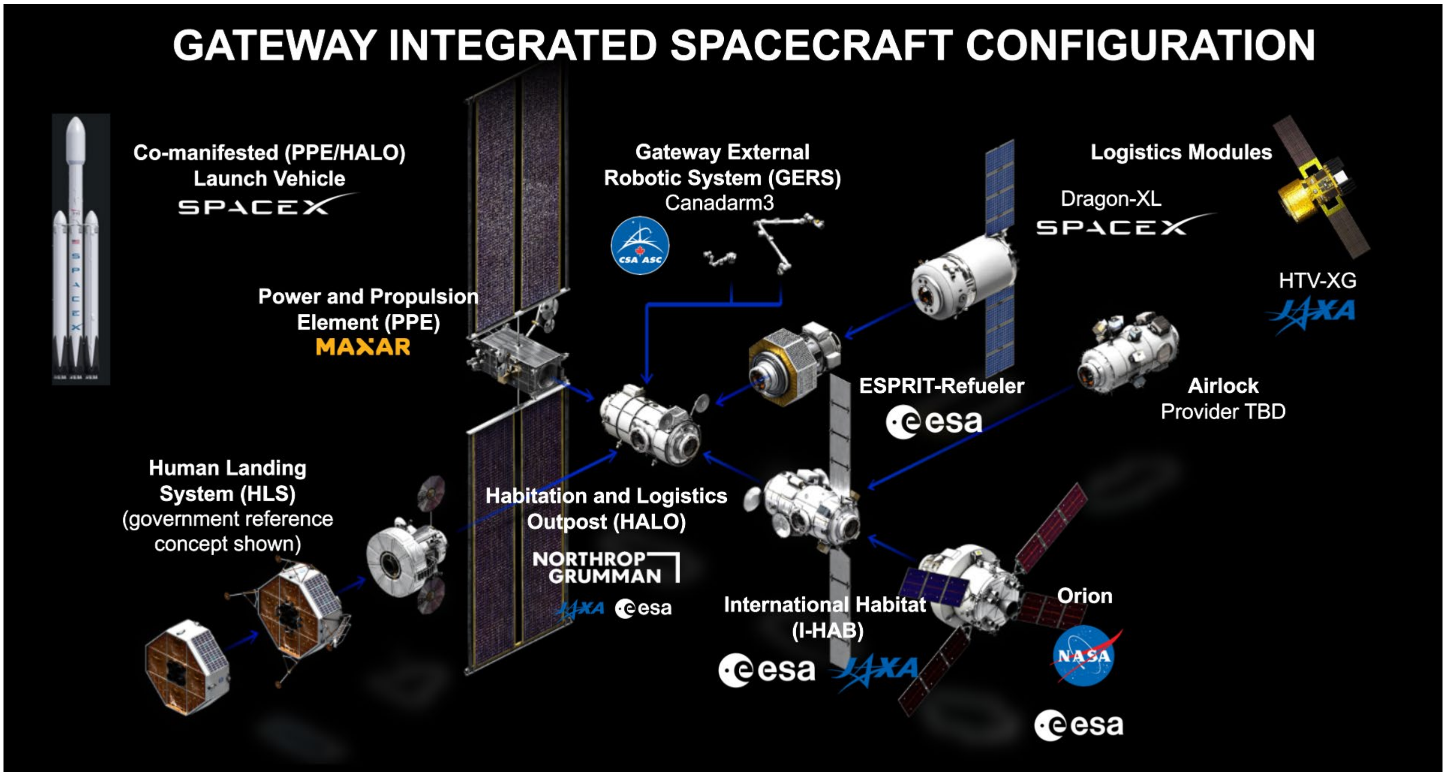
6 Andrew Jones, "China Outlines Pathway for Lunar and Deep Space Exploration," *SpaceNews*, November 28, 2022, https://spacenews.com/china-outlines-pathway-for-lunar-and-deep-space-exploration/.

7 Scott Vangen et al., "International Space Exploration Coordination Group Assessment of Technology Gaps for Dust Mitigation for the Global Exploration Roadmap," in *AIAA SPACE 2016* (American Institute of Aeronautics and Astronautics), accessed March 23, 2023, https://doi.org/10.2514/6.2016-5423.

8 Daniel L. Oltrogge and Salvatore Alfano, "The Technical Challenges of Better Space Situational Awareness and Space Traffic Management," *Journal of Space Safety Engineering* 6, no. 2 (June 1, 2019): 72–79, https://doi.org/10.1016/j.jsse.2019.05.004.\\uc0\\u8221{} {\\i{}Journal of Space Safety Engineering}, Space Traffic Management and Space Situational Awareness, 6, no. 2 (June 1, 2019

9 "Moon to Mars Objectives: Executive Summary," NASA, September 2022, https://www.nasa.gov/sites/default/files/atoms/files/m2m-objectives-exec-summary.pdf.

10 S. Creech, J. Guidi, and D. Elburn, "Artemis: An Overview of NASA's Activities to Return Humans to the Moon," *2022 IEEE Aerospace Conference (AERO)*, Big Sky, Montana, 2022, 1–7, https://doi.org/10.1109/AERO53065.2022.9843277.



Concept art for NASA's Gateway Program, which includes elements from international partners and government partners. Source: NASA, https://www.nasa.gov/gateway/overview.

being refined). The program involves crucial contributions from allied governments and industries. Hardware, software, and lessons learned from the Artemis program and other activities in LEO and on the ISS will lay the foundation for Mars:[11] human exploration (generally projected for the 2030s), scientific investigation, and eventual permanent settlement.[12] In particular, the Gateway serves important roles in infrastructure development (e.g., supply chains) and better understanding of the effects of extended deep-space missions on the human body—both crucial aspects of crewed space exploration.

International partners are critical for the success of the Artemis program. They are providing expertise, technology, and funding across the spectrum from basic science and engineering to specific software and hardware mission deliverables. A few examples highlight the benefits of leveraging the capabilities of US allies and partners.[13] The ESA is contributing to the construction and operation of the Gateway and the Orion service module. Canada is delivering several critical components of the Gateway,[14] while Japan and the ESA are building important components of habitation modules. Navigation, tracking, and communication capabilities are key contributions from Australia; an ESA program will also provide lunar telecommunications and navigation.[15] Other important hardware, subsystems, and expertise will be supplied by space agencies such as those of Italy and the United Kingdom.[16] Moreover, allied companies are partners in the design, development, and deployment of capabilities underlying the Artemis program.

11 Steve Mackwell, Lisa May, and Rick Zucker, "The Ninth Community Workshop for Achievability and Sustainability of Human Exploration of Mars (AM IX)," hosted by Explore Mars at The George Washington University, June 2022, https://www.exploremars.org/wp-content/uploads/2023/03/AM-9_Upload_v-1.pdf.

12 P. Kessler et al., "Artemis Deep Space Habitation: Enabling a Sustained Human Presence on the Moon and Beyond," *2022 IEEE Aerospace Conference*, 1–12, https://doi.org/10.1109/AERO53065.2022.9843393.

13 Here, country/agency designations simplify complex agreements between public and private entities, sometimes across borders, showcasing the need for processes and relations that enable allied cooperation.

14 Canadian Space Agency, "Canada's Role in Moon Exploration," Canadian Space Agency, February 28, 2019, https://www.asc-csa.gc.ca/eng/astronomy/moon-exploration/canada-role.asp.

15 "Moonlight," ESA, accessed March 9, 2023, https://www.esa.int/Applications/Telecommunications_Integrated_Applications/Moonlight.

16 Fulvia Croci, "Artemis Mission: Signed Agreement Between ASI and NASA," *ASI* (blog), Italian Space Agency, June 16, 2022, https://www.asi.it/en/2022/06/artemis-mission-signed-agreement-between-asi-and-nasa/.

NASA's Artemis I rocket carrying the Orion research spacecraft from Launch Complex 39B at NASA's Kennedy Space Center in Florida, November 16, 2022. Source: Andrew Parlette, https://commons.wikimedia.org/wiki/File:Artemis_I_Blast-Off_-_Flickr_-_aparlette.jpg.

Today, US and allied cooperation in space rests on the Artemis Accords,[17] a set of principles, guidelines, and best practices for peaceful civilian space exploration building on the Outer Space Treaty of 1967 and subsequent policies.[18] Key principles include peaceful operations, transparency, interoperability, and commitments to deconfliction and the collaborative management of orbital debris and space resources. The original group of eight signatories in 2020 has since expanded to twenty-three as of March 2023, with representation across the globe from the Americas, Europe, the Middle East, the Indo-Pacific, and Africa. Signatory nations host mature or developing industries directly or indirectly pertinent to space exploration (see Table 1), signaling strong potential for bilateral and multilateral collaboration. Notably, neither Russia nor China—the two largest competitors to allied space exploration—have signed, nor appear likely to sign, the Artemis Accords. Thus, it is imperative for the United States to follow through on its commitments to its allies and partners, demonstrating that it remains the partner of choice for open and transparent space exploration and scientific inquiry.

To project leadership in space exploration, the United States and its allies and partners ought to be first in returning humans to the Moon and landing astronauts on Mars. Most experts interviewed for this paper agreed that—with China and Russia also racing to these benchmarks—achieving these "firsts" is important for prestige, diplomacy, and establishing a strong foundation for a rules-based order in outer space, similar to that seen across traditional domains, with the goal of promoting long-term freedom and prosperity. Failure to achieve these "firsts" could arise due to Chinese achievements, insufficient allied funding and political will, geopolitical events, a catastrophic mission failure, or from the United States underutilizing the capabilities of its allies and partners, both in the public and private sectors. The latter becomes more likely due to protectionist policies, including caps on foreign contributions, and political interference in competition. Overall, early stakeholders in this new phase of space exploration will set the culture, norms, and standards that will underpin space activities for years to come—a major reason to strengthen the systems and processes that enable US-led collaboration with allies and partners.

Technological Opportunities and Challenges

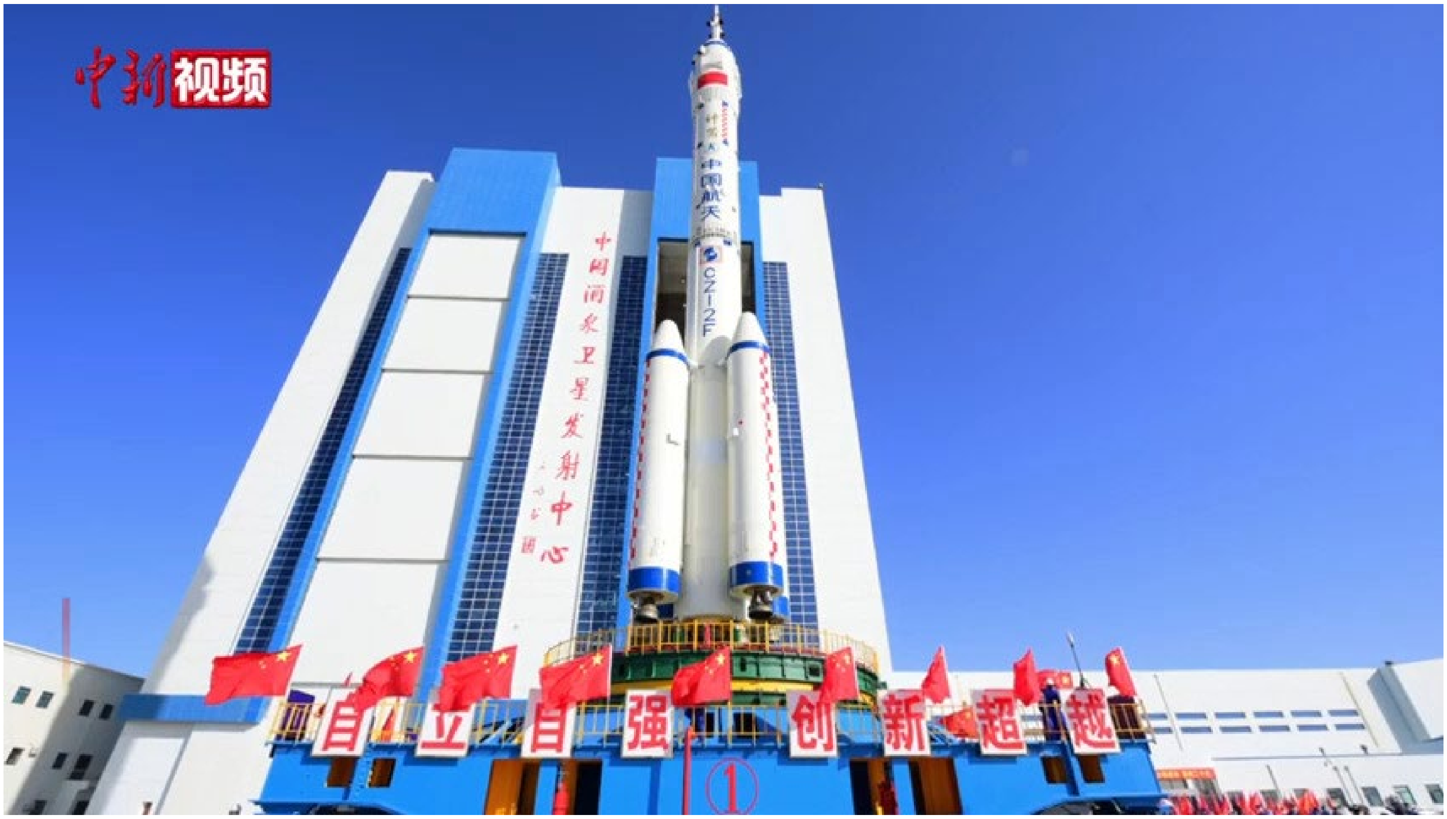
There are numerous opportunities to facilitate, enrich, and expand collaboration in space exploration between the United States and its partners and allies. At the same time, important challenges hold back current efforts to harness allied capabilities, pointing to opportunities to improve collaboration in the coming years.

Allied Opportunities in Space Exploration

Continuing to advance space exploration by both machines and humans requires costly, sophisticated, interdisciplinary technology development across sectors; this can only

17 "The Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids," NASA, October 13, 2020, https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf.

18 "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," United Nations, 1967, https://treaties.un.org/doc/Publication/UNTS/Volume%20610/volume-610-I-8843-English.pdf.



China is viewed as the preeminent competitor in space. Pictured here, the Shenzhou-14 has been used extensively by both the People's Liberation Army and Chinese commercial sector. May 29, 2022. Source: China News Service, https://commons.wikimedia.org/wiki/File:Shenzhou_14_roll_out.jpg.

be done through the aggregate efforts of the United States and its allies and partners from start to finish.[19] Such international cooperation, and cooperation between the public and private sectors, will not only overcome the major technical, logistical, and scientific challenges of space exploration, but also complement Earth-focused innovation initiatives in critical technologies (see Table 1).[20] For example, formal and informal strategies to leverage biotechnological advances for the expansion of bioeconomies[21] have been formulated for the United States,[22] Germany,[23] United Kingdom,[24] European Union,[25] India,[26] and others—including China.[27] Together, allied and partner space agencies play crucial roles as early

19 See "State Exploration and Innovation," UN Office of Outer Space Affairs, annual reports on national space activities and innovation accessed March 9, 2023, https://www.unoosa.org/oosa/en/ourwork/topics/space-exploration-and-innovation.html.

20 "Transforming Our World: The 2030 Agenda for Sustainable Development," United Nations, 2015, https://sdgs.un.org/sites/default/files/publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf; and "Exploring Space Technologies for Sustainable Development," UN Conference on Trade and Development, 2021, https://unctad.org/system/files/official-document/dtlstict2021d1_en.pdf.

21 "Report to the President: Biomanufacturing to Advance the Bioeconomy," US President's Council of Advisors on Science and Technology, December 2022, https://www.whitehouse.gov/wp-content/uploads/2022/12/PCAST_Biomanufacturing-Report_Dec2022.pdf.

22 White House, "Executive Order on Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy," White House Briefing Room, September 12, 2022, https://www.whitehouse.gov/briefing-room/presidential-actions/2022/09/12/executive-order-on-advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american-bioeconomy/; and White House Office of Science and Technology Policy, "Bold Goals for U.S. Biotechnology and Biomanufacturing: Harnessing Research and Development to Further Societal Goals," March 2023.

23 "National Bioeconomy Strategy," German Federal Government, July 2020, https://www.bmel.de/SharedDocs/Downloads/EN/Publications/national-bioeconomy-strategy.pdf?__blob=publicationFile&v=2.

24 "UK Innovation Strategy: Leading the Future by Creating It," UK Department of Business, Energy, and Industrial Strategy, July 22, 2021, https://www.gov.uk/government/publications/uk-innovation-strategy-leading-the-future-by-creating-it/uk-innovation-strategy-leading-the-future-by-creating-it-accessible-webpage.

25 Directorate-General for Research and Innovation (European Commission), *European Bioeconomy Policy: Stocktaking and Future Developments: Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions* (Luxembourg: Publications Office of the European Union, 2022), https://data.europa.eu/doi/10.2777/997651.

26 Narayanan Suresh and Srinivas Rao Chandan, "India Bioeconomy Report 2022," prepared for Biotechnology Industry Research Assistance Council by Association of Biotechnology Led Enterprises, June 2022, https://birac.nic.in/webcontent/1658318307_India_Bioeconomy_Report_2022.pdf.

27 Xu Zhang et al., "The Roadmap of Bioeconomy in China," *Engineering Biology* 6, no. 4 (2022): 71–81, https://doi.org/10.1049/enb2.12026.

Table 1: Allied and Partner Offerings in Key Space Exploration Technologies

This table includes select nations with a strong history of space- and/or Earth-related success within a specific technological segment (examples labeled "Now") and/or have burgeoning commercial sectors worth examining (examples labeled "Next"). Note: This table is not exhaustive.

Technology and Mission Goals	Value to US and Allied Strategy	Key Challenges to Harnessing Technology	Example of Allied Capability	Notable Allies and Partners with Capability
Launch and life support: rockets/vehicles (cargo/crewed), ground infrastructure, fuel/propulsion, guidance, habitats, rovers, spacesuits	Overcome fundamental constraints to moving payloads and people off Earth, in a safe and cost-effective manner	Low supply, capacity limits, reusability, geography, personnel, costs	**Now:** Thales Alenia Space's production facility in Italy uses advanced welding for pressurized modules	Australia, ESA, Germany, India, Israel, Italy, Japan, New Zealand, Poland, Singapore, South Korea, United Kingdom
Satellites: LEO, cislunar space, Moon, Mars	Navigation, communication, observation, sustainability, security	Traffic, space debris, launch, servicing, (cyber) security	**Now:** Fossa Systems (Spain) uses picosatellites for a low-power, open-source Internet of Things across applications	Canada, ESA, France, Germany, India, Italy, Japan, Luxembourg, Spain
Microelectronics, sensors, robotics, artificial intelligence (AI): imaging, security, medicine, food, construction, resource extraction, systems management	Basic science, edge computation, automation, autonomous operation to offset signal lag due to distance	Radiation, temperature, power, manufacturing and data storage off Earth, cybersecurity, human-machine teaming	**Now:** AI from Mission Control Space Services (Canada) will guide decision making by the Rashid rover (UAE) on the Moon; Rashid will be delivered by ispace Inc. (Japan)	Australia, Canada, Japan, Netherlands, South Korea, Taiwan, UAE, United Kingdom
Resources: in-situ resource identification, robotics, extraction/mining, processing, shipping	Basic science, sustainability, economic growth	Radiation, temperature, power, autonomy, infrastructure, supply chains, policy and law	**Now:** BHP, Rio Tinto, and Fortescue Metals are Australian leaders in autonomous haul trucks for mining	Australia, Brazil, Canada, Italy, Japan, Luxembourg, South Africa, United Kingdom
Energy: nuclear, hydrogen, solar, etc.	Operations, sustainability	Density, safety, capture/creation, storage, transmission, (cyber) security	**Next:** MT Aerospace AG (Germany) is partnering with ESA and the French Space Agency to establish a green hydrogen launch ecosystem	Australia, Canada, ESA, France, Germany India, Japan, Oman, Saudi Arabia, South Korea, UAE
Biotechnology: medicine, food, agriculture, materials; associated robotics, sensors, computation	Crew physical and mental health, sustainability, in-situ resource utilization	Controlled/closed-loop environments, extreme environments, reagent stability and storage, nutrition, security	**Next:** Solar Foods (Finland) produces a protein powder from microbes, air, renewable energy, and minerals/nutrients	Australia, Brazil, Canada, Finland, India, Israel, Italy, Singapore, Sweden, UAE
Manufacturing: materials, processes	Fuel requirements, sustainability, in-situ resource utilization, agility, crew health and operations	Radiation, temperature, gravity, automation, autonomy, waste, monitoring, maintenance, supply chain	**Next:** Space Forge (United Kingdom) is launching "microgravity as a service" for manufacturing in space with a reusable and scalable factory	Canada, ESA, Germany, Israel, Italy, Japan, United Kingdom

Sources: Compiled by the author, drawing on information from "Thales Alenia Space Strengthens Pressurized Module Production," *Aviation Week*, December 13, 2021, https://aviationweek.com/aerospace/commercial-space/thales-alenia-space-strengthens-pressurized-module-production; Jason Rainbow, "Spanish Startup to Upgrade Tiny Satellites to Take on Global IoT Market, *Space News*, January 17, 2023, https://spacenews.com/spanish-startup-to-upgrade-tiny-satellites-to-take-on-global-iot-market/; Elizabeth Howell, "UAE Lunar Rover Will Test 1st Artificial Intelligence on the Moon with Canada," Space.com, January 28, 2023, https://www.space.com/moon-artificial-intelligence-system-first-solar-system; "Australia Continues to Dominate the Use of Autonomous Haul Trucks," Comment, Mining-Technology.com (B2B news site), May 6, 2022, https://www.mining-technology.com/comment/australia-autonomous-haul-trucks/; "Launch Goes Green with Spaceport Hydrogen Plan, ESA, June 28, 2022, https://www.esa.int/Enabling_Support/Space_Transportation/Europe_s_Spaceport/Launch_goes_green_with_Spaceport_hydrogen_plan; Arttu Luukanen, "Producing Food in Space," *Room: The Space Journal of Asgardia*, no. 32 (2023), https://room.eu.com/article/producing-food-in-space; and Ryan Morrison, "Is the Future of Manufacturing in Space?," *Tech Monitor*, January 9, 2023, https://techmonitor.ai/technology/emerging-technology/uk-space-launch-spaceforge-virgin-orbit.

funders of the science, engineering, and business development of space and space-adjacent products and services that will both benefit from and drive space exploration in the coming decades; they also serve as early (and often sole) clients for these products and services.

Autonomous robotic system[28] are an illustrative example of how collaboration around a major technology objective for space exploration can overcome a series of challenges and deliver benefits across both Earth and space. Such systems rely on sophisticated integration of sensors, robotics, microelectronics, imaging, and computation. Depending on the target application, they must withstand extremes in temperature, radiation, gravity, pressure, resource constraints, and other parameters. Autonomous operation is imperative because of the vast distances that signals must travel (the one-way time delay for operating a robot on the asteroid closest to Earth that may be suitable for mining, 16 Psyche, is at least ten minutes).[29] Trusted (cybersecure) autonomous robotic systems will be critical for resource extraction, safety, human health, and sustainability in space environments; related technology development is benefiting Earth-based applications such as mining, surgery, supply chains, and transportation. The European Space Resources Innovation Center—a partnership of the Luxembourg Space Agency, the Luxembourg Institute of Science and Technology, and the ESA—is running an incubation program for early projects around utilizing space resources,[30] a salient example of how public and private entities can cooperate to drive capabilities for exploration and commercialization. All experts interviewed for this paper agreed that the quicker pace, receptiveness to risk, and sensitivity to costs and markets of commercial endeavors can benefit public-private partnerships for space exploration.

Challenges to Allied Space Exploration

Despite the affordances of international cooperation, systems and processes can make it difficult to harness allied capabilities. Protectionist activity by the United States and its allies and partners can arise when a single government has made large investments in research and development, hindering the transfer of technologies, personnel, information (including unclassified information), and data across borders. Many of the technologies shown in Table 1 appear on lists of critical, emerging, and breakthrough technologies from the United States,[31] European Union,[32] and other public and private organizations. This complicates collaboration, as many of these technologies are dual use and under intense Chinese scrutiny/competition, and are thus subject to export regulations—in some cases, even to US allies.

Notably, space exploration and the technology segments in Table 1 support concentrated, high-paying jobs with strong economic impact,[33] and are therefore subject to political protection from competition, from allies, and/or between the public and private sectors. For example, the US Congress's NASA Authorization Act of 2010 called for the reuse in the SLS of components of the Space Shuttle, with reliance on legacy suppliers, infrastructure, and personnel.[34] The resulting SLS is not reusable, and a single launch may cost upward of $1 billion.[35] In contrast, SpaceX (one of several companies developing rockets) claims that its Starship is fully reusable, has a larger payload, has much lower development costs (which have been partially funded by NASA), and—controversially—may have operational costs of less than $10 million per launch within the next few years.[36] Several experts interviewed for this paper suggested that a healthy sense of competition between the public and private sectors could encourage government space agencies to support ambitious timelines and budgets while upholding their commitment to safety.

Harnessing allied space capabilities will be key for constraining duplication of efforts and optimizing value creation, resource sharing, technology transfer, and costs. Over time, the hardware, software, and data from exploration missions will support off-Earth communities of increasing size, complexity, and duration in LEO, cislunar space, the Moon, Mars, asteroids, and beyond—underscoring the importance of harnessing allied capabilities in these technology areas for space exploration today.

28 Issa A. D. Nesnas, Lorraine M. Fesq, and Richard A. Volpe, "Autonomy for Space Robots: Past, Present, and Future," *Current Robotics Reports* 2, no. 3 (September 1, 2021): 251–63, https://doi.org/10.1007/s43154-021-00057-2.

29 Smiriti Srivastava et al., "Analysis of Technology, Economic, and Legislation Readiness Levels of Asteroid Mining Industry: A Base for the Future Space Resource Utilization Missions," *New Space* 11, no. 1 (2022): 21–31, https://doi.org/10.1089/space.2021.0025.

30 "ESRIC: Start-up Support Programme," ESRIC: European Space Resources Innovation Centre, accessed March 9, 2023, https://www.esric.lu/about-ssp.

31 "Critical and Emerging Technologies List Update," Fast Track Action Subcommittee on Critical and Emerging Technologies of the National Science and Technology Council, February 2022, https://www.whitehouse.gov/wp-content/uploads/2022/02/02-2022-Critical-and-Emerging-Technologies-List-Update.pdf.

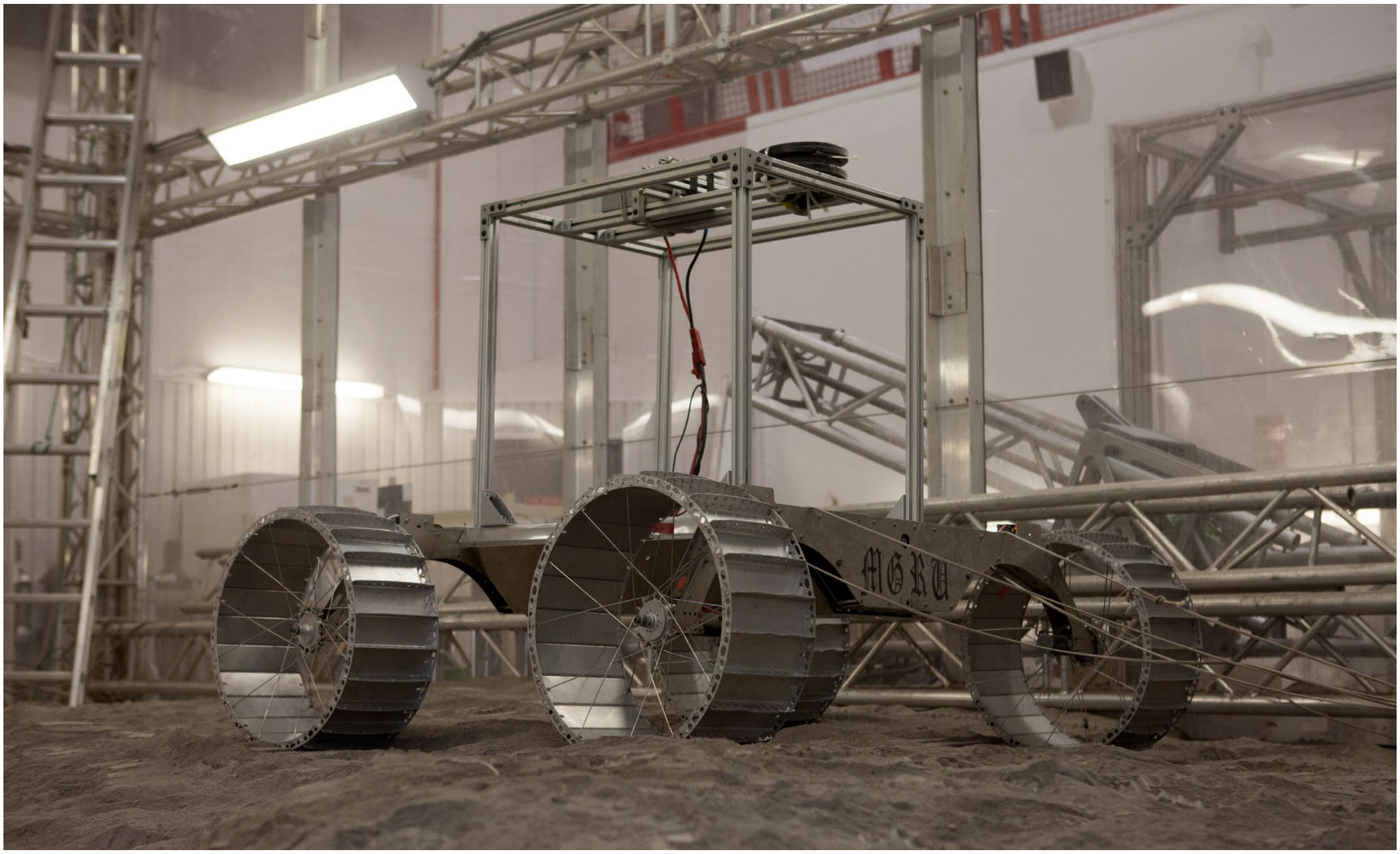
32 European Innovation Council, "Identification of Emerging Technologies and Breakthrough Innovations," January 2022, https://eic.ec.europa.eu/system/files/2022-02/EIC-Emerging-Tech-and-Breakthrough-Innov-report-2022-1502-final.pdf.

33 Yittayih Zelalem, Joshua Drucker, and Zafer Sonmez, "NASA Economic Impact Report 2021," Nathalie P. Voorhees Center for Neighborhood and Community Improvement, University of Illinois at Chicago, October 2022, https://www.nasa.gov/sites/default/files/atoms/files/nasa_fy21_economic_impact_report_full.pdf.

34 National Aeronautics and Space Administration Authorization Act of 2010, 42 U.S.C. 18301 (2010).

35 "The Cost of SLS and Orion," Planetary Society, accessed March 9, 2023, https://www.planetary.org/space-policy/cost-of-sls-and-orion.

36 Kate Duffy, "Elon Musk Says He's 'Highly Confident' That SpaceX's Starship Rocket Launches Will Cost Less than $10 Million within 2-3 Years," *Business Insider*, February 11, 2022, https://www.businessinsider.com/elon-musk-spacex-starship-rocket-update-flight-cost-million-2022-2.



A lightweight simulator version of NASA's Resource Prospector undergoes a mobility test in a regolith bin at the agency's Kennedy Space center in Florida. The Resource Prospector mission aims to be the first mining expedition on another world. Source: NASA/Kim Shiflett, https://commons.wikimedia.org/wiki/File:KSC-20170628-PH_KLS01_0073_(35596106876).jpg.

Recommendations and Conclusions

Harnessing allied capabilities is crucial for future space exploration, with major potential benefits to life on Earth as well. The US government, working alongside allied and partner governments, should therefore consider the following next steps:

Recommendation #1: US government actors—including Congress, the Department of Commerce's Bureau of Industry and Security, the State Department including its Directorate of Defense Trade Controls, and the Defense Technology Security Administration in the Office of the Secretary of Defense—should reexamine and reform Export Administration Regulations.[37] Priority should be given to potential reforms that strengthen the United States' position as an orchestrator of complex international collaborations and supply chains, in contrast to a paradigm of the United States as a globally dominant, unilateral player. Support from executive- and ministerial-level offices is essential.

Effects include**:**

- Promote removal of friction in international collaborations and public-private partnerships.
- Enable reciprocity in cooperation (including data transfer and potential to bid).
- Balance safety with risk.
- Render attractive the inclusion of US companies and government bodies in allied workflows, supply chains, and markets, particularly for businesses in emerging technologies.
- Support short-term economic and security goals as well as long-term diplomatic efforts, particularly with close allies and partners.

Recommendation #2: NASA and the National Space Council should collaborate with allied space agencies, both national

37 "Rethinking Export Controls."

and international, to identify opportunities to engage in space exploration at whatever level of contribution is individually appropriate, given the state of maturity of allied sectors (see Table 1) and geopolitics. For example, allies could contribute commodities or launch locations rather than mature costly software or hardware. Attention should be paid to maturing industries to identify opportunities for early relationships and processes that will accelerate space exploration.

Effects include**:**

- Decentralization to improve the resilience of space exploration to disruptions in funding, supply chains, politics, and unexpected but highly impactful events.
- Diplomacy and inspiration of young workers.
- Expansion of the community of active stakeholders in space exploration aligned with democratic values, with the United States serving as the trusted partner.

Recommendation #3: The Office of Science and Technology Policy, Office of the Secretary of Commerce, Department of Defense, and other US interagency actors should identify and support synergies between technology development for space exploration and for Earth-focused innovation in critical technologies.[38] New multistakeholder (cross-border) grants, fellowships, seed funding, and prizes should be modeled on current international efforts like XPRIZE and the Deep Space Food Challenge. Programs such as the NASA Innovative Advanced Concepts and the ESA Open Space Innovation Platform, which incubate early-stage innovations in space exploration, should be expanded to noncitizens.

Effects include:

- Risk-mitigated financial support of early and maturing technologies for space exploration.
- Exchange of human capital across public/private, international, Earth/space, and industry boundaries.

Recommendation #4: Through organizations like the United Nations Office for Outer Space Affairs, international stakeholders in space exploration—including space agencies, companies, philanthropic groups, and nongovernmental organizations—should formulate an actionable, unified multilateral space strategy that goes beyond the Artemis Accords. For example, while the Artemis Accords recognize "the global benefits of space exploration and commerce,"[39] they do not explicitly address commercial activity, and commercial enterprises are not signatories. Action is urgently needed, as it is conceivable that extraction and exploitation of lunar resources could begin in the very short term—in the mid 2020s. An expanded space strategy must include the commercial sector.

Effects include:

- Identification of pathways to create/strengthen linkages among stakeholders and eliminate choke points that render exploration vulnerable to disruption and negative outcomes.
- Establishment of rule of law and crisis-mitigation strategies spanning early crewed and uncrewed exploration missions through permanent human habitation off Earth, including commercial activity.

In conclusion, just as no one could have foreseen the precise progression from the Wright brothers' first flight to today's rapidly exploding telecommunications and space industrial ecosystems, one cannot expect to accurately predict the progression—or the ramifications—of today's space exploration to tomorrow's future. Nonetheless, international collaboration is certainly key to success. Now is the time to enhance the processes, relationships, and shared vision for space exploration, thereby expanding humankind's knowledge of the universe, improving life on Earth, and setting the stage for a reliable, routine, and prosperous space economy for all.

About the Author

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38 "Transforming Our World," United Nations.

39 NASA, "The Artemis Accords."

Integrating US and Allied Capabilities to Ensure Security in Space

by NICHOLAS EFTIMIADES

Introduction

Over the last two decades, the world entered a new paradigm in the use of space, namely the introduction of highly capable small satellites, just tens or hundreds of kilograms in size. This paradigm has forever changed how countries will employ space capabilities to achieve economic, scientific, and national security interests. As is so often the case, the telltale signs of this global paradigm shift were obvious to more than just a few individuals or industries. Air Force Research Laboratory's Space Vehicles Directorate began exploring the use of small satellites in the 1990s. The Air Force also established the Operationally Responsive Space program in 2007, which explored the potential use of small satellites. However, both research efforts had no impact on the US Department of Defense's (DOD's) satellite acquisition programs. The advancement of small satellites was largely driven by universities and small commercial start-up companies.[1]

The introduction of commercial and government small satellites has democratized space for states and even individuals. Space remote sensing and communications satellites, once the exclusive domain of the United States and Soviet Union, can now provide space-based services to anyone with a credit card. Eighty-eight countries currently operate satellites, and the next decade will likely see the launch of tens of thousands of new satellites.[2] Commercial and government small satellites have changed outer space into a more contested, congested, and competitive environment.

The United States has shared space data with its allies since the dawn of the space age.[3] Yet it also has a history of operating independently in space. Other domains of warfare and defense policy are more closely integrated between the United States and its allies and partners. The United States has military alliances with dozens of countries and strategic partnerships with many more.[4] In recent years, there have been calls to coordinate with, or even integrate allied space capabilities into US national security space strategy and plans. In this regard, the US government has made significant advances. However, much work needs to be done. There is pressure on the United States to act quickly to increase national security space cooperation and integration, driven by rapidly increasing global capabilities and expanding threats from hostile nations and orbital debris.

This paper examines the potential strategic benefits to US national security of harnessing allied space capabilities and the current efforts to do so, as well as barriers to achieving success. The paper identifies pathways forward for cooperating with allies and strategic partners on their emerging space capabilities and the potential of integrating US and allied capabilities.

The Security Environment in Space

The changing security environment in space is driving the United States and allies' collective desire to cooperate in the national security space. Several recent statements and actions demonstrate potential adversaries' plans and intentions to dominate the space domain. China and Russia have demonstrated offensive and defensive counterspace capabilities. In 2021, the two countries announced plans to build a joint International Lunar Research Station on the moon, although the path forward on this effort may have been impacted by the Russian invasion of the Ukraine.[5] The US Space Force notes this action would give those nations control of cislunar space, an area of balanced gravity between the Earth and moon. The movement of potential adversaries to cislunar space changes the strategic environment by forcing the United States to maintain surveillance of that region of space. In addition, Russia and China have threatened to

1 The pioneer in small-satellite design and production at this time was Surrey Satellite Technology Ltd. (SSTL) of Surrey University, United Kingdom.

2 Nicholas Eftimiades, "Small Satellites: The Implications for National Security," Atlantic Council, May 5, 2022, https://www.atlanticcouncil.org/in-depth-research-reports/report/small-satellites-the-implications-for-national-security/.

3 Examples include remote sensing and the global positioning system (GPS).

4 Claudette Roulo, "Alliances vs. Partnerships," US Department of Defense, March 22, 2019, https://www.defense.gov/News/Feature-Stories/story/Article/1684641/alliances-vs-partnerships/.

5 "International Lunar Research Station Guide for Partnership", Vol. 1.0, June 2021, http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html ; Andrew Jones, "China Seeks New Partners for Lunar and Deep Space Exploration," *Space News*, September 8, 2022, https://spacenews.com/china-seeks-new-partners-for-lunar-and-deep-space-exploration/; and "International Lunar Research Station Guide for Partnership," China National Space Administration, Vol. 1.0, June 2021, http://www.cnsa.gov.cn/english/n6465652/n6465653/c6812150/content.html.

Russian MiG-31 'Foxhound' supersonic interceptor jet carrying an anti-satellite weapon during the 2018 Victory Day Parade. Source: kremlin.ru, https://commons.wikimedia.org/wiki/File:2018_Moscow_Victory_Day_Parade_66.jpg.

destroy entire US orbital regimes.[6] China has also expressed its intention to be the world's leading space power by 2045.[7] In 2022, Chinese researcher Ren Yuanzhen of the Beijing Institute of Tracking and Telecommunications led a People's Liberation Army study to counter SpaceX's Starlink small satellite constellation. Ren boasted they had developed a solution to destroy thousands of satellites in the constellation.[8]

Benefits of Collaborating in Space

Collaborating may be defined as coordinating development programs and operational efforts of current or projected allied and partner space and related capabilities.[9] US interests would be to ensure these programs and operational efforts support US national security space strategy and planning objectives. Allied nations' interests are in leveraging extensive US space capabilities and establishing collective security. The United States, allies, and partners have a shared interest in establishing behavioral norms in space. Collaboration between allies in space capabilities would have numerous benefits, including the following:

Altering the calculus for offensive actions. A hostile nation or nonstate actor risks a stronger response from multiple nations when attacking a coalition (versus a single nation). If the United States and allies had interoperable or integrated space capabilities, then an attack on any single country's space systems would no longer be solely against the United States and would have impact on the collaborating

6 Matthew Mowthorpe, "Space Resilience and the Importance of Multiple Orbits, *The Space Review*, January 3, 2023, https://www.thespacereview.com/article/4504/1.

7 Ma Chi, "China Aims to Be World-leading Space Power by 2045," China Daily (state-owned daily), November 17, 2017, https://www.chinadaily.com.cn/china/2017-11/17/content_34653486.htm.

8 Stephen Chen, "China Military Must Be Able to Destroy Elon Musk's Starlink Satellites if hey Threaten National Security: Scientists," *South China Morning Post*, May 25, 2022, https://www.scmp.com/news/china/science/article/3178939/china-military-needs-defence-against-potential-starlink-threat.

9 Note that related capabilities could include software, sensors, SSA systems, ground stations, etc.

US Space Force Brigadier General Stephen Purdy, right, Space Launch Delta 45 commander, welcomes members of the Italian military at Launch Complex 40 at Cape Canaveral to observe the launch of the Italian COSMO-SkyMed Second Generation (CSG-2) Earth Observation Satellite aboard the American-made and launched SpaceX Falcon 9 rocket. Source: US Space Force, https://www.dvidshub.net/image/7026735/space-launch-delta-45-welcomes-italian-military-leaders-cosmo-skymed-launch.

or integrated systems of allies and partners. Changing the calculus for offensive actions could lead to increased deterrence against foreign aggression: "Partner capabilities increase both resilience and the perceived cost to an adversary, when an attack on one partner is seen as an attack on all," according to the US Air Force.[10]

Accessing geostrategic locations. Access to global geographic locations also provides access for ground-based space situational awareness (SSA); telemetry, tracking, and control (TT&C); and increasing launch resilience. Ground-based SSA requires globally distributed telescopes and radar systems. Allied collection systems operating in Japan, Australia, and territories of the United Kingdom, France, Germany, and others ensure all partners have access to global SSA data. Given that the United States has only two major space launch facilities, natural or manmade disasters could significantly erode the US ability to provide responsive space launch. Use of allied launch facilities could lessen US reliance on limited launch sites and thus mitigate that risk.

Burden-sharing in space. Allied investments in less costly smaller satellites, along with other space technologies, would increase their security and potentially reduce the financial burden on the United States to maintain space security. There have been positive developments in this realm, including Japan's 2022 National Security Strategy, which identified several new space systems the country intends to procure.[11] Given Russia's military aggression and the success of Space-X's Starlink satellites in supporting Ukraine, the European Union (EU) recently adopted the proposal to develop the Infrastructure for Resilience, Interconnection, and

10 Curtis E. Lemay Center for Counterspace Operations, "Counterspace Operations," US Air Force, Last Updated, January 25, 2021 https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-14/3-14-D05-SPACE-Counterspace-Ops.pdf .

11 *National Security Strategy of Japan*, Ministry of Foreign Affairs of Japan, Provisional Translation, December 2022, https://www.cas.go.jp/jp/siryou/221216anzenhoshou/nss-e.pdf.

China and Russia have proposed constructing a Sino-Russo International Lunar Research Station, a joint modular project proposed to strengthen international security cooperation and the monetization of space for both nations. Source:Shutterstock/ImageFlow

Security by Satellites (IRISS) constellation to provide broadband connectivity via up to 170 satellites.[12] The system, with an expected deployment date in 2025, expects to employ quantum cryptography and be available to governments, institutions, and businesses (in 2027). Canada's Department of National Defense is developing the Redwing optical microsat to provide space domain awareness (SDA).[13]

Establishing global norms and standards. The space domain lacks adequate rules of the road to regulate the behavior of spacefaring nations. As the United States and its allies and partners coordinate and perhaps integrate national security space systems, they also are in the position to shape norms and increase pressure on potential adversaries to accept global standards for acceptable space behavior.

Crisis management in space. Several allies have expressed the need to ensure their strategic autonomy—that is, not being wholly dependent on the United States and therefore free to act in their own interests. The EU's IRISS "system aims to enhance European strategic autonomy, digital sovereignty, and competitiveness."[14] Still, institutions such as NATO and the Quadrilateral Security Dialogue offer an avenue to explore collective options for crisis management in space by establishing agreed-upon terminology, codes of conduct, and response policies and procedures for emergencies or crises in the space domain.

Resiliency in the face of conflict. While seemingly unlikely, a conflict in the space domain would result in attrition of space-based services. Yet, unlike in other domains, a stockpile of

12 Andrew Jones, "European Union to Build Its Own Satellite-internet Constellation," *Space.com*, Future Publishing, March 1, 2023, https://www.space.com/european-union-satellite-internet-constellation-iriss.

13 David Pugliese, "Canadian Military Orders Space Surveillance Micro Satellite," *Space News*, March 10, 2023.

14 "Infrastructure for Resilience, Interconnection and Security by Satellites (IRISS) Constellation," European Parliament (video), in Jones, "European Union to Build Its Own Satellite-internet Constellation," *Space.com,* segment between 47 seconds and 55 seconds, https://cdn.jwplayer.com/previews/hMtl8Ak7.

space systems does not exist. The emerging commercial small satellite market now provides an opportunity for resiliency in space systems. Interoperable or integrated use of allied and US government and commercial space capabilities would provide improved resiliency in response to accident or attack.[15]

Bolstering industrial partnerships and reducing supply chain vulnerabilities. If cybersecurity standards are put in place, integrating allied manufacturing capabilities could diversify the US supply chain and reduce existing vulnerabilities. As a first step, the space-industrial supply chain must transition away from China and toward US allies and partners, who would then be able to enhance their production capabilities by contributing to interoperable or integrated space and associated systems. However, despite a long record of international procurement collaboration between the United States and its allies and partners, the outcomes of past programs have often been mixed.[16]

Existing Efforts toward Allied Integration

Collaboration does not merely mean standardization and interoperability. Rather, the effort to create an overall US and allied space vision is a necessary first step in integrating allied space capabilities in order to obtain interoperability. Through various partnerships and efforts, the US Space Force has led efforts with six allies and partners to create a unified vision for national security space cooperation.

Combined Space Operations Vision 2031

In 2022, the United States, Australia, Canada, France, Germany, New Zealand, and the United Kingdom signed the Combined Space Operations (CSpO) Vision 2031, which aims to "generate and improve cooperation, coordination, and interoperability opportunities to sustain freedom of action in space, optimize resources, enhance mission assurance and resilience, and prevent conflict." This shared vision establishes a framework to guide individual and collective efforts.[17]

CSpO participants' shared-objectives effort is a framework to guide individual national and collective efforts:

- Develop and operate resilient, interoperable architectures to enable space mission assurance and unity of effort.
- Enhance command, control, and communications capabilities and other operational linkages among CSpO participants.
- Foster responsible military behaviors, discourage irresponsible behavior, and avoid escalation.
- Collaborate on strategic communications efforts.
- Share intelligence and information.
- Professionalize space cadres and training.[18]

Training to Fight Together

Since 2018, the United States has been integrating allies and partners into space warfighting plans, most notably through Operation Olympic Defender, a US effort to synchronize with spacefaring nations to deter hostile acts in space. The annual Schriever Wargame—designed to explore critical space issues and advance space support across domains—also allows select allies and partners to coordinate defense-related space activities with the United States. In August 2022, US Space Command conducted its Global Sentinel exercise, which serves as US Space Command's premier security cooperation effort, with twenty-five participating countries. Over a one-week period, this series simulated scenarios focused on enhancing international partnerships, understanding procedures and capabilities, and integrating global SSA. These scenarios further allow participants to understand allies' and partners' capabilities and operating procedures, serving as a foundation for future collaboration.[19]

To date, the joint training efforts between the United States and its allies have been limited to tabletop exercises, thereby restricting participants' experience in real-world applications

15 B. Bragg, ed., "Allied/Commercial Capabilities to Enhance Resilience," NSI Inc., December 2017, https://nsiteam.com/leveraging-allied-and-commercial-capabilities-to-enhance-resilience/.

16 A successful example of coordinated global defense production includes the F-35, which is produced by over 1,900 companies based in the United States and ten additional nations. See "A Trusted Partner to Europe: F-35 Global Partnership," Lockheed Martin (video), https://www.lockheedmartin.com/en-us/who-we-are/international/european-impact.html.

17 Theresa Hitchens, "US, Close Allies Sign 'Call to Action' in Space Defense," *Breaking Defense*, February 22, 2022, https://breakingdefense.com/2022/02/us-close-allies-sign-call-to-action-in-space-defense/.

18 US Department of Defense, "Combined Space Operations Vision 2031," February 2022, https://media.defense.gov/2022/Feb/22/2002942522/-1/-1/0/CSPO-VISION-2031.PDF.

19 "25 Nations Participate in Global Sentinel 22," US Space Command, August 3, 2022, https://www.spacecom.mil/Newsroom/News/Article-Display/Article/3115832/25-nations-participate-in-global-sentinel-22.

Multinational and joint military space operators stand for a photo in the Combined Space Operations Center after the safe return of NASA's Commercial Crew Program Demonstration Mission 2. Source: US Air Force, https://www.dvidshub.net/image/7200037/space-traffic-monitoring-human-space-flight-rescue-vandenberg-units-provide-integral-support-nasa-missions.

of offensive and defensive counterspace measures.[20] Tabletop exercises do not test capabilities or demonstrate how well an ally or partner might perform in crises or conflict scenarios. Space capabilities are integrated into major military exercises conducted with allies but do not address offensive or defensive counterspace measures.[21]

Challenges and Barriers to Integration

While the United States recognizes the value of working with allies and partners in the space domain, myriad hurdles stand in the way to fully realize the competitive advantage space alliances and partnerships offer.

In total, US allies could bring a significant fraction of US capabilities. A systemic problem is how to leverage those capabilities in a coherent way. Limited coordination limits the values of those allied capabilities. Those capabilities are only additive to United States if there is good integration and understanding on how they will have a contributing effect.[22]

Lack of strategy to execute the vision for space. While a shared vision exists among the defense establishments of select allies and partners, there is little in the way of strategy or planning to fully realize that vision. Perhaps the greatest problem with the US approach to working with its allies and partners in space is that there is no coherent strategy for integrating allied space capabilities. Several subject matter

20 Just before this paper was published, the US Space Force announced a series of new cooperative agreements with Australia, Italy, and Peru covering partnership opportunities and data sharing. Sandra Erwin, "U.S. Space Command Announces New Cooperation Agreements with Allies," *Space News*, April 20, 2023, https://spacenews.com/u-s-space-command-announces-new-cooperation-agreements-with-allies/.

21 For example, such military exercises include Balikatan, Cobra Gold, Rim of the Pacific (RIMPAC), Northern Edge, Saber Strike, and Talisman Sabre.

22 Off-the-record online interview by the author with a close US ally, November 30, 2022.

experts interviewed for this study noted US public statements around the value of and desire to integrate allies, yet no interviewee was able to identify an existing strategy or plan to do so at any level of US government.

Bureaucratic impediments. Collaborating with allies is far easier than integrating multinational space capabilities. Allied integration must be done through a national-level strategy, integrating what, to date, are largely disconnected efforts between the National Space Council, National Security Council, the Office of the Assistant Secretary of Defense for Space Policy, US Space Command, the National Reconnaissance Office, and the Department of State. While each organization is credited with making strides in integrating allies (with varying degrees of success), the efforts are disjointed and lack connectivity and unified goals and strategy.[23]

Mind the gap. Allies and partners are attempting to understand existing gaps in the US national security space architecture and the capabilities they could provide to fill those gaps. Ironically, the CSpO Vision 2031 states that allies will collaborate "through identification of gaps and collaborative opportunities." With the onus almost exclusively placed on the ally or partner, interviewees noted nations' repeated requests to the United States to identify capability gaps in its projected architectures. The lack of information is due to the sensitivity of US defense gaps, with classified information making it more feasible for allies and partners to provide add-on capabilities rather than fully integrating assets.

Some level of gap analysis should be done by the United States to identify the niche areas that allies and partners could fill in the national security space architecture. That analysis should cover a period of at least five to ten years, thereby allowing allies to budget, develop, and deploy capabilities. Identifying capability gaps as requested by allies would ensure a future interoperable or integrated architecture. Primary focus areas should include space situational awareness, on-orbit servicing, communications, positioning, navigation, and timing (PNT), and cybersecurity. Each of these areas are baseline capabilities that should be interoperable or integrated between the United States and its allies and partners.[24]

Classification issues. There exists a widespread belief that the United States' overclassification of intelligence is hindering US and allied space security. This issue has been publicly acknowledged by several senior US military leaders. Misclassification might be a better word to describe the problem. In addition, the US system for sharing intelligence is cumbersome, requiring an exception to the normal production processes to share intelligence with allies. Experts (including myself) note cases where sharing space-related intelligence with allies was difficult due solely to organizational culture, established processes, poorly administered policies, and other bureaucratic impediments.[25]

Many of these classification-related problems have existed for decades—and the United States should not wait to figure out how to share information until its hand is forced by a crisis or war. There is an inability to share information, particularly information that can be integrated into a kill chain for weapon systems. The United States has integrated information-sharing systems in other warfighting environments, but as of yet, not in space. This lack of imagination even spreads down to the US combatant commands (COCOMs): allied integration would be enhanced if US COCOMs had joined with allied space personnel providing integrated PNT and communications.[26] Moreover, the US Space Force could deploy space attachés to select embassies, perhaps under the Office of Defense Cooperation, to further embed space security interests across the globe.[27]

Communications and data integration. After spending hundreds of millions of dollars to build the Joint Mission System to track satellites and space debris, the US Department of Defense still has no automated means to seamlessly integrate SSA data provided by allies into the US space surveillance system. One particularly high-level interview with a close ally called out the biggest issue as being communications, noting that it is impossible to discuss interoperable deterrence until this issue is addressed.[28]

Fifteen NATO members recently signed a memorandum of understanding to launch a Space Center of Excellence in Toulouse, France. This body could provide a mechanism for data integration and operational coordination. The Toulouse center is in addition to the already operating NATO Space

23 Interviewees noted difficulties in the US internal coordination efforts between the US Space Force's conduct of international relations, US Department of Defense acquisition, and national and defense policy formulation.

24 Note that on-orbit servicing is not a baseline capability, but should eventually become one.

25 The author travelled with then-Director of National Intelligence James Clapper, who was pursuing establishment of an intelligence exchange with a foreign country; the effort had limited success because the ODNI was unable to get analysts to release data. Notably, intelligence community information systems use "No Foreign Dissemination" as a default setting in the production of intelligence products; foreign disclosure of intelligence requires additional effort. It also should be noted that interviews conducted for this study with US and allied officials did not uncover any instances where space or related systems (or a national interest) were damaged due to overclassification of space intelligence.

26 This is the case at US INDOPACOM. See "Space Force Presents Forces to U.S. Indo-Pacific Command," Secretary of the Air Force Public Affairs, US Air Force (website), November 23, 2022, https://www.spaceforce.mil/News/Article/3227481/space-force-presents-forces-to-us-indo-pacific-command/.

27 Space Force already deploys a few liaison officers globally.

28 Off-the-record online interview by the author with a close US ally, December 5, 2022.

The H-IIA rocket lifts off from the Tanegashima Space Center in Japan. The H-IIA has been supporting satellite launch missions as a major large-scale launch vehicle with high reliability. Source: NASA, https://www.dvidshub.net/image/757785/present-day-japan-h-ii.

Centre at Allied Air Command in Ramstein, Germany, which serves as a single point for the requests and production of NATO space products.[29] As of February 2023, the US and Canadian governments are not founding members of the Toulouse Space Center effort.

Case Study: US-Japanese Space Integration

While allied integration has seen success across other warfighting domains, the same cannot be said for the space domain.[30] Space collaboration with Japan is illustrative of the challenges in integrating efforts.

Overclassification of information related to US programs and operation capabilities makes allied integration even more difficult. For example, France and Japan have publicly stated their intentions to build geo satellites for space domain awareness. Currently, a strategy to coordinate those systems with the operating US geosynchronous space situational awareness program (GSSAP) does not exist, demonstrating a lack of plans for data sharing, burden sharing, or coordination of mission operations.[31] However, Japan and the United States have agreed that space domain awareness data will be shared between the Japan Air-Self Defense Force and US Space Command starting in federal year 2023.

29 NATO, "NATO's Approach to Space," last updated February 16, 2023, https://www.nato.int/cps/en/natohq/topics_175419.htm.

30 An example of integrated international military operations would be the NATO International Security Armed Forces (ISAF) in Afghanistan. At its height, ISAF was more than 130,000 strong, with troops from fifty-one NATO and partner nations.

31 GSAP is a US geosynchronous space surveillance system, which operates like a space-based SSA system.

Overclassification of US intelligence is hindering cooperation with allies and partners. Two controllers work in the Global Strategic Warning and Space Surveillance System Center. Source: US Air Force, https://www.flickr.com/photos/usairforce/15536996634/.

In 2022, the government of Japan approached the United States about its interest in playing a role in the Space Development Agency's "Proliferated Warfighter Space Architecture,"[32] as Japan intends to launch a similar constellation of satellites for missile defense purposes. However, the United States has been unresponsive to Japan on how it could achieve integration. This is partly because the United States maintains concerns about Japan's level of information security, despite Japan's commitment to "strengthen and reinforce information security practices and infrastructure."[33] Yet, Japan has the world's third largest defense budget and is a spacefaring nation with launch infrastructure, years of experience, and advanced satellite manufacturing capabilities. In addition, Japan faces increasing threats from China and North Korea, providing incentive to expand its security relationship with the United States.[34] In 2010, the United States came to agreement with Japan to integrate SSA sensors into the Quasi-Zenith Satellite System (QZSS) PNT system.[35] However, to date, there is no plan on how to integrate the data.[36]

Policy Recommendations

There are several key actions the United States can take to integrate allies and partners into national security space efforts.

32 "The Proliferated Warfighter Space Architecture" is a layered network of military satellites and supporting elements; the architecture was formerly known as the "National Defense Space Architecture."

33 "Joint Statement of the Security Consultative Committee ('2+2')," Japanese Ministry of Foreign Affairs, 2, https://www.mofa.go.jp/files/100284739.pdf.

34 John Hill (deputy assistant secretary for space and missile defense, US Department of Defense), telephone interview with the author, January 2023.

35 QZSS operates at the same frequency and same timing as GPS. This service can be used in an integrated way with GPS for highly precise positioning. The additional US sensor is unknown.

36 Paul McLeary and Theresa Hitchens, "US, Japan to Ink Hosted Payload Pact to Monitor Sats," *Breaking Defense*, August 5, 2019, https://breakingdefense.com/2019/08/us-japan-to-ink-hosted-payload-pact-to-monitor-sats/.

Recommendation #1: The US Space Force should conduct a gap analysis to guide allied investments into space capabilities, prioritizing capabilities such as SSA, on-orbit servicing, communications, PNT, and cybersecurity. This gap analysis should identify in which areas the United States wants to collaborate with allies, identify opportunities for interoperability, and which areas are open to integration of capabilities.

Recommendation #2: It would benefit the US Space Force to have an outside entity analyze its internal policies, procedures, bureaucratic obstacles, and human capital levels to determine why the effort to integrate allies has been so minimally effective.

Recommendation #3: The US National Space Council should lead an interagency working group to develop a US government integrated strategy that establishes goals for and metrics to assess US and allied space capabilities and integration efforts.

Recommendation #4: The US Department of Defense and Office of the Director of National Intelligence should form a working group to establish best practices for sharing classified information with allies.

Recommendation #5: US Space Command should develop real-world exercises with allies and partners to test SDA, electronic warfare, and space control capabilities—all of which will be critical to deterring and, if necessary, responding to future space conflicts.

Recommendation #6: The US Departments of Defense and State should work toward consistency of approach in terms of governance of space activities, including through establishment of multilateral engagement and national regulations to allow flexibility and transportability of launch access at short notice.

Recommendation #7: The National Security Council should lead an interagency effort to establish consistency of national regulations between allies and partners (comparable laws and/or standards) so that systems and operations are transferable and receive mutual recognition and acceptance.

Conclusion

The United States and its allies and partners are moving toward sharing SSA data, understanding each other's policies and procedures, and collaborating on space operations. Still, much work needs to be done to expand collaboration and achieve interoperability (if desired) between rising space powers. Without a strong indication from the US government of what exactly it wants from its allies and partners—as well as what it is prepared to give in return—the United States will not be able to effectively harness the competitive advantages offered by allied space capabilities. It is incumbent on the United States and its allies to immediately embark on a way forward to jointly ensure a safe and secure environment in space. Failure to change current practices and act in a timely fashion will lead to increased space threats and diminished national and economic security.

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- **John Hill**, deputy assistant secretary of defense for space and missile defense, US Department of Defense
- **Komei Isozaki**, Japan Chair fellow, Hudson Institute
- **Mat Kaplan**, senior communications adviser, The Planetary Society
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- **Ron Lopez**, president and managing director, Astroscale U.S. Inc.
- **Douglas Loverro**, president, Loverro Consulting, LLC; former deputy assistant secretary of defense for space policy, US Department of Defense
- **Russ Matijevich**, chief innovation officer, Airbus U.S. Space & Defense, Inc.
- **Jacob Markish**, vice president, strategy and corporate development, Thales North America
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