

STRATEGIC TRAJECTORIES: ASSESSING CHINA'S SPACE RISE AND THE RISKS TO U.S. LEADERSHIP

HEARING BEFORE THE SUBCOMMITTEE ON SPACE AND AERONAUTICS OF THE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY OF THE HOUSE OF REPRESENTATIVES ONE HUNDRED NINETEENTH CONGRESS

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**STRATEGIC TRAJECTORIES:
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AND THE RISKS TO U.S. LEADERSHIP**

THURSDAY, DECEMBER 4, 2025

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 9:03 a.m., in room 2318, Rayburn House Office Building, Hon. Mike Haridopolos [Chairman of the Subcommittee] presiding.



SUBCOMMITTEE ON SPACE & AERONAUTICS

HEARING CHARTER

“Strategic Trajectories: Assessing China’s Space Rise and the Risks to U.S. Leadership”

Thursday, December 4, 2025

9:00 AM

2318 Rayburn House Office Building

Purpose

The purpose of the hearing is to examine the progress of the People’s Republic of China in achieving its goal of becoming a dominant space power. It will outline China’s objectives for its national space programs, both in terms of completing space missions and in advancing its geopolitical influence. The hearing will evaluate China’s space strategy, including the benefits of a consistent political direction, sustained funding, and its military-civil fusion approach. Finally, it will highlight the risks of ceding leadership in space exploration to China, with a particular focus on the Moon, as well as the broader economic, geopolitical, and national security consequences of China attaining preeminence in space.

Witnesses

- **Mr. Dean Cheng**, Senior Fellow, The Potomac Institute for Policy Studies
- **Mr. Clayton Swope**, Deputy Director, Aerospace Security Project, Center for Strategic and International Studies
- **Dr. Patrick Besha**, Founder, Global Space Group
- **Dr. Michael D. Griffin**, Co-President, LogiQ, Inc.

Overarching Questions

- What are the key objectives for China’s national space programs?
- What is the state of China’s space program, and to what extent does it represent a threat to U.S. global space leadership?
- What are the broader economic, geopolitical, and national security consequences of ceding space leadership to China?

Background

The People's Republic of China (PRC or China) presents the most credible challenge to the United States' interests in space. The PRC considers its space capabilities critical for achieving its economic and security goals. Moreover, China views the space domain as an essential component of its central planning and a key measure of its status as a global power, using its achievements in space to demonstrate technological capability and enhance its national reputation.

PRC National Strategy

When Xi Jinping was elected President of the PRC in 2013, he brought with him the "Chinese Dream" as a foundation of his ideological platform.¹ The Chinese Dream calls for the great rejuvenation of the Chinese nation, with a focus on modernization. It outlined President Xi's vision for China to evolve into a fully developed, world-leading, great power by 2049.² Along with the Chinese Dream, President Xi also established a corresponding "Space Dream," prioritizing the space program as central to national modernization and achieving China's great rejuvenation.³ Connecting China's space activities to the PRC's central planning efforts brought the space program to the forefront of the PRC's interests.

In 2014, the PRC initiated the Space Information Corridor (SIC), also known as the Space Silk Road. The SIC serves as the space element of the PRC's Belt and Road Initiative (BRI) and contributes to the PRC's "strategy to export surplus capacity, proliferate technical standards, and deepen foreign reliance on Chinese infrastructure."⁴ It offers Chinese space capabilities in exchange for partnerships and access to foreign markets while serving as the "digital glue" connecting BRI projects.⁵ By creating international partnerships, the SIC also provides opportunities for the PRC to deploy ground stations and other space infrastructure on foreign soil.

¹ Kirk A. Denton, *China Dreams and the "Road to Revival"*, Origins Current Events in Historical Perspective, <https://origins.osu.edu/article/china-dreams-and-road-revival>

² Johnathan P. Roll, Oliver J. Du Bois, *Redshift: The Acceleration of China's Commercial and Civil Space Enterprise & The Challenge to America A Strategic Report from the Commercial Space Federation*, (Sept. 2025) <https://commercialspace.org/wp-content/uploads/2025/09/CSF-Redshift-v6.pdf>

³ Kevin Pollpeter, Eric Anderson, Jordan Wilson, Fan Yang, *China Dream, Space Dream, China's Progress in Space Technologies (, and Implications for the United States*, IGCC, https://www.uscc.gov/sites/default/files/Research/China%20Dream%20Space%20Dream_Report.pdf

⁴ *Id.* at 2

⁵ Hema Nadarajah, *China: A Global Power's Celestial Ambitions*, Asia Pacific Foundation, (May 9, 2024) <https://www.asiapacific.ca/publication/china-global-powers-celestial-ambitions>

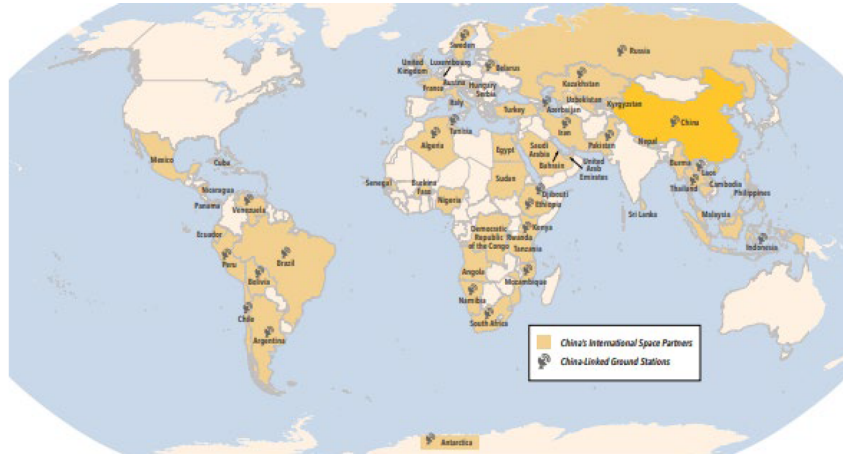


Figure 1: Map of International Space Cooperation with China. [Source: USCC]

The same year, the State Council of China released “Document 60,” which loosened restrictions on private capital investment into sectors of China’s space industry. This policy change was driven, in part, by the PRC’s focus on self-reliance for its space program, a principle emphasized throughout PRC planning documents and linked to the goal of modernization in the Chinese Dream.⁶ External forces also contributed, namely the U.S. policy of noncooperation with China. The Wolf Amendment, for example, has been included in Appropriations legislation every year since 2011, and prohibits the National Aeronautics and Space Administration (NASA), the Office of Science and Technology Policy (OSTP), and the National Space Council (NSpC) from using funds to work with the PRC or any associated entities.⁷ The prohibition on U.S.-China space collaboration resulted from growing national security concerns over the rapid advancement of the PRC’s space program, as well as concerns regarding Chinese technological espionage.⁸

President Xi also prioritized the PRC’s national security space efforts. In 2015, China recognized space as a warfighting domain.⁹ In doing so, the PRC undertook a reorganization of the People’s Liberation Army (PLA), which included the creation of a Strategic Support Force (SSF) to oversee space, cyber, and electronic warfare capabilities.¹⁰ Unlike an operational force, the SSF

⁶ *Id.* at 3

⁷ Alison Fong, *Working with China in Space*, American Security Project, (Jul. 15,

2024) <https://www.americansecurityproject.org/working-with-china-in-space/>

⁸ Christopher J. Griffin, Joseph Lin, *China’s Space Ambitions*, AEI, (Apr. 7, 2008)

<https://www.aei.org/articles/chinas-space-ambitions/>

⁹ Steve Lambakis, *Space as a Warfighting Domain: Reshaping Policy to Execute 21st Century Spacepower*,

National Institute for Public Policy (May 2021), [https://nipp.org/wp-content/uploads/2021/06/Space-as-a-](https://nipp.org/wp-content/uploads/2021/06/Space-as-a-Warfighting-Domain-pub-5.21.pdf)

[Warfighting-Domain-pub-5.21.pdf](https://nipp.org/wp-content/uploads/2021/06/Space-as-a-Warfighting-Domain-pub-5.21.pdf)

¹⁰ Keving L. Pollpeter, Michael S. Chase, Eric Heginbotham, *The Creation of the PLA Strategic Support Force and*

Its Implications for Chinese Military Space Operations, RAND, (Nov. 10, 2017),

https://www.rand.org/pubs/research_reports/RR2058.html

is “a unique organization tasked with the inherently joint mission of supporting all services with its space, cyber, and electronic warfare capabilities.”¹¹ The structure of the SSF demonstrates the PRC’s goal to centralize space operations and integrate space capabilities into all aspects of the PLA.

The multilateral focus on developing a domestic space program, commercial industry, and strengthening the PRC’s military space capabilities continues to guide Chinese space activities. PRC planning documents showcase the expansion of Chinese space activities and reflect the progress that the PRC has made on the pathway to becoming a global space power. A recent PRC white paper on space states that, “China will accelerate work on its space industry” and describes the PRC’s interest in developing “new business models for upscaling the space economy, such as travel, biomedicine, debris removal, and experiment services.”¹² Additionally, the white paper highlights the PRC’s interest in global space governance, including their plans to “actively participate in formulating international rules regarding outer space.”¹³ This includes efforts related to space environment governance, monitoring and response to near-Earth objects, planet protection, space traffic management, and the development and utilization of space resources. The white paper also outlines China’s interest in accelerating the development of a domestic legal regime for space to promote law-based governance of the space industry.¹⁴

The PRC’s future ambitions for space science are discussed in the National Mid-Term & Long-Term Plan for Space Science in China (2024–2050). The plan is the first long-term, national-level plan for space science, guiding both research activities and investments to realize a leading position in global space science by 2050.¹⁵ It outlines a deliberate, three-phase strategy to achieve leadership in space exploration and scientific research.¹⁶ Across the phases, the plan focuses on five scientific themes: the Extreme Universe, Space-Time Ripples, Panoramic View of Sun-Earth, Habitable Planets, and Biological and Physical Science in Space.¹⁷ Additionally, the plan aims to attract international participation in its space science projects and promote global collaboration with the PRC.¹⁸

While the national interest and associated funding have enabled the advancements of China’s space program, the PRC’s comprehensive planning efforts drive its progress. The PRC manages its space program through a combination of short-, medium-, and long-term national plans that establish goals and objectives for the Chinese space program and mandate funding to achieve

¹¹ *Id.* at 10

¹² China Aerospace Studies Institute, *China’s Space Program: A 2021 Perspective* The State Council Information Office of the People’s Republic of China, China Aerospace Studies Institute, (Jan 2022), <https://www.airuniversity.af.edu/Portals/10/CASI/documents/Translations/2022-02-16%20ITOW%20China's%20Space%20Program-%20A%202021%20Perspective.pdf>

¹³ *Id.* at 12

¹⁴ *Id.* at 12

¹⁵ *Id.* at 2

¹⁶ Jie Gao, China Brief Notes, *PRC Unveils New Space Plan*, The Jamestown Foundation, (Nov. 5, 2024 4:42PM) <https://jamestown.org/program/prc-unveils-new-space-plan/>

¹⁷ Andrew Jones, *China set to unveil long-term vision for space science*, SpaceNews, (Sep. 20, 2024) <https://spacenews.com/china-set-to-unveil-long-term-vision-for-space-science/>

¹⁸ Dennis Normile, *China’s ambitious new space plan includes call to bring home a bit of Venus’s atmosphere*, Science, (Oct. 17, 2024 5:05PM) <https://www.science.org/content/article/china-s-ambitious-new-space-plan-includes-call-bring-home-bit-venus-s-atmosphere>

them.¹⁹ Notably, the PRC has repeatedly demonstrated an ability to achieve its goals on the schedule established by these plans.²⁰ This consistency showcases the credibility of the PRC space program and highlights how quickly China has moved from aspirational planning to concrete achievements. The rise of the Chinese space program is a result of systematic and sustained planning, combined with a strict and unwavering commitment to successfully execute the goals and objectives set by these plans.

PRC Organizational Structure and Military-Civil Fusion

China's space program benefits from the PRC's Military-Civil Fusion Development Strategy, a state-directed system that aligns civil, military, and commercial entities under a unified national strategy. This structure supports China's long-term strategic objectives by removing barriers between sectors and ensuring that all space activities align with national goals. However, the lack of transparency makes external assessments of the program difficult, as it becomes challenging to distinguish between civilian activities and those intended for military use.²¹

Given the dual-use nature of most space technologies, the PRC views space power as inseparable from military power and has focused on space as a key enabler of achieving its military modernization goals.²² The PRC has been keenly focused on space capabilities since its first widespread use by the U.S. during the first Gulf War.²³ Not only did the PRC realize the value of space, but it also acknowledged the asymmetry between U.S. and Chinese space capabilities at the time.²⁴ Bridging this gap and eliminating the U.S. military advantage in space is a key objective of the Chinese space program efforts.

Since 2015, the PLA SSF has managed the PRC's military space program. In 2024, the PLA reorganized the SSF into three components, including the Aerospace Force (ASF).²⁵ The ASF "is responsible for nearly all PLA space operations, including space launch and support; space surveillance; space information support; space telemetry, tracking, and control; and space warfare."²⁶ Additionally, the China Manned Space Agency (CMSA), which manages human

¹⁹ Kevin Pollpeter, *PRC Space and Missile Capabilities*, CNA, (Apr. 13, 2023) <https://www.cna.org/reports/2023/05/Kevin-Pollpeter-Testimony-April-13-2023-on-PRC-Space-and-Missile-Capabilities.pdf>

²⁰ United States- China Economic and Security Review Commission (Nov. 2019), *China's Ambitions in Space: Contesting the Final Frontier [Report]*, <https://www.uscc.gov/sites/default/files/2019-11/Chapter%204%20Section%203%20-%20China%E2%80%99s%20Ambitions%20in%20Space%20-%20Contesting%20the%20Final%20Frontier.pdf>

²¹ U.S. Department of State (May 2020), *Military-Civil Fusion and the People's Republic of China [Report]*, <https://www.state.gov/wp-content/uploads/2020/05/What-is-MCF-One-Pager.pdf>

²² *Id.* at 2

²³ Khye Eastin, *A Domain of Great Powers: The Strategic Role of Space in Achieving China's Dream of National Rejuvenation*, Mapping China's Strategic Space, (May 10, 2024) <https://strategicspace.nbr.org/a-domain-of-great-powers-the-strategic-role-of-space-in-achieving-chinas-dream-of-national-rejuvenation/>

²⁴ Kevin Pollpeter, Elizabeth Barrett, April Herlevi, *Deterring China's Use of Force in the Space Domain*, (May 2025) <https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2025-05-19%20Deterring%20China's%20Use%20of%20Force%20in%20Space.pdf?ver=wAcgo4Ea0biL5scDuYHMeA%3D%3D>

²⁵ Ying Yu Lin, Tzu-Hao Liao, *RIP, SSF: Unpacking the PLA's Latest Restructuring*, The Diplomat, (Apr. 23, 2024) <https://thediplomat.com/2024/04/rip-ssf-unpacking-the-plas-latest-restructuring/>

²⁶ U.S. Department of Defense (2024), *Military and Security Developments Involving the People's Republic of China*, <https://apastyle.apa.org/style-grammar-guidelines/references/examples/report-government-agency-references>

spaceflight, operates under China's highest military authority, the Central Military Commission (CMC).²⁷ Notably, through the SSF restructuring, the ASF was placed directly under the CMC.

China's civil space program is led by the China National Space Administration (CNSA), which falls under the management of the Ministry of Industry and Information Technology, and is responsible for overall space program planning and engagement with international partners.²⁸ Unlike NASA, the CNSA does not function as an operational space agency; instead, it fulfills a diplomatic and administrative role, coordinating with foreign partners and guiding high-level programmatic decisions. The CNSA engages two national state-owned enterprises, China Aerospace Science and Technology Corporation (CASC) and China Aerospace Science and Industry Corporation (CASIC), to develop spacecraft and related technologies.²⁹

The third element of the Chinese space program is its commercial space sector. The PRC's private space industry is composed of a government-directed network of quasi-private companies that are either created or supported through state policy to drive innovation and expand the nation's industrial capacity.³⁰ China's interest in a domestic commercial space sector was influenced by the PRC's belief that private industry could help the PRC overcome the limitations that its state-owned enterprises faced in terms of innovation or capacity.³¹ While they are typically described as private enterprises, these companies operate within the strategic framework set by the Chinese government and frequently carry out national objectives.³² For example, Chinese space companies are required to provide the PRC with their technologies and expertise upon request.³³ This allows the PRC's military space program to benefit directly from advancements made by China's private space industry. In addition to promoting the development of a private space sector, China has prioritized the export of products and services from its domestic industry, including through a dedicated space export promotion agency.³⁴ Notably, there are currently over 500 commercial space companies in China.³⁵

PRC Investment in Space

China's Military-Civil Fusion model complicates efforts to accurately assess the full scale of its national investment in space. The PRC can coordinate resources across sectors while also limiting transparency around its total expenditures. Open-source reporting indicates that China's

²⁷ Taylor Lee, Peter Singer, *China's Space Program Is More Military Than You Might Think*, (July 16, 2021), <https://www.defenseone.com/ideas/2021/07/chinas-space-program-more-military-you-might-think/183790/>

²⁸ China, Space Security Portal, (Aug. 2023) <https://spacesecurityportal.org/states/china>

²⁹ The China National Space Administration (CNSA), The Planetary Society, <https://www.planetary.org/the-china-national-space-administration-cnsa>

³⁰ Ryan Nelson, Taylor Rhoten, Brian McCarthy, *Eastern Stars Rising: The Rise of China's Commercial Space Industry*, War on the Rocks, (Jul. 29, 2025) <https://warontherocks.com/2025/07/eastern-stars-rising-the-rise-of-chinas-commercial-space-industry/>

³¹ Henry Boyd, Erik Green, Meia Nouwens, *China's commercial space sector*, IISS, (Aug. 21, 2025) <https://www.iiss.org/online-analysis/charting-china/2025/08/chinas-commercial-space-sector/>

³² *Id.* at 2

³³ *Id.* at 2

³⁴ Nathaniel Rome, *China's Space Export Strategy*, Space Policy, 2023, [https://doi.org/10.1016/j.spacepol.2023.101574.\(https://www.sciencedirect.com/science/article/pii/S0265964623000413\)](https://doi.org/10.1016/j.spacepol.2023.101574.(https://www.sciencedirect.com/science/article/pii/S0265964623000413))

³⁵ *Id.* at 31

total space budget was approximately \$20 billion in 2024.³⁶ For comparison, in 2024, the U.S. space budget was reported to be around \$79 billion.³⁷ While the two countries' budgets indicate an imbalance in national space spending, this may not capture the complete level of state investment, as there is limited official PRC information on its space budget, and reported budget figures often underestimate China's annual space investment. For example, the Department of Defense estimates that the PRC spends 40% to 90% more than it announces in its public defense budget.³⁸ Although the publicly available accounting of China's space budget appears modest compared to U.S. spending, the scope and scale of Chinese space activities indicate the PRC is allocating funding that isn't captured by its budget.³⁹ Additionally, China benefits from significantly lower labor costs and other added services, which also contribute to the funding imbalance.⁴⁰

The lack of a clear division between civilian and military spending in the space domain has provided China with an advantage when scaling its space programs and mobilizing funding for strategic initiatives, while obscuring the amounts the government is allocating. The structure of China's system allows for rapid expansion, long-term strategic planning, and sustained operations across the full range of space activities.

Chinese Space Programs & Capabilities

China is executing a diverse portfolio of activities related to its space program, from human space exploration and space science to infrastructure modernization and commercialization. Through China's short-, medium-, and long-term plans, the PRC provides insight into both past efforts and future. The following describes China's space activities across major space segments.

Launch

The Long March family of rockets has been developed and manufactured by CASC since the late 1960s. First launched in April 1970, the Long March series has been used for most Chinese space launches.⁴¹ In recent years, launch cadence has increased significantly, with China attempting 68 orbital launches in 2024.⁴² Developing a domestic space launch capability represents one of the PRC's longest-standing ambitions for space. Independent launch capabilities provide access to orbit and enable all operations within the space domain, aligning directly with China's pursuit of space independence and creating opportunities to provide launch services to other nations.

³⁶ Michal Pietrzak, *Economic and Social Aspects of the Space Sector Development Based on the Modified Structure–Conduct–Performance Framework*, World, <https://www.mdpi.com/2673-4060/6/2/79>

³⁷ *Id.* at 36

³⁸ *Id.* at 26

³⁹ Jack Kuhr, *China to Invest Heavily in its Race to the Moon*, Payload, (May 18, 2023)

<https://pavloadspace.com/china-to-invest-heavily-in-its-race-to-the-moon/>

⁴⁰ Namrata Goswami, *China in Space: Ambitions and Possible Conflict*, *Strategic Studies Quarterly*,

https://www.airuniversity.af.edu/portals/10/ssg/documents/volume-12_issue-1/goswami.pdf

⁴¹ John Dotson, *China's Long March Rocket Program Sees Both Dramatic Successes and Failures in Spring 2020*,

The Jamestown Foundation (May 15, 2020 4:07PM) <https://jamestown.org/program/chinas-long-march-rocket->

[program-sees-both-dramatic-successes-and-failures-in-spring-](#)

[2020/#:~:text=The%20early%20months%20of%202020,mid%2DMarch%20and%20early%20April.](#)

⁴² Johnathan McDowell, *Space Activities in 2024*, Jonathans Space Report, (Jan. 24, 2025)

<https://planet4589.org/space/papers/space24.pdf>

Currently, CASC is developing a new class of heavy and super-heavy-lift launch vehicles designed to compete with U.S. capabilities and carry out China's long-term space ambitions.⁴³ These launch vehicles include the Long March 10, a human-rated, three-stage rocket intended to support China's goal of landing astronauts on the Moon by 2030. As well as the Long March 9, a reusable super-heavy lift vehicle is being developed for deep space missions and large-scale infrastructure deployment.

The PRC also continues to support the development of a domestic commercial launch industry, which currently consists of over 20 well-established launch companies.⁴⁴ While these companies are private, they still operate within a national strategic framework and benefit from China's Military-Civil Fusion strategy. They're also supported by a funding structure with multiple investor streams, which includes a significant increase in investment from Chinese city and provincial government sources.⁴⁵ This approach has increased China's overall launch capacity and has introduced a broader range of launch providers focusing on innovation, development cycles, and industrial scalability.

China aims to reduce costs, increase launch cadence, and directly compete with U.S. commercial providers such as SpaceX, ULA, and Blue Origin.⁴⁶ CASC's updated architecture for the Long March 9, for example, shifted from a traditional expendable model with four boosters to a fully reusable, methane-fueled design, which is visually similar to SpaceX's Starship system, indicating that China recognizes the value of reusable launch vehicles.⁴⁷

PRC companies such as LandSpace and Galactic Energy are also pursuing reusability as a core capability of their launch vehicles. LandSpace's Zhuque-2 became the first methane-fueled rocket to reach orbit in 2023, and future variants are planned with a reusable first stage.⁴⁸ Galactic Energy is developing the Pallas-1 rocket, which features similar design elements, including grid fins and landing legs. The launch vehicle is intended to rival Falcon 9 in both capability and cost efficiency.⁴⁹ While still in its early stages, these developments indicate a shift in China's approach to launch vehicle architecture. China recognizes the economic value of reusable systems, as well as their strategic value in supporting high-frequency launch operations and long-duration deep space missions.⁵⁰

⁴³ *Id.* at 12

⁴⁴ *Id.* at 31

⁴⁵ *Id.* at 2

⁴⁶ United States- China Economic and Security Review Commission (Apr. 2025), *Hearing on the Rockets Red Glare: China's Ambitions to Dominate Space* [Hearing Transcript], https://www.uscc.gov/sites/default/files/2025-04/April_3_2025_Hearing_Transcript_0.pdf

⁴⁷ Andrew Jones, *China unveils fully reusable Starship-like rocket concept*, SpaceNews, (Nov. 14th, 2024) <https://spacenews.com/china-unveils-fully-reusable-starship-like-rocket-concept/>

⁴⁸ Reuters, *China beats rivals to successfully launch first methane-liquid rocket*, Reuters, (Jul. 11, 2023) <https://www.reuters.com/technology/space/china-beats-rivals-successfully-launch-first-methane-liquid-rocket-2023-07-12/>

⁴⁹ Andrew Jones, *Chinese launch startup Galactic Energy raises \$154 million for Pallas-1 reusable rocket*, SpaceNews, (Dec. 20, 2023) <https://spacenews.com/chinese-launch-startup-galactic-energy-raises-154-million-for-pallas-1-reusable-rocket/>

⁵⁰ *Id.* at 46

Launch Infrastructure

The PRC heavily invests in its space infrastructure to expand its capacity and enable new capabilities. China operates five ground-based launch sites,⁵¹ including three inland launch sites that have been operational for decades: the Jiuquan Satellite Launch Center, which serves as the launch site for crewed missions; the Taiyuan launch site, which specializes in polar orbit launches; and the Xichang Satellite Launch Center, which supports missions to geostationary orbit. China also maintains the Wenchang Space Launch Site, located on Hainan Island off the southern coast of China. Wenchang began operating in 2016 and is used to launch a range of missions, with a focus on Long March-5 and -7 launch operations.⁵² Finally, China also conducts sea-based launches using a ship-based platform.⁵³

The Hainan International Commercial Aerospace Launch Center, which is collocated with government launch facilities at the site, supports several commercial space endeavors. Hainan, which conducted its first mission in 2024, is China's first launch site dedicated to commercial operations.⁵⁴ A phase two upgrade for Hainan is also ongoing. It will include two new launch pads, a commercial aerospace command and control center, a rocket assembly and testing facility, and a tracking, telemetry, and command station.⁵⁵

Human Space Exploration

PRC human exploration efforts consist of two lanes: human operations in low-Earth orbit (LEO) and crewed missions to the Moon and other deep space destinations. Since launching the first taikonaut into orbit in 2003 and becoming the third country to independently send humans into space, the PRC has continued to launch more taikonauts and conduct increasingly complex missions.⁵⁶

Low-Earth Orbit

One of the main elements of China's human spaceflight program is the *Tiangong* space station. The development of *Tiangong* is occurring in several phases, beginning with the launch of the *Tiangong-1* and *Tiangong-2* laboratories in 2011 and 2016, respectively.⁵⁷ These space stations were used to demonstrate and mature a range of technologies, such as capabilities for rendezvous and refueling. The current *Tiangong* station was assembled between 2021 and 2022 and consists of three modules: the Tianhe core module, which houses command systems and crew quarters, as well as the two laboratory modules, Wentian and Mengtian, equipped with experimental racks

⁵¹ *Id.* at 2

⁵² Wenchang Space Launch Centre, China Space Report, <https://chinaspacereport.wordpress.com/facilities/wenchang/>

⁵³ chinadaily.com.cn, *China's Smart Dragon 3 rocket launches satellites from sea*, China Services INF, (Jan. 14th 2025) <https://govt.chinadaily.com.cn/s/202501/14/WS678e199e498ecc7e1f72db90/chinas-smart-dragon-3-rocket-launches-satellites-from-sea.html>

⁵⁴ Zhao Lei, *China launches 18 satellites from Hainan commercial spacecraft launch site*, China Daily, (Mar. 11, 2025) <https://www.chinadailyhk.com/hk/article/606741>

⁵⁵ Xinhua, *2nd phase of Hainan commercial spacecraft launch site under construction in S China*, English, (Sep. 6th, 2025, 9:37 PM) https://english.www.gov.cn/news/202509/06/content_WS68bc38fcd6d0868f4e8f560f.html

⁵⁶ Space.com Staff, *Making History: China's First Human Spaceflight*, Space.com (Sep. 28, 2005) <https://www.space.com/1616-making-history-china-human-spaceflight.html>

⁵⁷ Daisy Dobrijevic, Andrew Jones, *China's space station, Tiangong: A complete guide*, Space.com, (Aug. 15, 2023) <https://www.space.com/tiangong-space-station>

used for conducting scientific research. In its current form, the *Tiangong* station is around 20% of the mass of the International Space Station (ISS).⁵⁸

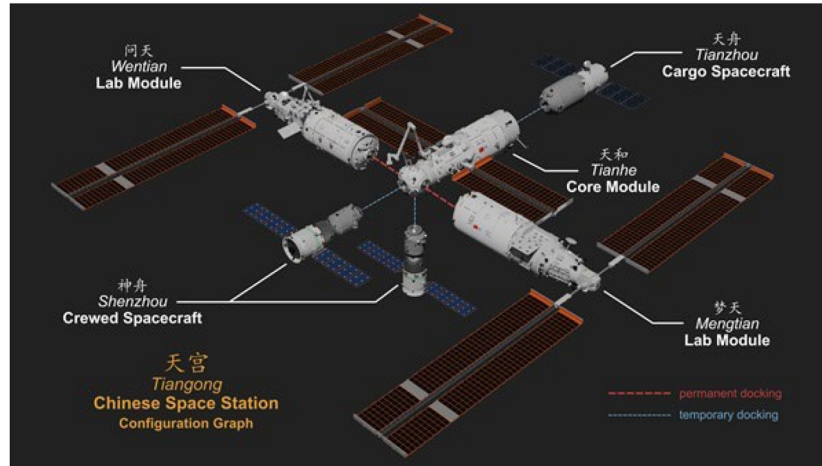


Figure 2: Tiangong Space Station [Source: Astronomy.com]

The PRC is also planning upgrades to *Tiangong*, including the addition of three new modules to enhance overall research and support large extravehicular experiments.⁵⁹ Additionally, the PRC plans include the development of a large-scale space-survey telescope, similar to NASA's Hubble Space Telescope, designed to operate in tandem with *Tiangong*.⁶⁰

Since becoming operational, the PRC has conducted regular six-month crew rotations, comprised of three taikonauts per rotation. In October 2025, the PRC's seventh crew arrived at *Tiangong* to take over operations.⁶¹ These crews conduct a range of research projects while on station, with a primary focus on areas related to deep space exploration, including the study of human physiology in microgravity, closed-loop life support systems, and materials science experiments.⁶² In addition to carrying out Chinese research projects, the PRC utilizes *Tiangong* as a tool for international engagement. For example, in 2018, 27 countries, including several U.S.

⁵⁸ Mike Wall, *China's Shenzhou 20 astronauts arrive at Tiangong space station (video)*, Space.com, (Apr. 23, 2025) <https://www.space.com/space-exploration/missions/chinas-shenzhou-20-astronauts-arrive-at-tiangong-space-station>

⁵⁹ Andrew Jones, *China wants to make its Tiangong space station bigger and better*, Space.com, (Oct. 28, 2024) <https://www.space.com/china-expand-upgrade-tiangong-space-station>

⁶⁰ Xinhua, Huaxia, *Flagship Chinese space telescope to orbit with space station*, English News, (Aug. 18th, 2023, 11:20 PM) <https://english.news.cn/20230818/4f3205e5a4ea40ec9e80d2a3c170f0c6/c.html>

⁶¹ Andrew Jones, *China reveals crew for Shenzhou 21 mission to Tiangong Space Station, including nation's youngest astronaut (video)*, Space.com, (Oct. 30, 2025) <https://www.space.com/space-exploration/human-spaceflight/china-reveals-crew-for-shenzhou-21-mission-to-tiangong-space-station-including-nations-youngest-astronaut-video>

⁶² *Id.* at 57

allies, submitted proposals for projects onboard *Tiangong*.⁶³ Additionally, under an agreement signed between China and Pakistan in February 2025, China will host and train Pakistani astronauts prior to a series of joint, short-duration missions to *Tiangong*.⁶⁴

Tiangong and, more broadly, China's presence in low-Earth orbit have strategic implications. As the International Space Station nears its expected retirement in 2030, a gap in U.S. crewed operations in low-Earth orbit could potentially emerge if U.S. commercial platforms are not yet fully deployed at the time of transition. In such a scenario, *Tiangong* may become the world's only human outpost in orbit, expanding Beijing's influence over access to low-Earth orbit and potentially forcing nations to engage with China as the primary, or only, avenue for scientific collaboration in space.⁶⁵

The Moon & Other Deep Space Destinations

The PRC is also interested in sending taikonauts to other planetary bodies. The Moon currently serves as the focus for the Chinese space program, with the goal of landing its taikonauts on the lunar surface by 2030.⁶⁶

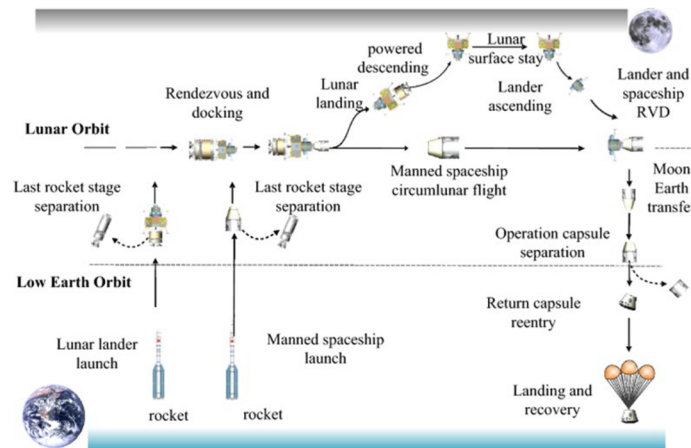


Figure 3: Concept of Operations for China's Crewed Lunar Landing Mission [Source: Springer]

In 2004, the PRC introduced its lunar exploration program, named Chang'e. The program was designed to be a multi-phase lunar exploration, beginning with the deployment of lunar rovers

⁶³ Andrew Jones, *International experiments selected to fly on Chinese space Station*, SpaceNews, (Jun. 13, 2019) <https://spacenews.com/international-experiments-selected-to-fly-on-chinese-space-station/>

⁶⁴ Julian Dossett, *China and Pakistan agree to fly 1st foreign astronaut to Chinese space station*, Space.com, (Apr. 9 2025) <https://www.space.com/space-exploration/human-spaceflight/china-and-pakistan-agree-to-fly-1st-foreign-astronaut-to-chinese-space-station>

⁶⁵ China Power Team, *"What's Driving China's Race to Build a Space Station?"*, China Power, December 7, 2016. Updated April 21, 2021. Accessed November 5, 2025. <https://chinapower.csis.org/chinese-space-station/>

⁶⁶ Yidong Gu, Jin Ba, *Space exploration in China*, Journal of Physics: Conference Series, <https://iopscience.iop.org/article/10.1088/1742-6596/2877/1/012049/pdf>

and concluding with the return of samples from the lunar surface.⁶⁷ Between 2007 and 2024, China launched six Chang'e missions to the Moon, including two orbiters to map and image the surface (Chang'e 1 and 2); two landers to demonstrate soft landings and deploy rovers (Chang'e 3 and 4); and two spacecraft that conducted lunar sample return missions (Chang'e 5 and 6).⁶⁸ Notably, the Chang'e 4 mission, in 2019, represented the first soft-landing on the far side of the Moon, and Chang'e 6, in 2024, was the first mission to collect and return samples from the far side of the Moon.⁶⁹

Two additional Chang'e missions are scheduled: Chang'e 7, which will perform lunar surface exploration and surveying activities in 2026, and Chang'e 8, which will test and demonstrate technologies for building infrastructure on the surface of the Moon in 2028.⁷⁰ These precursor missions will build out Chinese capabilities and demonstrate key technologies, all structured to support planned human exploration efforts through the PRC's International Lunar Research Station (ILRS). The ILRS was established through a 2021 Memorandum of Understanding between China and Russia to build a research facility on the Moon's surface.⁷¹

The ILRS is designed to be a comprehensive and scalable facility that can perform multidisciplinary, multi-target, large-scale scientific and technological activities.⁷² Research objectives for ILRS include conducting a geological survey of the Moon, lunar-based astronomy observations, space environment observations of the Sun-Earth-Moon system, lunar-based fundamental science experiments, and lunar in-situ resource utilization.⁷³

Following the Chang'e 8 mission, the PRC has planned a series of missions that, by 2035, will construct a scientific facility with basic functions and essential supporting elements around the lunar south pole, a site considered strategically important due to the potential presence of water ice.⁷⁴ Once built, China plans to operate the ILRS facility while also expanding its lunar presence through a second phase, in which the PRC will add additional facilities (both at the Moon's equator and on the far side), deploy power and communications infrastructure, and introduce new capabilities to support mobility.⁷⁵

As part of the preparation for future human lunar missions, in 2025, the PRC completed the first integrated landing and ascent test of its *Lanyue* crewed lunar lander, validation tests of the Long

⁶⁷ *Id.* at 66

⁶⁸ Katie Holland, *Chinese Lunar Exploration Program*, National Space Centre, (Apr.29, 2024) <https://www.spacecentre.co.uk/news/space-now-blog/chinese-lunar-exploration-program/>

⁶⁹ *Id.* at 68

⁷⁰ *Chang'e Missions*, Orbital Data Explorer Help, https://ode.rsl.wustl.edu/MARS/pagehelp/Content/Missions_Instruments/Change/Intro.htm

⁷¹ Lukasz Kobierski, *China and Russia Agree to Build Lunar Research Station*, Warsaw Institute, (Mar. 15, 2021) <https://warsawinstitute.org/china-russia-agree-build-lunar-research-station/>

⁷² *International Lunar Research Station (ILRS)*, Deep Space Exploration Laboratory of CNSA, (May, 2023) https://www.unoosa.org/documents/pdf/copuos/2023/TPs/ILRS_presentation20230529_.pdf

⁷³ Lin XU, Hui LI, Zhaoyu PEI, et al. *A Brief Introduction to the International Lunar Research Station Program and the Interstellar Express Mission (J/OL)*. *Chinese Journal of Space Science*, 2022, 42 (4): 511-513. 2024-07-17. 2025-11-07. <https://www.sciengine.com/doi/10.11728/cjss2022.04.yg28>

⁷⁴ *Id.* at 6

⁷⁵ Andrew Jones, *China plans to build moon base at the lunar south pole by 2035*, Space.com, (Sep. 10, 2024) <https://www.space.com/china-moon-base-south-pole-2035>

March 10 rocket, and pad abort testing for the *Mengzhou* crewed spacecraft.⁷⁶ The PRC is also preparing for additional testing and validation efforts prior to conducting a crewed lunar mission. This includes trials of a robotic prototype of *Lanyue* in 2027 and 2028 as well as an uncrewed joint *Mengzhou-Lanyue* mission in either 2028 or 2029.⁷⁷ China also plans to conduct an in-flight maximum dynamic pressure escape test of *Mengzhou* next year.⁷⁸ Additionally, China is preparing for flight testing of Long March 10, but hasn't stated a timeline for its completion.⁷⁹

While officially framed as a scientific endeavor, the ILRS also functions as a diplomatic and strategic tool for the PRC. China's goal is to have 50 countries participate in the ILRS, and the PRC has made extensive efforts to attract international partners.⁸⁰ China has used ILRS in recent years to build partnerships with non-Western-aligned countries, with a particular emphasis on developing nations seeking new pathways for space cooperation.⁸¹ The ILRS is also closely linked to China's broader foreign policy approach, including the Digital Silk Road, which plans to integrate its space-based infrastructure into international development plans. ILRS is also a foil to NASA's Artemis Accords, which 59 countries have signed.⁸² This strategy supports long-term access to lunar resources, advances in in-situ resource utilization (ISRU), and extends China's geopolitical reach in space.

Spacecraft and Satellites

As part of its endeavor to become a great space power, the PRC is developing a range of satellite capabilities while also enabling private sector opportunities. The PRC is working to expand its global influence and increase foreign technical dependencies on China through systems like the Beidou satellite navigation network, as well as observation platforms and state-backed broadband constellations.

China is developing a layered space information network that can provide both the PLA with secure, independent, and comprehensive battlespace awareness, as well as competitive commercial services. A primary component of this infrastructure is the Beidou Satellite Navigation System, which is China's alternative to the U.S. Global Positioning System (GPS).⁸³

⁷⁶ Andrew Jones, *China completes landing and takeoff test for crewed moon lander*, SpaceNews, (Aug. 7, 2025) <https://spacenews.com/china-completes-landing-and-takeoff-test-for-crewed-moon-lander/>

⁷⁷ Marissa Martin, *China Is Going to the Moon by 2030. Here's What's Known About the Mission—and Why It Matters*, RAND.org, (Nov. 13, 2025) <https://www.rand.org/pubs/commentary/2025/11/china-is-going-to-the-moon-by-2030-heres-whats-known.html>

⁷⁸ Mark Thompson, *China Tests the Crew Escape for its New Lunar Capsule*, universetoday.com, (June 20, 2025) <https://www.universetoday.com/articles/china-tests-the-crew-escape-for-its-new-lunar-capsule>

⁷⁹ Andrew Jones, *China targets 2026 for first Long March 10 launch, new lunar crew spacecraft flight*, SpaceNews.com, (Oct. 30, 2025) <https://spacenews.com/china-targets-2026-for-first-long-march-10-launch-new-lunar-crew-spacecraft-flight/#:~:text=Discounted%20Access,challenges%20and%20workload%20were%20significant.>

⁸⁰ *China's International Lunar Research Station*, spacesecurity.wse.jhu.edu, (Jul. 28, 2024)

<https://spacesecurity.wse.jhu.edu/2024/07/28/chinas-international-lunar-research-station/>

⁸¹ United States- China Economic and Security Review Commission (Nov. 2022), *Report to Congress*, https://www.uscc.gov/sites/default/files/2022-11/2022_Annual_Report_to_Congress.pdf

⁸² Jeff Foust, *Latvia to sign Artemis Accords*, SpaceNews, (Nov. 1, 2025) <https://spacenews.com/latvia-signs-artemis-accords/>

⁸³ China Aerospace Studies Institute, *To Be More Precise: BEIDOU, GPS, and the Emerging Competition in Satellite-Based PNT*, Air University, (May 20 2024),

Beidou provides the PLA with access to precision navigation, timing (PNT), and communications capabilities, without reliance on foreign systems. China is also promoting international adoption of Beidou through its broader Digital Silk Road initiative.⁸⁴

Outside of Beidou, China is also developing the Guowang satellite constellation, a state-directed program that will deploy approximately 13,000 communications satellites to low-Earth orbit, competing with Western systems such as Starlink.⁸⁵ While officially described as a communications network, Guowang is widely assessed to be a dual-use system and can integrate broadband data services with surveillance and signals intelligence capabilities.⁸⁶ This system aims to improve the PLA's ability to operate and monitor in multiple regions worldwide. Additionally, companies such as the Shanghai Spacecom Satellite Technology (SSST) are also developing satellite constellations. SSST is building Qianfan, or Thousand Sails, which is a planned constellation of 14,000 satellites in LEO that will provide communications and broadband data services country-wide.⁸⁷

An increasing focus of China's space program is the development of In-Space Servicing, Assembly, and Manufacturing (ISAM) technologies. These capabilities are strategically important, as they allow for satellites to have extended lifespans, enhanced maneuverability, and greater operational flexibility. China began pursuing this objective with a successful in-space propellant transfer demonstration in 2017, and the technology is now used to support the routine resupply and maintenance of the *Tiangong* space station.⁸⁸ ISAM technologies are also being tested in higher orbits. In January 2022, the Shijian-21 satellite conducted a mission in geosynchronous orbit, where it rendezvoused with a defunct Beidou satellite, captured it using a robotic arm, and moved it to a higher "graveyard" orbit.⁸⁹ More recently, in June 2025, the newer Shijian-21 and Shijian-25 satellites appeared to experiment with docking and propellant transfer between the two spacecraft.⁹⁰

<https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2024-05-20%20To%20Be%20More%20Precise%20-%20Beidou.pdf>

⁸⁴ Reconnectiong Asia, *Mapping China's Digital Silk Road*, Reconnecting Asia, (Oct. 19, 2021)

<https://reconasia.csis.org/mapping-chinas-digital-silk-road/>

⁸⁵ Greg Gillinger, *Developing and testing China's Guowang constellation*, The Space Review, (Jun. 16, 2025)

<https://www.thespacereview.com/article/5004/1>

⁸⁶ Andrew Jones, *China's Guowang launch raises questions about satellite purpose and transparency*, SpaceNews, (Jan. 7, 2025) <https://spacenews.com/chinas-guowang-launch-raises-questions-about-satellite-purpose-and-transparency/>

⁸⁷ Sydney Nystrom, David Zou, Peter Garretson, *Thousand Sails: Why Low Earth Orbit is the Next Frontier for Great Power Competition between the U.S. and China*, Space Policy Review, https://www.afpc.org/uploads/documents/Thousand_Sails-Why_Low_Earth_Orbit_is_the_Next_Frontier_for_Great_Power_Competition_between_the_US_and_China_-_Final.pdf

⁸⁸ Stephen Clark, *Tianzhou 1 freighter achieves China's first in-space refueling demo*, Spaceflight Now, (Apr. 27, 2017), <https://spaceflightnow.com/2017/04/27/tianzhou-1-freighter-achieves-chinas-first-in-space-refueling-demo/>

⁸⁹ *Shijian-21 Satellite*, eoPortal, (Jan. 31, 2022) <https://www.eoportal.org/satellite-missions/shijian-21>

⁹⁰ U.S. Senate Committee on Commerce, Science, & Transportation (Sep. 3, 2025), *There's a Bad Moon on the Rise: Why Congress and NASA Must Thwart China in the Space Race* [Hearing], https://www.commerce.senate.gov/2025/9/there-s-a-bad-moon-on-the-rise-why-congress-and-nasa-must-thwart-china-in-the-space-race_2

These advancements demonstrate China's progress in developing ISAM capabilities while also presenting dual-use implications. Under the Military-Civil Fusion strategy, a satellite designed for servicing missions could also be repurposed to interfere with, inspect, or collect intelligence on assets belonging to the United States. In this context, China's ability to refuel satellites would also enable them to conduct frequent orbital maneuvers without depleting their propellant reserves, in turn improving the survivability of the satellites and complicating monitoring and tracking capabilities.⁹¹

The PRC's interest in developing and deploying satellite capabilities also extends to lunar orbit. As part of past Chang'e lunar missions, China has deployed several satellites to the cislunar domain, including the Queqiao-1 and 2 communications satellites, which enabled both of China's landings on the far side of the Moon.⁹² Moreover, the PRC is planning to develop comprehensive communications and positioning, navigation, and timing (PNT) capabilities for the cislunar domain. The PRC's proposal spans three phases and centers around deploying additional satellites, introducing new capabilities, and expanding the cislunar orbits it operates in.⁹³ The current, first phase will focus on providing communications relay services for missions to the south pole and far side of the Moon as well as validating a range of communications, PNT, and remote sensing capabilities. This will be followed by a second phase where China will deploy additional satellites to extend its capabilities, providing comprehensive coverage of the Moon. Following the establishment of robust lunar communications and PNT capabilities, the PRC plans to extend these capabilities and establish a deep space communications and PNT system.⁹⁴

Sample Return

For China's space science program, a major focus is currently the development of sample return capabilities. The PRC has demonstrated its competence in this domain through a series of Chang'e lunar sample return missions. While continuing to execute lunar exploration objectives, China is also extending its sample return efforts to interplanetary targets. The Tianwen-2 mission, which launched in May 2025, marks China's first attempt to retrieve samples from another planet and will test technologies for navigating, collecting, and returning material from low-gravity environments.⁹⁵ The subsequent mission in the Tianwen program, Tianwen-3, is scheduled for launch in 2028 and is intended to collect and return samples from the surface of Mars.⁹⁶ If successful, this mission could precede the NASA-European Space Agency joint

⁹¹ Kristin Burke, *China's SJ-21 Framed as Demonstrating Growing On-Orbit Servicing, Assembly, and Manufacturing (OSAM) Capabilities*, China Aerospace Studies Institute, (Dec. 2021) <https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2021-12-09%20SJ-21%20and%20China%27s%20OSAM%20Capabilities.pdf>

⁹² Planetary Society, *Queqiao-2: China's bridge for lunar exploration*, <https://www.planetary.org/space-missions/queqiao-2-chinas-bridge-for-lunar-exploration>

⁹³ Andrew Jones, *China wants a lunar satellite constellation to support deep space missions*, *SpaceNews.com*, (Oct. 5, 2023) <https://spacenews.com/china-wants-a-lunar-satellite-constellation-to-support-deep-space-missions/>

⁹⁴ *Id.* at 93

⁹⁵ Son Jianlan, *Tianwen-2 Sets Out for Asteroid Sampling and Comet Exploration*, *Bulletin of the Chinese Academy of Sciences* (Jun. 26, 2025) https://bcas.cas.cn/head/202506/t20250626_1046258.html

⁹⁶ Hou, Z., Liu, J., Pang, F. et al. *In search of signs of life on Mars with China's sample return mission Tianwen-3*. *Nat Astron* 9, 783–792 (2025). <https://doi.org/10.1038/s41550-025-02572-0>

mission in returning the first Martian surface samples to Earth through NASA's Mars Sample Return program, and would represent a major milestone in China's scientific capabilities.

Chairman HARIDOPOLOS. Good morning. The Subcommittee on Space and Aeronautics will come to order. Without objection, the chair is authorized to declare recesses of the Subcommittee at any time.

Welcome to today's hearing: Strategic Trajectories Assessing China's Space Rise and the Risks to the United States Leadership. I will recognize myself for 5 minutes for our opening statement.

The topic today will address—is nothing more than a critical issue and defining challenge for this Committee. Understanding China's bold ambitions, addressing their unapologetic drive for dominance in space. We are at the start of the next age of exploration; one where humanity is not just observing the cosmos but acting on its observations and beginning to inhabit it.

For those who are new to this issue, the question we should be asking as we explore beyond the planet is, will humanity carry forward the American values of economic and political freedom or those of the Chinese Communist Party (CCP)?

For generations, the United States led humanity into space with unmatched ingenuity and without a true rival. However, that situation is changing as China moves methodically, relentlessly, and ruthlessly to tighten the script on space capabilities and seek the strategic advantages by any means possible.

History reminds us that great power competition shapes the destiny of civilizations. Just as the rivalry between Spain and Great Britain define oceans in the 16th and 17th Century, the competition between the United States and China will define the space domain today. Whoever leads beyond Earth will shape the future of Earth.

Let's go back to 1957, China's ambitions goes back decades. Moments after Sputnik shook the world, Chairman Mao declared we too will make satellites. That declaration ignited a vision that has never faded.

In 1992, China set into motion Project 921, its human space flight program which continues today. In recent years, China's pace has surged in part due to the declaration of the space stream, which transformed aspirations into coordinated missions for dominance.

China's space sector has then surged forward, aimed to compete with America's world-leading commercial space industry. This is not an accident; it is strategic. To be clear, the objective is not merely to keep up, their objective is to outpace, outmaneuver, and ultimately defeat our Nation, the United States of America.

But America is not standing still. In my district, Kennedy Space Center, we surpassed 100 launches just 2 weeks ago, 95 launches came from one company, SpaceX who first launched in 2006. China is not even close with around 73 launches.

Still, Beijing is pressing ahead. Their plans include landing their astronauts on the lunar surface by 2030 and constructing research space on the Moon South Pole by 2035. They are also launching historic firsts. China has already returned lunar samples from the far side of the Moon, the first to do so.

Next, they intend to launch a Mars-sample return mission in 2028. A timeline that may beat the United States. In low-Earth orbit, we plan to de-orbit our own space station. China has main-

tained a continuous human presence on its own space station since 2021 where their astronauts serve in 6-month rotations.

In the coming years, China intends to deploy its own space-based internet service and expand its global alternative to GPS (Global Positioning System). And while these Committees' jurisdiction covers commercial and civil space programs, we cannot ignore their army's rapidly advancing space and counter-space capabilities. Their systems are designed to threaten, disrupt, and if necessary, take out United States assets in space.

So, again, I ask: Will humanity move forward with American values of economic and political freedom or those of the communist Chinese? The reality is stark. China possesses a real, immediate, and long-term threat to the United States leadership in space. And, fortunately, today's witnesses will provide us with more detailed overview of Chinese trajectory in history, strategy, and intentions. They will also share recommendations about how this Committee and Congress should respond to this true challenge.

I thank our distinguished panel today for being here today and sharing their expertise with us. And I look forward to a serious, productive, conversation about the challenges we face today.

But before I move forward, I would like to ask for unanimous consent for a statement from the Full Committee by Dr. Babin to present that copy.

And without objection, so that is ordered.

[The prepared statement of Chairman Babin follows:]

Thank you, Mr. Chairman, for holding today's hearing on this critical topic.

A central priority of my service in Congress has been to strengthen U.S. competitiveness in research and development, science, and technology. As Chairman of this committee, I have consistently emphasized the importance of this goal, focusing not only on ensuring the United States maintains its position as a global leader on Earth but also in space.

To achieve this, we must acknowledge the growing challenges posed by the Chinese Communist Party.

The CCP has made no secret about its ambition to emerge as the world's foremost leader in space exploration and innovation. Since the election of President Xi in 2013, the CCP has deepened the connection between its space program and its broader national goals of domestic and military modernization.

This increased focus has led to greater attention and resources for its space program, resulting in several recent accomplishments that cannot be overlooked.

China has maintained a crewed presence in low-Earth orbit since 2021, using its Tiangong [Tee-Yen-Gong] space station.

In 2024, China became the first and only nation to return samples from the far side of the Moon.

This year, China conducted a series of tests to develop major components and systems that will support its future lunar missions, demonstrating that the CCP is both committed and working expeditiously toward its goal of landing taikonauts on the Moon by 2030.

The U.S. cannot afford to fall behind. If China takes the lead in space exploration, it will set the rules of the road. Our values - not those of the Chinese Communist Party—must shape those rules.

To ensure that the United States retains its leading role in space, Congress must understand China's capabilities, its future plans, and the pace at which the CCP is completing its objectives. That is the purpose of today's hearing.

A clearer understanding of China's space program will guide this committee's work on space policy for the remainder of this Congress.

I was in the Oval Office when President Trump signed the last full NASA authorization bill into law in March 2017. It was a crucial step in the right direction, but much has happened in the years since.

In the coming weeks, our committee will consider a new NASA authorization bill that will provide urgently needed direction to the agency. I look forward to working with my colleagues to send this bill to the President's desk.

However, China's achievements extend beyond its government space activities. A report by the Commercial Space Federation, released in September, highlights significant growth in China's investment in its commercial space industry.

America's commercial space sector is the envy of the world, but maintaining that status is not guaranteed, and our leadership is far from assured. Next year, our committee will consider new commercial space legislation that builds on the *Commercial Space Act of 2023*, which I was proud to lead.

As I said during our commercial space hearing last September, we can either be tethered to Earth by red tape while the Chinese move ahead—or we can act decisively. This bill will help ensure the continued growth of our commercial space sector.

We have a lot of work ahead of us, but with Congress, stakeholders, and the administration working together, we can keep America at the helm as we enter the next era of space exploration.

I am pleased to welcome today's excellent panel of witnesses. Several of you are no strangers to this committee. I look forward to your testimony and the opportunity to engage with you this morning.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Chairman Haridopolos follows:]

The topic we will address today is nothing less than a critical issue and defining challenge for this committee: understanding China's bold ambitions and addressing their unapologetic drive for dominance in space.

We are at the start of the next age of exploration. One where humanity is not just observing the cosmos but acting on its observations and beginning to inhabit it.

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Now, let's go back to 1957. China's ambitions stretch back decades. Moments after Sputnik shook the world, Chairman Mao declared, "We too will make satellites." That declaration ignited a vision that has never faded.

In 1992, the People's Republic of China set in motion Project 921, its human spaceflight program, which continues on to this day.

In recent years under President Xi, China's pace has surged, in part due to his declaration of a Chinese "space dream", which transformed aspirations into a coordinated national mission for dominance.

China's commercial space sector has since surged forward, aimed to compete with America's world-leading commercial space industry. This is not accidental. It is strategic.

And to be clear, the objective is not merely to keep up. Their objective is to outpace, outmaneuver, and ultimately defeat the United States.

But America is not standing still. In my district, at the Kennedy Space Center, we surpassed 100 launches just two weeks ago. Roughly 95 percent of those launches came from a single commercial company, SpaceX, who first launched in 2006. China is not even close at around 73 launches.

Still, Beijing is pressing ahead. Their plans include landing taikonauts on the lunar surface by 2030 and constructing a research base at the Moon's South Pole by 2035.

They are also achieving historic firsts. China has already returned Lunar samples from the far side of the Moon—the first to do so.

Next, they intend to launch a Mars sample-return mission in 2028, a timeline that may beat the United States.

In low-Earth orbit, while we plan to deorbit our own space station, China has maintained a continuous human presence on its own space station since 2021, with taikonauts serving six-month crew rotations.

In the coming years, China intends to deploy its own space-based internet service and expand its global alternative to GPS.

And while this committee's jurisdiction covers commercial and civil space programs, we cannot ignore the People's Liberation Army's rapidly advancing space and counterspace capabilities. Their systems are designed to threaten, disrupt, and if necessary, take out U.S. assets in space.

So again, I ask: Will humanity carry forward the American values of economic and political freedom or those of the Communist Chinese Party?

The reality is stark. China poses a serious immediate and long-term threat to U.S. leadership in space.

Today's witnesses will provide us with a more detailed overview of China's trajectory: its history, strategy, and intentions.

They will also share recommendations about how this committee and Congress should respond to this mercurial challenge.

I thank our distinguished panel of witnesses for being here today and sharing your expertise with the subcommittee.

I look forward to a serious and productive discussion of the challenges before us.

Chairman HARIDOPOLOS. And with that, I want to recognize our Ranking Member, Mrs. Foushee, from North Carolina for her opening statement. Thank you so much.

Mrs. FOUSHEE. Thank you, and good morning. And thank you Chairman Haridopolos for holding today's hearing to review China's space activities and the implications for the United States Space Program. I want to also welcome our distinguished witnesses, thank you for being here.

It is no surprise that we are here today to assess China's space rise and the risks to U.S. leadership. China's ascending space capabilities are fast approaching strategic comparability with the United States. This is intentional. Xi Jinping's space dream stresses the importance of China dominating the space domain.

The recently released 2025 annual report to Congress of the U.S., China, economic, and security review commission states that China has embarked on a whole of government strategy to become the world's preeminent space power. These are not near projections or rhetoric.

China is methodically carrying out increasingly sophisticated space capabilities in its efforts to dominate. China has joined the ranks of only the U.S. and Russia in launching humans into space.

To date, China has become only the second Nation to land and operate a spacecraft on Mars. In addition, China operates a continuously crewed space station in low-Earth orbit and has racked up a number of firsts, including landing on and collecting and returning samples from the far side of the Moon and placing communications satellites around the Moon and more. That is not all. China has publicly announced its plans to land humans on the surface of the Moon by 2030, establish a permanent International Lunar Research Station (ILRS) by 2025, and acquire samples from Mars and return them to Earth in the early 2030s.

In 2024, China released its first Mid-and Long-Term Plan for Space Science in which it aims to achieve top-tier international ranking in major space science areas by 2050.

Further, China is aggressively investing in and enabling a quasi-commercial space sector, as well as growing its international partnerships.

Why does it matter? The People's Republic of China (PRC) for which there is no distinction between civil and military space knows that leadership in space has brought the United States invaluable geopolitical soft power, significant and beneficial international alliances, economic growth fueled by innovation, bold and

inspiring missions that drive and attract STEM (science, technology, engineering, and mathematics) talent, and national security advantages.

How we navigate China's ascending space capabilities today has direct impacts on every American—our banking, communications, weather prediction, agriculture, natural resource management and national security, for example, all rely on space systems.

Threats to the U.S. presence and leadership in space could put at risk a critical backbone of our social, security, and economic systems.

And how are we navigating China's space rise? The Trump Administration appears to believe that attacking research university, gutting our Federal STEM workforce, withdrawing from international engagement, and significantly underinvesting—investing rather, in research and development (R&D) is the answer.

Just look at this stark comparison between China's space science plans and those of the Trump Administration as prepared by the Planetary Society. Is this a winning strategy?

While I am pleased that the Nancy Grace Roman Space Telescope on which both Duke and North Carolina Central University in my district collaborate is maintained in making excellent progress, ceding so many transformational space science missions to China alone will send a dangerous message.

As Ranking Member of this Subcommittee, I have expressed before, I will not stand for handing the keys to lunar exploration or space leadership to China. This is a pivotal moment. We on this Subcommittee and the Science Committee have a responsibility and an obligation to advance sound policies that ensure and sustain America's civil and global leadership in space.

We must meet this challenge with bold policies, robust investments, and a unified vision to preserve our Nation's leadership in space exploration and innovation.

We also need to critically navigate our coexistence with China in space. For example, are there areas where limited engagement in China, such as on space flight safety could serve U.S. interests?

At this time, Mr. Chairman, I would ask for unanimous consent to permit Representative Don Beyer to attend this hearing and ask questions of the witnesses.

[The prepared statement of Mrs. Foushee follows:]

Good morning and thank you Chairman Haridopolos for holding today's hearing to review China's space activities and the implications for the United States space program. I want to also welcome our distinguished witnesses. Thank you for being here.

It is no surprise that we are here today to assess China's space rise and the risks to U.S. leadership. China's ascending space capabilities are fast approaching strategic comparability with the United States. This is intentional.

Xi Jinping's "Space Dream" stresses the importance of China dominating the space domain. The recently released 2025 annual report to Congress of the U.S.-China Economic and Security Review Commission states that "China has embarked on a whole-of-government strategy to become the world's preeminent space power."

These are not mere projections or rhetoric. China is methodically carrying out increasingly sophisticated space capabilities in its effort to dominate. China has joined the ranks of only the U.S. and Russia in launching humans into space. To date, China has become only the second nation to land and operate a spacecraft on Mars. In addition, China operates a continuously crewed space station in low-Earth orbit and has racked up a number of "firsts:"

Including landing on—and collecting and returning samples from—the far side of the Moon; emplacing communications satellites around the Moon, and more.

That is not all. China has publicly announced its plans to land humans on the surface of the Moon by 2030, establish a permanent international lunar research station by 2035, and acquire samples from Mars and return them to Earth in the early 2030s.

In 2024, China released its first Mid-and Long-Term Plan for Space Science in which it aims to achieve “top-tier international ranking” in major space science areas by 2050. Further, China is aggressively investing in and enabling a quasi-commercial space sector as well as growing its international partnerships.

Why does it matter? The People’s Republic of China, for which there is no distinction between civil and military space, knows that leadership in space has brought the United States invaluable geopolitical soft power, significant and beneficial international alliances, economic growth fueled by innovation, bold and inspiring missions that drive and attract STEM talent, and national security advantages. How we navigate China’s ascending space capabilities today has direct impacts on every American. Our banking, communications, weather prediction, agriculture, natural resource management, and national security, for example, all rely on space systems. Threats to the U.S.’s presence and leadership in space could put at risk a critical backbone of our social, security, and economic systems.

And how are we navigating China’s space rise? The Trump Administration appears to believe that attacking research universities, gutting our Federal STEM workforce, withdrawing from international engagement, and significantly underinvesting in research and development is the answer. Just look at this stark comparison between China’s space science plans and those of the Trump Administration, as prepared by the Planetary Society. Is this a winning strategy?

China advances its space science efforts as America considers retreat

As China moves forward with an ambitious slate of missions, the U.S. weighs deep cuts to NASA's science portfolio.

	CHINA	UNITED STATES
 Earth's Magnetic Field	 Solar wind Magnetosphere Ionosphere Link Explorer. Launching in 2026.	 Magnetospheric Multiscale Mission Operational. Terminated in FY26 PBR.
 Universe / Exoplanets	 Xuntian Space Telescope Launching in 2026.	 Nancy Grace Roman Space Telescope Cut by 58% in FY26 PBR. Launching in 2027.
 Asteroid Apophis	 Apophis Recon Swarm Proposed for 2027 launch.	 OSIRIS-Apophis Explorer Operational. Terminated in FY26 PBR.
 Exoplanets	 Earth 2.0 Space Telescope Launching in 2028.	 Habitable Worlds Observatory Under study for 2030s. 90% cut in FY26 PBR.
 Mars Sample Return	 Tianwen-3 Launching in 2028.	 Mars Sample Return In development. Canceled in FY26 PBR.
 Jupiter	 Tianwen-4 Launching in 2029.	 Juno Operational. Terminated in FY26 PBR.
 Gravitational Waves	 Taiji-2 Launching in 2030.	 Laser Interferometer Space Antenna ESA partnership. 2030s. Canceled in FY26 PBR.
 Venus	 Venus Atmosphere Sample Return Proposed for 2033.	 DAVINCI and VERITAS In development. 2031. Canceled in FY26 PBR.
 Ice Giant Planets	 Neptune-Triton Mission Under study for 2038.	 Uranus Flagship Mission Under study for 2030s. Canceled in FY26 PBR.

CREDIT: MAXWELL ZHU AND CASEY DREIER

THE PLANETARY SOCIETY

Image: Maxwell Zhu and Casey Dreier

While I'm pleased that the Nancy Grace Roman Space Telescope—on which both Duke and North Carolina Central University in my district collaborate—is maintained and making excellent progress, ceding so many transformational space science missions to China alone would send a dangerous message.

As Ranking Member of this Subcommittee, I have expressed before: I will not stand for handing the keys to lunar exploration—or space leadership—to China. This is a pivotal moment. We, on this Subcommittee and in the Science Committee, have a responsibility and an obligation to advance sound policies that ensure and sustain America's civil and global leadership in space.

We must meet this challenge with bold policies, robust investments, and a unified vision to preserve our nation's leadership in space exploration and innovation. We also need to critically navigate our co-existence with China in space. For example, are there areas where limited engagement with China, such as on spaceflight safety, could serve U.S. interests?

By strengthening our strategic focus, funding, and global partnerships, we can ensure that the United States remains the leader in space for decades to come.

I hope our witnesses will give us concrete recommendations on how to ensure U.S. leadership in the strategic competition with China, and what Congress should consider as we work to reauthorize NASA, not only on highly visible programs such as Artemis, low-Earth orbit, and science—But also on the consequential roles of technical standards, regulatory policies, and international partnerships and diplomacy that have far-reaching influence for United States space activities and much more.

At this time, Mr. Chairman, I ask for Unanimous Consent to permit Representative Don Beyer, to attend this hearing and ask questions of the witnesses.

Thank you, and I yield back.

Chairman HARIDOPOLOS. Without objection, that is ordered. Next, we have—I want to recognize our Ranking Member, the Ranking Member on the Full Committee, Ms. Lofgren for a comment as well.

Ms. LOFGREN. Well, thank you, Mr. Chairman, and for today's hearing. The topic is very important for our work here in the Science Committee, and the Federal Science Technology and Innovation Enterprise.

As we know, China is making unprecedented investments in research and development across science and technology, and space is a core component of this strategy. They represent a real threat to the United States' long history as the undisputed global leader in space. And it is critical that we understand the PRC's current capabilities, their plans, as well as their strategic objectives.

At the same time, it is also critical that we redouble our commitment to supporting and stewarding a strong, robust space program that continues to push the boundaries in Earth and space science in human space flight exploration and space technology development.

You know, in the very first Science Committee hearing in this Congress, we heard from expert witnesses about the state of U.S. science and technology, and that China was actually leading in 37 of 44 critical technologies. In my remarks at that hearing, I said we couldn't ignore the reality outside the four walls of this hearing room.

The new Administration was actively and with unprecedented speed and ferocity, apparently seeking to tear down and undermine some of the very scientific foundations upon which our leadership has been so painstakingly built.

Now, we are here 10 months later and the Administration has not relented in its destructive endeavors. The U.S. Science and Technology Enterprise continues to take blow after blow. NASA

(National Aeronautics and Space Administration) and the Space Enterprise has not been spared.

This summer, the Administration launched a pressure campaign of intimidation against the entire NASA civil servant workforce. And now the agency has lost nearly 4,000 people over 20 percent of the civil servant workforce. And there doesn't seem to be a strategy in determining who should leave and who should stay.

And just over the last couple of months, largely under the cover of a government shutdown, NASA has been rushing to shutter nearly half of the Goddard Space Flight Center's main campus.

I simply do not understand how anyone reconciles rhetoric about competing with China while pulling the rug out from under our own research enterprise. I don't want to speak for our witnesses, but I expect we are about to hear that China is not culling its talent and technical capabilities, that is not undermining its universities, and turning the world's brightest minds away. Yet, that is what our Federal Government is being forced to do today by really an out-of-control White House and OMB (Office of Management and Budget).

Congress needs to step up to the bat. The clock's ticking. As this Administration continues to cripple our science and technology enterprise, China is deliberately and systematically implementing long-term plans.

Now, I have no doubt that all of us on both sides of the aisle serving on this Committee want to ensure U.S. leadership in space. But words are cheap, and actions are priceless. It is up to us on this Committee and in Congress to take the necessary actions that will sustain our global leadership in space and in science and technology more broadly.

Anything less is an invitation to take—let China take the mantle in space and in so much more.

So with that, Mr. Chairman, I thank you, and I yield back.

[The prepared statement of Ms. Lofgren follows:]

Good morning, and thank you Mr. Chairman, for holding today's hearing. I also want to thank our expert witnesses for being here.

This topic is incredibly important for our work here on the Science Committee and the federal science, technology, and innovation enterprise. China is making unprecedented investments in research and development across science and technology, and space is a core component of their strategy. They represent a very real, constant threat to the United States' long history as the undisputed global leader in space. It is critical that we understand the PRC's current capabilities, plans, and strategic objectives. At the same time, it is also critical that we redouble our commitment to supporting and stewarding a strong, robust space program that continues to push the boundaries in Earth and space science, human spaceflight exploration, and space technology development.

In the first Science Committee hearing of this Congress, we heard from expert witnesses about the state of U.S. science and technology, and that China is actually leading in 37 of 44 critical technologies. In my opening remarks, I said that I could not ignore the reality outside of the four walls of this hearing room:

The new Administration was actively, and with unprecedented speed and ferocity, apparently seeking to tear down and undermine some of the very scientific foundations upon which our leadership has been so painstakingly built.

Unfortunately, here we are, ten months later, and the Administration has not relented in its destructive endeavors. The U.S. science and technology enterprise continues to take blow after blow, to this very day. NASA and the space enterprise has not been spared. This summer, the Administration launched a pressure campaign of intimidation against the entire NASA civil servant workforce, and now the agency has lost nearly 4,000 people—over 20% of its civil servant workforce, with no apparent strategy in determining who should leave and who should stay. And, just over

the last couple of months—largely under the cover of a government shutdown—NASA has been rushing to shutter nearly half of the Goddard Space Flight Center's main campus.

I could go on with the insults and injuries this Administration sees fit to impose upon this nation's space program, but I will spare us. I'll simply repeat something else I said in February: I simply do not understand how anyone reconciles rhetoric about competing with China with pulling the rug out from under our own research enterprise.

I do not want to speak for our witnesses, but I anticipate that we are about to hear that China is not culling its talent and technical capabilities, nor is it undermining its universities and turning the world's brightest minds away. Yet, that is what our federal government is being forced to do today by an out-of-control White House and OMB. Congress needs to step up.

The clock is ticking. As this Administration continues to cripple our science and technology enterprise, China is deliberately and systematically implementing its long-term plans.

I have no doubt that all of us serving on this Committee want to ensure U.S. leadership in space. Words are cheap, but actions are priceless. It is up to us on this Committee and in Congress to take the necessary actions that will sustain our global leadership in space, and science and technology more broadly. Anything less is an invitation for China to take the mantle in space and more.

Thank you, and I yield back.

Chairman HARIDOPOLOS. Thank you. We are now going to introduce our witnesses.

First, our first witness today is Dr. Dean Cheng who serves as senior fellow at the Potomac Institute for Policy Studies.

Our second witness is Dr. Clayton Swope who serves as the deputy director of this aerospace security project at the Center for Strategic and International Studies (CSIS).

Our third witness is Dr. Patrick Besha who is the founder of the Global Space Group.

And our final witness is Dr. Michael Griffin who serves as the co-president of LogiQ, Inc.

I would like to thank each of our witnesses for joining us today. And our first speaker today will be Mr. Cheng for 5 minutes to present his testimony. Welcome to the Committee.

**TESTIMONY OF MR. DEAN CHENG, SENIOR FELLOW,
THE POTOMAC INSTITUTE FOR POLICY STUDIES**

Mr. CHENG. Thank you very much, sir. Chairman Haridopolos, Ranking Member Foushee, Ranking Member Lofgren, thank you for the opportunity to be here today. My comments are purely my own.

As the opening remarks noted, the Chinese Communist Party sees space as vital. Space from the CCP's perspective contributes to all aspects of comprehensive national power—military, economic, diplomatic, political, scientific, and technological, even cultural. One of the key benefits this PRC sees from engaging heavily in space is the experience gained in things like systems integration and systems engineering, which then redounds throughout the Chinese economy in all of its various aspects.

Space from the CCP's perspective is also vital because we live in the information age. And space is central for establishing information dominance in a world where information is the new currency of power, economic power, military power, international power.

To this end, the Chinese are using space to develop their domestic techno-economic base. Two key concepts in this regard: One is dual circulation, creating essentially a walled-off domestic economy

where foreign players are not part of the supply chain, engaging in intense, internal competition to generate new technology and efficient production, which they will then go out and compete globally against the rest of the world, including American companies. And the other element here is military-civil fusion, which is ensuring that every renminbi serves both civil and military purposes.

And we see in particular the Chinese shift from a state-owned enterprise-centric approach to one that also embraces commercial enterprises as a key part of the overall Chinese effort to improve their overall space industrial complex.

In this regard, then, the Chinese have a plan, and that plan is very much the core of the threat to the United States. In essence, the Chinese are striving to build out their space capabilities, whether it is an array of satellite networks and constellations, including mega constellations, a cis-lunar capacity to support a sustained long-term presence both on the Moon and in cis-lunar space, replete with lunar Position, Navigation, Timing (PNT), and communication support and, of course, building out a robust military space capability as reflected in the Military Aerospace Force.

Second, to buildup their space industrial base, which will include commercial as well as state-owned enterprise elements, but has also seen the creation of regional aerospace industrial complexes in places like Wuhan, away from Beijing and Shanghai, and finally building in dual use. Military civil fusion is about creating a melded, fused national industrial base that can serve as both the military and civilian demands.

Here the Chinese have a huge advantage and much of the opening remarks by the respected Members highlights this. China sticks to a plan. It creates a plan, and it sticks to it for decades. And the benefit there is programmatic stability, budgetary stability, staff stability. I know I will have a job on this project for years and decades, and the people I work with will be the same ones.

Very quickly, specifically, on the PLA aspect, the People's Liberation Army, the PLA poses a multifaceted threat in part because China views space holistically: satellites, ground segment, data links. The threat to American space systems, therefore, is not simply the very sexy image of anti-satellite systems, but also jamming and cyber attacks. And we have seen the intelligence community accuse China of engaging in things like Volt Typhoon, implanting malware in critical infrastructure. But we should also note that the Chinese being very close observers of other people's wars have undoubtedly learned lessons, such as operation Spider Web in Ukraine, the use of drones launched within an adversary's country to attack critical infrastructure, which in this case should be considered to include to space capability.

The other aspect of the threat, however, is the industrial and standards aspect. The growth of Chinese commercial space poses a very different, but nonetheless threatening, challenge. Why shouldn't other countries buy from PRC commercial companies? And Huawei leads the way in demonstrating how China has been very much able to use commercial capabilities to achieve inroads where it does not therefore have to use the military.

Thank you very much to the Committee for the opportunity to be here today.
[The prepared statement of Mr. Cheng follows:]

“Strategic Trajectories: Assessing China’s Space Rise and the Risks to U.S. Leadership”

**Testimony before
House Science, Space, and Technology Committee,
Space and Aeronautics Subcommittee**

December 4, 2025

Dean Cheng

My name is Dean Cheng. I am a non-resident Senior Fellow with the Potomac Institute for Policy Studies. The views I express in this testimony are my own, and should not be construed as representing any official position of the Potomac Institute for Policy Studies.

Introduction

Over the past three decades, the People’s Republic of China (PRC) has been undertaking a steady effort to expand its range of space capabilities. This includes a range of satellite constellations that serve both military and civilian purposes. It is important to understand, however, that China’s development of space capabilities does not mirror the American or Soviet or Russian experiences. Indeed, China’s space program has followed a different path from either the United States or the Soviet Union.

The U.S. space program is said to have begun on December 8, 1941, in the belief that satellites could have allowed earlier detection of the Japanese fleet and averted Pearl Harbor. The same might be said for the Soviet Union, which experienced the surprise of the June 22, 1941, German invasion. There is no real equivalent in recent Chinese history of a similar strategic surprise. China’s two wars with Japan, as well as its conflicts in Korea, with India and Vietnam, and on the Sino-Soviet border did not begin with a thunderclap surprise, in which better intelligence information, such as that afforded from space, might have averted the conflict.

Moreover, China has, until recently, been poorer than either superpower, and even today considers itself a less-developed country. It has always, therefore, had relatively fewer resources to commit to its space program. Consequently, the PRC has sought to maximize the payoff of each renminbi

spent on space, applying aerospace capabilities towards economic development and diplomatic openings, as well as military modernization.

China's Evolving Space Capabilities from Mao to Hu

Since the 1950s, China's space program has been producing capabilities relevant for both civilian and military purposes. The program is considered to have been founded in 1958, soon after U.S.-trained scientist Qian Xuesen forwarded "A Proposal to Establish China's Defense Aviation Industry" to the senior Chinese leadership. This document called for the creation of an aerospace industry, which would not only design and build aircraft, but also rockets and missiles. His proposal was incorporated into the "National Long-Term Plan for the Development of Science and Technology, 1956-1967," a broad blueprint for the development of Chinese scientific and technical capabilities.¹

Longtime Chinese leader Mao Zedong subsequently called for an indigenous Chinese space program, stating at the Second Plenum of the Eighth Party Congress in May 1958 that "we should also manufacture satellites."² This reflects longstanding highest level leadership support for China's space program. The Chinese leadership subsequently established the Fifth Research Academy of the Ministry of National Defense, responsible for missile development, with Qian as its head. Chinese histories generally date the start of China's space, missile, and strategic weapons programs to the founding of the Fifth Academy. The initial space program, Project 581, reflects this 1958 start date.

Mao's vision of a Chinese space program following on the heels of Sputnik was extraordinarily ambitious for a nation that was still largely peasant, illiterate, and recovering from nearly twenty years of continuous war. Indeed, it was excessively ambitious, as China's human, financial, and industrial resources proved insufficient to sustain any kind of space development effort. Space capabilities nonetheless remained an official goal, embodied in the "two bombs, one satellite"

¹ Yanping Chen, *China's Space Activities, Policy and Organization, 1956-1986*, Ph.D. dissertation, George Washington University (1999), 7, and Deng Liqun, ed., *China Today: Defense Science and Technology*, volume one (Beijing: National Defence Industry Press, 1993), p. 32.

² Deng Liqun, ed., *China Today: Defense Science and Technology*, volume one (Beijing: National Defence Industry Press, 1993), p. 356.

(*liangdan yixing*, 两弹一星) program. This slogan referred to the creation of an atomic bomb, a hydrogen bomb, and a satellite. It reflects the reality that China's space efforts have long been tied to broader strategic goals, as well as strategic capabilities. The term "two bombs, one satellite," moreover, referred not only to programmatic objectives, but also to the idea of homegrown development of advanced capabilities. The PRC has long been proud of its space capabilities, in part because much of it has been indigenously developed, a trend that continues to this day.

China's space program, including its manned space program, were invigorated in the late 1980s by the efforts of four Chinese scientists: optical physicist Wang Daheng, nuclear physicist Wang Ganchang, electrical engineer Yang Jiachi, and electronics engineer Chen Fangyun.³ These highly respected scientists, all of whom had ties to China's space and nuclear weapons programs, argued to Deng Xiaoping that unless China was willing to invest in high technology, it could never technologically or economically catch up with the West. Conversely, investments in high technology would not only improve China's level of science and technology, but would also help foster high-tech industries. These investments would, in turn, produce economic and military benefits.

Deng was so intrigued by their report that he initialed his copy with the instructions that this plan had to be acted upon without delay. This led to the National High-Technology Research and Development Plan (*guojia gao jishu yanjiu fazhan jihua*, 国家高技术研究发展计划), also known as Plan 863.⁴ The initial Plan 863 proposal focused on seven areas, including aerospace.⁵ The initial plan included two programs related to manned spaceflight. First was Project 863-204, which called for developing a new, large launch vehicle as part of a space transportation system capable of servicing a small space station. Second was Project 863-205, which aimed to launch a small space

³ Evan Feigenbaum, *China's Techno-Warriors* (Stanford, CA: Stanford University Press, 2003), p. 141.

⁴ Material drawn from *Guojia Gao Jishu Yanjiu Fazhan Jihua 863*, in FBIS-CHI, July 21, 2000. For further discussion of the creation of Plan 863, see Feigenbaum, *China's Techno-Warriors*, 141-143.

⁵ The initial seven areas were automaton, biotechnology, energy, information technology, lasers, new materials, and space technology. Feigenbaum, *China's Techno-Warriors*, 157. The CMSEO website, however, lists them as biotechnology, aerospace technology, information technology, advanced defense technology, automation, energy, and new materials.

station with advanced capabilities, as well as associated scientific and technical research to support manned spaceflight.

After Deng's departure, China's space program continued to benefit from investment and high level support. Under Jiang Zemin (1992-2002), China deployed both low-earth orbit and geosynchronous weather satellites (the *Fengyun* series), and improved geosynchronous communications satellites (the Dongfanghong-3 series) and recoverable satellites with varying payloads (the Fanhui Shi Weixing-2 series). Chinese Earth observation capabilities also improved. In 1999, in cooperation with Brazil, China deployed the China-Brazil Earth Resources Satellite (CBERS), its first electro-optical imaging satellite capable of beaming its pictures directly down to Earth. China subsequently launched several similar satellites with no Brazilian involvement; these are known as the Ziyuan series, to distinguish them from the CBERS satellites. In 2000, China launched two *Beidou* regional navigation satellites into geosynchronous orbit, at an altitude of approximately 24,000 miles, becoming only the third country to deploy its own position and navigation system. This system also has a communications function, which was employed during the 2008 Sichuan earthquake relief operations.⁶

After succeeding Jiang as party general secretary in 2002, Hu Jintao maintained support for China's space program. During his two terms, China deployed a variety of additional satellites, including improved versions of the *Fengyun* and *Ziyuan* satellites, and a variety of satellites as part of the *Shijian* ("Practice" or "Application") program. The Chinese also deployed a number of *Yaogan* satellites equipped with synthetic aperture radars (SAR), which can provide high resolution images through clouds or other obscurations.

Under Hu, China also orbited several manned spacecraft (the Shenzhou program) and initiated the nation's lunar exploration program, launching the Chang'e-1 and -2 lunar probes (discussed below). Supporting these programs was a space-industrial complex that is believed to number over 200,000 people today. Two major aerospace conglomerates, the China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation

⁶ "Lu Jing: Satellite Communications—The Information Bridge during Earthquake Relief Operations", Speech before the Chinese Communications Studies Association, (September 26, 2008), <http://www.czcom.cn/Article/8591>.

(CASIC), manufacture the full range of space systems, including launch vehicles, satellites, and ground equipment, and the associated sub-systems and support items.

China's space program under Xi Jinping has continued to expand. China has continued to develop a variety of satellite capabilities under the "Practice (*Shijian*; 实践)" program name. This has included the Shijian-17, which was the first Chinese satellite with a robotic arm, and the Shijian-21, which apparently deployed a subsatellite. Under Xi, the PRC has also deployed the *Gaofen* series of earth observation satellites, substantially improving China's ability to conduct global space-based surveillance. China's domestically produced *Beidou* position, navigation, and timing (PNT) constellation has also been modernized, consequently enjoying worldwide use.

To be sure, these investments in space capabilities have not solely been for military purposes. Indeed, Deng's admonition to focus on national economic development still seems to resonate in many aspects of China's space program. Chinese development of earth observation satellites, PNT systems, and weather satellites all support Chinese economic development objectives. Nevertheless, these systems also provide the PLA with experience in the launch and operation of satellites, the undertaking of space surveillance, and a better understanding of both the capabilities and limitations of space-based systems.

In addition to civilian and dual use systems, the PLA developed counter-space capabilities during the Hu era. This included the PLA's test of a direct ascent, kinetic kill anti-satellite (ASAT) system in January 2007. Launched from the Xichang Satellite Launch Center, the Chinese ASAT destroyed a defunct Fengyun-1C weather satellite in low orbit. In the process, China also generated a massive amount of space debris.⁷ Almost three years later, in January 2010, China conducted what was termed an anti-missile test, involving "two geographically separated missile launch events with an exo-atmospheric collision also being observed by space-based sensors," according to the U.S. Department of Defense.⁸ This test, however, likely also helped Chinese scientists

⁷ Leonard David, "China's Antisatellite Test; Worrisome Debris Cloud Encircles Earth," Space.com, (February 2, 2007), <http://www.space.com/3415-china-anti-satellite-test-worrisome-debris-cloud-circles-earth.html>.

⁸ "China: Missile Defense System Test Successful," *USA Today*, (January 11, 2010), http://www.usatoday.com/news/world/2010-01-11-china-missile-defense_N.htm.

improve their ASAT system. In August 2010, two Chinese microsatellites were deliberately maneuvered into close proximity, and apparently “bumped” each other.⁹ China has since tested an anti-satellite system aimed at geosynchronous orbits, a capability no other nation has developed.¹⁰ Notably, the Shijian-21 towed a dead satellite into a higher (graveyard) orbit, demonstrating a clear potential military as well as civilian application.¹¹ In short, its sustained space development efforts of the past three decades have provided China with the material and experiential basis for undertaking *military* space operations in the future, whether for regional or global contingencies.

Space and PLA Concepts of Modern Warfare

Just as China was pursuing broad-based economic modernization under Deng and his successors, a revolutionary shift in the nature of warfare was taking place. Modern warfare, as demonstrated in conflicts in the Middle East and southeast Europe, was increasingly dependent on the quality of forces and weapons, rather than quantity. The U.S.-led coalition performance against Iraq in Operation Desert Shield/Desert Storm served as a wake-up call for the PLA, demonstrating that modern high-technology had fundamentally altered the operational art. As the then-Deputy Director of the PLA’s Academy of Military Science (AMS), the PLA’s “think-tank,” observed: “the Gulf War marked a big step forward in both military theory and practice.”¹²

The PLA engaged in extensive analysis of coalition operations and sought to incorporate the resulting lessons into their own approach to war. The result was a thorough revision of almost every aspect of PLA thinking about future conflict. In 1993, the PLA produced a new set of “Military Strategic Guidelines for the New Period,” introducing the concept of “local wars under modern, high-tech conditions.” These guidelines constitute “the highest level of national guidance

⁹ William Matthews, “Chinese Puzzle,” *Defense News*, (September 6, 2010), available at <http://www.defensenews.com/story.php?i=4767907>.

¹⁰ Brian Weeden, “Through a Glass Darkly: Chinese, Russian, and American Anti-Satellite Testing in Space,” *The Space Review*, (March 17, 2014), <https://www.thespacereview.com/article/2473/1>.

¹¹ Andrew Jones, “China’s Shijian-21 Towed Dead Satellite to a High Graveyard Orbit” *Space News* (January 27, 2022) <https://spacenews.com/chinas-shijian-21-spacecraft-docked-with-and-towed-a-dead-satellite/>

¹² SHI Yukun, “Lt. Gen. Li Jijun Answers Questions on Nuclear Deterrence, Nation-State, and Information Age,” *China Military Science* 3 (1995), in FBIS-CHI.

and direction” to the Chinese armed forces.¹³ In a December 1995 speech to the Central Military Commission, Jiang emphasized the importance of these new guidelines when he charged the PLA with undertaking the “Two Transformations” (*liangge zhuanbian*, 两个转变). These included a shift from a military focused on quantity to one focused on quality, and from a military preparing for “local wars under modern conditions,” to one that was preparing for “local wars under modern, high-tech conditions.”¹⁴

According to PLA assessments, “local wars under high-tech conditions” were marked by several key characteristics. The most important feature was the increasing reliance on joint operations as the basic form of military operations, and the attendant demand for improved command, control, communications, and intelligence (C3I), in order to coordinate and integrate the disparate forces, especially across the broader field of operations at much higher operational tempos.¹⁵

As envisioned by the PLA, joint operations would involve multiple services operating together across significant distances. The Gulf War, for example, sprawled across some 140 million square kilometers and included forces ranging from armored units to aircraft carriers and long-range bombers.¹⁶ The successful conduct of joint operations on this vast geographic scale would therefore require close coordination, extensive communications, and precise navigation and positioning information, both for units and for the growing plethora of precision munitions. Moreover, joint operations also required coordination of combat and logistical forces and the ability to command and control operations across five domains: the traditional ones of land, sea, and air, but increasingly also outer space and the electromagnetic domain.

¹³ David Finkelstein, “China’s National Military Strategy: An Overview of the ‘Military Strategic Guidelines,’” in Roy Kamphausen et al., eds., *Right-Sizing the People’s Liberation Army: Exploring the Contours of China’s Military* (Carlisle, PA: Strategic Studies Institute, 2007), 82.

¹⁴ Qinsheng Zhang and Bingyan Li, “Complete New Historical Transformations—Understanding Gained from Studying CMC Strategic Thinking on ‘Two Transformations,’” *Jiefangjun Bao*, (January 14, 1997), in FBIS-CHI.

¹⁵ Chinese Military Encyclopedia Committee, *Chinese Military Encyclopedia*, volume two (Beijing: Academy of Military Science Press, 1997), 126-127.

¹⁶ Houqing Wang and Xingye Zhang, eds., *The Science of Campaigns*, (Beijing: National Defense University Press, 2000), 400.

This need for improved C3I, spanning greater distances and in support of 24/7 operations, influenced PLA assessments of the importance of space for future military operations. In this light, the PLA recognized space capabilities as playing an essential role in “local war under modern, high-tech conditions.” The 70 satellites that were brought to bear against Iraq in the Gulf War provided the U.S. military, according to PLA estimates, with 90% of its strategic intelligence, and carried 70% of all transmitted data for coalition forces.¹⁷ Indeed, these assets were the first to be employed, since they were essential for the success of subsequent campaign activities. As one Chinese analysis observed, “Before the troops and horses move, the satellites are already moving.”¹⁸

The PLA’s conception of future wars was refined under Hu, with the information domain playing a more prominent role. From “local wars under modern, high-tech conditions,” the PLA now expected to engage in “local wars under informationized conditions.” This new phrase appeared in 2002 and was incorporated into China’s 2004 defense white paper. “Informationized conditions,” in this context, did not simply refer to computers and cyberwarfare. Rather, the informationized battlefield (*xinxihua zhanchang*, 信息化战场) is one in which all relevant military activities, including tactics, operations, and decision-making, are digitized, and military materials and equipment are managed through advanced information technology. The shift in terminology reflected the PLA’s conclusion that, among the various high technologies, the most important are those relating to information management.

This emphasis on the information domain was also reflected in an apparent modification of the “campaign basic guiding concept (*zhanyi jiben zhidao sixiang*, 战役基本指导思想)” during the 2000s. The concept, a distillation of military laws and theories, is intended to serve as a guide for PLA officers planning, organizing, and prosecuting campaign-level operations. In some ways, it parallels the “principles of war,” which the U.S. Army defines as “the most important non-physical factors of war that affect the conduct of operations at the strategic, operational, and tactical levels,”

¹⁷ Yubiao Gao, ed., *Joint Campaign Course Materials* (Beijing: Academy of Military Science Press, 2001), 54.

¹⁸ Qingjun Gao, “Characteristics and Deficiencies of Space Reconnaissance in High-Tech Local Wars,” *Journal of the Academy of Equipment Command and Technology* (1, 16, 2005).

while taking into account contemporary conditions.¹⁹ In 2025, joint operations are still seen as a key part of “informationized local wars,” the current characterization of the wars the PLA is preparing to fight and win. “If one wishes to fight victorious wars then one must improve joint operations capacity, based on networked information system-of-systems, as well as all domain operational capabilities.”²⁰

This is in part because, from the PRC’s perspective, space is fundamentally linked to overall national security. In December 2004, Hu gave a speech outlining the “historic missions of the PLA in the new phase of the new century” (*xinshiji xinjieduan wojun lishi shiming*, 新世纪新阶段我军历史使命). These “new historic missions” included safeguarding China’s expanding national interests, specifically including access to space (*taikong*, 太空) and the electromagnetic sphere.²¹ The speech also clearly charged the PLA with undertaking military space missions. Hu observed that “maritime security, space security, and electromagnetic spectrum security are already vital regions for national security,” requiring Chinese military preparations to secure them.²² The incorporation of space into the specific responsibilities of the PLA under the “new historic missions” indicated a growing view of space as essential to Chinese national security.

This higher profile for space is reflected in a range of authoritative PLA and Chinese government sources. In the 2020 edition of the *Science of Military Strategy*, a chapter is devoted to discussing military conflict in the new domains of space and cyber (as well as biological and artificial intelligence) domains, where the authors note that the importance of space has grown significantly

¹⁹ Headquarters, Department of the Army, *FM 3-0 Operations* (Washington, DC: Department of the Army, 2022), pp. 1-7, A-1-A-5.

²⁰ National Defense University Socialist Theory with Chinese Characteristics Research Center, “Firmly Grasping the Party’s Strong Military Goal in the New Era,” *Qiushi* (April 15, 2018) http://www.qstheory.cn/dukan/qs/2018-04/15/c_1122670090.html

²¹ The other historic missions include guaranteeing the continuing rule of the CCP, safeguarding national economic development, and helping ensure world peace. Hu Jintao, “See Clearly Our Military’s Historic Missions in the New Period of the New Century”, (December 24, 2004), available on the official National Defense Education website of Jiangxi province, <http://gfjy.jxnews.com.cn/system/2010/04/16/011353408.shtml>. For further discussion of the “new historic missions,” see Daniel Hartnett, *Towards a Globally Focused Chinese Military: The Historic Missions of the Chinese Armed Forces* (Alexandria, VA: CNA Corporation, 2008).

²² Hu Jintao, “See Clearly Our Military’s Historic Missions in the New Period of the New Century”, December 24, 2004, <<http://gfjy.jxnews.com.cn/system/2010/04/16/011353408.shtml>>

for both military and broader national purposes.²³ A separate chapter is devoted to discussing the development and expansion of military aerospace capabilities.²⁴ The 2015 National Security Law specifically mentions outer space as an area where Chinese security interests must be preserved. Similarly, China's 2015 defense white paper refers several times to space as a "commanding height" in the international strategic competition. In the 2019 defense white paper, outer space is described as an area where China's national interests must be safeguarded: "outer space is a critical domain in international strategic competition. Outer space security provides strategic assurance for national and social development."²⁵ As the PLA's military guidelines have shifted again, to "informationized local wars," the role of space has become ever more salient.

China's Evolving Concepts of Military Space Operations

Various PLA writings consistently emphasize five broad styles (*yangshi*, 样式) or mission areas: space deterrence, space blockades, space strike operations, space defense operations, and provision of space information support.²⁶

Space Deterrence (kongjian weishe, 空间威慑)

Space deterrence is the use of space capabilities to deter or coerce an opponent, preventing the outbreak of conflict, or limiting its extent should conflict occur. By displaying one's own space capabilities and demonstrating determination and will, the PLA hopes to induce doubt and fear in an opponent, so that they either abandon their goals or limit the scale, intensity, and types of operations. Space deterrence is not aimed solely, or even necessarily, at deterring actions in space, but rather, in conjunction with nuclear, conventional, and informational deterrence capabilities and activities, they seek to influence an opponent's overall perceptions and activities.

²³ Academy of Military Science Strategy Research Department, *The Science of Military Strategy* (Beijing: Military Science Press, 2020), pp. 142-180.

²⁴ Academy of Military Science Strategy Research Department, *The Science of Military Strategy* (Beijing: Military Science Press, 2020), pp. 391-401.

²⁵ PRC State Council Information Office, *China's National Defense in the New Era* (Beijing: State Council Information Office, 2019), <http://www.andrewerickson.com/2019/07/full-text-of-defense-white-paper-chinas-national-defense-in-the-new-era-english-chinese-versions/>.

²⁶ This section draws upon Lianju Jiang, *Space Operations Teaching Materials* (Beijing: Military Science Press, 2013), 126-154.

Both the 2005 and 2013 volumes referenced above suggest that there is a perceived hierarchy of space deterrence actions, perhaps akin to an “escalation ladder.” First, “displays of space forces and weapons” (*kongjian liliang xianshi*, 空间力量显示) occur in peacetime, or at the onset of a crisis. The goal is to warn an opponent, in the hopes of dissuading them from escalating a crisis or pursuing courses of action that will lead to conflict. Second, “military space exercises” (*kongjian junshi yanxi*, 空间军事演习) are undertaken if displays of space forces and weapons are insufficient to compel an opponent to alter course. They can involve actual forces or computer simulations, and are intended to demonstrate one’s capabilities but also military preparations and readiness. At the same time, such exercises will also improve one’s military space force readiness. Third, “space force deployments” (*kongjian liliang bushu*, 空间力量部署) are seen as a significant escalation that occurs when one concludes that an opponent is engaged in preparations for war, and involve the rapid adjustment of space force deployments, including the recall of certain space assets and modifications of orbits or behavior of others. As with military space exercises, this measure is not only intended to deter an opponent, but should deterrence fail, may improve one’s own preparations for combat.

Chinese sources term the final step of space deterrence “space shock and awe strikes” (*kongjian zhenshe daji*, 空间震慑打击). If the three previous, non-kinetic measures are insufficient, the PLA suggests punitive strikes to warn an opponent that one is prepared for full-blown conflict in defense of the nation. Such strikes are seen as “the highest, and final, technique” (*zuigao xingshi he zui hou shouduan*, 最高形式和最后手段) to deter and dissuade an opponent. Employing hard- and soft-kill methods, one would attack an opponent’s physical space infrastructure or data links, respectively. If this succeeds, opposing decision-makers will be shaken and cease their activities. If it fails, an opponent’s forces will still have suffered some damage and losses.

Space Blockade (kongjian fengsuo zuozhan, 空间封锁作战)

Space blockades involve the use of space and terrestrial forces to prevent an opponent from entering space and gathering or transmitting information through space. Chinese writings suggest that there are several types of space blockades. First is physically obstructing an adversary’s operations, such as blockading terrestrial space facilities, including launch and TT&C sites and missions control centers, or preventing spacecraft from entering certain orbits. Second is

obstructing launch windows by delaying launches. In the past, some American space launches have been delayed because fishing and pleasure boats were present down-range.²⁷ Third are information blockades, which can take several forms. For instance, by interfering with an opponent's data links, one can effectively neutralize an orbiting satellite by hijacking its control systems or preventing ground control from issuing instructions. Alternatively, one can contaminate or block the data that the satellite is gathering or transmitting. Yet another form involves "dazzling" a satellite using low-powered directed energy weapons against its sensors or other systems. In each case, the intent is to achieve a "mission kill," whereby the satellite cannot perform its functions, but is not necessarily destroyed.

Space Strike Operations (kongjian tuji zuozhan, 空间突击作战)

Space strike operations involve space and other forces undertaking offensive operations against an enemy's land, sea, air, and space assets. They are therefore not limited to attacks against the adversary's space infrastructure. Space strike operations, in the Chinese view, are marked by "integrated operations; stealth and surprise; key point strikes; rapid, decisive action." In this formula, "integrated operations" reflects all the aspects discussed earlier, with an additional emphasis on exploiting stealth and surprise. "Key point strikes," part of the general guiding thought for space operations, denotes the reality that neither side is likely to field large numbers of space systems, so planning for maximum effect and efficiency is important. "Rapid, decisive action" refers to the need to use space strikes to seize the initiative in a campaign. By overwhelming an opponent, and sustaining strikes afterwards, one can gain the initiative and ideally achieve operational goals and conclude the conflict. At the same time, due to the limited space platforms and weapons likely to be available, and their fragility and expense (which limits numbers acquired), space strike operations are likely to be of relatively limited duration.

Defensive Space Operations (kongjian fangyu zuozhan, 空间防御作战)

Defensive space operations are intended to counter an opponent's space strike operations by safeguarding one's own space forces and defending key strategic and campaign targets from

²⁷ "Atlas 3 Scrubbed to Tuesday," *Space Daily*, (May 21, 2000), <http://www.spacedaily.com/news/eutelsat-00g.html>; and Jessica Orwig, "A Rocket Launch Monday Was Delayed Because of a Boat," *Business Insider*, (October 28, 2014), <http://www.businessinsider.com/why-rocket-launch-delayed-by-a-boat-2014-10>.

enemy space strike operations. Defensive space operations include defense against ballistic and cruise missiles, defense of space-related bases and infrastructure, and “spacecraft defensive operations.” The latter involve a combination of active and passive measures, including camouflage and reduction of spacecraft radar, infrared and electronic signatures so that their capabilities and identity are obscured, shifting to “swarms” of small satellites to improve resilience if one or more component satellites are lost, and hardening satellites to allow them to survive attacks from directed energy weapons. In addition, ground controllers can move satellites if there are indications that they might be attacked.

Space Information Support Operations (kongjian xinxi zhiyuan zuozhan, 空间信息支援作战)

In the 2005 edition of *Military Astronautics*, provision of information support by space systems was listed as the second task, after space deterrence.²⁸ In the 2013 PLA teaching materials, it is now the fifth of five tasks. This suggests that space information support operations, while still important, are being eclipsed by more active space offensive and defensive operations. Indeed, as one Chinese analyst observes, as space resources become ever more important, and military aerospace technology, especially those related to offensive space operations, steadily develop, space force development will shift from providing information support towards securing space dominance.²⁹

Nonetheless, in the context of informationized warfare, space information support will be integral to achieving space dominance. As the 2013 edition of the *Science of Military Strategy* notes, “space information support is now and for a long time into the future will be the main form (*zhuyao fangshi*, 主要方式) by which various nations apply space strength.”³⁰ As the PLA emphasizes joint operations, it will increasingly depend on space-based systems to provide information support, especially as Chinese forces move farther and farther away from Chinese territory (and therefore, land-based information support infrastructure). Key tasks within “space information support” (*kongjian xinxi zhiyuan*, 空间信息支援)” to ground, air, and naval forces include space

²⁸ Xianqi Chang, *Military Astronautics*, (Beijing: National Defense Industries Press, 2005), 304-309.

²⁹ Rukun Tan, *Operational Strength Construction Teaching Materials* (Beijing: Military Science Press, 2012), 170.

³⁰ Academy of Military Science Strategy Research Department, *The Science of Military Strategy* (Beijing: Military Science Press, 2020), 181.

reconnaissance and surveillance, missile early warning, communications and data relay, position, navigation, and timing services, and Earth observation, such as geodesy, hydrographics, and meteorology. These capabilities will likely be of growing importance to the PLA, as it shifts towards more globally oriented force.

Creation of the PLA Strategic Support Force and Military Aerospace force

Further reinforcing China's military focus on space has been the establishment of dedicated aerospace forces within the PLA. In 2015, the PLA established the PLA Strategic Support Force (PLASSF). The PLASSF combined the PLA's electronic warfare, network warfare, and space warfare capabilities. This included what had previously been specific departments under the General Staff Department (GSD), such as the GSD Third Department (responsible for signals intelligence) and the GSD Fourth Department (responsible for electronic intelligence and electronic warfare). It also involved the transfer of key space facilities that had been part of the GAD, including China's launch sites, satellite control centers, TT&C facilities, and fleet of space surveillance ships.³¹

One reason for the establishment of the SSF appears to be to shift from a task or mission-oriented approach to warfare (e.g., reconnaissance, strike) to one more focused on specific domains.³² The PLASSF, as a service, will be responsible for planning, force construction, and operations within the information domain, including space operations. While the GAD had space responsibilities, it was neither a service nor a war-fighting entity. The GAD's main tasks were supporting military research and development, including new weapons, as well as managing China's nuclear and space facilities. Creating the PLASSF effectively created a service that was more focused on space warfighting doctrine and forces, rather than space systems and capabilities.

³¹ Because of China's emphasis on influencing adversary commanders and staffs, some political warfare elements from the General Political Department have also been incorporated into the SSF.

³² John Costello and Joe McReynolds, *China's Strategic Support Force: A Force for a New Era*, INSS China Strategic Perspectives 13 (Washington, DC: National Defense University Press, 2018), 12.

Moreover, this new service was “intended to create synergies between disparate information warfare capabilities, in order to execute specific types of strategic missions.”³³ By combining various information-related departments, offices, and bureaus across the PLA, many of the organizational stovepipes that impeded programmatic and doctrinal coordination were effectively eliminated. In the case of space operations, the PLASSF’s Space Systems Department now oversees GAD space facilities and units responsible for space-based C4ISR (such as space-based remote sensing) that had resided in the GSD.³⁴

At the same time, by embedding the PLASSF Space Systems Department alongside the Network Systems Department, responsible for cyber and electronic warfare, there is greater ability to integrate space operations with other activities in the information domain. Chinese writings emphasize the importance of electronic and network warfare as key means of establishing space dominance, as soft-kill (e.g., laser dazzlers, cyber attack methods against TT&C facilities and onboard systems) approaches are an essential complement to hard-kill (e.g., direct ascent anti-satellite missiles, co-orbital anti-satellite systems) ones. By placing all of these capabilities in the same service, albeit in separate subordinate departments, PLA space dominance efforts will benefit from enhanced coordination and integration. In this regard, unlike many other nations, China is not pushing the development of a “space force,” so much as an “information warfare force,” with a substantial space capability embedded within it.

In April 2024, however, the PLA dissolved the PLASSF. The component elements were established as independent “major arms (*da bingzhong*, 大兵种),” specifically the Military Aerospace Force (*junshi hangtian budui*; 军事航天部队), the Networkspace or Cyberspace Force (*wangluo kongjian budui*; 网络空间部队), and the Information Support Force (*xinxi zhiyuan budui*; 信息支援部队). The PLA now describes itself as comprising four “major services (*da junzhong*; 大军种),” the PLA Ground Forces, PLA Navy, PLA Air Force, and PLA Rocket Force, and the four

³³ John Costello and Joe McReynolds, *China’s Strategic Support Force: A Force for a New Era*, INSS China Strategic Perspectives 13 (Washington, DC: National Defense University Press, 2018), p. 5.

³⁴ John Costello and Joe McReynolds, *China’s Strategic Support Force: A Force for a New Era*, INSS China Strategic Perspectives 13 (Washington, DC: National Defense University Press, 2018), p. 20.

“major arms.”³⁵ This would seem to suggest a structure of four domain-oriented services, and four “strategic/functional forces.”³⁶ As some PLA analyses have suggested, this is based on the idea that the services are focused on respective main operational domains (*zhuyao zuozhan lingyu*; 主要作战领域), with specific missions and equipment to differentiate them. The “arms” are described as “strategic branches (*zhanlue bingzhong*; 战略兵种)” or “relatively independent branches (*xiangdui duli bingzhong*; 相对独立兵种)” reflect the growth of new strategic domains and vital operational domains. These “arms” will be able to undertake certain missions independently, but can also be task-organized to join with other forces to undertake specific missions.³⁷

The Military Aerospace Force (MAF) is responsible for space surveillance and space situational awareness, as well as deploying space systems. Consequently, it controls most of the PRC’s space infrastructure, inheriting the “base (*jidi*; 基地)” organizational structure from the PLASSF, which in turn had been bequeathed that structure from the GAD.

Chinese Lunar Program

The development of China’s space capabilities has not been wholly oriented towards explicit military objectives. Well before the establishment of the PLASSF and subsequent MAF, the Chinese had already authorized the Chinese Lunar Exploration Program (CLEP). The Chang’e program, named after a goddess of Chinese mythology who lives on the Moon (with her pet, “Jade Rabbit”), began in 2004. It has its own leading small group (like the manned program) and its own leadership structure separate from the China National Space Administration.

The lunar program has followed a three-step approach. The first step was to place satellites in *lunar orbit* to ensure that China’s launch vehicles and TT&C networks were sufficient to place spacecraft in the lunar vicinity. The deployment of lunar orbiters would also allow for mapping of

³⁵ “The Chinese PLA Embraces a New Type of Services and Arms Structure,” Defense Ministry Net (April 19, 2024) <http://www.mod.gov.cn/gfbw/xwfy/zjzh/16302059.html>

³⁶ Joe McReynolds, John Costello, “Planned Obsolescence: The Strategic Support Force in Memoriam (2015-2024),” *Jamestown Foundation China Brief* (XXIV, #9, April 26, 2024) <https://jamestown.org/planned-obsolescence-the-strategic-support-force-in-memoriam-2015-2024>

³⁷ Ruoyu Wang, “Military Aerospace Force, Cyberspace Force, Information Support Force—After 75 Years, What New Types of Services and Branches Have Been Added?” Shanghai ObserverNet (October 4, 2024) <https://www.163.com/dy/article/JDLB5EM4051481US.html>

the Moon's gravitational field and allow imaging of the lunar surface to determine suitable landing sites. The second step was to *soft-land* probes on the lunar surface. This was a substantially more difficult task, since relatively few states have actually landed spacecraft on the Moon. It would require even more precise control of spacecraft functions, including being able to trim and adjust the spacecraft's attitude relative to the lunar surface. The deployment of a rover would also increase weight and add additional complications to the mission (e.g., how to deploy the rover, and how to keep it operational during the long lunar night which lasts roughly two weeks). The third step is to undertake *sample retrieval* missions, where Chinese probes would bring lunar material back to Earth for further study. The weight involved is even greater, since the lander would have to carry sufficient fuel to at least depart the lunar surface, whether to reach a lunar orbiter module or to return straight to Earth. As of 2025, the PRC has fulfilled all three of these steps, including retrieving samples from the lunar far side, a region hitherto only observed from orbit.

A key part of the Chang'e-4 and Chang'e-6 missions was the need to maintain communications with the landers. Since both operated on the far side of the Moon, it would be impossible to establish direct communications with the landers. Consequently, the Chinese deployed the *Queqiao*-series of data relay satellites. Queqiao-1 was deployed to LaGrange Point-2 (L-2). Launched in May 2018, it arrived at L-2 some 24 days later. From its location 250,000 miles from Earth (and 40,000 miles from the Moon), it relays data and instructions from Earth to the Chang'e-4/Yutu-2 probe.³⁸ Queqiao-2 is in an elliptical lunar orbit, and supported the Chang'e-6 sample retrieval mission.

Politically, China's lunar program has demonstrated an ability to undertake cutting edge scientific programs, as demonstrated in the innovative Chang'e-4 and Chang'e-6 probes. In terms of direct military benefits, its value is more limited. China is not in a direct space race with any other state, nor is it racing to establish settlements or "space colonies." While there are theories of how one might employ a lunar base to undertake surveillance or even kinetic operations against terrestrial

³⁸ Alice Shen, "What You Need to Know about Chang'e-4, China's Mission to the Far Side of the Moon," *South China Morning Post*, (January 3, 2019), <https://www.scmp.com/news/china/science/article/2180587/what-you-need-know-about-change-4-chinas-mission-far-side-moon>.

targets, the costs associated with such ambitions would be enormous. Surveillance platforms on the Moon, for example, would be almost 240,000 miles from Earth. To obtain high resolution images would be enormously costly. It is not at all clear that such efforts would win a cost-benefit analysis against systems in standard earth orbits (LEO, MEO, GEO), or even air-breathing systems.

Instead, the most likely military benefits are in terms of improvements in Chinese space support capabilities, thus expanding the volume of space employed for military purposes. The deployment of the *Queqiao-1* satellite marked the first time that any nation has deployed an “application” satellite, i.e., one not oriented towards scientific surveys and exploration, to any of the LaGrange points. While there are some orbits that go beyond the geosynchronous belt (e.g., High Earth orbits and the graveyard orbit for inoperative satellites), the objects are still largely within the range of current space objective surveillance and identification (SOSI) systems. However, few SOSI systems are oriented towards general surveillance of the cis-lunar space between the geosynchronous belt and the Moon. By deploying “application” satellites to this area, China is challenging its own SOSI networks. This suggests that in the coming years, Beijing will develop a substantial SOSI network capable of surveilling a substantial volume of space—which will be under the control of the MAF.

One element of this network that recently became operational is a 16-story, 35 meter array in Las Lajas Argentina. It is operated by the China Satellite Launch and Tracking Control General, which used to be subordinated to the GAD and now belongs to the PLASSF.³⁹ (In the past, China used its space program to justify establishing facilities in a number of countries, including Namibia, Kiribati, and Pakistan.)

Other states will also have to upgrade their own SOSI capabilities, as more and more states operate in the cis-lunar region. Until they have done so, however, China can try and “lose” one or more satellites in that volume of space. Such systems could serve as a strategic reserve, replacing satellites in lower orbits that might be destroyed or damaged in wartime. In theory, the *Queqiao*

³⁹ Cassandra Garrison, “China’s Military-Run Space Station in Argentina Is a ‘Black Box,’” Reuters, (January 31, 2019), <https://www.reuters.com/article/us-space-argentina-china-insight/chinas-military-run-space-station-in-argentina-is-a-black-box-idUSKCN1PP012>.

could be used as a data relay satellite for purely terrestrial purposes. This would be by no means optimal, but attempting to destroy the satellite would be very difficult and likely engender a popular outcry by polluting a key region of space. If China were to expand its lunar footprint, it could well deploy a number of Queqiao-type satellites to L-2 or other LaGrange points, and create a data relay constellation that would be a challenge to track.

At the same time, because there has been less international attention to cis-lunar space, deployment of Chinese anti-satellite systems into that area would complicate adversary contingency planning and attribution capacity. At present, most anti-satellite systems are ground-launched (such as the Chinese anti-satellite system used in 2007) or co-orbital (such as the Russian Burevestnik system).⁴⁰ By contrast, an anti-satellite system coming from beyond GEO would significantly expand the volume of space that would have to be kept under surveillance.

An additional strategic military benefit from the Chinese lunar program is that it supports the broad goal of “military-civil fusion.” This phrase refers to China’s effort “to leverage breakthroughs in the civilian science and technology (S&T) sector” in order to meet the military’s science and technological requirements.⁴¹ This is reflected in the shift in Chinese writings from calling for “civil-military integration” (*junmin jiehe*, 军民结合) to the more ambitious concept of “military-civil fusion” or “civil-military melding” (*junmin ronghe*, 军民融合). The idea of “fusion” or “melding” underscores the need for a broader reorganization of the national economy, so that the civilian and military sectors are served by a common industrial base.⁴² Indeed, as one Chinese analysis points out, the goal of MCF is not to encourage civilian use of military technology, or

⁴⁰ Theresa Hitchens, “Russia Builds New Co-orbital Satellite: SWF, CSIS Say,” *Breaking Defense*, (April 4, 2019), <https://breakingdefense.com/2019/04/russia-builds-new-co-orbital-satellite-swf-csis-say/>.

⁴¹ Philip C. Saunders and Joel Wuthnow, “Conclusion: Assessing Chinese Military Reforms,” in Phillip C. Saunders et al., eds., *Chairman Xi Remakes the PLA: Assessing Chinese Military Reforms* (Washington, DC: National Defense University Press, 2019), p. 718. See also Brian Lafferty, “Civil Military Integration and PLA Reforms” in the same volume.

⁴² Innovation Department, Beijing University Science and Technology Park, “An Outline of the Development of Our Nation’s Civil-Military Fused Enterprises,” (April 15, 2019), <http://www.chinahightech.com/html/paper/2019/0415/521151.html>.

military use of civilian technology, but to generate complementarity between efforts to enhance military production and general economic development.⁴³

The lunar program, with its demands for larger boosters (as required by the Chang'e-5 lander with its returning payload), further presses Chinese industry to support systems integration, systems engineering, and precision manufacturing. These improvements will aid Chinese development of better military systems, whether ICBMs, unmanned aerial vehicles, or military spacecraft—all of which are products from the same state-owned enterprises as are part of the Chinese space-industrial complex.

More importantly, the CLEP, as well as China's human spaceflight program, encourage the overall development of China's aerospace work force, with benefits for all of China's space programs, military and civilian, with further spill-over effects for the broader economy. Major, "glorious" (*weida*, 伟大) projects can attract human talent, while the implementation of such projects helps train that talent.⁴⁴

Conclusion

For the PLA and Chinese national security decision-makers, the Information Age and the Space Age are inextricably linked. Both eras have been heavily influenced by the growth in computing power and the role of telecommunications. Indeed, China's first series of satellites, the Dongfanghong-2, were communications satellites, rather than early warning satellites. Chinese analyses of recent wars underscore the intimate relationship between these two realms when it comes to warfighting. Modern wars have demonstrated the linked relationship between information and space, where space systems play a central role in the collection, transmission, and exploitation of information. Consequently, "seizing the space information advantage as a high

⁴³ Benyao Shu, "The Real Impact of the Human Spaceflight Project on Military-Civil Fusion-Style Development's Strategic Thought," *Journal of the National Defense University* (#2, 2013)

⁴⁴ Benyao Shu, "The Real Impact of the Human Spaceflight Project on Military-Civil Fusion-Style Development's Strategic Thought," *Journal of the National Defense University* (#2, 2013).

ground is the first decisive condition for seizing information dominance, space dominance, air dominance, naval dominance, land dominance, and therefore the initiative in wartime.”⁴⁵

By dominating space, one gains several advantages in terms of access to information and managing information flows. First, one’s combat forces can be much more effective because enemy and friendly force dispositions will be known. Second, because the battlefield is more transparent, commanders can respond in real-time or near-real time to enemy actions, and widely separated units drawn from a variety of services can act in a highly integrated manner. Third, by dominating space, one has secured the most important portion of the battlefield: the information space. This facilitates command and control and enables long-range, precision strikes. Friendly casualties are reduced, while one’s own actions are much more effective.

For Chinese military planners, these advantages are further enhanced by certain geographic and strategic realities. Even now, the PLA is not oriented towards conducting extensive military operations far from China’s shores. Instead, it remains focused on regional flashpoints such as Taiwan, the Korean peninsula, the South China Sea, and the Sino-Indian border. For Beijing, the consistent concern since the 1980s has been on “local wars.” Such wars are not only limited in means, but also are expected to occur mainly on China’s periphery. Space information support is less important, given the plethora of Chinese intelligence gathering platforms and dense communications networks, but space denial and counter-space capabilities are essential in countering any adversary (e.g., the United States, Japan, and Taiwan).

However, as its resources grow and its interests expand, China may become more dependent on space-based systems to provide intelligence about the military situation in places such as the Arabian Sea and the central Pacific or to maintain communications with PLA facilities in Djibouti and elsewhere (on Djibouti, see the chapter by Isaac Kardon in this volume). This is not to say that China will become as dependent on space as the United States, much less that its space architecture will resemble the American one. But China may become more dependent on space to sustain intelligence gathering and global communications than it has been in the past.

⁴⁵ Lanzhou Military Region Headquarters Communications Department, “Space Information Support and Its Influence on Future Terrestrial Operations,” *Military Art* (#10, 2003).

China's interests in lunar exploration, as documented in this chapter, support broader efforts to develop its military space capabilities. Investments in lunar exploration, whether in terms of improving the industrial base, advancing SOSI networks, or familiarizing the PLASSF with operations in the regions beyond the geosynchronous belt, all contribute to developing China's space warfare capabilities, and therefore its information warfare capabilities. This is a reminder of China's "whole-of-society" approach to national security.

Dean Cheng, Non-resident Senior Fellow, Potomac Institute for Policy Studies; Non-resident Fellow, George Washington University Space Policy Institute

Dean Cheng is currently a non-resident Senior Fellow at the Potomac Institute for Policy Studies, and a non-resident fellow with the George Washington University Space Policy Institute. He was recently a senior advisor to the China program at the US Institute of Peace. In 2022, he retired after 13 years with the Heritage Foundation, where he was a senior research fellow on Chinese political and security affairs, and wrote on various aspects of Chinese foreign and defense policy.

Prior to joining the Heritage Foundation, he was a senior analyst with the China Studies Division (previously, Project Asia) at CNA from 2001-2009. Before joining CNA, he was a senior analyst with Science Applications International Corporation (SAIC) from 1996-2001. From 1993-1995, he was an analyst with the US Congress' Office of Technology Assessment in the International Security and Space Division, where he studied the Chinese defense industrial complex.

He is the author of *Cyber Dragon: Inside China's Information Warfare and Cyber Operations* (NY: Praeger Publishing, 2016), and *China and the New Moon Race* (Washington, DC: George Washington University Space Policy Institute, January 2025), as well as a number of papers and book chapters examining various aspects of Chinese security affairs. Recent publications include:

- **“The People’s Republic of China and the Information Age: Dealing with Informationization and Intelligence-ization,”** in *The Great Power Competition, Vol. VI, The Rise of China*, ed. by Adib Farhadi, Mark Grzegorzewski (Cham, Switzerland; Springer Publishing, 2025). Examines Chinese views of information, including the role of artificial intelligence and efforts at “intelligence-ization,” especially in the Chinese military.
- **“Avoiding Self-Deterrence in the Context of Nuclear Ambiguity: The Case of the People’s Republic of China,”** in *Avoiding Self Deterrence in the Context of Nuclear Ambiguity*, ed. by Dr. Lawrence Kuznar, Dr. Belinda Bragg, et. al. (Washington, DC: NSI, June 2024)
- **“China and Space: The Next Frontier of Lawfare,”** in *Lawfare* (July 30, 2023). Examines likely Chinese legal warfare efforts as applied to outer space.
- **“Divergent US and Chinese Views of Information, Deterrence, and Future Warfare,”** in *The Journal of Policy and Strategy* (II, #3, 2022). Examines Chinese writings on deterrence, especially nuclear, and highlights differences with American approaches and concepts.
- **“Space and Chinese National Security: China’s Continuing Great Leap Upwards,”** in *The PLA Beyond Borders*, ed. by Joel Wuthnow, Arthur Ding, and Philip Saunders (Washington, DC: NDU Press, 2021). An examination of Chinese space activities beyond the GEO orbital regime, including cis-lunar, interplanetary, and deep-space activities.

- **“An Overview of Chinese Thinking About Deterrence,”** in *NL Annual Review of Military Studies 2020*, ed. by Frans Osinga and Tim Sweijts (NY: Springer Publishing, 2020)

Mr. Cheng has testified before Congress on various Chinese security issues. He has spoken at the USSTRATCOM Deterrence Symposium, the USSTRATCOM Space and Cyber Symposium, and the National Space Symposium. He has also lectured at the US National Defense University, George Washington University, and MIT.

Chairman HARIDOPOLOS. Thank you, Mr. Cheng.
Next, we have Mr. Swope for 5 minutes. You are recognized.

**TESTIMONY OF MR. CLAYTON SWOPE,
DEPUTY DIRECTOR, AEROSPACE SECURITY PROJECT,
CENTER FOR STRATEGIC AND INTERNATIONAL STUDIES**

Mr. SWOPE. Thank you, Chairman Haridopolos, Ranking Member Foushee, Ranking Member Lofgren, and distinguished Members of the Committee. I am honored to share my views with you on this important topic. CSIS does not take policy positions, so the views represented in this testimony are my own and not those of my employer.

The People's Republic of China is methodically executing an ambitious space agenda that aims to prove that China is a world power in space without equal. Beijing is using space in ways that provide direct, tangible benefits to its military and its economy, while also fostering national pride and unity. Every new space technology, skill, and industrial capacity acquired by the PRC will be used to provide the People's Liberation Army, a battlefield advantage, as well as power civilian and commercial innovation and economic growth.

So what is China doing today? Space fits squarely into the PRC's economic development policies to increase its industrial might. The PRC has built satellite and rocket factories and associated supply chains, launch facilities, ground stations, and space object tracking systems. China is developing on-orbit technologies, such as in-space refueling, highly maneuverable satellites, space station nuclear and solar power, and satellite docking and captured technology.

To date, China has not shown that it can conduct space launch at the same scale or build satellites as fast as the United States. But China is working to close that gap and master reusable launch. It just tested a reusable launch vehicle within the last 24 hours.

China is already launching satellite constellations. The PRC Civil Space Program has methodically checked off achievements in human space flight and uncrewed exploration that will probably culminate in a human landing on the Moon by 2030.

China has already built three space stations and conducted six robotic lunar missions, and a mission to Mars. China is on track to be the first country to return samples of Mars to Earth.

China has deployed space capabilities that allow the PLA to monitor what is happening on Earth and in space, communicate with its forces throughout the Indo-Pacific region, and navigate with a high level of precision. The PLA is fielding an increasingly sophisticated toolkit of counter-space weapons that can threaten U.S. and allied satellites.

To date, China has mostly copied the U.S. playbook in space. But China is doing things that no one else has done. China was the first Nation to land on and conduct a sample of return from the far side of the Moon. China conducted the world's first satellite refueling in geosynchronous orbit within the last few months.

China operates the first and only communication satellite in an orbit around an Earth-Moon Lagrange point. So what can the United States do? How should we think about this? If the United States is in a race with China, it is a race that has no end. Other

than an end associated with the rise and fall of nations in a time-frame measured over centuries.

Chairman, to your point, like the contest between England and Spain, I also think the contest between Rome and Carthage. These races last centuries.

China is running such a race. With its focus on military civil fusion, Beijing is marshalling its technical and manufacturing resources to enhance its overall national power with space playing a key role.

The importance of space and national power is also recognized by the United States. With President Trump noting in July that space systems power exploration, defense, and communication, and that the Nation will ensure the American flag remains the ultimate symbol of leadership across the final frontier.

Though the PRC space power is growing, the United States can retain its lead and ensure it remains the world's most consequential space power. To do so, we must use our strongest advantages. We have a maturity of still growing space innovation ecosystem; we have a space economy built on free-market principles; and we have a coalition of willing and international partners who want and choose to work with the United States.

These characteristics of our national space power are force multipliers and should be harnessed in the same way that Beijing uses military civil fusion to advance the defense, economic security, scientific objectives, and prestige of our Nation.

In 1963, Edward Teller, a scientist who played a critical role in the Manhattan project testified before Congress on strategic developments, saying that I believe that in a race for knowledge, we will win. But I believe that in a race in which we are not running, or running halfheartedly, we have been losing, and we will continue to lose.

Today, we as a nation may face a similar situation in space. We have many advantages over the PRC, structural advantages that we can use to maintain our edge, but to do so we need to start running.

[The prepared statement of Mr. Swope follows:]



**Statement before the
House Committee on Science, Space, and Technology
Space and Aeronautics Subcommittee**

***“Strategic Trajectories: Assessing China’s Space
Rise and the Risks to U.S. Leadership”***

A Testimony by:

Clayton Swope

Deputy Director, Aerospace Security Project
Center for Strategic and International Studies

December 4, 2025

Swope: Written Testimony, Committee on Science, Space, and Technology, December 4, 2025

Chairman Haridopolos, Ranking Member Foushee, and distinguished Members of the Committee, I am honored to share my views with you on this important topic. CSIS does not take policy positions, so the views represented in this testimony are my own and not those of my employer.

The People's Republic of China (PRC) is methodically executing an ambitious, multi-faceted space agenda that—at the highest level—aims to prove that China is a world power in space without equal. Beijing is using space in ways that provide direct, tangible benefits to its military and economy, while also fostering national pride and unity. China is fielding satellites that provide the ability to identify, characterize, and track objects of all sizes in the Indo-Pacific region and move data and information around the world—both to and from space and in orbit. China is building out infrastructure on Earth and developing technologies in space that will support the future growth of a PRC-aligned space ecosystem. China is extending the footprint of its human spaceflight activities from low Earth orbit to the Moon and aiming to be the first country to bring back samples of another planet to Earth.

Every new space technology, skill, and industrial capability acquired by the PRC will be used to provide the People's Liberation Army (PLA) a battlefield advantage, as well as power civilian and commercial innovation and economic growth in China. Beijing will derive national and economic advantages from today's space race, as one of the PRC's core strategies is military-civil fusion.¹ China will seek to use all its national power to obtain an edge in space. The United States—the world's most important spacepower—uses space in the same way, as a foundational pillar of our national strength. Though the United States, by most metrics, remains the most consequential nation in space, China is motivated to close the gap and has demonstrated through its actions, measured over decades, that it wants to win. To date, China has mostly copied the U.S. playbook, but China is starting to increasingly set its own course.

Charting the PRC's Rise in Space

What China is doing today in space cannot be properly understood without assessing what it has done over the last 70 years. Throughout the first five decades of its space program, beginning in the 1950s, China focused on military, technological, and industrial development. China's earliest space efforts—the Two Bombs, One Satellite initiative—focused entirely on military objectives.² In quick succession, China tested an atomic bomb (1964) and hydrogen bomb (1967) and launched its first satellite (1970). In the 1980s and 1990s, China sought to market its space launch capabilities to international customers and restarted its human spaceflight program, which had been paused in the 1970s. The last years of the 20th century witnessed the beginning of China's rise as a global economic juggernaut, growth of its middle class, military modernization, and an increased focus on space.

Over the last 25 years, the PRC's civil space programs have methodically checked off technical achievements in human spaceflight and uncrewed exploration that will likely culminate in a crewed landing on the Moon within five years. China has already built three space stations, conducted six robotic lunar missions, launched two lunar relays, and executed a mission to Mars. This progress has happened rapidly. China did not launch

¹ "The Chinese Communist Party's Military-Civil Fusion Policy," U.S. Department of State, <https://2017-2021.state.gov/military-civil-fusion/>.

² "The 'Two Bombs and One Satellite'," The State Council Information Office of the People's Republic of China, July 13, 2022, http://english.scio.gov.cn/m/featured/chinakeywords/2022-07/13/content_78321940.htm.

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its first space science mission until 2003, which is the same year China placed an astronaut into orbit for the first time.³ Meanwhile, China has developed and deployed space capabilities with direct applicability to military operations that allow the PLA to monitor what is happening on Earth and in space, communicate with its forces throughout the Indo-Pacific region, and navigate with a high level of precision using its BeiDou system.⁴

China is heavily focused on ramping up its production capabilities to support its growing space program. China has built satellite and rocket manufacturing facilities and associated supply chains, launch facilities, ground stations, and space object tracking systems, which includes ships designed for space tracking and telemetering. Much of this infrastructure is located inside China—nearly a vertically integrated space ecosystem—but some elements are in other countries, such as ground stations and space object tracking facilities. Simultaneously, Beijing has used the establishment of terrestrial space infrastructure and membership in the coalition supporting the PRC-led equivalent to the Artemis program—called the International Lunar Research Station—to build and strengthen diplomatic relations, particularly with the Global South, similar to how it’s used the Belt and Road Initiative.⁵ Russia is the co-lead of the ILRS initiative. The PRC is also developing on-orbit infrastructure and technologies, such as in-space refueling, highly maneuverable satellites, space-based nuclear and solar power, space-based data centers, and satellite docking and capture technologies. Terrestrial and on-orbit space infrastructure is the foundation of future spacepower—equivalent to power grids; undersea cables; roads, railroads, and airports; data centers, and gas refineries, pipelines, and stations on Earth.

China has also built—while continuing to test and deploy new technologies and increase the scale and sophistication of its systems—networks of satellites designed to keep tabs on what is happening on Earth and in space. Such technologies have civilian applications, such as for agriculture, disaster response, and insurance purposes, but also military uses. China has several satellites which have—based on public information—no peers. China launched a remote-sensing satellite, called Yaogan-41, into geostationary orbit in December 2023.⁶ The satellite can conduct continuous surveillance of the Pacific and Indian Oceans, as well as Taiwan and Mainland China. Paired with data from other Chinese surveillance satellites, Yaogan-41 could provide China an unprecedented ability to identify and track car-sized objects throughout the entire Indo-Pacific region and put at risk numerous U.S. and allied naval and air assets operating in the region.⁷ China has other surveillance satellites in low Earth orbit and geosynchronous orbit, as well as a new one in medium Earth orbit.⁸ In addition to building capabilities to support military operations on Earth, the PLA is

³ “Double Star factsheet,” European Space Agency, https://www.esa.int/Science_Exploration/Space_Science/Double_Star_factsheet and “Yang Liwei, China’s first man in space,” CGTN, April 25, 2025, <https://news.cgtn.com/news/2025-04-25/Yang-Liwei-China-s-first-man-in-space-1CRp6L9OiR2/p.html>.

⁴ Argyris Kriezis, “GPS Faces Growing Competition from China’s BeiDou,” Payload, September 4, 2024, <https://payloadspace.com/gps-faces-growing-competition-from-chinas-beidou/>.

⁵ Andrew Jones, “China wants 50 countries involved in its ILRS moon base,” Space News, July 23, 2024, <https://spacenews.com/china-wants-50-countries-involved-in-its-ilrs-moon-base/>.

⁶ Andrew Jones, “China launches large classified optical satellite towards geostationary orbit,” Space News, December 15, 2023, <https://spacenews.com/china-launches-large-classified-optical-satellite-towards-geostationary-orbit/>.

⁷ Clayton Swope, “No Place to Hide: A Look into China’s Geosynchronous Surveillance Capabilities,” CSIS, January 19, 2024, <https://www.csis.org/analysis/no-place-hide-look-chinas-geosynchronous-surveillance-capabilities>.

⁸ “Space Threat Fact Sheet,” U.S. Space Force, September 2025, <https://www.spaceforce.mil/About-Us/Fact-Sheets/Fact-Sheet-Display/Article/4297159/space-threat-fact-sheet/> and Andrew Jones, “China launches mystery Yaogan-45 spy sat,

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also developing and fielding an increasingly sophisticated toolkit of counterspace weapons that can threaten U.S. and allied satellites.⁹

Looking back over the past several decades, China has mostly copied the U.S. space playbook. It is scaling its ability to build, launch, and operate satellites and spacecraft; developing reusable space launchers; deploying satellites to conduct surveillance and reconnaissance of Earth; planning a crewed mission to the Moon; and operating a modular space station. But China is not only mirroring the United States anymore—it is doing things no one else has done. China was the first nation to land on and conduct a sample return from the far side of the Moon.¹⁰ In 2025, China conducted what many suspect was the world's first satellite refueling operation in geosynchronous orbit—though the United States has conducted life-extension missions, similar to refueling, and is planning for a refueling mission in geosynchronous orbit in 2026 and conducted a fueling and servicing mission in low Earth orbit in 2007.¹¹ Since 2018, China has operated the world's first and only communications satellite in an orbit around the Earth-Moon L₂ Lagrange point.¹² China is ramping up operations in very low Earth orbit, aiming to place a 300-satellite surveillance constellation there.¹³ China is already operating what might be the only synthetic aperture radar satellite in very low Earth orbit.¹⁴ China is also demonstrating a high level of space operational acumen. The PRC is maneuvering its satellites in a way that suggests not only an understanding of what U.S. satellites are doing but also that Chinese satellites have a way to counter U.S. actions—Chinese satellites have reportedly maneuvered to counter U.S. efforts to inspect them.¹⁵ In the coming years, what China does in space will probably continue to surprise us.

Elements of National Space Power—Comparing the PRC to the United States

A comparison between China's presence in space today and ten years ago, in 2015, illustrates the breadth and scope of China's rapid rise in space—and may also foreshadow what to expect in the next ten or twenty years. In 2015, China launched 19 rockets and put around 40 satellites into orbit.¹⁶ As of late November 2025, China has had nearly 80 launches and placed around 250 payloads into orbit in 2025.¹⁷ By comparison, the United States has had over 160 successful space launches and placed over 2,000 payloads into orbit this year

expands Geesatcom constellation,” Space News, September 9, 2025, <https://spacenews.com/china-launches-mystery-yaogan-45-spy-sat-expands-geesatcom-constellation/>.

⁹ Clayton Swope, Kari A. Bingen, Makena Young, and Kendra LaFave, “Space Threat Assessment 2025, CSIS, April 25, 2025, <https://www.csis.org/analysis/space-threat-assessment-2025>.

¹⁰ Simone McCarthy, “China's Chang'e-6 moon mission returns to Earth with historic far side samples,” CNN, June 25, 2024, <https://www.cnn.com/2024/06/25/china/china-change-6-moon-mission-return-scnp-intl-hnk>.

¹¹ Stephen Clark, “China jumps ahead in the race to achieve a new kind of reuse in space,” Ars Technica, July 8, 2025, <https://arstechnica.com/space/2025/07/china-jumps-ahead-in-the-race-to-achieve-a-new-kind-of-reuse-in-space/>.

¹² Luyuan Xu, “How China's lunar relay satellite arrived in its final orbit,” The Planetary Society, June 15, 2018, <https://www.planetary.org/articles/20180615-quejiao-orbit-explainer>.

¹³ Ling Xin, “China's bullet-shape satellite test paves the way for very low orbit surveillance network,” South China Morning Post, May 14, 2025, <https://www.scmp.com/news/china/science/article/3310148/chinas-bullet-shape-satellite-test-paves-way-very-low-orbit-surveillance-network>.

¹⁴ Li Yali, “China launches first low-inclination orbit SAR satellite ‘Haishao-1,’” Phys Org, July 3, 2025, <https://phys.org/news/2025-07-china-inclination-orbit-sar-satellite.html>.

¹⁵ “The Integrity Flash, Issue 104,” Integrity ISR, September 1, 2024, <https://isruniversity.com/wp-content/uploads/2025/02/integrity-flash-104.pdf>.

¹⁶ Zhu Xi, “19 Rockets and 43 Satellites! Year-Round Review of China's Space Developments in 2015,” People's Daily Online, December 31, 2015, <https://en.people.cn/n3/2015/1231/e90000-8997611.html>.

¹⁷ Space Data Navigator, AEI, <https://spacedata.aei.org/>.

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as of late November 2025—with around 1,700 of those being Starlink satellites and over 100 being Amazon Leo satellites.¹⁸

To date, the only entity—worldwide—to have mastered vertical landing and reusability of orbital-class boosters at scale is SpaceX, though Blue Origin too demonstrated it can vertically land a booster rocket. A company in China may, however, attempt a vertical landing of an orbital-class rocket within the next few months.¹⁹ Meanwhile, several other entities in China are working on reusable launch vehicles, as Beijing has made mastering reusable rockets a key national priority.²⁰ As of November 2025, eight companies in China have successfully conducted orbital launches.²¹ All but two of the operational rockets developed by these companies are small-lift space launch vehicles, as most of China's larger launchers are built and operated by state-owned enterprises. But there are a variety of medium- and heavy-lift rockets under development, by companies and state-owned enterprises, that could become operational in the next few years, potentially alleviating China's launch bottleneck.²² China already operates a reusable space plane, which commentators have compared to the U.S. X-37B, and is developing other similar vehicles.²³

China launched the first satellite in what was intended to be its first low Earth orbit broadband constellation, called Hongyun, in 2018. Yet by November 2025, not one of China's proposed mega constellations was close to full operation, with Guowang "national network"—a planned 13,000 satellite constellation—having less than 150 satellites in orbit. Meanwhile, Starlink has over 8,000 active satellites and Amazon, which started launching production satellites in the last year, has over 100 satellites in orbit. However, Guowang may be picking up speed, as it has conducted around 10 launches since December 2024.²⁴ In addition to providing broadband, Guowang may serve as the backbone for a plug-and-play system that incorporates satellites having synthetic aperture radar, electro-optical sensors, or other payloads.²⁵ Other than Guowang, China is

¹⁸ Ibid.

¹⁹ Andrew Jones, "China is about to start trying to land and reuse its rockets," Space News, August 25, 2025,

<https://spacenews.com/china-is-about-to-start-trying-to-land-and-reuse-its-rockets/>.

²⁰ Peter W. Singer and Alex Nova, "China is working on reusable rockets—and a strategic leap in space power," Defense One, August 14, 2025, <https://www.defenseone.com/ideas/2025/08/china-working-reusable-rocketsand-strategic-leap-space-power/407453/>.

²¹ "Sizing Up China's Commercial Launchers," China Space Monitor, November 23, 2025,

<https://chinaspacemonitor.substack.com/p/sizing-up-chinas-commercial-launchers>.

²² Andrew Jones, "New rocket plans continue to emerge to support China's growing space ambitions," Space News, August 22, 2025, <https://spacenews.com/new-rocket-plans-continue-to-emerge-to-support-chinas-growing-space-ambitions/>; and

"The Launch Bottleneck Holding up China's Starlink," China Space Monitor, March 16, 2025,

<https://chinaspacemonitor.substack.com/p/the-launch-bottleneck-holding-up>.

²³ "Reusable Chinese spacecraft lands successfully - state media," Reuters, September 6, 2020,

<https://www.reuters.com/world/china/reusable-chinese-spacecraft-lands-successfully-state-media-2020-09-06/> and Daniel Shats and Peter Wood, "Chinese Spaceplane Programs," China Aerospace Studies Institute, Prepared by BluePath Labs, November 2021, <https://bluepathlabs.com/wp-content/uploads/2024/05/chinese-spaceplane-programs.pdf>.

²⁴ Andrew Jones, "China sends 10th group of Guowang broadband satellites into orbit with Long March 8A launch," Space News, August 25, 2025, <https://spacenews.com/china-sends-10th-group-of-guowang-broadband-satellites-into-orbit-with-long-march-8a-launch/>.

²⁵ Stephen Clark, "China's Guowang megaconstellation is more than another version of Starlink," Ars Technica, August 20, 2025, <https://arstechnica.com/space/2025/08/china-may-have-taken-an-early-lead-in-the-race-for-a-military-megaconstellation/>.

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actively launching several other low Earth orbit communications constellations: Qianfan “Thousand Sails”, GEESATCOM, and Tianqi.²⁶ More Chinese constellations are in the works.²⁷

To date, China has not shown that it can manufacture and conduct space launch at the same cadence as companies, mainly SpaceX and Rocket Lab, in the United States—but China is diligently working to close that manufacturing gap and working to master reusable space launch technologies. According to a Chinese source, as of April 2025, “37 satellite manufacturing plants have already been commissioned, 13 are under construction, and another 8 are at the planning stage.”²⁸ Many of these facilities are projected to be able to produce at least 100 satellites each year, with one factory in Hainan province expected to eventually produce over 1,000 satellites per year.²⁹ If these manufacturing facilities meet their target production rates, China would be capable of manufacturing over 4,000 satellites per year. If China commits more of its manufacturing might to building satellites, it could even eclipse these numbers. For reference, SpaceX alone can make 70 satellites per week—at a rate that translates to over 3,500 satellites per year.³⁰ Amazon says it can build five satellites per day—meaning possibly around 1,800 per year.³¹

China is also making strides in other important areas. Amazon successfully tested a 100 Gbps optical intersatellite link between its prototype satellites in 2023.³² As of 2025, Starlink optical intersatellite links operate at speeds up to 200 Gbps between satellites in low Earth orbit.³³ Meanwhile, a Chinese company claims to have tested a 400 Gbps optical intersatellite link between two low Earth orbit satellites in March 2025.³⁴ China is also aiming to leapfrog the United States on space-based positioning, navigation, and timing, which has unambiguous military and non-military purposes. China is planning to launch its next generation BeiDou system from 2029 to 2035.³⁵ At the same time, the United States seems to be considering the value of China’s multi-orbit approach—BeiDou satellites are in three different orbits—for its next-generation GPS

²⁶ Andrew Jones, “China launches first satellites for Thousand Sails megaconstellation,” Space News, August 6, 2024, <https://spacenews.com/china-launches-first-satellites-for-thousand-sails-megaconstellation/>; “Geely Launches 11 Satellites for 4th Orbital Plane, Advancing Integrated Space-Earth Mobility Ecosystem,” Geely, August 11, 2025, <https://www.geely.com/en/news/2025/geely-launch-11-satellites-4th-orbital-plane>; and “China Expands Satellite Constellations to Enhance Smart Connectivity,” Beijing Post, <https://beijingpost.com/china-expands-satellite-constellations-to-enhance-smart-connectivity>.

²⁷ “Honghu-3,” Baidu.com, <https://baike.baidu.com/item/Honghu-3/64762413>.

²⁸ 你好太空2022. “中国有多少卫星工厂,” [How Many Satellite Factories Does China Have?] April 22, 2025. <https://www.bilibili.com/opus/1058634152000094227>.

²⁹ “China to build factory in Hainan that makes 1,000 satellites a year,” CGTN, April 6, 2024, <https://news.cgtn.com/news/2024-04-06/China-to-build-factory-in-Hainan-that-makes-1-000-satellites-a-year-1sAsJw3Sv2Y/p.html>.

³⁰ Michael Kan, “SpaceX Offers Rare Peek Inside a Starlink Satellite Factory, Tips ‘Mini Lasers,’” PC Mag, August 26, 2025, <https://www.pcmag.com/news/spacex-offers-rare-peek-inside-a-starlink-satellite-factory-tips-mini-lasers>.

³¹ Thomas Kohnstamm, “Everything you need to know about Project Kuiper, Amazon’s satellite broadband network,” About Amazon, June 3, 2025, <https://www.aboutamazon.com/news/innovation-at-amazon/what-is-amazon-project-kuiper>.

³² Amazon Staff, “Amazon’s Project Kuiper completes successful tests of optical mesh network in low Earth orbit,” About Amazon, December 13, 2023, <https://www.aboutamazon.com/news/innovation-at-amazon/amazon-project-kuiper-oisl-space-laser-december-2023-update>.

³³ “Satellite Technology,” Starlink, <https://www.starlink.com/technology>.

³⁴ Andrew Jones, “China Makes High-Speed Laser Links in Orbit 400-gigabit-per-second intersatellite comms reduce the need for ground stations,” IEEE Spectrum, May 12, 2025, <https://spectrum.ieee.org/satellite-internet-china-crosslink>.

³⁵ Xinhua, “China sets build next-generation BeiDou system,” China Daily, November 28, 2024, <https://www.chinadaily.com.cn/a/202411/28/WS6747f9b7a310f1265a1d0134.html>.

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system. A geostationary test satellite for the next generation GPS network was launched in August 2025.³⁶ A company in China has also tested technologies for uncrewed commercial reusable spacecraft.³⁷ Varda Space Industries, a U.S. company, has already conducted several reentries and received U.S. regulatory approval for unlimited future reentries.³⁸

Space for Science and Exploration—and National Prestige

China's political leaders have worked to equate the nation's successes in space to the success and leadership of the party. By all accounts, those endeavors have paid off, as the people of China take tremendous pride in the country's civil space accomplishments. Between 1992, when China stood up the China Manned Space Program, and 2022, China achieved all its original human spaceflight goals, including the operation of a crewed spacecraft, mastering rendezvous and docking, and building a modular space station. China has maintained a continuous human presence in low Earth orbit for three years on its Tiangong-3 space station and demonstrated it can safely and reliably ferry humans and cargo to and from low Earth orbit.³⁹ China is pursuing the development of commercial cargo resupply capabilities for its space station.⁴⁰ When the International Space Station is deorbited in 2030, China will doubtless continue to operate its space station. It remains to be seen if the United States has allocated sufficient resources to ensure the availability of a commercially operated space station for U.S. and allied use by 2030. China also has plans for a robust docket of uncrewed deep space science missions, including an asteroid sample-return mission launched in 2025 and upcoming missions to Mars and Jupiter.

Currently, however, the focus of China's civil space program is undeniably the Moon, with a crewed lunar landing planned by 2030. In April 2024, a senior Chinese space official reaffirmed that timeline, noting that the "program development" for major mission components, including the Long March 10 rocket, Mengzhou crewed spacecraft, Lanyue lunar lander, and lunar landing space suits, was already complete.⁴¹ Meanwhile, timelines for critical components of NASA's Artemis III mission, most notably the Human Landing System, are in flux and risk delaying NASA's schedule for returning astronauts to the Moon.⁴² China also has two uncrewed missions in the works: Chang'e 7 planned for 2026 and Chang'e 8 planned for 2028. Chang'e 8 will test technologies required to build a permanent base. Both uncrewed missions play a role in China's plans for the International Lunar Research Station, a "scientific experimental facility consisting of sections

³⁶ Sandra Erwin, "U.S. eyes geostationary orbit for next-gen GPS," Space News, September 23, 2024, <https://spacenews.com/u-s-eyes-geostationary-orbit-for-next-gen-gps/>.

³⁷ Andrew Jones, "Commercial Chinese rocket launches small returnable spacecraft to orbit (video)," Space.com, December 20, 2023, <https://www.space.com/commercial-chinese-rocket-ispace-launches-returnable-spacecraft>.

³⁸ Garret Reim, "Space Ops: FAA OKs Unlimited Reentries For Varda Capsules," Aviation Week, June 25, 2025, <https://aviationweek.com/space/space-exploration/space-ops-faa-oks-unlimited-reentries-var-da-capsules>.

³⁹ Global Desk, "Shenzhou 20 Mission astronauts dock with Tiangong space station. Here's what happened," The Economic Times, April 24, 2025, <https://economictimes.indiatimes.com/news/international/us/shenzhou-20-mission-astronauts-dock-with-tiangong-space-station-heres-what-happened/articleshow/120596549.cms>.

⁴⁰ Andrew Jones, "China to launch 2 new space station cargo spacecraft on commercial rockets in 2025," Space News, February 4, 2025, <https://spacenews.com/china-to-launch-2-new-space-station-cargo-spacecraft-on-commercial-rockets-in-2025/>.

⁴¹ Andrew Jones, "China on track for crewed moon landing by 2030, space official says," Space News, April 24, 2024, <https://spacenews.com/china-on-track-for-crewed-moon-landing-by-2030-space-official-says/>.

⁴² Josh Dinner, "SpaceX Starship timeline delays astronaut moon landing for NASA's Artemis 3 mission to 2028: Report," Space.com, November 17, 2025, <https://www.space.com/space-exploration/spacex-starship-timeline-delays-astronaut-moon-landing-for-nasas-artemis-3-mission-to-2028-report>.

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on the lunar surface, in lunar orbit and on Earth.”⁴³ The first phase of the base will be built by 2035 in the lunar south pole. China and Russia are also planning to build a lunar nuclear power station to support the base.

Looking beyond the Moon, Beijing will continue to pursue new space exploration achievements—exploring the cosmos is a core part of Xi Jinping’s “space dream.”⁴⁴ Mars features prominently in the PRC’s 2050 space science strategy, unveiled in October 2024, and a roadmap released in March 2025 by the Deep Space Exploration Laboratory (e.g., China’s equivalent to the Jet Propulsion Laboratory).⁴⁵ Two goals related to Mars—sending an uncrewed probe around 2020 and landing humans on the Martian surface around 2050—were outlined in a 2010 space science and technology roadmap published by the Chinese Academy of Science.⁴⁶ China accomplished the first of these goals in 2021 with the Tianwen-1 mission. With the Tianwen-3 mission, scheduled for launch in 2028, China will likely achieve something no nation has done before: returning Martian samples to Earth. In 2021, a senior Chinese official spoke about crewed missions to Mars in 2033, but that date seems unlikely.⁴⁷ A more realistic estimate is probably no sooner than 2040, which aligns with a presentation by the Deep Space Exploration Laboratory in 2023.⁴⁸

Space for Technological and Industrial Development

The aerospace industry fits squarely into the long-term technological and economic development strategies and “new industrialization” policies of the PRC.⁴⁹ President Xi has unambiguously affirmed the importance to China in developing its space industry.⁵⁰ The 15-year National Medium- to Long-Term Program (MLP) for Science and Technology Development, launched in 2006, outlined plans for 16 major special projects, often called megaprojects, intended to advance national goals and China’s indigenous engineering and technological capabilities—one of these megaprojects was space-related: building a second-generation BeiDou satellite navigation network.⁵¹ In 2015, Beijing unveiled its Made in China 2025 initiative, which

⁴³ “China outlines blueprint for international lunar research station,” Xinhua, The State Council Information Office of the People’s Republic of China, September 6, 2024, http://english.scio.gov.cn/international/exchanges/2024-09/06/content_117411749.html.

⁴⁴ “Backgrounder: Xi Jinping’s Vision for China’s Space Development,” Xinhuanet, April 24, 2017, http://www.xinhuanet.com/english/2017-04/24/c_136232642.htm.

⁴⁵ “National Mid- and Long-term Plan for Space Science in China,” National Space Science Center, Chinese Academy of Sciences, October 28, 2024, http://english.nssc.cas.cn/pub/202410/20241028_692867.html and Andrew Jones, “China has a planetary exploration roadmap focused on extraterrestrial life,” Post on X.com, March 26, 2025, https://x.com/AJ_FJ/status/1904778023896760724.

⁴⁶ Yongxiang Lu, “Science & Technology in China: A Roadmap to 2050,” Chinese Academy of Sciences, 2010, https://archive.org/details/isbn_9783642048227/.

⁴⁷ “China plans its first crewed mission to Mars in 2033,” Reuters, June 24, 2021,

<https://www.reuters.com/business/aerospace-defense/china-plans-its-first-crewed-mission-mars-2033-2021-06-24/>.

⁴⁸ International Lunar Research Station (ILRS), Deep Space Exploration Laboratory of CNSA, Presentation to UNOOSA, May 2023, https://www.unoosa.org/documents/pdf/copuos/2023/TPs/ILRS_presentation20230529.pdf.

⁴⁹ “China front-loads future with new industrialization,” China Daily, The State Council of the People’s Republic of China, December 4, 2023, https://english.www.gov.cn/news/202312/04/content_WS656d32c7c6d0868f4e8e1df3.html.

⁵⁰ “Xi Jinping calls for accelerating progress in China’s space endeavors,” CGTN, September 23, 2024, <https://news.cgtn.com/news/2024-09-23/Xi-calls-for-accelerating-progress-in-China-s-space-endavors-1x8mrMw5G3a/p.html>.

⁵¹ “The National Medium- to Long-Term Program for Science and Technology Development,” The State Council of the People’s Republic of China, https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf and “The Rise of China’s Industrial Policy,”

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aimed to extend the goals of the MLP to 2025 and focused on advancing indigenous capabilities across ten industrial sectors, which included the aerospace sector and, within that sector, space launch technologies.⁵²

Beijing has also emphasized the need to harness indigenous industry partners. In 2014, Beijing implemented a new policy that created opportunities for private sector space development.⁵³ A 2022 white paper on space released by the central government recognized industry as a “critical element of the national strategy.”⁵⁴ Development plans on the national, provincial, and district levels incorporate aerospace-related industrial goals. Emerging space technologies and space resources are also playing into China’s industrialization initiatives. In an October 2024 lecture, a member of the Chinese Academy of Engineering discussed building a gigantic space-based solar power array in geosynchronous orbit.⁵⁵ In 2025, scientists in China shared a plan for using space resources and defending Earth from asteroids.⁵⁶ The upcoming Chang’e 8 lunar mission involves testing technologies for in-situ resource utilization on the Moon.⁵⁷ Chinese scholars have also discussed using in-situ resources for the construction of infrastructure on Mars.⁵⁸ China is also developing a satellite constellation for artificial intelligence-enabled computing in space.⁵⁹

Recommendations

If the United States is in a race with China, it is a race that has no end, other than an end associated with the rise and fall of nations in a timeframe measured over centuries. This race is a test of endurance and will take place over an indeterminate period of time. China is certainly running such a race. With its focus on military-civil fusion, Beijing is marshalling its technical and manufacturing resources to enhance its overall national power—with space playing a key role. The importance of space to national power is also recognized by the United States, with President Trump noting in July 2025 that space systems “power exploration, defense, and communication” and that the nation will ensure “the American flag remains the ultimate symbol of leadership across the final frontier.”⁶⁰

University of California Institute on Global Conflict and Cooperation, 2022, https://ucigcc.org/wp-content/uploads/2022/06/Naughton2021_Industrial_Policy_in_China_Chapter-3.pdf.

⁵² “Made in China 2025 and Industrial Policies: Issues for Congress,” Congressional Research Service, December 12, 2024, https://www.eversysreport.com/files/2024-12-12_IF10964_281255f5df5f94f6bd3c68c4daf8e8e3e040f5a8.pdf.

⁵³ Jeff Foust, “Assessing China’s commercial space industry,” The Space Review, January 27, 2020, <https://www.thespacereview.com/article/3872/1>.

⁵⁴ “China’s Space Program: A 2021 Perspective,” The State Council Information Office of the People’s Republic of China, January 28, 2022, https://english.www.gov.cn/archive/whitepaper/202201/28/content_WS61f35b3dc6d09c94e48a467a.html.

⁵⁵ Mrigakshi Dixit, “China plans space solar station with half-mile-long arrays for unprecedented power,” Interesting Engineering, January 10, 2025, <https://interestingengineering.com/energy/china-plans-massive-space-solar-station>.

⁵⁶ “Chinese scientists unveil blueprint for asteroid defense and resource utilization call for int’l collaboration,” Xinhua, September 6, 2025, <https://english.news.cn/20250906/df4a2a5eb79a4e4e955ab3d3e14ba5af/c.html>.

⁵⁷ Andrew Jones, “China to 3D-print bricks on the moon using lunar dirt in 2028 to pave way for future base (video),” Space.com, April 10, 2025, <https://www.space.com/space-exploration/human-spaceflight/china-to-3d-print-bricks-on-the-moon-using-lunar-dirt-in-2028-to-pave-way-for-future-base-video>.

⁵⁸ Jiawen Liu, Hui Li, Lijun Sun, Zhongyin Guo, John Harvey, Qirong Tang, Haizhu Lu, and Ming Jia, “In-situ resources for infrastructure construction on Mars: A review,” International Journal of Transportation Science and Technology, March 2022, <https://www.sciencedirect.com/science/article/pii/S204604302100006X>.

⁵⁹ Andrew Jones, “China launches first of 2,800 satellites for AI space computing constellation,” Space News, May 14, 2025, <https://spacenews.com/china-launches-first-of-2800-satellites-for-ai-space-computing-constellation/>.

⁶⁰ “Presidential Message on Space Exploration Day,” The White House, July 20, 2025, <https://www.whitehouse.gov/briefings-statements/2025/07/presidential-message-on-space-exploration-day/>.

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Though the PRC's space power is growing, the United States can retain its lead in space and ensure it remains the world's most consequential space power. To do so, we must take full advantage of our strongest advantages—a mature, yet still growing, space innovation ecosystem; a space economy built on free-market principles; and a coalition of willing international partners who want and choose to work with the United States, because these nations believe in a future of humankind in space that matches our own vision. These characteristics of U.S. national space power are force-multipliers for every dollar spent by the U.S. government on space activities and should be harnessed, in the same way that Beijing uses military-civil fusion, to advance the defense, economic security, scientific and space exploration objectives, and prestige of our nation.

To capitalize on the U.S. space innovation ecosystem, policymakers should recognize the role of stable government spending and program direction in doing several things that help advance U.S. national space power: 1) funding basic and early stage (i.e., technology readiness level one or two) research and development applicable to space which a company might view as too risky to undertake with its own money; 2) funding activities in space, such as science and exploration, which do not have strong non-government business cases but can generate new ideas and innovation that feed back into the space economy; and 3) funding activities to pursue government objectives in a way that they create opportunities and lower costs for other entities to try out their ideas and technologies. The Commercial Lunar Payload Services program is an example of the latter activity, as it was structured in a way that created lower cost ride-sharing opportunities for non-NASA entities into space and to the Moon. The Commercial Orbital Transportation Services program, which began in the mid-2000s, is another program that aimed to provide a broader benefit to the space economy, while also providing cargo transportation services to the International Space Station.

A strong and growing U.S. space economy strengthens U.S. economic and national security. The U.S. space economy, which operates on free-market principles, can facilitate the process of creative destruction, generating new ideas and businesses. Over the last 15 years, U.S. companies have succeeded in increasing their share of and growing existing space markets (i.e., commercial launch and satellite communications) and creating new or maturing developing markets (i.e., commercial remote sensing, human spaceflight, and reentry services). The most effective way that policymakers can accelerate the flywheel powering the success of U.S. companies in space is to identify how existing regulations or procedures (i.e., on spectrum, launch and reentry, and export control and International Traffic in Arms Regulations) might be holding back free-market forces and artificially slowing the growth of U.S. space companies. Regulations that incentivize the status quo over innovation should be reevaluated. Once identified, policymakers should consider how to change and modernize rules with the goal of optimizing them towards facilitating more commercial growth in space for U.S. companies. The Trump administration, as well as past ones, have sought to update and modernize such rules along these lines—continuing this work is important. Proposals for new regulations or authorizations for commercial space activities should be scrutinized, as they would add more bureaucracy to an already bureaucratized business.

Finally, unlike the PRC, the United States has a long list of international friends who want to partner with it in space—the growing list of signatories to the Artemis Accords and roster of countries contributing to the

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Artemis program stands as unambiguous proof that nations want to partner with the United States.⁶¹ The recently launched NISAR (NASA-ISRO Synthetic Aperture Radar) satellite is another example of the value of partnerships.⁶² NASA supplied a radar, while India provided a satellite bus, a second radar, and the rocket that launched the satellite into orbit. Selfishly, the United States should cultivate and strengthen such relationships, particularly with nations who bring money to the table. Pooling resources, including money and talent, with international partners will allow the United States to do more in space and, diplomatically, increase the odds that U.S. values and free-market principles are reflected in humankind's future activities on the Moon and across the Solar System. International space partnerships are also an effective soft power tool, whose impact on shaping global geopolitics and strengthening a world order in America's image should not be underestimated.

In 1963, Edward Teller, a Hungarian emigrant to the United States who played a critical role in the development of the atomic bomb, testified before the Senate Foreign Relations Committee on nuclear strategy and weapons development saying that, "I believe that in a race for knowledge we [the United States] will win. But I believe that in a race in which we are not running or running half-heartedly we have been losing and we will continue to lose."⁶³ Today, we as a nation face a similar situation in space. We have many advantages over the PRC that we can use to maintain our edge—but to do so, we need to start running.

⁶¹ "List of Signatories by Date," NASA, <https://www.nasa.gov/wp-content/uploads/2024/10/signatories-02.pdf?emrc=98e326> and "Artemis Partners," NASA, <https://www.nasa.gov/artemis-partners/>.

⁶² "NISAR," NASA, <https://science.nasa.gov/mission/nisar/>.

⁶³ "Nuclear Test Ban Treaty: Hearings Before the Committee on Foreign Relations," U.S. Congress, U.S. Government Printing Office, 1963, <https://books.google.com/books?id=qkovAAAAAAAJ&pg=PR1#v=onepage&q&f=false>.

Clayton Swope**Deputy Director, Aerospace Security Project and Senior Fellow, Defense and Security Department, Center for Strategic and International Studies**

Clayton Swope is the deputy director of the Aerospace Security Project and a senior fellow in the Defense and Security Department at the Center for Strategic and International Studies (CSIS). Before joining CSIS, Swope led national security and cybersecurity public policy for Amazon's Project Kuiper, an initiative to increase global broadband access through a constellation of satellites in low Earth orbit. While at Amazon, he also worked on cloud policy issues. Prior to his time at Amazon, Swope served as a senior adviser on national security, space, foreign affairs, and technology policy issues for a member of the U.S. House of Representatives. He also worked for more than 14 years at the Central Intelligence Agency, serving largely in the Directorate of Science and Technology. He holds a bachelor of science in mechanical engineering from the University of Notre Dame.

Chairman HARIDOPOLOS. Thank you, Mr. Swope. Next, we have Dr. Besh. I keep pronouncing your incorrectly, I want to make sure I—

Dr. BESH. Besh.

Chairman HARIDOPOLOS. Thank you. You are recognized for 5 minutes.

**TESTIMONY OF DR. PATRICK BESH,
FOUNDER, GLOBAL SPACE GROUP**

Dr. BESH. Thank you, Chairman Haridopolos, Ranking Member Foushee, and Ranking Member Lofgren, and distinguished Members of the Committee. Thank you for the opportunity to provide my perspective on China's space strategy and its implications for the U.S. You know, when I started at NASA 20 years ago as a specialist on China, the country had just launched their first astronaut into orbit and had not yet launched their first lunar mission. How times have changed?

Today, the U.S. and China are the two most powerful spacefaring Nations, engaged in a long-term strategic competition that spans multiple elements.

Geopolitics, national security, economic competitiveness, social and cultural influence, and science. I will briefly discuss each major area. Geopolitics, national pride, and prestige have been central drivers of China's space program since its establishment. Today, human space flight missions are most closely associated with these goals, including its current space station and planned human lunar landing and the International Lunar Research Station. Human spaceflight is extraordinarily expensive and highly symbolic.

And so, therefore, serving very powerful signalling function. The geopolitical stakes were once summed up by Lyndon Johnson as: In the eyes of the world, first in space means first period; second in space is second in everything.

Today, the importance of space has only grown with our national security and economy relying on it. Developing a major space program has also exercised in compelling excellence from propulsion and material science to industrial organization and the supply chains, space missions pull and push the development of new technologies while adhering to the highest quality standards. In essence, such missions provide a tangible measure of a nation's economic strength in geopolitical power.

Second, our ability to operate in space is integral to national security, including our utilization of Position, Navigation, and Timing, reconnaissance communications. The same holds true for all major space powers. Second, space has always been intensely dual use. From military-funded civilian startups to federally funded research centers that build both civil and military spacecraft.

In China, a similar phenomenon is referred to as military-civil fusion. It is part of a comprehensive effort to exploit the best innovation wherever it may exist. In 2019, images of Chang'e 4 on the far side of the Moon were celebrated in the Great Hall of the People. Xi Jinping held it as—the mission as a demonstration of a new type of whole nation system.

Social and cultural influence also shapes the strategy of the space program. Spaceflight is the core part of the China Dream of

national rejuvenation—a return to the country’s preeminent place at the center of the world and now the expansion of civilization deeper into the solar system.

Tying together China’s ancient and modern cultures is a hallmark of Xi Jinping thought and a push to promote the country’s unique cultural identity while legitimizing party rule. One way this is symbolized is the use of traditional mythology in the naming of the space missions.

Economic competitiveness is a measure of how well a nation’s firms compete globally. It can provide insight into firm productivity, or how efficiently inputs are turned into profits and services. China’s state-owned enterprises typically lag its private sector firms in productivity. For this reason, it expanded the commercial space sector, which is now the world’s second largest after the U.S. However, under a state capitalist model, the commercial sector is still robustly controlled by the state from capital markets to firm management.

Core to the Nation’s competitiveness is its manufacturing; China’s ability to outproduce and outscale others is reflected in its roughly one-third share of all manufacturing in the world. With this comes process knowledge, not simply the building instructions, but the hands-on knowledge of how to build, how to innovate, and how to become more efficient. China has hundreds of space companies competing to drive down costs through process and scale efficiencies. As space becomes commoditized, this approach will greatly improve its economic competitiveness, just as it has in other sectors such as solar.

The pursuit of science and the expansion of knowledge is evident. And the country’s recent achievements as you have mentioned, the first return of lunar samples since 1976, the first successful landing on Mars—a second country to land on Mars successfully.

Its latest science strategy covering the next 25 years proposes ambitious missions to Jupiter and Saturn—Jupiter and Neptune, excuse me. Other key strategies such as “Made in China 2025” also prioritizes space. Success in these goals such as building infrastructure on the lunar South Pole and returning samples from Mars would mark exceptional world-class—world first achievements with significant national prestige and soft-power effects.

We are engaged not so much in a space race, but a long-term broad, strategic competition. I recommend a few measures that could support an enduring American advantage. Support Earth and space science robustly, including strategic missions of national importance, establishing a long-term Artemis mission manifest; and advance a strategic international cooperation.

I recently left NASA, but I had great optimism that the agency and its partners in industry can, if appropriately funded, continue to achieve the highest level of excellence. Thank you.

[The prepared statement of Dr. Besha follows:]

**Statement of
Dr. Patrick Besha
Founder, Global Space Group
before the
Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
United States House of Representatives**

December 4, 2025

Chairman, Ranking Member, and distinguished Members of the Subcommittee, thank you for the opportunity to provide my perspective on China's space strategy and its implications for the US. When I started at NASA nearly 20 years ago as a specialist on China, the country had just launched their first astronaut into orbit and had not yet launched their first lunar mission. How times have changed.

Today, the US and China are the two most powerful spacefaring nations, engaged in a long-term strategic competition that spans multiple elements: geopolitics; national security; economic competitiveness; social and cultural influence; and, science. I'll briefly discuss each major area in the context of China's space program.

Geopolitics, national pride and prestige have been central drivers of China's space program since its establishment. Today, human spaceflight missions are most closely associated with these goals, including its current space station and planned human lunar landing and International Lunar Research Station. Human spaceflight is extraordinarily expensive and highly symbolic, performing a powerful signaling function. The geopolitical stakes were once summed up by Lyndon Johnson: "In the eyes of the world, first in space means first period; second in space is second in everything." Today, the importance of space has only grown, with our economy and national security reliant on it. Developing a major space program is also an exercise in compelling excellence - from propulsion and materials science to industrial organization and supply chains. Space missions pull and push the development of new technologies while adhering to the highest quality standards. In essence, such missions provide a tangible measure of a nation's economic strength and geopolitical power.

Secondly, our ability to operate in space is integral to national security including our utilization of position, navigation and timing systems; reconnaissance; communications, and other technologies. The same holds true for all major space powers. Second, space has always been intensely dual-use, from military-funded civilian startups to federally-funded research centers that build both civil and military spacecraft. In China, a similar phenomenon is referred to as "military-civil fusion", and is part of a comprehensive effort to exploit the best innovation wherever it may exist. In 2019, images of *Chang'e 4* on the far side of the moon were celebrated in the Great Hall of the People. Xi Jinping hailed the mission as a demonstration of a "new type of whole-nation system".

Social and cultural influence also shapes the strategy of the space program. Spaceflight is a core part of the China Dream of national rejuvenation - a return to the country's preeminent place at

the center of the world and now, the expansion of civilization deeper into the solar system. Tying together China's ancient and modern cultures is a hallmark of Xi Jinping Thought and a push to promote the country's unique cultural identity while legitimizing Party rule. One way this is symbolized is the use of traditional mythology in the naming conventions of its space missions.

Economic competitiveness is a measure of how well a nation's firms compete globally. It can provide insight into firm productivity, or how efficiently inputs are turned into products and services. China's state-owned enterprises typically lag its private sector firms in productivity. For this reason, it expanded the commercial space sector, which is now the world's second largest after the US. However, under its state capitalist model, the commercial sector is still robustly controlled by the state, from capital markets to firm management.

Core to the country's competitiveness is its manufacturing. China's ability to out-produce and out-scale others is reflected by its roughly one-third share of all manufacturing in the world. With this comes process knowledge, not simply the building instructions, but the hands-on knowledge of how to build, innovate and become more efficient. China has hundreds of space companies competing to drive down costs through process and scale efficiencies. As space becomes commoditized, this approach may greatly improve its economic competitiveness (just as it has in other sectors such as solar).

The pursuit of science and the expansion of knowledge is evident in the country's recent achievements such as the first return of lunar surface samples since 1976 and the successful landing on Mars in 2021, making China only the second country to do so. Its latest space science strategy covering the next 25 years proposes ambitious missions to Jupiter and Neptune. Other key strategies such as "Made in China 2025" also prioritize space. Success in goals such as building infrastructure on the lunar South Pole and returning samples from Mars would mark exceptional world-first achievements, with significant national prestige and soft power effects.

We are engaged not so much in a space race but a long-term, broad strategic competition. I recommend a few measures that could support an enduring American advantage: Support Earth and space science robustly, including strategic missions of national importance such as planetary defense and next-generation space observatories; Establish a long-term Artemis mission manifest; and, advance a strategic international cooperation approach. I recently left NASA, but I have great optimism that the Agency and its partners in industry can, if appropriately funded, continue to achieve the highest level of excellence.



Dr. Patrick Besha

Dr. Besha is the Founder of the Global Space Group. He previously served as the Senior Policy Advisor in the Office of the Administrator at NASA Headquarters focusing on global space exploration; economic and policy evaluations of major civil/commercial space initiatives; national security space issues; and, international relations.

He previously served as the overall Asia lead, with primary responsibility for China and India, in the Office of International and Interagency Relations at NASA. Proficient in Mandarin Chinese and Samoan languages, he is a former Boren China Fellow and returned Peace Corps Samoa volunteer.

He has authored and edited publications for NASA, OECD, World Bank, Institute for Global Conflict and Cooperation at the University of California, World Economic Forum, United Nations Development Program, UNESCO, and academic journals. Most recently, he co-authored *NASA's Planetary Defense Strategy*, and co-edited *The Economic Development of Low-Earth Orbit*. He received his PhD in Public Policy from George Washington University with a dissertation focused on China's national innovation system, renewable energy and space technology.

Chairman HARIDOPOLOS. Thank you, Dr. Beshka. Finally, we have Dr. Griffin of his first 5 minutes. Welcome to the Committee.

**TESTIMONY OF DR. MICHAEL D. GRIFFIN,
CO-PRESIDENT, LOGIQ, INC.**

Dr. GRIFFIN. Chairman Haridopolos, Ranking Members Foushee and Lofgren, and Members of the Committee, I thank you for the invitation to appear before you to discuss what I believe to be a critically important topic. To the point of this hearing, the Chinese Communist Party's goals in space and its rising capability to implement them could not be more clear. China is going to the Moon. No access to classified information or other special knowledge is required to realize this.

In my statement for the record, I have noted well over a dozen open source references from among many more that could be offered, describing their progress in developing the heavy-lift launch vehicles, crewed lunar lander, lunar surface suit and rover, and Earth return vehicle that will enable the execution of an Apollo-style mission to the lunar surface.

Going to the Moon is a very hard thing. They may or may not make it by the publicly referenced date of 2030, but that is not important. What is important is China is going to the Moon. The problem facing us is not China's rise. We cannot control what China is doing. We can only control what we are doing. Of those efforts, I am forced to say that mediocrity would be an improvement. We have squandered a 60-year head start on pioneering the space frontier to a nation that, without reason or provocation on our part, has chosen to become our adversary.

For a self-declared adversary to occupy a human frontier that we can no longer reach, should be understood as an existential concern, if only because of their own words on the matter.

From Ye Peijian, China's former director of lunar exploration missions at the 2017 Beijing Space Congress, I quote: "The Cosmos is an ocean. The Moon is the Diaoyu Islands. Mars is Huanan Island," which we call Scarborough Shoal. "If we can go, but don't go, future generations would condemn us. Once others are there, once others have occupied, no matter how much you wanted to go, you couldn't."

This is a stunning statement. The United States and its allies and partners would never think to say that if we reach the Moon while others cannot, they cannot also go there. The fact that key figures in the Chinese Communist Party hold this view should be of the utmost concern. But what is our response?

When I appeared before this Committee on January 17 of 2024, I had offered a rather blunt assessment of NASA's plan for human return to the Moon. I said it will not work in any reasonable timeframe. Additional misgivings have been more recently offered by former NASA administrator Jim Bridenstine in September 2025 Senate hearing and by the NASA Aerospace Safety Advisory Panel, both referenced in my statement for the record.

To avoid offering criticism without a solution in the 2024 statement, I submitted a system architecture for human lunar return that could be implemented with systems available today or near term. I and my colleague, Dr. Lisa Porter, who contributed signifi-

cantly to both that testimony and today's, subsequently offered a more comprehensive paper on that architecture available online and incorporated for reference in my statement for the record for this hearing. Others have also suggested alternative system architectures for human and lunar return missions.

However, NASA, two successive Presidential Administrations, and the Congress that oversees them have so far chosen to continue on a path that cannot work, and which even if it could poses a level of crew risk that should be considered unacceptable.

I will repeat my recommendation from 23 months ago. The Artemis III mission and those beyond should be canceled, and we should start again, proceeding with all deliberate speed. We have lost a lot of time, we may or may not be able to return to the Moon before the Chinese execute their own first landing, or we may.

Space is hard, and despite the progress that China is making, mission success is guaranteed to no one. But though we may not win at this first step, we cannot cede the pursuit and leave the playing field to others.

The true risk the United States faces right now is not just in failing to return to the Moon before China, but in failing to commit to what winning really means. In the long run, winning is about being first, and then remaining to establish the protocols, the governance rules, and ultimately the culture and the values—the primacy of the individual over the State, the rule of law, the right to own property, the bounty of the free market—that others who wish to join us on the human frontier must embrace.

Establishing the foundations for that future cannot be accomplished without a sustained commitment. I am confident that China fully understands this. Thank you.

[The prepared statement of Dr. Griffin follows:]

Witness Statement for the Hearing

Strategic Trajectories: Assessing China's Space Rise and the Risks to U.S. Leadership

**U.S. House of Representatives
Committee on Science, Space and Technology**

**Rayburn House Office Building
Room 2318**

Michael D. Griffin

4 December 2025

Oral Statement

Chairman Haridopolos, Ranking Member Foushee, and members of the Committee: I thank you for the invitation to appear before you to discuss what I believe to be a critically important topic.

To the point of this hearing, the Chinese Communist Party's (CCP) goals in space and its rising capability to implement them could not be more clear: China is going to the Moon. No access to classified information or other special knowledge is required to realize this. In my statement for the record, I have noted well over a dozen open-source references, from among many more that could be offered, describing their progress in developing the heavy lift launch vehicles, crewed lunar lander, lunar surface suit and rover, and Earth return vehicle that will enable the execution of an Apollo-style mission to the lunar surface. Going to the Moon is a very hard thing, and they may or may not make it by the publicly referenced date of 2030, but that is not important. What is important is, China is going to the Moon.

But the problem facing us is not China's rise. We cannot control what China is doing. We can only control what we are doing. Of those efforts, I am forced to say that mediocrity would be an improvement.

We have squandered a 60-year head start on pioneering the space frontier to a nation that, without reason or provocation on our part, has chosen to become our adversary. For a self-declared adversary to occupy a human frontier that we can no longer reach should be understood as an existential concern, if only because of their own words on the matter. From Ye Peijian, China's former General Director of lunar exploration missions, at the 2017 Beijing Space Congress¹:

“The cosmos is an ocean, the Moon is the Diaoyu Islands, Mars is Huangyan Island [Scarborough Shoal]. If we can go, but don’t go, future generations would condemn us. Once others are there, once others have occupied, no matter how much you wanted to go you couldn’t.”

This is a stunning statement. The United States and its allies and partners would never think to say that, if we reach the Moon when others cannot, they cannot also go there. The fact that key figures in the Chinese Communist Party hold this view should be of the utmost concern.

But what is our response? When I appeared before this Committee on January 17th, 2024, I offered a rather blunt assessment of NASA’s plan for human return to the Moon: it will not work in any reasonable timeframe. Additional misgivings have more recently been offered by former NASA Administrator Jim Bridenstine in a 3 September 2025 Senate hearing², and by the NASA Aerospace Safety Advisory Panel³.

To avoid offering criticism without a solution, in my 2024 statement for the record I submitted a system architecture for human lunar return that could be implemented with systems available today or in the near term. I and my colleague, Dr. Lisa Porter, who contributed significantly to both that testimony and today’s, subsequently offered a more comprehensive paper on that system architecture, available online⁴ and incorporated for reference in my statement for the record for this hearing. This approach was provided to NASA in 2021 as an alternative to that selected for Artemis III. Others have also suggested alternative system architectures for human lunar missions. However, NASA, two successive administrations, and the Congress that oversees them have so far chosen to continue on a path that cannot work and which, even if it could, poses a level of crew risk that should be considered unacceptable.

I will repeat my recommendation from 23 months ago: the Artemis III mission and those beyond should be canceled and we should start over, proceeding with all deliberate speed. We have lost a lot of time, and we may not be able to return to the Moon before the Chinese execute their own first landing. Or we may; space is hard and despite the progress that China is making, mission success is guaranteed to no one. But though we may not win at this first step, we cannot cede the pursuit and leave the playing field to others.

The true risk the United States faces right now is not just in failing to return to the Moon before China, but in failing to commit to what winning really means. In the long run, winning is about being first and then remaining, to establish the protocols, the governance rules, and ultimately the culture and values – the primacy of the individual over the state, the rule of law, the right to own property, the bounty of the free market – that all others who wish to join us on the human frontier must embrace. Establishing the foundations for that future cannot be accomplished without a sustained commitment. I am confident that China fully understands this.

Statement for the Record

To go to the Moon is a very hard thing, requiring at a minimum certain key elements of space infrastructure. These include a human lander to get to and return from the lunar surface from lunar orbit, a lunar surface suit and rover for life support and mobility, an Earth return vehicle sufficiently robust to survive a very challenging atmospheric entry, and the heavy-lift launch vehicles to get all of this equipment to the Moon. While publicly available detailed technical information is sometimes lacking, a plethora of open-source reporting makes it quite clear that China is working aggressively on these system elements and is linking them in a straightforward system engineering approach. From all indications, China is doing the right things and doing them right.

China's approach to its first human lunar mission is, like that for Apollo, relatively uncomplicated – to the extent that any human spaceflight mission can be described as “uncomplicated”. First announced⁵ in 2020, the dual-launch mission begins with the deployment of the two-stage Lanyue lunar lander⁶ (with its accompanying surface rover) in low lunar orbit (LLO) by the Long March 10 heavy-lift launch vehicle⁷. The lander will remain in this parking orbit to await the arrival of the crew in the Mengzhou Earth return vehicle⁸ with the second Long March 10 launch. Following rendezvous in LLO and transfer of two crew to Lanyue, the crew descends to the lunar surface, executes its mission, and returns to LLO for rendezvous with Mengzhou and subsequent return to Earth. Figure 1 depicts this straightforward mission plan⁹.

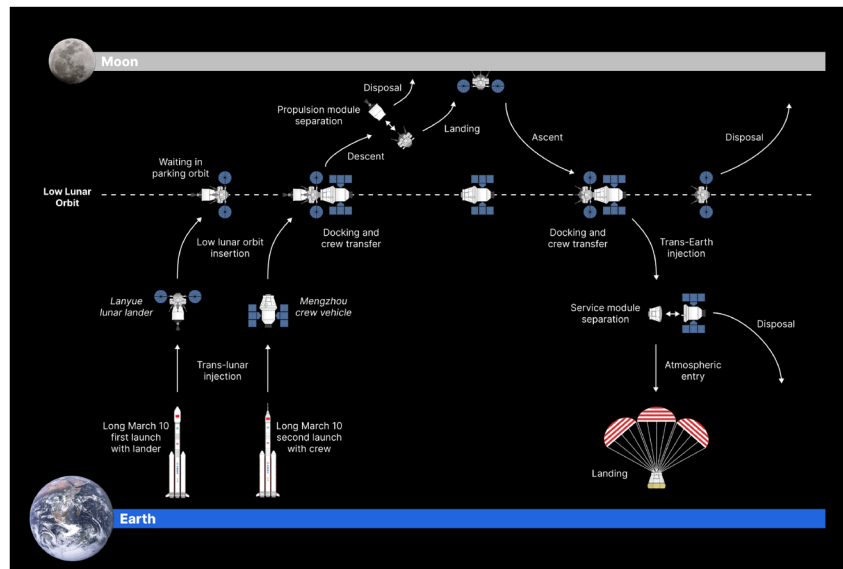


Fig. 1 – Chinese Human Lunar Mission Plan (Credit: Kaynouky, Wikimedia Commons, <https://creativecommons.org/licenses/by-sa/4.0/deed.en>)

Progress on the required system elements has been timely, impressive and widely reported. Long March 10 has completed a lengthy series of ground tests and, per a 30 October 2025 announcement¹⁰, is scheduled for a late-2026 orbital flight test. In May 2020, a prototype of the Mengzhou crew vehicle executed a successful high-speed “skip entry” such as would be required for return from the Moon⁸, and in June 2025 a Mengzhou test article demonstrated a successful pad abort test¹¹. A successful landing test of the Lanyue lunar lander was completed in August 2025 in an Earth-based test fixture designed to emulate the low gravity in which the lander must actually function^{12,13,14}. Finally, in February 2025 the Chinese Manned Space Agency (CMSA) revealed the designs of its planned lunar surface suit and rover^{15,16}. Either the Chinese Communist Party is going to an enormous amount of trouble to fool the world that it has a credible plan to put its people on the Moon by 2030 and is making steady progress toward that goal or, as inferred from continuing reports in the trade press¹⁷, they are actually doing so. My guess is that the latter view is correct.

China’s progress is not only evident in the civil space arena; they are making ever more use of space as a military domain. As U.S. Space Force Chief of Space Operations General Chance Saltzman noted in a recent interview, “The pace with which they put counterspace capabilities into play is mindboggling”¹⁸. More quantitatively, according to the most recent space threat fact sheet published by Space Force intelligence, China had more than 1,189 satellites in orbit as of July 2025, representing an on-orbit increase of about 927% since the end of 2015.¹⁹

Moving beyond the CCP’s aggressive behavior in near-Earth space, there are real concerns about what China could do in cislunar space, the region between geostationary orbit and the Moon. It may be recalled that when China executed its impressive lunar farside landing and sample return with Chang’e 6, the sample was returned to Earth on a low-energy trajectory, spending almost 3 weeks in cislunar space^{20, 21}. During this time it would have been very difficult, if not impossible, for the U.S. to track this uncooperative target. If we could not track Chang’e 6, what else can China store in cislunar space, beyond our sight and beyond our reach, as a war reserve or for a “Pearl Harbor” style decapitation strike against our own space assets?

The Chinese military space buildup is concerning on its face, but the national security implications for the United States go well beyond raw power projection. Nations that choose to lead the exploration and development of the space domain become both its pioneers and its guardians. Even a casual reading of history shows that every great nation was on the frontiers of its time; this is almost a defining characteristic of great powers. For the U.S. not to be able to put its own and international partner astronauts on the Moon, to be watching on the internet while an adversary power does so, makes a statement about a shift of global power and preeminence that China fully understands²² and that we ought not to allow.

When a society can do things that others cannot, it commands a degree of respect that is by itself a valuable national security asset, possibly more so than in many instances of the exercise of “hard power”. Quite simply, the very best people want to come to the place where the very best things are being done. It is quite instructive to observe how many key figures in the Manhattan and Apollo programs were immigrants, a number that was hugely out of proportion to the rest of the population. To quote an observation by my colleague and former Deputy Under Secretary of Defense for Research and Engineering Dr. Lisa Porter, the United States is a country where a six-sigma individual can flourish. They are the people who create, in the words of another quote attributed to JFK, the rising tide that lifts all boats. Space exploration attracts such people. That is something in which we should take pride and is an asset to be nourished.

People and nations align themselves with leaders; for most of the last 80 years that has been the United States, in partnership with our European and Western Pacific allies. Are we prepared to relinquish that leadership to China? If not, and if we view preeminence in space as part of that leadership and therefore an element of national security, then it is again necessary, as it was in the 1960s, to prioritize urgency of execution. But national security, including the inseparable facet of economic security, cannot be attained only through “urgency”. Urgent execution is important for the reasons noted above, but it is also necessary to establish the foundations for sustained presence on the Moon and, later, beyond. The activities and infrastructure that are required for a useful, sustained presence on the frontier – communications, navigation, power systems, landing fields, mining and mineral rights, space domain awareness – all involve protocols, “rules of the road”, and legal structures (including property rights), that cannot be established if we are late to return to the Moon and cannot be enforced if, once we do return, we do not remain.

The point is that value systems matter. The United States mounted one of the most powerful yet non-aggressive responses in history to the Soviet Union’s launch of Sputnik. Had the first satellite been launched by the United Kingdom, the United States might have been a bit chagrined that we weren’t first, but the response would simply not have been the same. The values of the United Kingdom and our own are highly aligned; the values of the United States and the Soviet Union were about as antithetical as it was possible to be. That difference was critical to our response to Sputnik, as it should have been. Apollo was a pile of poker chips put on the table in a gamble by President Kennedy to demonstrate the superiority of the Western values of freedom and democracy over the totalitarianism of the Soviet Union. Our tactical response was brilliant; our strategic mistake was to fail to realize that “beating” the Soviets to the Moon should not have been the end of our pursuit, but the beginning. We cannot make that mistake again, because we are now facing a self-declared adversary who, through its own history, understands this completely.

But even without an adversary, we should be pushing forward with all deliberate speed. As a country, we tend to rise to an existential challenge when we have no other recourse – our response to the Covid 19 pandemic offers an immediate example. But the survival of the U.S., and of what we stand for, depends on recognizing that it’s not just about “getting there” to beat

an adversary, it's about recognizing what Neil Armstrong's words, "one small step" truly meant: one small step, not one final step. Apollo 11 was to be the beginning, not the end.

I had the great privilege of testifying before the Congress with Neil on two occasions, and I recall that on one of those he pointed out that the purpose of space exploration was to create options for our grandchildren. It cannot be said better – our work today will not benefit ourselves; its purpose is to provide opportunities for those who follow us on to the next human frontier.

Decisions on a frontier are made, standards are set, and values are established by the people who show up, not by those who stay home and watch. Importantly, "showing up" means committing not only to the hard work of initial exploration, but also to the even harder work of building a lasting human presence. It's not enough to plant a flag, one must plant the seeds for generations to come, the infrastructure to enable revisiting, building, mining, etc., to benefit from what the "New Frontier" offers. That requires standards to be selected, rules to be written, and – again from JFK – "new knowledge to be gained and new rights to be won". We, meaning ourselves and our allies and partners, must be the ones to do this. Without this commitment, getting there first will be but a fleeting victory.

As hard as it will be to return, we must commit to the even harder work that follows. No lesser goal is appropriate for the United States.

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A System Architecture for Human Lunar Return

Michael D. Griffin
Lisa J. Porter

[Authors' Note: This paper was published online on 12 October 2024, based upon a system architecture developed in 2021. When the approach was conceived, the Space Launch System (SLS) was progressing (all too slowly) toward its maiden launch while neither Starship nor New Glenn were yet close to flight. There is no near-term substitute for SLS for putting human-mission-class payloads into translunar insertion (TLI) and so we continue to embrace the approach outlined below for initial U.S. human lunar return. However, with the thought that the U.S. should commit to permanent presence on the space frontier, a broader approach to heavy-lift launch is required. We would suggest a competition for 45+ metric tons to translunar insertion (TLI), similar in structure to NASA's COTS program for cargo to ISS, which led to the Cygnus and Dragon cargo delivery capability we have today.

Further, prior to 2024, the Centaur III upper stage was in production while the Centaur V was not yet certified. Today the reverse is true, so it would likely be more appropriate to use a shortened version of Centaur V for the lunar orbit insertion (LOI) stage discussed below than to return Centaur III to production. This is a minor point in the architecture, but we cite it for completeness.]

Abstract

The history of and the present approach to U.S. human lunar landing missions are discussed, with attention to the importance of maintaining leadership in space from the perspective of U.S. global stature and influence. The NASA Artemis lunar mission architecture and plans are outlined and programmatic and technical issues contributing to the complexity and fragility of the present mission design are discussed. An alternative dual-launch architecture is offered and a point-design within that architecture is assessed. The proposed design assumes a crewed lander based on existing technology, incorporates flight proven systems for other elements, and is shown to meet NASA's basic Artemis requirement – four crew to the lunar South Polar region for a week – with significantly reduced complexity and crew and mission risk.

Introduction

The United States currently faces many significant threats and challenges, some of which feel eerily familiar for those who lived through the Cold War era, a time when a daunting adversary affected almost every aspect of our country's policies and actions. The impact of that time on the psyche of our country cannot be underestimated; it has profoundly shaped the lens through which we view the world today, particularly with respect to China and its global ambitions.

Perhaps one of the most striking examples of this is in our civil space program, where a Cold War style competition in space was recently acknowledged by NASA Administrator Bill Nelson. Among other things, he explains why it is important that the United States accomplish a return to the Moon before China can do so: “I don’t want them to get there and say, ‘This is ours. You stay out.’”¹

Interestingly, China’s former General Director of lunar exploration missions, Ye Peijian, stated the following at around the same time:

“The cosmos is an ocean, the Moon is the Diaoyu Islands, Mars is Huangyan Island [Scarborough Shoal]. If we can go, but don’t go, future generations would condemn us. Once others are there, once others have occupied, no matter how much you wanted to go you couldn’t.”²

Clearly, both countries understand the importance of “being first”; history teaches us that the rules, standards and values of a new frontier are established by those who show up, not by those who stay home. This point was eloquently articulated by President John F. Kennedy in his September 1962 speech at Rice University:

“The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in this race for space.

... this generation does not intend to founder in the backwash of the coming age of space. We mean to be a part of it – we mean to lead it. For the eyes of the world now look into space ... and we have vowed that we shall not see it governed by a hostile flag of conquest, but by a banner of freedom and peace.

... Yet the vows of this Nation can only be fulfilled if we in this Nation are first, and, therefore, we intend to be first.”³

With that in mind and recognizing that we are again in competition with a self-declared adversarial power, it is important to examine our nation’s plan for achieving and maintaining preeminence in human space exploration and development. Recognizing that the last human lunar landing in the Apollo Program occurred more than a half-century ago, a brief recap of the achievements of that era might be helpful to set context for the discussion to follow.

How it was Done Before: Apollo Overview

Following President Kennedy’s May 1961 speech calling for the nation to “commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth”⁴, NASA conceived and led the Apollo Program, culminating in six landings (of seven attempts) on Apollo 11-17 from 1969-72. This was accomplished at a cost of \$25.8 B in 1973 dollars (\$257 B in 2020 dollars) in expenditures from 1960-73. Of that total, \$4.0 B (1973

dollars) was expended for flight operations for Apollo 7-17, at a cost of \$355-447 M per mission.⁵ Figure 1 depicts the Apollo mission profile.

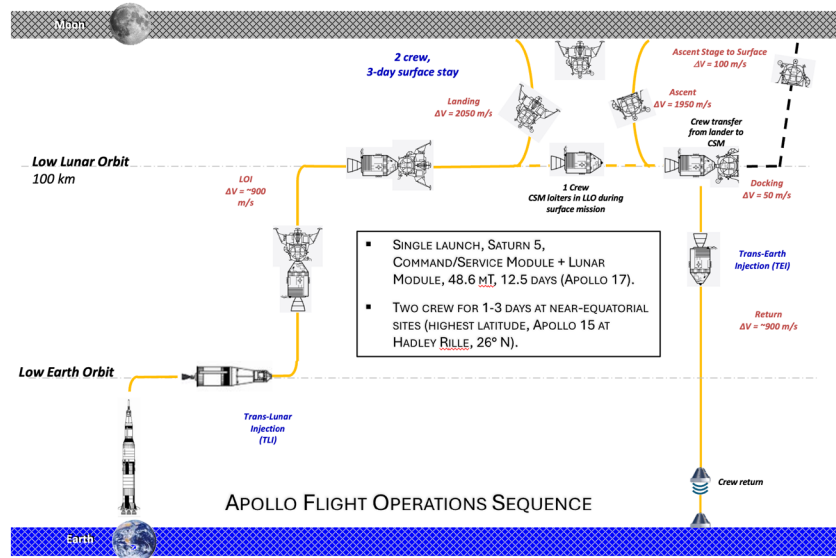


Fig. 1. Apollo Flight Operations Sequence

After Apollo

The Apollo Program was cancelled in a series of decisions by the Nixon Administration in 1969-70, with residual hardware used in four Skylab missions in 1973-74, the Apollo-Soyuz mission in 1975, for museum displays at NASA's Johnson, Kennedy and Marshall Space Centers, or scrapped. There was no strong or consistent support at the national level for human lunar return following Apollo's termination. Presidents George H. W. Bush and George W. Bush each proposed that NASA should undertake to return to the Moon; in both cases their successors canceled those efforts without significant Congressional objection.

Historians, policy makers, NASA leaders and engineers have debated this lack of sustained interest in human lunar exploration and development for two generations, with many reasons having been advanced, all of them likely carrying some element of truth. Probably the most common refrain expressed has been that "Apollo was not sustainable", meaning that it was not affordable. That Apollo was not sustained is an observed fact, but the view that NASA and the nation could not afford continued lunar exploration is difficult to credit.

By 1971-72, with the successful initial missions of Apollo 11-12 accomplished, the immensely valuable experience of the Apollo 13 rescue behind them, and with an increased level of operational experience, hardware maturity and overall system capability, NASA executed two lunar landing missions per year at a cost of less than \$900 M/year in 1973 dollars, about \$7.4 B in 2020 dollars. At NASA's post-Apollo budgetary low point of about \$3 B in 1974, sustaining this two-mission-per-year tempo would have consumed only about a third of the agency's budget in an era when over 50% of that budget was allocated to human spaceflight. Apollo was not fiscally "unsustainable"; it simply was not sustained in favor of other priorities.

Why not? We submit that a major reason, sometimes cited by others, is that with the "race" to the Moon having been "won", there was no clear reason to continue. The lunar landings were risky and there were always competing claims on limited budgets.

But winning a race is a tactical, not a strategic, goal. Two and a half millennia ago, Sun Tzu observed that "Strategy without tactics is the slowest route to victory. Tactics without strategy is the noise before defeat."⁶ Apollo was brilliantly executed from a tactical perspective, but in the absence of a long-term strategy for the exploration and development of the space domain, something never prioritized by policy makers in the Apollo era after Kennedy, why continue?

We offer that the proper strategic goal for our nation and its partners is to lead the world into a new human domain. The imperative to expand the human range is as old as the human race; it is a goal to be pursued *whether we have an adversary or not*. It is not a race and should not be framed as such; there is no finish line. While having a formidable adversary during the Apollo era against which we felt the existential need to "win the space race" pushed us to a remarkable accomplishment, that motivation in itself should not have defined our national strategy. And we must not allow ourselves to fall into that trap again.

We believe that former Presidential Science Advisor John Marburger came closest to articulating the true essence of the imperative of human space exploration in a 2006 speech, observing that "The question about the Vision (for Space Exploration) boils down to whether we want to incorporate the Solar System in our economic sphere, or not."⁷ We think that is exactly right. In the long run, human exploration, the expansion of our range of action, has always paid dividends, usually not to the individual pioneers (for whom such ventures tend to be quite hazardous) but to the generations that follow. If that were not true, if the motivation to "see over the next hill" did not pay off in the long run, it would have been weeded from the gene pool long ago.

But we must acknowledge that human space exploration is not for the faint of heart nor, from Oscar Wilde's famous definition of a cynic, is it for people who "know the price of everything and the value of nothing". And we must recognize that the decisions we make today will determine whether we lead in the "great adventure" of space, as Kennedy described it, or whether we "founder in the backwash" of other pioneers whose values do not reflect our own.

Artemis Overview

Beginning in 2017, successive administrations under Presidents Trump and Biden have supported a renewed human lunar exploration initiative, the Artemis Program. The core Artemis mission requirement is to place a crew of four on the lunar surface for about a week, with longer stays leading to the establishment of a lunar base to follow.

Artemis I, conducted in November-December 2022, was a successful uncrewed circumlunar swingby, a development flight test for the Space Launch System (SLS) and the Orion crew vehicle⁸. Post-flight inspection has surfaced concerns about the integrity of the Orion heat shield⁹; these will be addressed prior to Artemis II, again a circumlunar swingby mission but with a crew of four¹⁰.

Mission architectures for Artemis III and beyond invoke a critical new feature, the use of a near-rectilinear halo orbit (NRHO) as a staging orbit for landing missions. Halo orbits are solutions to the circular restricted 3-body problem (CR3BP) of orbital mechanics¹², which describes the motion of a small body moving under the influence of two larger bodies circling their common center of mass, e.g., the Orion spacecraft in the Earth-Moon system. NASA has chosen an approximately 3,000 km x 70,000 km, 9:2 halo orbit, for Artemis, so named because a spacecraft in that orbit makes nine orbital revolutions every two lunar months.

Artemis III is scheduled to conduct the first crewed landing mission in the program; Figure 2 depicts the orbital architecture and shows how the NRHO staging area is used in the flight operations sequence.¹¹ Two crew members will make the landing, with two remaining with the Orion crew module in NRHO.

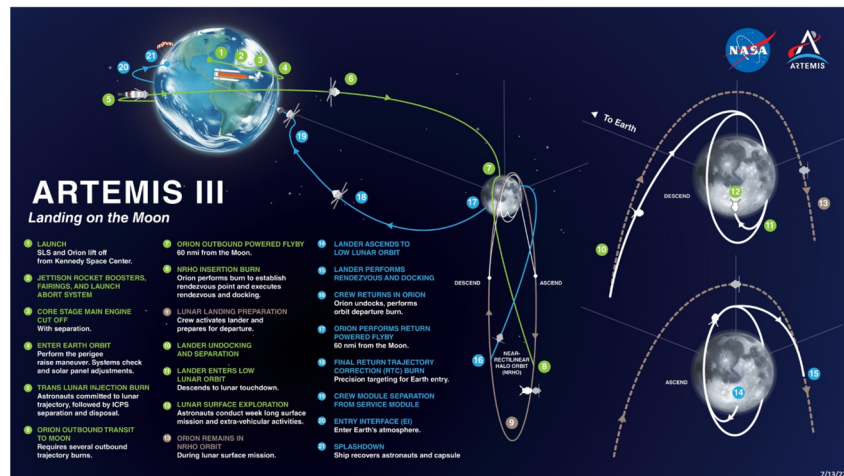


Fig. 2. The Artemis III Flight Plan (Credit: NASA)

Landing missions after Artemis III will stage at the Gateway, shown in Figure 3, a small space station consisting of a habitation module and a power and propulsion element.¹³ Gateway is to be deployed in NRHO on the uncrewed Artemis IV mission.

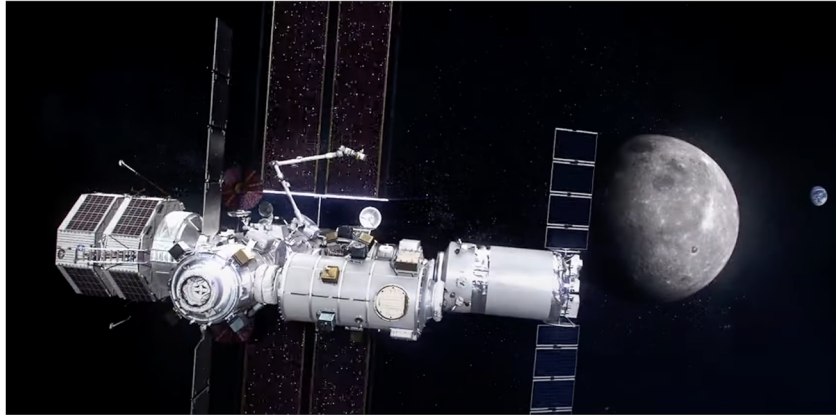


Fig. 3. Artist's Concept of Gateway in NRHO (Credit: NASA)

The Artemis V mission and those to follow will use Gateway as a transfer node and supporting element for the lander, which is pre-deployed to NRHO prior to crew launch, and Orion, which will remain docked at Gateway while the crew descends to the lunar surface in the Human Landing System (HLS).

NASA is using a “commercial service” acquisition model for many elements of the Artemis program, wherein the agency rents or purchases services rather than taking delivery of hardware built by prime contractors. In the current plan, NASA is responsible for:

- Definition of the mission architecture.
- Crew delivery (by means of SLS and Orion) to NRHO for rendezvous with the pre-deployed HLS or, when available, Gateway.
- Crew return from NRHO to Earth surface.

The HLS contractors are responsible for:

- Design and production of their HLS elements.
- Delivery of the uncrewed HLS to NRHO and, when available, rendezvous with Gateway.
- Uncrewed HLS loiter in NRHO for up to 60-90 days (NASA HLS-R-0322 threshold/objective) while awaiting crew arrival.^{14,15}
- Crew delivery from NRHO to the lunar surface and vice versa.

SpaceX was selected in 2021 for the Artemis III mission and received a second award in 2022 for a later landing mission.¹⁶ A team led by Blue Origin was selected in 2023 to execute the Artemis V mission.¹⁷

Given the constraint of staging operations through NRHO, the planned sequence of flight operations for the two contractors is somewhat similar. A fuel depot/transfer vehicle is placed in low Earth orbit (LEO) and subsequently filled by multiple flights of either the SpaceX Starship or the Blue Origin New Glenn. The required number of tanker flights has not yet been definitively announced in either case but is variously estimated to be 10-20 for SpaceX.¹⁸ For SpaceX, the uncrewed lander is launched, fueled in LEO and deployed to NRHO. For Blue Origin, a tanker is filled in LEO and sent to NRHO where it refuels the separately deployed Lander.

Following the SLS/Orion crew launch and rendezvous with the HLS in NRHO, the crew leaves NRHO in a half-day transfer to a polar low lunar orbit (LLO), a parking orbit to set up the descent and landing near the lunar South Pole. The NRHO selected by NASA and shown in Figure 2 has a period of approximately 6.5 days, permitting optimal access to and return from the lunar surface on that schedule. The HLS departs the surface for LLO and the subsequent half-day transfer to NRHO and rendezvous with Orion or (beginning with Artemis V) the Gateway/Orion assembly, 6.5 days after initially leaving NRHO. Figure 4 shows the Artemis III mission design¹⁹ while Figure 5 recasts it in the same format as employed elsewhere in this discussion. Figure 6 shows the Artemis V approach, which differs from Artemis III with the inclusion of the Gateway and of a lander refueling operation in NRHO.¹⁹

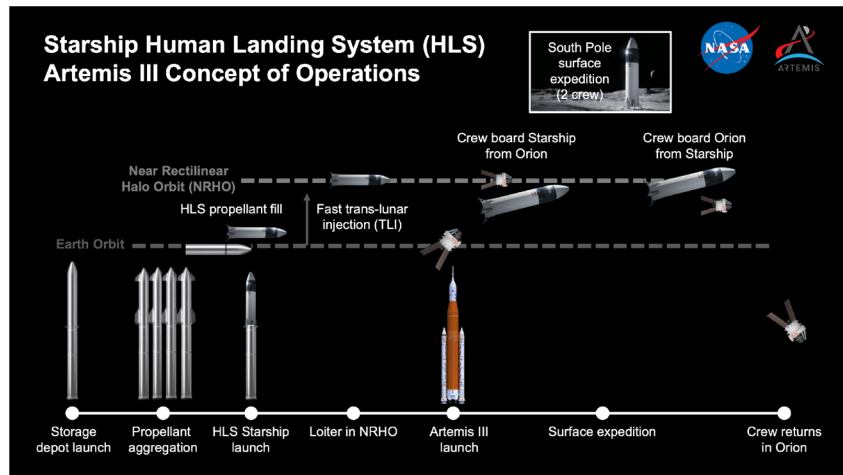


Fig. 4. Artemis III Mission Sequence (Credit: NASA¹⁹)

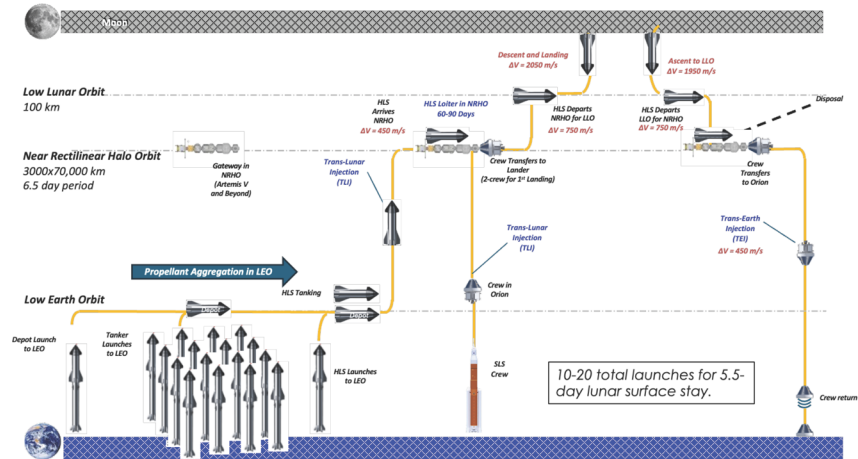
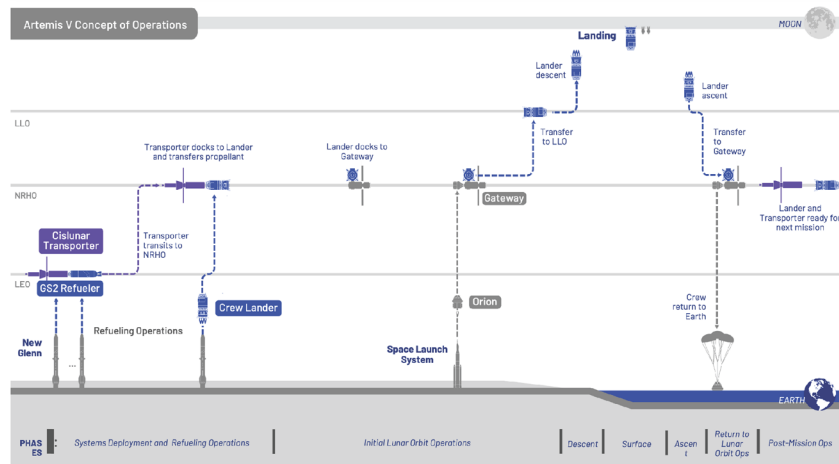


Fig. 5. Artemis III Concept of Operations

Fig. 6. Artemis V Concept of Operations (Credit: NASA¹⁹)

Preliminary Observations

Compared to the Apollo architecture, the Artemis mission designs are very complex. Complexity equates to increased risk to mission success, or worst yet, to crew risk, and should be accepted only when simpler alternatives will not meet mission requirements.

This widely accepted principle of engineering design does not appear to apply to Artemis. From first principles, to put four people on the Moon should not require significantly more total mass and complexity than to execute two Apollo-style missions with two people each. There are differences, of course. To remain on the surface for 5.5 days is more difficult than to do so for three days. The Saturn V translunar insertion (TLI) mass for Apollo 17 was approximately 48 mT^{20,21}; the presently advertised limit for the SLS Block 2 is 46 mT.²² Finally, the lunar poles present a more difficult landing challenge than the Apollo equatorial region landing sites. But at the system level, these differences would not appear to pose as much difficulty or to require as much complexity as the Artemis architectures would imply.

Crew Risk

The Artemis mission architecture imposes significant crew risk. An optimal half-day return to the “mother ship” in NRHO is possible only on 6.5-day centers. An urgent abort from the lunar surface can require up to 3.6 days to return to NRHO²³, and Orion does not have the capability to leave NRHO to rescue a crew from a lander stranded in a lower orbit.

Beyond crew risk, the Artemis architecture poses significant mission risk in two very fundamental ways. First, both contractor mission designs require multiple launch, docking and automated on-orbit cryogenic propellant transfer operations. From the laws of simple statistics, any mission requiring the execution of multiple independent events for its accomplishment will be challenging, even if each individual operation is judged to have a high probability of success. Table 1 illustrates this point; as a simple example, if it is assumed that each operation in a required sequence of events has a 98% chance of being successful, an attempt to execute fifteen such events in a row will fail about 25% of the time. Each of the proposed contractor mission designs requires many more individual operations than offered in this example. Second, both designs will require cryogenic propellant boiloff rates at levels that so far are only theoretically possible; the technology to achieve such levels has never been demonstrated. (See below.) In traditional program management parlance, this is equivalent to putting a TRL-1 technology on the critical path, something that should never be done.

Cumulative Reliability of Multiple Independent Events				
Single Operation Reliability	Number of Operations			
	5	10	15	20
99%	0.95	0.90	0.86	0.82
98%	0.90	0.82	0.74	0.67
97%	0.86	0.74	0.63	0.54
96%	0.82	0.67	0.54	0.44
95%	0.77	0.60	0.46	0.36

Table 1. Cumulative Reliability of Multiple Independent Events

Regarding the implications of Table 1, it is sometimes suggested that multiple repetitive operations such as planned for Artemis III and Artemis V and beyond do not create a significant mission risk because if a single tanking flight, docking, or propellant transfer operation fails, another can quickly be launched. This view ignores the long history of recovery from spaceflight anomalies, especially if a failure might involve a component or system that is common to a crew system. It also ignores the much more extensive history of responses to aircraft accidents, where, in recognition of the fact that failures are often due to a systemic design flaw and are therefore not “independent events”, a significant failure due to an unknown cause often results in the grounding of an aircraft model until the cause is understood and a remedy is implemented. Thus, because Table 1 assumes independence of events, it offers an upper bound to the mission success probabilities provided.

Cryogenic Propellant Boiloff

Of even greater concern is the unsolved problem of controlling cryogenic propellant boiloff for the lander and the various tankers and fuel depots required to implement the Artemis mission architecture. Solar heating of the propellant tanks in space causes the propellant to boil, resulting in an increase in internal pressure that must be relieved by venting the tanks before burst pressure is reached. This poses numerous problems for any deep-space mission design using cryogenic propellants.

The lunar lander must be pre-deployed to NRHO, as it makes no sense to launch a crew unless the lander is known to be available. This imposes a significant loiter requirement for the uncrewed lander, which employs cryogenic propellants in both of the selected mission designs. A similar requirement exists for propellant storage in LEO for the unknown time required for the multiple tanker flights to deliver the required total propellant mass. Finally, the thermal environment to which the lander is exposed on the lunar surface can be worse than that in space.

The present experience with cryogenic propellant maintenance in space is largely with the Centaur III upper stage of the Atlas V launch vehicle. Flight history for the uninsulated Centaur

III shows an average loss rate of about 2.4%/day for liquid oxygen (lox, LO₂) and 15%/day for liquid hydrogen (LH₂). Model results indicate that 3-layer multi-layer insulation (MLI) could reduce this to about 1.5%/day and 5%/day for LO₂ and LH₂, respectively. Theoretical results for active refrigeration indicate the possibility of achieving boiloff rates of as low as 0.1%/day.²⁴ (Flight history for the lox/methane propellant combination is not yet available.) Table 2 shows the effect of these various assumptions on long-term deep-space mission designs using cryogenic propellants.

%Propellant Remaining vs. Time					
Daily Propellant Loss Rate	Number of Days				
	1	5	30	60	90
15% (LH ₂ , no insulation)	86	47	1.1	0.01	0
5% (LH ₂ , 3-layer MLI)	95	78	22	5.0	1.1
2.5% (LO ₂ , no insulation)	97.5	88	47	22	10.5
1.5% (LO ₂ , 3-layer MLI)	98.5	93	64	41	26
0.1% (Active cooling, theoretical)	99.9	99.5	97	94.2	91.4

Table 2. Propellant Fraction vs. Time for Various Boiloff Rates

It is clear from Table 2 that a 60-90 day loiter requirement for a cryogenic lander is untenable with present technology; even a month would be impractical. By itself, a 5-day stay on the lunar surface (assuming the thermal environment to be no worse than in space) would pose a significant design challenge for a cryogenic propellant lander. The ability to maintain cryogenic propellants in proper condition for long periods of time in space is a critical technology for future space development but to assume that it will be available for near-term lunar missions is unwise.

Getting to the Lunar Surface

This is a complex issue that is important to explore carefully. To that end, it is helpful to examine Fig. 7, NASA's schematic diagram showing the approximate ΔV requirements for various paths to and from the lunar surface following the 3.2 km/s TLI ΔV for departure from LEO.²⁵ That requirement is common to all subsequent mission phases and will not be further considered here. Also ignored are variations in the TLI requirement due to the 18-year cycle of lunar orbit plane inclination from 18.4°-28.6° relative to the ecliptic plane. The present focus is on options for reaching the surface from an inbound Earth-Moon trajectory and for returning home.

Only "split missions" are discussed here, i.e., missions in which a crew return vehicle is left in a lunar orbit while the lander descends from that orbit to the lunar surface and returns to it for crew vehicle rendezvous and Earth return. The split can occur after both vehicles are injected

into the same lunar orbit (as for Apollo) or because they are deployed separately from Earth (as for Artemis), but wherever it occurs, this separation generates critical operational constraints.

While Fig. 7 offers a very useful summary of various options for reaching the lunar surface from translunar coast, it can be misleading unless care is taken to understand certain points. The diagram depicts two essentially symmetrical “ladders”, each with several “rungs” representing different options for reaching the lunar surface from the inbound translunar trajectory or returning to Earth on the outbound trans-Earth trajectory.

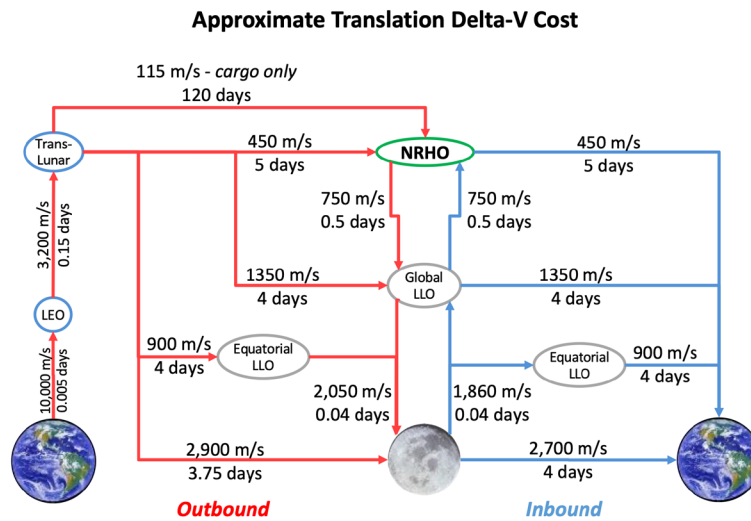


Fig. 7. ΔV Requirements for Alternative Lunar Landing Architectures²⁵

The lowest rung of the red ladder represents a descent directly to the lunar surface from translunar coast and the lowest rung of the blue ladder represents a return to Earth directly from the lunar surface. While this technique was used for the landings of the robotic Surveyor missions of the 1960s, it is inapplicable to split missions such as Apollo or Artemis, where an Earth return vehicle, e.g., Orion, remains in a parking orbit while a separate lander descends to the surface.

A similar observation applies to the highest rung of the inbound ladder, which represents the family of ballistic lunar transfers²³ and is distinguished by the approximately 120-day transfer time and the low ΔV requirement of 115 m/s to inject into NRHO from translunar coast. As

noted in Fig. 7, these trajectories may prove useful for future cargo delivery but are not of interest for human lunar missions due to their prohibitively long transfer times.

The other lunar landing options considered in Fig. 7 go through LLO as a “parking orbit”, used here as a general concept that can refer to several kinds of orbits. In this sense, both NRHO and LLO can be parking orbits and there can be more than one, depending on the architecture. LLO is a special case in this discussion, because it is common to all architectures considered here. Unlike Apollo, in the Artemis architecture the Orion crew vehicle remains in NRHO and does not itself transfer to LLO. However, the Artemis landers stage through LLO to set up the descent to the selected near-polar landing site, and similarly on ascent for proper phasing for the return to NRHO.

A key point noted in Fig. 7 is that the ΔV requirements for the descent to the lunar surface from a low lunar parking orbit and the reverse on ascent, shown as 2,050 m/s and 1,860 m/s respectively, are the same for any landing from a 100 km altitude circular parking orbit, whether polar (for global access) or equatorial (as in Apollo). This is the basic lander performance requirement, regardless of how the lander is delivered to its parking orbit. To simplify the subsequent discussion, this requirement is rounded to descent and ascent requirements of 2,050 m/s and 1,950 m/s respectively, for a total of 4.0 km/s as the minimal requirement for the lander element.²³ As with the 3.2 km/s ΔV TLI maneuver, this requirement is common to all options shown in Fig. 7 and is therefore not a discriminating feature among them.

The choice of parking orbit inclination, the angle at which it crosses the lunar equator, constrains the allowable landing locations because it corresponds to the highest latitude over which the lander passes. Further, because once established the orbit plane is fixed in inertial space (neglecting small perturbations that are not relevant here), the selection of a parking orbit also constrains certain arrival, landing and departure conditions. Below are summarized some of the key features and constraints associated with the various options.

The easiest and safest lunar landing missions are to the near-equatorial regions accessible from low-inclination (i.e., near-equatorial) parking orbits. Constraints such as those on landing sun-angle may apply, but from a purely orbital mechanics perspective, the crew can arrive in LLO and land at any time and, more importantly, can depart the surface for the crew return vehicle at any time. In turn, the crew return vehicle can depart for Earth at any time. These features are important when resource constraints or a hardware failure mandate an urgent return.

Insertion into near-equatorial LLO from translunar coast and departure from LLO on a trans-Earth insertion (TEI) trajectory can be accomplished for a ΔV expenditure of 900 m/s or less. It is worth noting that “near equatorial” is a loosely defined term: the latitude limit for a given mission is a function of the intended surface stay time (in a two-week cycle of optimal launch opportunities) and the lander ΔV reserve available for a plane change on ascent. As a guide to what constitutes an “equatorial” mission, the highest latitude Apollo-era landing was for the 3-day Apollo 15 mission to Hadley Rille, at 26° N.

Next easiest and safest are missions to the lunar polar regions. The lander can be deployed to polar LLO at any time with a lunar orbit insertion (LOI) ΔV of about 900 m/s. For the same ΔV expenditure, the crew vehicle can subsequently be inserted into the lander LLO for rendezvous on twice-monthly windows, with margin depending on selection of the translunar coast time at Earth departure and insertion ΔV reserves on arrival. This is not a safety issue and should not pose a significant operational constraint. Importantly, the crew can abort from near-polar sites to the safety of the mother ship at any time. However, the Orion/lander stack may be required to loiter in LLO for many days prior to Earth return, depending on the alignment of the polar LLO orbital plane with respect to the range of trans-Earth injection vectors reachable within the remaining Orion capabilities. If the surface stay is chosen to accommodate the optimal Earth return window and no urgent abort is required, the TEI ΔV from LLO is the same as that for near-equatorial orbits, about 900 m/s. If “anytime return” to Earth is required, the crew vehicle must have a remaining ΔV margin of up to 1,350 m/s to reach trans-Earth coast under the worst-case LLO plane alignment, i.e., 90° from the desired direction.²³

Much more challenging are mid-latitude landing missions. Earth launch opportunities for crew vehicle rendezvous with a lander pre-deployed to LLO are the same as for polar missions, but once accomplished, the landing crew may need to loiter in LLO for many days, waiting for the intended landing site to rotate underneath the LLO plane. If “anytime launch” for crew vehicle Earth departure is required, a ΔV of up to 1,350 m/s²³ may be required for LLO insertion. Because the landing site must be in the plane of the crew vehicle orbit on ascent, return from the surface is possible only on two-week centers, again with margin on either side depending on the lander maneuvering reserve. Then, after rendezvous in LLO, it may again be necessary for the crew to loiter in LLO for alignment with the desired Earth departure trajectory. If “anytime return” is desired, then a departure ΔV of up to 1,350 m/s may be required. These challenges may make it advisable to postpone crewed mid-latitude missions until sufficient surface infrastructure has been robotically deployed to the intended site to allow a lengthy stay in the event of problems with either the lander or crew vehicle. Figure 8 illustrates the basic geometry.

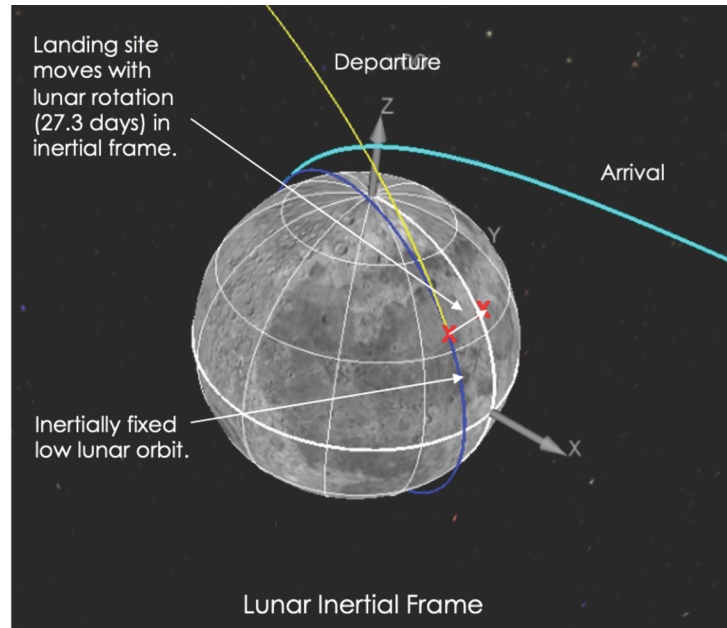


Fig. 8. Landing Site Translation Between Arrival and Departure at the Moon³²

Staging Through NRHO

The above observations allow a more nuanced interpretation of Fig. 7, because not all “global access” missions pose the same constraints. While polar missions are more difficult than equatorial region missions, they are significantly safer and easier than mid-latitude landings. For non-equatorial split missions, the requirements for lander and crew vehicle should not be conflated. Lander deployment to a polar LLO never requires more than a 900 m/s insertion ΔV , and the lander is not required to carry propellant for Earth return. For the crew vehicle, especially for near-term lunar landing missions, it is almost certainly undesirable from a system engineering perspective to trade a significant amount of LLO insertion ΔV to protect an arbitrary schedule for departure from Earth. Thus, in most cases the 1,350 m/s “Global LLO” ΔV requirement shown in Fig. 7 should be regarded as a bounding requirement and not used as an architectural discriminator.

The one aspect of polar landing missions where the bounding “Global LLO” ΔV of 1,350 m/s noted in Fig. 7 may be important is for Earth return. As previously stated, for equatorial or polar region missions the crew can always depart the lunar surface for an urgent abort to LLO and for

equatorial region missions can always return home. However, for polar missions where urgent return to Earth is required because of a problem with the crew vehicle rather than the lander, the situation is different. The orbital plane of the crew vehicle must be favorably aligned for the departure trajectory or a higher departure ΔV is required, varying on a two-week cycle between 900-1,350 m/s, discussed later in more detail. The Artemis architecture solves this problem with a rendezvous of crew and lander in NRHO prior to the transfer to polar LLO, but at the price of other constraints which, as discussed here, are of greater concern from a system perspective.

These requirements are summarized in Table 3. It is seen that the use of NRHO as a node in the architecture imposes a net additional ΔV requirement of more than 1,000 m/s on the lander as compared with staging directly through LLO, assuming in all cases that the lander carries its own LOI propellant, again to be discussed later. From a system engineering perspective, this is an undesirable constraint to impose on the lander element of the architecture. From the rocket equation for a single-stage lander (per the Artemis contractor designs) and $\Delta V = 1,000$ m/s and $g = 9.81$ m/s:

$$\begin{aligned} \frac{M_i}{M_f} &= e^{\Delta V / g I_{sp}} \\ &= 1.2542 \text{ for } \text{LO}_2/\text{LH}_2 \text{ } (I_{sp} = 450 \text{ s}) \\ &= 1.3273 \text{ for } \text{LO}_2/\text{CH}_4 \text{ } (I_{sp} = 360 \text{ s}) \end{aligned} \quad (1)$$

e.g., a gross mass increase of 25% for a hydrogen-fueled design and 33% with methane fuel. The mass penalty would be less for a two-stage lander (not contemplated for Artemis by either of the selected contractors) but is still significant.

The lander is at the far end of the chain of maneuvers (the “ ΔV gear train”) required to reach the lunar surface and return to Orion. While not as important as the concerns about crew safety, mission reliability and cryogenic fuel storage raised previously, it is good engineering practice to absorb the ΔV penalty for lander LLO insertion elsewhere in the maneuver chain. The justification for failing to do so in the Artemis architecture is not apparent.

An architectural approach that addresses this and the other concerns raised here is outlined below. For purposes of comparison with Artemis III, only the requirements for a polar region mission are considered in detail, with occasional reference to corresponding features of equatorial or mid-latitude missions when informative.

Lander/Crew Vehicle Split-Mission ΔV Requirements Summary									
Mission Design	ΔV (m/s)								
	Lander (w/Integrated ΔV Propellant)					Crew Vehicle			Total Mission ΔV
	LOI	Transfer to LLO	Descent /Ascent	Return from LLO	Lander Total	LOI	TEI	Crew Vehicle Total	
Near-Equatorial	900	0	4,000	0	4,900	900	900	1,800	6,700
Global LLO (min/min)	900	0	4,000	0	4,900	900	900	1,800	6,700
Global LLO (min/max)	900	0	4,000	0	4,900	900	1,350	2,250	7,150
Global via NRHO	450	750	4,000	750	5,950	450	450	900	6,850

Table 3. ΔV Requirements Summary for Split-Mission Lunar Landing Options

Dual-Launch Lunar Landing Architecture

The approach proposed here employs two Space Launch System (SLS) missions launched from Earth to LLO, each augmented with a presently existing (though soon to be out of production) Centaur III upper stage to be used for LOI, as outlined below and depicted in Figure 9.

1. The SLS Block 2 cargo variant (46 mT to TLI²⁶) launches a payload consisting of an uncrewed, fully fueled, two-stage storable propellant lander and a partially fueled Centaur III LOI stage.
2. The Centaur III injects the 32 mT lander into polar LLO to await rendezvous with crew in Orion. There is no cryogenic propellant storage limit; lander stationkeeping ΔV is less than 100 m/s/yr.²⁷
3. At a later time, the Orion crew vehicle is launched on an SLS Block 2 crew variant (43 mT to TLI²²), also with a Centaur III LOI stage, for insertion of the fully fueled Orion into LLO, followed by rendezvous with and crew transfer to the lander.
4. The lander descends to the surface and the crew executes its mission. No fixed surface stay is required to permit return to the crew vehicle in LLO for equatorial or polar region missions. For polar region missions, the window for Earth return is constrained by the combination of allowable surface stay and orbital loiter and the Orion maneuvering reserve (up to a maximum of 1,350 m/s). For mid-latitude missions, the same observations about LLO loiter for return to Earth apply, and there are additional constraints on the surface stay to accommodate crew vehicle rendezvous, as previously discussed.
5. The crew returns to LLO in the lander ascent stage for rendezvous with and transfer to Orion, following which the ascent stage executes a controlled surface disposal maneuver if desired.
6. The crew returns to Earth at a time consistent with Orion LLO loiter capability and maneuvering reserve.

This approach is based on the observation that the lander design poses the most challenging requirements and should drive the mission design. Given the approximately 315 second specific impulse attainable with storable propellants, it is likely advantageous for the lander to carry only the propellant required for descent/ascent, which for that reason is assumed here. The use of an LOI stage also decouples the lander design from the method of inserting it into lunar orbit, a potentially attractive feature. Finally, the LOI stage offers potential additional value, as discussed below.

For a liquid oxygen/liquid hydrogen (LO_2/LH_2) lander design, the trade on gross launch mass likely favors an integrated design, with the lander carrying its own LOI ΔV propellant. However, as discussed above, it is unrealistic from a system engineering perspective to impose a significant loiter requirement, almost always a feature of a split mission, on a cryogenic element, even if the gross mass trade favors an integrated lander design.

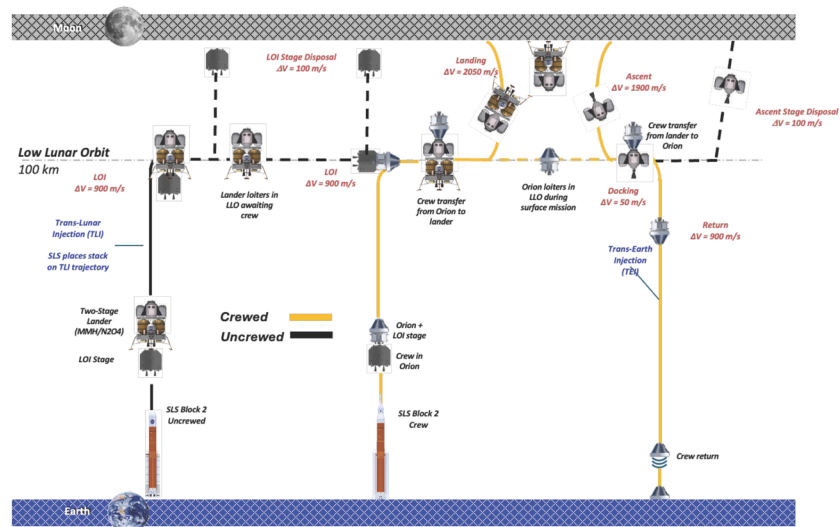


Fig. 9. Dual-Launch Concept of Operations

With this approach, the lander penalty for staging through NRHO in comparison to doing so through LLO is even more severe than shown in Table 3. If the lander is injected into lunar orbit (either NRHO or LLO) via a separate LOI stage (or is refueled in NRHO as in the Artemis V architecture), the lander departing from NRHO (whether from Gateway or not) must carry additional propellant for the 1,500 m/s round trip to LLO. In this case, the lander gross mass penalty for staging through NRHO is

$$\begin{aligned}
\frac{M_i}{M_f} &= e^{\Delta V / g I_{sp}} \\
&= 1.4047 \text{ for } \text{LO}_2/\text{LH}_2 \text{ } (I_{sp} = 450 \text{ s}) \\
&= 1.5292 \text{ for } \text{LO}_2/\text{CH}_4 \text{ } (I_{sp} = 360 \text{ s})
\end{aligned} \tag{2}$$

or about 40% and 53% for lox/hydrogen and lox/methane, respectively. It is unwise to impose such a requirement on the most challenging element of the architecture.

Lander Deployment

The key constraint for this mission design is the allowable mass that can be injected into LLO with the Centaur III stage while remaining within the SLS Block 2 specification of 46 mT to TLI.

The relevant specifications for the Centaur III, the single-engine Atlas V upper stage employing an RL-10C-1 lox/hydrogen engine, are²⁸:

I_{sp}	– 450.5 s
Dry Mass	– 2.247 mT
Propellant	– 20.83 mT (max)
Gross Mass	– 23.08 mT
Diameter	– 3.05 m
Length	– 12.68 m

Assuming a representative 100 km altitude circular parking orbit as noted earlier and applying the rocket equation for the LOI maneuver

$$\frac{M_f}{M_i} = e^{-\Delta V_{LOI} / g I_{sp}} = \mathcal{R}_{LOI} \tag{3}$$

with

$$\begin{aligned}
M_i &= 46 \text{ mT} = \text{SLS Block 2 TLI maximum payload} \\
\Delta V_{LOI} &= 950 \text{ m/s} = 900 \text{ m/s insertion } \Delta V + 50 \text{ m/s margin} \\
g &= 9.81 \text{ m/s}^2
\end{aligned}$$

Thus,

$$\mathcal{R}_{LOI} = 0.8066 \tag{4}$$

hence

$$M_f = 37.1 \text{ mT} = \text{Net payload to 100 km LLO} \tag{5}$$

and

$$M_p = M_i - M_f = 8.90 \text{ mT} = \text{Propellant required for lander LOI} \quad (6)$$

To account for propellant boiloff from the Centaur III on a nominal 4-day translunar coast, note that the total LO_2/LH_2 propellant load is apportioned according to the RL-10C-1 oxidizer/fuel mixture ratio of 5.5:1.²⁹ Thus, the masses of oxidizer and fuel are respectively

Mass of $\text{LO}_2 = 7.529 \text{ mT}$

Mass of $\text{LH}_2 = 1.369 \text{ mT}$

As a first approximation, the lox at about 90 K warms the liquid hydrogen fuel to its boiling point of about 20 K, causing it to vent to relieve excess tank pressure. Assuming a 3-layer MLI insulation wrap as discussed earlier, about 5% of the fuel will boil off each day. Including a day of margin, about 25% of the original LH_2 propellant, or 342 kg, will be lost during translunar coast. The total fuel load can then be conservatively sized as:

$$\begin{aligned} &1.369 \text{ mT} = \text{LH}_2 \text{ mass required for LLO insertion} \\ &+ 0.342 \text{ mT} = \text{5 days fuel loss due to boiloff} \\ &1.711 \text{ mT} = \text{LH}_2 \text{ mass required at TLI} \end{aligned}$$

Rounding up to 2.0 mT of fuel provides additional margin for unusable fuel and protects against the possibility of an oxygen-rich shutdown. It is similarly conservative to assume an 8.0 mT oxidizer load, for a total propellant load of 10.0 mT. The mass budget for the lander deployment to LLO is then:

SLS Block 2 TLI Payload	46.0 mT
Less: Dry Mass, Centaur III	(2.3 mT)
Less: Propellant Mass	(10.0 mT)
Less: Airborne Support Equipment	(1.7 mT)
Subtotal, LOI Requirements	(14.0 mT)
Maximum Allowable Lander Mass	32.0 mT

For reference, the Apollo 17 lunar module mass was 16.2 mT, excluding the lunar rover it carried, and sustained a crew of two for three days on the Moon.³⁰ Conservative scaling suggests that a 4-crew lander using the same propellant combination can be built for no more than twice the mass of a 2-crew version. Nearly all transportation systems enjoy economies of scale; it is unlikely that lunar landers will prove to be an exception.

As an interesting comparison, a storable propellant lander design with integrated LOI capability at a specific impulse of 315 seconds yields about the same lander mass deployed in LLO, albeit with a higher dry mass and therefore less net useful payload. A separate LOI stage offers other potential benefits as well, yet to be discussed, but as both techniques will work and as the

lander element is not yet designed, it would be a useful trade study to determine the best approach for lander deployment to LLO.

Crew Vehicle Deployment

Applying a similar analysis as above to the Orion crew vehicle with NASA's published data³¹ for the Artemis II circumlunar mission (in SI units),

Orion Post-TLI Mass	– 25,900 kg
Usable Propellant	– 8,635 kg

Rounding conservatively for analysis purposes, it is assumed that Orion post-TLI mass is

$$M_{\text{Orion}} = M_{fO} = 27 \text{ mT}$$

Using the same LOI ΔV and Centaur III parameters as above and allocating 700 kg margin yields the mass to be inserted into LLO, $M_f = 30 \text{ mT}$. From the rocket equation, the mass to TLI is then

$$M_{iO} = M_{fO} e^{\Delta V / g^{Isp}} = 37.2 \text{ mT} \quad (7)$$

The required propellant load is

$$M_{pO} = M_{iO} - M_{fO} = 7.2 \text{ mT}$$

which is rounded here to 8 mT for additional margin including that for propellant boiloff. The combined Orion/Centaur stack mass of 38 mT is thus well within the SLS Block 2 (crew variant) limit of 43 mT to TLI²². This is helpful because the configuration will likely require additional structural support beyond the existing SLS payload adaptor and accommodations for co-manifested payloads.^{31,36}

Coming Home

After ascent from the lunar surface, rendezvous with and crew transfer to Orion, the TEI maneuver is performed to depart LLO, escape from the Moon's gravity and return to Earth. Recapping earlier comments, for a polar region mission it is necessary to depart at one of the two opportunities each month when the LLO plane is sufficiently well aligned with the required departure direction that an acceptable departure ΔV can be had.

The required departure ΔV also depends on the desired transfer time, which is difficult to calculate accurately for a Moon-Earth trajectory. A spacecraft departing the lunar environment spends a significant amount of time subject to the gravitational influence of three bodies – Earth, Moon and Sun – none of which is completely dominant. The relatively simple two-body orbital mechanics analyses that work well for a satellite near the Earth are not adequate in this

case and it is necessary to resort to more complex methods that are beyond the scope of this discussion.³² The results are shown in Table 4 and Figure 10, which give the required transit time vs. the incremental Δv that is required to be added to the 1.633 km/s circular orbit velocity for TEI from a 100 km altitude LLO.

Transfer duration (days)	Departure Δv (km/s)
2	1.33
2.5	1.08
3	0.94
3.5	0.87
4	0.83
4.5	0.81
5	0.80

Table 4. Δv vs. Trip Time for Departure from 100 km Circular Lunar Orbit³²

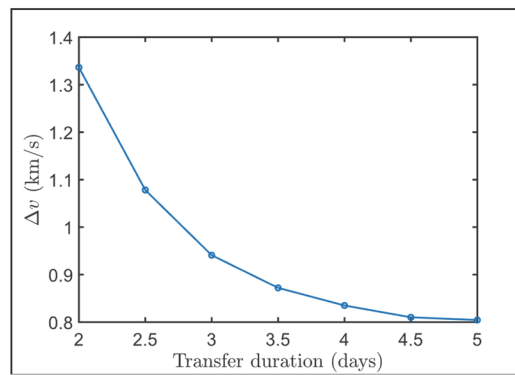


Fig. 10. Δv vs. Trip Time for Departure from 100 km Circular Lunar Orbit³²

It is seen that a LLO departure Δv of 900 m/s or less is suitable for transfer times of about 3.25 days or more. The Orion main engine is an Aerojet AJ10-190 storable propellant engine well characterized from its use on the Space Shuttle.³³ Key Orion propulsion system parameters are:

$$\begin{aligned} M_{\text{prop}} &= 8,635 \text{ kg (usable)} \\ I_{\text{sp}} &= 316 \text{ s} \end{aligned}$$

which yields a total ΔV capability for the spacecraft of 1,195 m/s. Conservatively allocating 195 m/s for rendezvous, proximity operations, docking, course corrections and reserve leaves 1,000 m/s for the TEI ΔV and subsequent minor course corrections.

With this, the calculation of the allowable departure window around the twice-monthly optimum alignment is straightforward. As noted earlier and neglecting small perturbations, the Orion LLO plane is fixed in inertial space as it revolves with the Moon around the Earth in a 27.3-day period. Thus, the ΔV requirement to compensate for misalignment of the plane varies sinusoidally over that period from the optimum to the worst case, i.e., orthogonal to the desired direction. For transfer times in the range of 3.25-3.75 days, there are two five-day windows in each lunar month when return to Earth is possible within the allocated 1,000 m/s Orion TEI capability, four days each month where return may be possible depending on fuel consumption during the mission, and two seven-day windows where the required ΔV exceeds or is unacceptably close to Orion's maximum performance capability. The worst-case loiter (whether in orbit or by extending the surface stay) does not exceed eight days.

Optimizing LOI Stage Utility

To this point the LOI stage, for which the Centaur III is assumed here, has been treated as a single-purpose element of the architecture, included to perform spacecraft insertion into LLO from translunar coast. The assumed constraints are the required LOI ΔV and the 46 mT maximum TLI payload capacity of the SLS Block 2, with the allowable lander mass a derived quantity. This approach offers the merit of simplicity but does not take advantage of the full capability of the Centaur III.

An alternative approach is to assess the system performance if the Centaur III is fueled to its maximum capacity, resulting in a launch mass beyond what the SLS Block 2 can deliver to TLI, with the Centaur then used to make up the difference. SLS performance would be degraded but that of the Centaur would be enhanced, leading to the question of what payload increase might be possible. An exact answer depends upon launch vehicle performance analysis that is well beyond the scope of this work. However, a good approximation can be obtained subject to the assumption that the SLS ascent to LEO with the heavier payload is substantially the same as in the baseline case, except that the Exploration Upper Stage (EUS)^{34,35,36} arrives in LEO with less fuel than in the nominal case.

As noted in Fig. 7, the SLS Exploration Upper Stage (EUS) must provide a ΔV_{TLI} of about 3.2 km/s from LEO for TLI, with the exact value depending upon details of orbital mechanics and launch epoch that are not important here. With additional Centaur propellant and lunar payload mass, the stack will be heavier than 46 mT and cannot reach TLI velocity. However, the EUS provides the same total impulse regardless of the mass of the stack. Thus, applying the rocket equation for the EUS at burnout for the base case, the mass ratio for the EUS and its payload stack is:

$$\frac{M_F}{M_I} = \frac{(M_{EUS} + M_i)}{(M_{EUS} + M_{pEUS} + M_i)} = e^{-\Delta V / g I_{spEUS}} = \mathcal{R}_{EUS} \quad (8)$$

where

- $\mathcal{R}_{EUS}$ = Mass ratio for EUS with 46 mT TLI payload.
- M_F = Burnout mass of EUS plus payload stack, base case.
- M_i = Initial mass of EUS plus payload stack, base case.
- M_{EUS} = EUS empty mass = 14.11 mT.³⁵
- M_{pEUS} = EUS propellant mass = 129 mT.³⁵
- M_i = Initial mass of 32 mT lander plus partially fueled Centaur, etc.
- = Maximum SLS Block 2 payload to TLI = 46 mT.
- I_{spEUS} = Specific impulse of EUS RL-10C-3 = 460.1 s.²⁹

hence $\mathcal{R}_{EUS}$ and therefore the achievable ΔV for the base case are known.

When additional Centaur propellant and lunar payload mass are added, the EUS mass ratio becomes:

$$\begin{aligned} \mathcal{R}_{EUS}^+ &= \frac{M_F^+}{M_I^+} = \frac{(M_{EUS} + M_i + \Delta M_p + \Delta M_{pL})}{(M_{EUS} + M_{pEUS} + M_i + \Delta M_p + \Delta M_{pL})} = \frac{(M_F + \Delta M_p + \Delta M_{pL})}{(M_i + \Delta M_p + \Delta M_{pL})} \\ &= e^{-(\Delta V - \Delta V^+) / g I_{spEUS}} = e^{-\Delta V / g I_{spEUS}} e^{\Delta V^+ / g I_{spEUS}} = \mathcal{R}_{EUS} e^{\Delta V^+ / g I_{spEUS}} \quad (9) \end{aligned}$$

Dividing numerator and denominator on the right by M_i and recognizing that $M_F/M_i = \mathcal{R}_{EUS}$, Eq. (9) becomes

$$e^{\Delta V^+ / g I_{spEUS}} = \frac{\mathcal{R}_{EUS}^+}{\mathcal{R}_{EUS}} = \frac{1 + \frac{\Delta M_p + \Delta M_{pL}}{\mathcal{R}_{EUS} M_i}}{1 + \frac{\Delta M_p + \Delta M_{pL}}{M_i}} \quad (10)$$

where

- ΔM_p = Additional propellant mass in fully fueled Centaur = 10.83 mT.
- ΔM_{pL} = Additional lunar payload mass.
- ΔV^+ = Velocity to be gained by the Centaur III + ΔM_{pL} to reach ΔV_{TLI} .
- = Centaur velocity increment to compensate for additional EUS payload.

For the Centaur, with the added payload mass above the SLS Block 2 TLI limit, two maneuvers approximately 3.5 days apart are performed to inject the increased payload mass, $M_i + \Delta M_{pL}$, into LLO. The first of these is ΔV^+ , to reach TLI velocity after EUS burnout, and the second is ΔV_{LOI} , for injection into LLO following translunar coast. Neglecting the change in mass due to

propellant boiloff during the translunar coast and assuming an LOI burn to depletion, the mass ratio for the Centaur in the new application is

$$\mathcal{R}_C^+ = \frac{M_f^+}{M_i^+} = \frac{(M_f + \Delta M_{PL})}{(M_i + \Delta M_p + \Delta M_{PL})} = e^{-(\Delta V^+ + \Delta V_{LOI})/g_{lsp}} = e^{-\Delta V_{LOI}/g_{lsp}} e^{-\Delta V^+/g_{lsp}} \quad (11)$$

Dividing numerator and denominator by M_i and applying Eq. (3),

$$\mathcal{R}_C^+ = \frac{\mathcal{R}_{LOI} + \frac{\Delta M_{PL}}{M_i}}{1 + \frac{\Delta M_p + \Delta M_{PL}}{M_i}} = \mathcal{R}_{LOI} e^{-\Delta V^+/g_{lsp}} \quad (12)$$

or

$$e^{\Delta V^+/g_{lsp}} = \frac{\mathcal{R}_{LOI}}{\mathcal{R}_C^+} = \frac{\mathcal{R}_{LOI} + \frac{\Delta M_{PL}}{M_i}}{1 + \frac{\Delta M_p + \Delta M_{PL}}{M_i}} \quad (13)$$

The system of Eqs. (10) and (13) can be solved numerically for ΔM_{PL} and ΔV^+ . Recognizing that minor differences exist among EUS performance parameters as cited in the literature, for those used here,

$$\begin{aligned} \Delta M_{PL} &= 5.8 \text{ mT} \\ \Delta V^+ &= 722 \text{ m/s} \end{aligned}$$

Because minor trajectory differences can matter to the overall launch vehicle performance, a detailed simulation is required to determine an exact result. However, it seems likely that a payload increase of at least several tons to LLO would result from the inclusion of an LOI stage in the system architecture.

Summary and Final Thoughts

The dual-launch lunar mission architecture presented here offers a simpler, lower crew and mission risk option to meet NASA's top-level requirements for the Artemis program – four crew to a lunar pole for a week – while remaining within (or very close to) Orion's present 21-day in-space operational limit³⁷, even with a worst-case loiter in LLO for TEI. The mission design allows return from the surface to Orion at any time. A 3.5-day return to Earth is available at any time for an equatorial region mission, or with no more than an 8-day loiter in LLO for a polar region mission. Many fewer and far less complex operations are required than for either of the current Artemis architectures, and no new technology such as in-space cryogenic propellant transfer or long-term storage is required.

Many design details remain to be defined. Examples include structural support interfaces between Centaur and Lander/Orion, modification of the SLS launch platform to accommodate additional stack height, similar alterations to the Vertical Assembly Building at NASA-KSC, etc. Such details are critical but are beyond the scope of the present discussion.

The present mission design was selected for its simplicity (if that term can reasonably be applied to a lunar landing mission) but offers many possible options for improvement that should be assessed in more detail than can be done here. We begin with further examples of the need to avoid unnecessary risk in achieving mission success:

- 1) For early lunar return missions, especially the first, would it be wise to minimize mission elapsed time by selecting the surface stay to enable a favorable TEI geometry with minimal LLO loiter?
- 2) Is it wise to target a lunar pole for the first lunar landing in six decades? The poles are characterized by poor viewing and lighting conditions for landing, more difficult terrain, unknown surface characteristics and restricted Earth return opportunities as compared to the equatorial regions. Staging through NRHO is not well suited to equatorial missions, whereas the present approach accommodates them. Is it wise to begin a program of human lunar return by taking on any challenge not absolutely required? How does doing so advance either the tactical or strategic goals of the U.S. human spaceflight program?

We also offer several more technically oriented suggestions for further consideration:

- 1) A sensitivity study should be performed to assess the parameter space within which the mission design presented here is applicable and to optimize the design within that space.
- 2) The approximate analysis presented here for the estimated payload increase obtained with a fully fueled Centaur III LOI stage should be refined through re-optimization of the SLS ascent profile to take advantage of the upper stage for both LOI and TLI.
- 3) The 100 km altitude circular LLO parking orbit assumed here for convenience is unlikely to be the optimum choice. For example, would it be better engineering practice to select a slightly higher parking orbit to provide a more generous TEI window for Orion, at the expense of imposing an increase on the lander ΔV requirement? What is the best balance between these competing requirements? Is a circular orbit the best option? The system-level benefit from a careful assessment of parking orbit design could be significant.
- 4) Improved versions of the legacy RL-10 exist and will be used on the United Launch Alliance Vulcan Centaur and the SLS Block 2 Exploration Upper Stage.^{29,34,35,36} Is it worthwhile to re-engine the Centaur III for the specialized LOI stage of this architecture to obtain the additional specific impulse, approximately 10 seconds, that could be available?
- 5) Storable “green” propellants³⁸ have been demonstrated in flight³⁹ and are expected to come into routine use over the course of the next decade. Given the advantage offered in terms of higher specific impulse, lower toxicity and greater ease of handling, is this a technology upgrade that should be considered for the lunar lander and, if so, does that meaningfully affect the trade

between the benefits of an integrated lander design vs. those associated with the use of the LOI stage, especially the additional payload enabled by optimal use of that stage?

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Prior to re-joining DoD, Mike was Chairman and Chief Executive Officer of Schafer Corporation, a professional services provider in the national security sector. He has served as the King-McDonald Eminent Scholar and professor of Mechanical and Aerospace Engineering at the University of Alabama in Huntsville, as the Administrator of NASA, and as the Space Department Head at the Johns Hopkins University Applied Physics Laboratory. He previously held numerous executive positions in industry, including President and Chief Operating Officer of In-Q-Tel, CEO of Magellan Systems, and EVP/General Manager of Orbital ATK's Space Systems Group.

Griffin's earlier career includes service as both Chief Engineer and Associate Administrator for Exploration at NASA, and as the Deputy for Technology at the Strategic Defense Initiative Organization. Prior to joining SDIO in an executive capacity, he played a key role in conceiving and directing several "first of a kind" space tests in support of strategic defense research, development, and flight-testing. These included the first space-to-space intercept of a ballistic missile in powered flight, the first broad-spectrum spaceborne reconnaissance of targets and decoys in midcourse flight, and the first space-to-ground reconnaissance of ballistic missiles during the boost phase. He also played a leading role in other space missions at the John Hopkins University Applied Physics Laboratory and NASA's Jet Propulsion Laboratory.

Mike has been an adjunct professor at the University of Maryland, Johns Hopkins University and George Washington University, teaching spacecraft design, applied mathematics, guidance and navigation, compressible flow, computational fluid dynamics, spacecraft attitude control, estimation theory, astrodynamics, mechanics of materials, and introductory aerospace engineering. He is a registered professional engineer in California and Maryland, and the lead author of some two dozen technical papers and the textbook *Space Vehicle Design*.

He is a member of the National Academy of Engineering and the International Academy of Astronautics, an Honorary Fellow and former president of the American Institute of Aeronautics and Astronautics, an Honorary Fellow of the Royal Aeronautical Society, a Fellow of the American Astronautical Society and of the Institute of Electrical and Electronic Engineers, and a member of the Alabama Engineering Hall of Fame. He is the recipient of numerous honors and awards, including the NASA Exceptional Achievement Medal, the AIAA Space Systems Medal, the AIAA Goddard Astronautics Award, the National Space Club's Goddard Trophy, the Rotary National Award for Space Achievement, the Missile Defense Agency's Ronald Reagan Award, and was twice awarded the Department of Defense Distinguished Public Service Medal, the highest award that can be conferred on a civilian. In recognition of his contributions to the *Pluto New Horizons* mission, Asteroid 159999 Michaelgriffin was named in his honor.

Griffin obtained his B.A. in Physics from the Johns Hopkins University, which he attended as the winner of a Maryland Senatorial Scholarship. He holds Master's degrees in aerospace science from Catholic University, electrical engineering from the University of Southern California, applied physics from Johns Hopkins, civil engineering from George Washington University, and business administration from Loyola University. He received his Ph.D. in aerospace engineering from the University of Maryland and has been recognized with honorary doctoral degrees from Florida Southern College and the University of Notre Dame.

Mike is a 6,000-hour commercial pilot and multiengine instrument flight instructor and holds an Extra Class Amateur Radio license.

Chairman HARIDOPOLOS. Thank you, Dr. Griffin. I thank each of the witnesses for their testimony. I will now recognize myself for 5 minutes for questions.

Mr. Cheng, if you would, there has been a lot of discussion about schedules and the idea that the United States and China, of course, are in this race not only to the Moon but beyond. But there has also been this unique conversation that each one of you brought it up in the sense that China seems to stay on schedule a little better than the United States at this point, despite, as I think everyone in this room knows, we put an additional \$10 billion into NASA during the bill that we passed in July. That said, what allows China to stay on schedule? And what can we learn from their, at this point, success in staying on schedule?

Mr. CHENG. Mr. Chairman, I think that one of the ironies here is that the very authoritarianism that is a hallmark of the Chinese system does grant certain benefits. One of which is the ability to coerce a workforce, an overall government. But, two, because the CCP has set a target, whether it is to put a man in orbit or to put Chinese boots on the Moon, that is then translated to programmatic imperatives across the bureaucracy, which is not to say that there aren't bureaucratic resistance centers within the system.

But when it is high profile, when it is Xi Jinping or his predecessor, Hu Jintao, or his predecessor Jiang Zemin, who says, "You will make this happen," woe betide the bureaucracy that chooses to fight it.

Alongside that is an economic structure that allows 5-year plans, which allows again the budgetary stability. If it is in the 5-year plan, it is bureaucratically approved, everyone is going to go along with this, and conversely the budget and therefore the staffing is stable for at least 5 years.

This is an enormous benefit with regards to "I have set a target. We are funding it. There will not be cuts because of a new Congress, a new President, a new legislature, a new director, and do not get in the way, not of these sorts of programs."

Chairman HARIDOPOLOS. Mr. Swope, to build on that idea, you had mentioned in your comments there are relationships within China between their main space agency as you put competitors within China. What are they doing differently in China with their quote, "private sector," wherever you can say it about a communist system with a private sector, that they are doing that we can maybe improve upon and learn from?

Mr. SWOPE. Thank you, Mr. Chairman. And I think the Ranking Member mentioned quasi commercial space. That is how I think we should view it. It may be financed partly by private sector money, but in addition to money from the central government, it also has money from provinces and local and municipalities.

But one thing that I think we should think about with regards to how China operates then, I look at the quote on the wall here, "Where there is no vision, the people perish," from Proverbs. I think a lot of what Mr. Cheng said, too, is true here. When you have the ability to kind of march in the same direction for such and extended period of time, you are going to achieve things that you wouldn't if you had more uncertainty.

But I think they are missing out, though, is the free molecules that we have in our system where it does encourage innovation. You are not constraining innovation into a certain goal. That is a benefit to the United States that the PRC just does not have structurally in their system.

So I don't know if we should necessarily want to replicate how they approach that top-down approach to the commercial, the quasi commercial sector. I think our free-market principles based approach where you do have that chance for innovation and new ideas to percolate up through the ether, that is the best way to do it. I don't think we should try to alter the way that we innovate.

Chairman HARIDOPOLOS. And, Mr. Cheng, again, if I could. There is a lot of conversation about the Belt and Road that the Chinese have used across the world, and I think manipulate countries with dead issues along the line. What should we be fearful of as far as moving forward as they try to do much the same with space?

Mr. CHENG. Ironically, one aspect that we should be very worried about is the application of space technology to Chinese Belt and Road Initiative investments here on Earth. When the Chinese build a pipeline, a cell phone network, a telecommunications structure on Earth, timing signals are essential. And if the Chinese are funding it, one should not expect that those investments across the world in key areas, in key countries, in key regions, for key resources are going to use GPS rather than BeiDou.

And that means that these countries are in a sense potentially signing up without perhaps even realizing it. A structural vulnerability to create a structural dependence that will far outlast whoever is in the Presidential Palace or in the parliament leading their respective governments.

Chairman HARIDOPOLOS. Thank you so much. I will now recognize our Ranking Member from North Carolina, Mrs. Foushee, for 5 minutes. You are recognized.

Mrs. FOUSHEE. Thank you, Mr. Chairman. Dr. Besha, can you tell us about your former role at NASA and why you are no longer with the agency?

Dr. BESHA. Sure. Thank you for the question, Ranking Member Foushee. I started at NASA as a China specialist back in 2007. I advised every administrator, including as a junior staffer to Administrator Griffin until early 2025, including joining high-level NASA delegations to China, and I was a China expert in the administrator's office. Earlier this year, the Technology, Policy, and Strategy Office was eliminated, and myself and about a dozen colleagues were riffed.

Mrs. FOUSHEE. So you were the top expert and advisor on China at NASA and you were riffed? That is beyond puzzling, and I would say incredibly alarming.

From reading your bio, I see that you are fluent in Mandarin Chinese. Based on your observation of recent Chinese media, can you describe how China is perceiving and responding to the actions taken by this Administration such as eviscerating and driving out the Federal STEM workforce, including a 20 percent hemorrhage at NASA, gutting NASA science, attacking research university, and drastically cutting U.S. investment and research and development?

Dr. BESHA. Yes, I would say that most of the discussion is about expanding their own science industrial science technology industrial base. You know, expanding their funding for science programs, for technology. And to the extent they compare it with cuts in the United States, I have seen that as well. I think the criticism is muted, and I think they are probably content to watch what happens here happen as they greatly expand their own industrial base.

Mrs. FOUSHEE. As I said in my statement, this is a pivotal time for U.S. leadership in space. And we on this Committee have a responsibility to act. So to each of you on the panel, what should this Committee prioritize as we look to reauthorize NASA and sustain U.S. global leadership in space? I would like to start with you, Dr. Beshar, and then move to Dr. Griffin, Mr. Swope, and Mr. Cheng.

Dr. BESHAR. Well, I think your authorization is very important in that it helps set some guidance for how the agency should pursue its programs and plans. Emphasizing space science, Earth science is critical, especially a balance between, say, let's call it, generally, you know, NASA-led projects and private sector. We still need strategic missions. We need very large missions. Mars sample return, it is not going to be a cheap mission. It is not going to be inexpensive. It is going to cost money.

We also need to understand what comes after Artemis III, right? With some clarity on what is the intention? Is it a long-term stand on lunar surface, or are going onto Mars? We need some clarity. And then to the extent we can kind of advance some more robust international relations policy, that would be helpful to compete with a strategic competitor that is using international cooperation.

Mrs. FOUSHEE. Dr. Griffin.

Dr. GRIFFIN. Thank you, Ms. Foushee. I would make a couple of comments. In answer to the chairman's question a few moments ago about sticking to the plan, I would have commented that sticking to a plan is important when the plan makes sense.

China is sticking to a plan that makes sense. It looks a lot, in fact, like what the United States did for Apollo. Provably, that worked. We have stuck to a plan that does not make sense. So this Committee, an authorization Committee, should not authorize the agency to continue down a path that does not make sense.

The plan matters. I have enough history here to recall the *Authorization Act* by this Committee in 2005 that required me as the then administrator of NASA to use to the maximum extent possible the existing assets from shuttle and those that remained from space station and Apollo.

That is that the administrator of that time was required to use the system that we had. We seem to have lost track of that today. Again, sticking to a plan that will not work for Artemis III and beyond makes no sense.

Mrs. FOUSHEE. Mr. Swope.

Mr. SWOPE. Thank you. I think when NASA spends its money, it is good to think about two different things. If NASA can spend its money in a way that it can do its mission, but then also enable private sector actors to try out business ideas or new innovations, like the Commercial Lunar Payload Services Project with ride-sharing opportunities, I think that is great for the U.S. innovation ecosystem.

The second thing is really I think when NASA spends money on things like basic research and development and science, that also feeds into innovation at the very early part of it. Without science, we would never have something like the Manhattan Project. We would never have had the radio. James Maxwell's theories proven by Reinhardt's Hertz led to Marconi's radio.

I look at those investments that the government makes, that NASA makes that is critically important to that innovation ecosystem as well. So, I think in both those cases, when you are looking at NASA authorization, look at it in a way where you are the genesis of that innovation ecosystem, that flywheel that really powers the U.S. national security and economic security in a way that the PRC just can't match.

Mrs. FOUSHEE. Can you indulge me 30 seconds for Mr. Cheng to answer, please? Thank you.

Mr. FONG [presiding]. Sure.

Mr. CHENG. Ma'am, absolutely. Sure. It matters what this Committee chooses to push as a priority. The problem is, a failure to achieve whatever targets are set has no consequences. So if I were to give a recommendation to this Committee, I would say that whatever it is that this committee feels should be the priorities for NASA—and my colleagues, frankly, I think are far better qualified—I am focused primarily as a China analyst, ma'am, not really a space person.

One, it needs to be bipartisan to make very clear throughout our system that this is something that everyone is pushing for; and, two, that there are consequences, budgetary, legal, and others, to the agency, to supplying companies. If they fail to deliver on time and on budget that it will not be a, "Well, OK, let's try again next year" attitude. That there are consequences.

Mrs. FOUSHEE. Thank you for that, and I yield back.

Mr. FONG. Thank you. I now recognize the representative from Florida, Mr. Webster, for 5 minutes.

Mr. WEBSTER. Thank you, Mr. Chairman. I appreciate the opportunity. Thank you for appearing as witnesses for this very important subject.

Dr. Griffin, in your testimony, written testimony, you mentioned the fact that it is important to be first, and that history teaches us that those that show up first usually get to write the rules and standards and set the direction of what, where we are going and what is going to happen. That comes from just showing up. And, in your opinion, are we staying at home, or are we showing up?

Dr. GRIFFIN. Well, at present, sir, in line with the comments I made in my oral statement, we are staying home because the approach we are advocating is not going to work. The train may have left the station, but the train is headed over the cliff. The importance of showing up, as you put it, is that—in line with Mr. Cheng's comments—the people who are there are the ones who established the GPS timing signals or the BeiDou timing signals. The people who are there establish the communications protocols. The people who are there establish the rules of the road for space traffic management and other things.

If we are watching from the sidelines it will be China that is establishing those things. And with respect to the future for the rest of the humans on Earth, that will not go well.

Mr. WEBSTER. Well, that is, I guess, my second question then. What will happen if China sets a standard and guides the development, rules, and norms of space? What would be the result?

Dr. GRIFFIN. Then other nations will look to China and will choose to align themselves with China because they are the ones who are in space. The rest of the world will look to China as the technological leader of the world. Lyndon Johnson was not wrong, 50 years ago, when he said that first in space is first and second in space is second everywhere.

Mr. WEBSTER. OK. Thank you, very much. I appreciate it. I yield back.

Mr. FONG. Thank you very much. I now recognize the Representative from California, Mr. Whitesides, for 5 minutes of questions.

Mr. WHITESIDES. Thank you. I want to thank the chair and Ranking Member for organizing this substantive hearing. It is good to see you all. It is good to see my old friend Dr. Griffin and others.

Let's start with Mr. Swope. You note in your prepared testimony that China is likely to achieve something no nation has done before, returning martian samples to Earth. With the mission launching in 2028, NASA's scientific Mars exploration program has been methodically building toward the return of dozens of scientifically selected samples; the highest priority of multiple decadal surveys that the agency is not settled on the plan to collect them.

And the Fiscal Year 2026 President's budget request would eliminate the program entirely, the scientific significance of abandoning this effort will be enormous. What would, in your view, be the geopolitical significance if the U.S. were to abandon its plan to retrieve scientifically selected samples from Mars while China moves forward on its own crash program to return martian samples?

Mr. SWOPE. Thank you for that question. It is the historic opportunity for humankind to maybe find evidence that there was life that originated on a planet that is not Earth. That is not really measurable, the significance of that discovery. What that could mean, I mentioned the impact on innovation from science. What that could mean down the road, the country that is the first to do something like that, to control that.

I don't know if I trust the PRC to do that in a way that benefits the planet, that benefits our Nation. So I think the huge impact is beyond just geopolitics that you could pull off a mission like that. I think it has science and long-term implications that maybe what is conceivably the most important discovery in the history of humankind.

Mr. WHITESIDES. Thank you. For Mr. Swope or Mr. Besha, you all state that one of our advantages over the Chinese is our allies, international cooperation. Of course, the Administration has proposed cutting a wide swath of international space missions in its budget. Fundamentally, how does this impact our ability to compete with China? Either of you can answer.

Dr. BESHA. So, there is another competition going on that is international, right? And so, we are very conscious at NASA of how we were and how we expand our cooperation, because this allows

us to influence. So Artemis Accords are a good example. We have a set of principles and values that we want to make shared. So we want other countries to agree with us on our set of principles. China is doing the same thing with the ILRS, the International Lunar Research Station.

They have a set of principles, and they are looking to get a group of nations aligned with them to move forward. The difference between the two are Artemis accords and ILRS is that ILRA actually offers programmatic cooperation, as well. And so whereas the accords are nonbinding, this is programmatic. And so countries can join them on the surface of the Moon.

And now when they start making those first steps toward norms, toward standards, they will have a coalition of countries along with them. And this bleeds over into other areas say at the United Nations, other topics and things like that. And so it is basically a competition of influence internationally.

Mr. WHITESIDES. In the interest of time, I am going to cut to my last question, which is for Dr. Griffin, who, by the way, I worked for about 25 years ago. I think. I can't remember.

Anyway, Dr. Griffin, you are probably the closest to the agency today of this panel. Although, Dr. Besha, you were there recently. So either of you can answer this question. I think it is important that we expose what is the current state of NASA? So we have lost 4,000 people, primarily senior staff, but also junior staff, new employees, and recently promoted staff. Goddard's getting taken apart, JPL (Jet Propulsion Laboratory) is getting cut. You know, there is just turmoil. Morale has dropped, but I don't want to put words in your mouth. What do you perceive as the current state of NASA, you know, at the end of 2025?

Dr. GRIFFIN. Regrettably, I am not that close to NASA anymore. It has been 16 years since I was there, and more. But from outside, I would offer the perspective that as much as I regret the damage to individual people and the loss of—notable loss of technical competence that goes with massive cuts like that, an agency without a proper, clearly defined, high-priority mission is a rudderless agency.

It almost doesn't matter. It might just not matter what actually happens at the agency until and unless we have a mission to put the United States first among equals on the human frontier.

If that is done properly, the right people will come to the agency, the budget will be supported, all of those good things will come true. It starts with defining what you want to do and then backing it up.

Mr. WHITESIDES. Thanks. I yield back. Thanks.

Mr. FONG. I now recognize the Representative from Texas, Mr. Self, for 5 minutes for questions.

Mr. SELF. Thank you, Mr. Chairman. Wow. Lots to unpack here. First of all, Mr. Cheng, you said that you were more a China expert than a space expert. So we talked a little bit about free markets. I think Mr. Swope did. Talk to us about the challenges that China has and any results from the recent plenum. Because they have economic challenges, their economy—and when I think back to the Soviet Union, the Soviet Union was 10 feet tall until they weren't.

So I need to know what you think as a China expert just in the economic and the results from the recent plenum?

Mr. CHENG. Sir, I am always very concerned when folks talk about the slowdown of the Chinese economy, which we do seem to be seeing, and promptly equate that with the collapse of the Soviet Union. I think it was Winston Churchill who made the observation that there is a great deal of ruin in a nation.

And when you would only look at North Korea, a fraction of China's economy, much worse off, and yet has managed to survive to caution that whatever problems we are seeing in the Chinese economy—and we are seeing some—making that leap to that it is a collapse.

What I would note is that Xi Jinping is continuing the policies of his predecessor Hu Jintao and frustrating efforts at expanding the role of the private sector of markets, et cetera, in China, that Chinese economic reform pretty much came to an end in 2004, and has not been renewed under Xi Jinping.

But, strikingly, one of the exceptions to that is in the aerospace sector, where private companies are, in fact, encouraged and welcome. Quasi private in some ways, but nonetheless motivated by more classic market principles than State direction.

Mr. SELF. Dr. Griffin, you have been very clear that Artemis III on won't work. Tell us exactly why not. Is it the complexity? Is it the crew risk? Is it the fuel versus demand? So why exactly do you think it won't work? I have read your paper, but what is the bottom line as to why you are recommending we cancel this and go a different direction?

Dr. GRIFFIN. The quick bottom line is that an architecture which requires a high multiple number of refueling flights in low-Earth orbit, no one really knows how many, uses a technology that has not yet ever been demonstrated in space is very unlikely to work, unlikely to the point where I will say and have said it cannot work.

Secondarily, the length of time required for the Earth departure ship to remain in low-Earth orbit almost guarantees that the propellant you have loaded will boil off before it can fully be used, and the requirement of the lander to occupy lunar orbit waiting for the crew for 60 to 90 days guarantees that the fuel will boil off.

I do not see a way with the current technology we have to overcome those problems, and, therefore, we should not pursue that line of approach.

Mr. SELF. OK. Probably, and I will ask who would like to answer this. The Lagrange regions, L1 and L2, are prime real estate. Do we, should we deploy them as a first strike to get something into the L1 through L5, perhaps, to include relay positioning, navigations, timing beacons, space-domain, sensors, so forth and so on? Is that a critical mission?

Dr. GRIFFIN. To whom is the question directed, sir?

Mr. SELF. Mr. Cheng.

Mr. CHENG. Sir, first off, the Chinese have already deployed equipment there. I believe that this is one of those regions that will wind up becoming much more strategically centered. It would be beneficial to us to establish a presence, probably not military because that opens the door to propaganda by others but certainly scientific, but, most importantly, application, communications

relay, data relay, things like that that have an economic as well as scientific benefit.

Mr. SELF. Well, let me ask you because GPS—because I think the Chairman mentioned a Chinese-style GPS. We know that GPS spoofing is now a real thing on the battlefields around the world. So why would we not go with something other than GPS?

Mr. CHENG. I think that my understanding is that these orbits—deploying items into those orbits can become extremely complex, but, yes, if the issue here is GPS robustness, that is absolutely a major concern from a security perspective.

Mr. SELF. And I think we—my time is done. I think we have a magnetic field sort of alternative.

Mr. Chairman, I yield back.

Mr. FONG [presiding]. The Subcommittee stands in recess subject to the call of the Chair.

[Recess.]

Chairman HARIDOPOLOS [presiding]. Welcome back.

For our next, Ms. Salinas, you are recognized for 5 minutes.

Ms. SALINAS. Thank you, Mr. Chair, and thank you to our Ranking Member, and thank you to our witnesses for being here today.

In my district, NASA and its partners helped to support a very robust economy of small manufacturers that supply components to a lot of these missions, and these are really good local jobs that help to build talent and expertise across the country.

Several months ago, we held a hearing on the Artemis program, and I asked how we can continue to support this workforce. I was told that we achieve that by building hardware and actually flying these missions. In other words, we need to signal consistency and predictability to workers in industry.

And this question is to anyone who would like to answer. What can we learn from China about the value of long-term planning and predictability, and how has their approach benefited their economy and their workforce more broadly?

Mr. CHENG. So, ma'am, the Chinese often describe their space program—not their space program, describe space as being, quote, unquote, very dense in high technology. If you take a look at a satellite, it has advanced materials; it has computers; it has communications equipment, solar panels. But above all, it has systems integration and systems engineering. All of those systems have to be able to work together in orbit and, since the end of the Space Shuttle, you are not going to bring it back for repairs.

The Chinese have used their aerospace program as a training ground for systems integrators and systems engineers, and one prime example of this is COMAC, the Commercial Airline Corporation of China, which is going to compete with Boeing. They took an entire cadre of folks from CASC, the China Aerospace Science and Technology Corporation, a state-owned enterprise, and said, all of you, your systems engineers, systems integrators, you will now go to COMAC, another state-owned enterprise. And it jump-started their ability to do systems integration in the commercial airline industry thanks to the education and training and on-the-job experience in aerospace.

Ms. SALINAS. Dr. Besha?

Dr. BESHA. Thanks. You know, I think there are some things we might want to learn from China, but China is actually learning quite a bit from the United States.

When I was at NASA, I ran a study, the civil space supply chain study where we looked at manufacturers across the U.S. that were engaged in the Artemis program, and what we found is that small businesses are the bedrock for the program. It is mostly small businesses.

And what I think China is learning, actually, from us is you can't only rely on a state-owned enterprise, a massive conglomerate. You actually need to go and find smaller companies that can produce bespoke parts and things like that that can then feed up into the larger enterprise, and we do that very well. And our supply chain integration is actually very good.

The second thing I think China is learning from us is the ability for space to upgrade technology. So you may have valves that work well on automobiles, but when you have to make them space qualified, it is another quality control process. So it upgrades a lot of the technology in the process along the way. They are learning that, and it is a process that they can extend to other industries as well.

Ms. SALINAS. Thank you.

Dr. GRIFFIN. I would like to take a turn at that. I don't want to surpass China. I don't think the United States can or should try to surpass China by behaving like China. I want us to rely on our free market principles that encourage and allow and reward successful innovators to compete.

The role of the government in this particular enterprise, since going to the Moon is not remotely a commercially successful activity in anything like the near future, the role of government is to establish the point that we are creating a program. We are going to sustain it. We, the United States with our allies and partners, are going to be on the Moon for the foreseeable future, and we, by doing that, we establish a demand signal which will allow the best and brightest in industry to come forward to produce those capabilities.

If the U.S. Government does not set that kind of a consistent demand signal, then we should not expect industry to invest alongside.

Ms. SALINAS. Thank you.

Mr. Swope, would you like to answer?

Mr. SWOPE. Yes. I just thought about when I was in high school, I had friends that their family owned a factory that built—machines that built mattresses. So I thought about the time that it takes to really ramp up to do something like the Artemis program, and to me that is where that commitment, that stability is needed from a government standpoint, the demand signal, but also put the money on the table to say this is what we want to buy. So then that trickles down through all those other suppliers.

And I also worked for Derrick Hilmer years ago, and I remember going out on the Olympic Peninsula, and I found a company that was building something for Blue Origin. I am like this is super cool. And all the time it took for that to ramp up, it just can't turn on a dime. So I think that is the biggest lesson there for companies

like that at the very, very back end of that. It takes time to get to the point where we are building a rocket that is going to go to the Moon.

Ms. SALINAS. That is right.

And I think to your point that I think many of you are making, if President Trump's proposed 24 percent cut to NASA's budget, which will actually go into effect, what could we see in terms of the long-term implications for our workforce and, thus, our ability to compete with China?

Dr. Beshu?

Dr. BESHU. So the supply chains around a lot of these projects—

Chairman HARIDOPOLOS. Please keep your comments to a minimum. We are already over time.

Ms. SALINAS. Oh, I am sorry. I did not realize that.

Dr. BESHU. Supply chains are very extensive. They affect a lot of suppliers, and some of these suppliers are single-source suppliers. So they have one customer in some cases, and that customer is NASA.

Ms. SALINAS. Thank you. I yield back.

Chairman HARIDOPOLOS. Thank you.

Next we have the Congressman from Georgia, Mr. McCormick, for his 5 minutes. You are recognized.

Mr. MCCORMICK. Thank you, Mr. Chair.

It is interesting just in the last line of questioning, I heard each one of you point back to the supply chains, single-source in competitive markets. One of the problems with competition, which I am all for. I am all for capitalism competition, but when you have a monopoly of several critical minerals that a foreign adversary or at least a peer competitor controls, what are we doing for a solution for that? I mean, I don't see it.

Because right now we basically don't have a competitive market. We don't have a market. All we have is one country that controls all the resources for something that in the military it probably supplies thousands—no, hundreds of thousands of parts. They are literally the bottleneck, and it is probably one of the reasons that our fleet readiness for all aircraft is around 50 percent, which is atrocious. If we get into a war, we are done.

And in space, which is something that is, obviously, the final frontier, if you will, what do we do to prevent that from being a choke point for us? They literally have us by the neck. What are we doing? What is a good solution? And I don't want to hear generalities of open market because we don't have an open market. We have a monopolistic system.

What can we do—and I have my own ideas so I hope we get somebody that gives me a good answer so I don't have to interject my own opinion. But I will start with you, Mr. Cheng.

Mr. CHENG. To break your question into several smaller buckets, first off, while China has an advantageous position, it is not the sole producer of rare earth—rare earth actually is a terrible misnomer. I think other more scientifically learned folks prefer platinum group metals.

There are other places that do produce them. There is, unfortunately, only one facility in the United States, and one of the rea-

sons for this has been additional regulatory considerations, including environmental, that basically say, well, if you are going to mine that, you have to do X, Y, and Z. Suffice to say the Chinese are not as enthusiastic about environmental regulations.

The other aspect here is that whatever the rare earths are that you mine you have to process them, and that is enormously polluting. And the Chinese have been more than happy to be the primary rare earth processor. So you may mine it in India. You may mine it in Canada. It still gets shipped to China for processing.

I believe back around 2018, the United States broke ground for a domestic rare earth processing facility. To be honest, sir, I don't track that very closely. I don't know what the status of that is. But if you want to break the Chinese monopoly, it is not enough to open up more mines. It is absolutely essential to open additional non-China located processing facilities for rare earth minerals.

Mr. McCORMICK. So Mr. Chair, I will just go to that because I am already halfway through my time, and that is how it works here.

I will accentuate your point. We have 10 rare earth mills we have no access to, except for through China right now. Another 10 that we have limited access at best. Our regulatory burden and our inability to mine and process these rare earth minerals have put us not only at a strategic disadvantage but, actually, in a worrisome position for any future conflict. We are not ready, simply not in the military sense or especially in the space sense.

We think—and this is something I challenge both sides of the aisle to look at realistically—just because we don't pollute when we get these minerals we are going to use anyway doesn't mean that they are not polluting 10 times worst than we would with the same minerals that we are going to buy anyway and use anyway.

So it is not conservationism. It is not a smaller blueprint of carbon emissions when you buy it from China. It is just pretending like we are not polluting when we are actually polluting more. I just want to be very realistic about this.

The future is America using resources we have without the regulatory burden that makes it too expensive to do because we are going to have access regardless, or the alternative is don't be competitive. That is not going to happen. We are America.

So I challenge both sides of the aisle to take a realistic look at we have to have access to these things, and we will do it cleaner, better, and cheaper if we are not putting overregulatory burdens on the American businesses. And so let's just take a really honest look at this scientifically, domestically, so we have a chance into the next century.

And with that, I yield.

Chairman HARIDOPOLOS. Thank you.

I now recognize the representative from Illinois, Mr. Foster.

Mr. FOSTER. Thank you, Mr. Chair.

On the subject of rare earths and permanent magnets specifically, there is a model that the government is in the process of succeeding at that I am really a fan of, and it is a company called Nira, which has spun up through decades of federally funded research in Minnesota that has got a way—and they are building a significant skill factory to make permanent magnets with a BH

product and energy density comparable to the best neodymium iron-boron magnets, and the input materials there are basically rust and ammonia, nothing else.

And it is really an impressive thing, and it has to do with decades of research, government-funded research led, interestingly, by an immigrant born in China. So there are a bunch of lessons I think that we should learn from that, one of which is to not push away foreign talent from our shores because of unfounded worries.

Now, I have been worried for a long time about the fragility and the dual use of nature of all of the systems we are putting into low-Earth orbit. Now, we are talking about, you know, we are having at least two major U.S. companies put big satellite arrays in low-Earth orbit. The Chinese have at least two companies. The Europeans are doing it.

You know, everyone's first worry is about the Kessler Syndrome where you just have a big cascade of collisions, which I think is unlikely because of the altitude and the rapidity of the orbit decay, but it is still something to worry about because some of these systems are not really in low-Earth orbit but somewhat higher. And so this is something that I think we are going to have to need international understanding on because this is a big problem.

The fragility is also a real issue. You know, one thing that has worried me for a while is the refueling that was mentioned. I guess Dr. Griffin shares my skepticism of how easy it will be to make it work. But, you know, the scenario for starships, for example, and other similar missions is to go put these in low-Earth orbit, refuel them with 10 refueling missions, OK.

Now, I don't know if you have noticed, but these starships have a tendency to like detonate themselves from time to time. And the issue comes up, what happens if one of those explodes fully fueled in low-Earth orbit, and the debris field from that is potentially frightening.

I was just wondering has anyone looked at this particular problem when, you know, SpaceX is talking about running hundreds of starship missions a year in some scenarios? You know, do we actually—are we going to need understandings on the accidental destruction of everything in low-Earth orbit in addition to big worries about how that could happen deliberately by even a not very talented adversary?

Is there anyone that can speak to this?

Dr. BESH. A few comments on that. So I think in terms of space debris, it is a huge issue, and it is not an issue that any one company can solve, right. And I think China was recently in the news because one of their Shenzhou human capsules was hit by debris. Our Space Station is also occasionally hit by debris. We have shielding that can withstand about 3 millimeters particle size of debris.

China has continued to do EVA (extravehicular activity) missions outside their own space station. They had additional armor, additional shielding to their space station. They recognized this as a major issue, and it is affecting their crown jewel, their human spaceflight program.

So we are both in some senses on the same page that this is a problem that we need to solve, and it is only going to get worse,

as you mentioned, with these very large vehicles that potentially could not reenter appropriately.

Mr. FOSTER. Has anyone looked specifically at the issue of these very large vehicles and what happens when one detonates in low-Earth orbit? Because I actually had Claude Code write me a simulation of it, which I am not willing to quote the results from, but it was, you know, people then studying Kessler Syndrome for decades. And there are computer codes that do that pretty well, and I guess we must have a pretty good idea of how many fragments of what sizes are liberated when something blows up on the launchpad at least.

So it seems like we have the information to understand, you know, the size of the debris field and the damage it will do to, you know, very militarily important assets, you know, including the Golden Dome, which is now talking about many tens of thousands of additional assets in low-Earth orbit with many countries having an incentive to accidentally on purpose destroy them all.

So I was just wondering if that is something that really we need some more study on. All right. So I guess I am now down to 15 seconds, so I will just—if any of you have thoughts on that and could respond for the record, I would be really interested. That is something we have to keep our eye on.

And I think, ultimately, we are going to have to negotiate with China and the other countries, space-faring countries to come up with some understanding. We can't just go off doing what we are currently doing.

Thank you. I yield back.

Chairman HARIDOPOLOS. With that, I recognize the representative from Utah, Mr. Kennedy, for 5 minutes.

Mr. KENNEDY. Chairman Haridopolos, thank you for holding this important hearing on the space race with China, and I want to be very clear where I stand. The Chinese Communist Party is a major threat to our national security. For years, I have been calling attention to the Chinese Communist Party being a dangerous and aggressive adversary. We must expose their every underhanded and subversive action. Passivity on our part will only be rewarded with more aggression.

There are some voices that would question why going back to the Moon should be a priority given we have already achieved it. I would counter that this isn't just about national pride. It is a national security imperative to beat China to the Moon because the Chinese Communist Party intends to establish a lasting presence with exclusionary zones for their own economic and national security benefits.

It is important that we understand where China's space program is at and how we can do everything in our power to win this race because the stakes are too high.

And thanks to the witnesses for their testimonies.

Dr. Griffin, I have a question for you. I am a cosponsor of Chairman Hill's *Taiwan and American Space Assistance Act* to establish a partnership between TASA (Taiwan Space Agency) and NASA. And, of course, we have the Artemis accords with 60 countries. Can you describe, Dr. Griffin, the importance of these international partnerships to maintaining U.S. preeminence in space?

Dr. GRIFFIN. I would offer the view that if the United States is not willing to partner with other nations in the world to be on the space frontier, then they will have no alternative but to partner with China or they can choose to stay home. It is my observation that every nation that reaches a technological level where they can do something in space wants to. In some ways, it is like owning the only swimming pool in your neighborhood. You become an attractive nuisance.

So since that is observably true, nations that can do space want to do so but the barriers to entry are very high, the United States can lower those barriers or we can watch while China lowers those barriers. I think the latter course of action is not what I would recommend.

Mr. KENNEDY. Thank you for that response.

China has also used radioisotope power systems to survive the lunar nights since 2019, giving it the only continuous presence on the Moon, and it plans to launch more missions using this technology in 2028.

The use of landers, by contrast, are limited to 14 days because they can't operate through the lunar night, and NASA has not incentivized commercial providers to adopt radioisotope power systems at this point.

Dr. Besha, thank you for your testimony earlier. How can the United States leverage commercially developed radioisotope power systems that China has to ensure our lunar landers can survive the night and operate continuously on the surface?

Dr. BESHA. Thank you.

Well, the U.S. actually does have commercial companies that are exploring radioisotope power systems. Some of them are here today. I think the advantage here is they are looking at a couple of different ways to do it, a couple of different approaches. They are using different fuels. They are using in there amboresium. They are using things like that, fuels that we haven't traditionally used in the past. So that is going to be an advantage.

I don't think China is using commercial companies to do their radioisotope power systems. They are very much part of the China nuclear energy agency and the associated industries below that. But, you know, I think our approach of multiple different approaches, seeing what works, doing some demonstrations and then start flying them, demos on clips missions, on, you know, the next flight opportunity to prove them out is the right approach.

Mr. KENNEDY. Thank you for that answer.

Mr. Swope, I have a question for you as well. As Acting NASA Administrator Duffy announced plans for fission nuclear reactor on the Moon by 2030, and I am very supportive of that effort, can you tell us where China stands technologically on establishing nuclear power systems on the Moon?

Mr. SWOPE. Thanks for that question. I can speak to what China has said. They have said they want to work with Russia to build a nuclear power station for their International Lunar Research Station. So they are thinking the same way, and it makes a lot of sense.

To your point about the length of the lunar night, it has to have power in order to keep those electronics warm so they don't break.

So I am not surprised that China is moving in that direction. I think the approach of the acting administrator to look at industry in the United States to see if they can come up with good ideas, novel ways to do that innovation, like Dr. Besha said as well, is the best approach. I think we are going to come out ahead on that.

Mr. KENNEDY. Thank you very much.

Chairman Haridopolos, I yield back.

Chairman HARIDOPOLOS. Thank you, Congressman Kennedy.

Next we have—I recognize the Representative from Virginia. Mr. Beyer, 5 minutes. Welcome to the Committee.

Mr. BEYER. Mr. Chairman, thank you very much and thank you for letting me wave on. And thank you, all of you, for your testimony today.

Dr. Besha, I am particularly grateful to have you here. You mentioned in your testimony the importance of supporting Earth and space science robustly, and you made a great point about the downstream, national security consequences, of doing that or not doing that. I care about this a lot.

The National Science Foundation headquarters is a few blocks from my home, and we have been very upset about this Administration's attacks on Federal science funding this year. The NASA science mission cut by 47 percent, 56 percent at the National Science Foundation. Lots of other Federal science agencies have just been gutted.

Could you discuss how these cuts to our core science programs are going to affect our national science programs and our national security downstream?

Dr. BESHA. Well, I think there are a couple of ways to look at funding for basic R&D. No. 1, it is very much a public good. You know, it is a national good that we can't identify a profit immediately but we should do it, right, basic science, the fundamentals of science. These trickle down eventually into applications, but initially, you know, basic R&D funding that provides funding benefits.

And that is the strength of the U.S. system versus China, to be honest. We have invested in basic R&D for the last 50 years as part of the system we set up. China hasn't invested that much. They have taken a lot of our hard work.

The second thing is world first. So you are not going to be a world first by simply seeing what everyone else is doing and then copying it, right. And so you do have to do that initial hard work to develop world-first successes like Mars first sample return, you know, habitable worlds, observatories, exoplanets, research, things like that that we have never really done before.

And the final thing is, you know, it is not just basic R&D. We create these missions, these astrophysics missions, things like James Webb Space Telescope. We are at the cutting edge. We are developing mirrors of such high refinement that these also have other applications, not just in science but in, you know, military applications, industrial applications, and things like that.

So there is very much a cross-pollination between these. They are not simply only for science.

Mr. BEYER. Let me follow up on the two because you have the basic research, but then I am really concerned, too, about the science workforce. Once again, we heard the National Science

Foundation right down the street, that virtually all of their postdocs, their graduate students, the people that were getting ready for their long careers were washed out and that many of them were not able to figure out how they are going to finish their Ph.D. programs.

And the real concern is that they are looking for opportunities in Germany, in England, in France. There is this reverse brain drain of our best young science people. I don't know. Hopefully they are not going back to China. Although, I am sure some of them are doing that, too.

You know, for decades we have been the country of tracking top-tier candidates from around the world to come here and study and make their whole careers in science. We looked at the fact that it is a plurality, if not a majority of our U.S. Nobel Prize winners were born in a different country.

How concerned are you about losing our investment in our next generation of science leaders?

Dr. BESH. Very concerned, right. Science is often multigenerational, and so we have very accomplished scientists that are later in their careers. They teach the middle-tier scientists, and those middle-tier scientists teach the postdocs. The postdocs teach the graduate students, and the graduate students—you know, on and on and on.

If you wipe out one of those cohorts, the postdocs, for example, in a lot of ways you are wiping out a generation for that science, and it is not easy to jump right down. You are losing that mentorship. You are losing a lot of that talent, so it is very concerning.

I think if they were to go overseas, for example, you know, they, perhaps, could come back. You know, nothing is necessarily permanent. We have had waves. Things go in waves. I would be more concerned if this persisted for a longer time.

Mr. BEYER. Thank you.

Mr. Chairman, the morning is getting on, and I yield back the balance of my time.

Chairman HARIDOPOLOS. Congressman Beyer, I appreciate it.

We are going to go for round two with questions. I am going to take the next 5 minutes and turn it over to Mrs. Foushee and we will go from there.

Dr. Griffin, you mentioned a few times now about Artemis III and your concerns, and I think those concerns have been heard today, of course. But I want to address specifically on the China issue and the potential of their Moon opportunity and what loss of mission might they face as they move forward with their plans on the Moon and beyond.

Dr. GRIFFIN. Thank you. That is an interesting question. The loss of mission probability, of course, involves not lives but wasted money and wasted time. When we speak of loss of crew, that is a different thing. So for loss of mission, I will point out that during Apollo, we estimated that to be about 10 percent, and we lost one of the seven missions, which we sent to the Moon. And for a statistically small sample, it turns out we had it about right.

China's approach to exercise their first missions to the Moon is quite a lot like Apollo. So I would estimate that they have a pretty

similar loss of mission probability as Apollo did. So I would say 10 percent or maybe a little bit lower because there has been a lot more experience over the last several decades.

So my answer is less than 10 percent, and I tried to explain why.

Chairman HARIDOPOLOS. Thank you, Dr. Griffin. I appreciate it.

Mr. Cheng, if we could, I want to get in the idea of if we lose this race to China, and this is why we are all here today, to make sure we do not lose that race, what position will the Communists have an advantage on as we talk about the standards of the future? We talked a little bit about GPS and other technologies. What are other concerns should we somehow lose this space race?

Mr. CHENG. So let me first emphasize that in this context, we are, in a sense, in a relay of marathons. That you may win this—you may be fastest in the second leg or the third leg, but that doesn't mean that you have won.

So in this context here, it is a matter of who will make it back to the Moon first, but much more important will be who will be able to sustain a presence on the Moon. The Artemis programmers talk about a manned station for 1 month out of the year. I suspect that the Chinese are much more thinking 12 months out of the year.

If that is the case and we are talking about who is setting the standards for not just communications and PNT, but everything from keep-out zones for health and safety reasons to scheduling for insertion, in essence, what will be the language of cislunar space travel? Will it be English or will it be Chinese?

And from the Moon, we potentially then go further outbound. The Chinese already talk about going to Mars. Certainly with a sample retrieval mission. Probably with human space flight in the out years. Again, being first matters. Being there persistently matters, and that, too, is about setting the rules, setting the industrial standards, the business, literally the dollars and renminbi, as well as the law and order aspects.

Chairman HARIDOPOLOS. Thank you.

Mr. Swope, on the question of the International Space Station (ISS), we know about the potential of the United States bringing it back down to Earth. What kind of impact might that have in this space race?

Mr. SWOPE. Thanks for the question.

I think we have to think about what we are trying to achieve in low-Earth orbit, their science there, their prestige there, look at that transition to a commercial approach to space stations, and really is NASA putting enough money on the table to make that work. I think that is the big question I am asking in my head when I think about what happens after the ISS.

I do think there are impacts to the prestige and science. I think determining what the level of those impacts are really determines what that gap is and the capabilities that we want and that we don't have. We will still have a lot of international partners that will want to work with the United States, but I don't think that looks great.

If we do have a gap, we can't have people in low-Earth orbit. I think that hurts our ability to go beyond low-Earth orbit with human spaceflight, too, and that is something that I think we need

to quantify as well. What does that hurt us for Artemis if we don't have the International Space Station or something like that that we can do experiments with people of how they live in space. There are impacts there, too, that I think we need to consider.

Chairman HARIDOPOLOS. Thank you.

I will yield back now.

Mrs. Foushee, you are recognized for 5 minutes.

Mrs. FOUSHEE. Thank you, Mr. Chairman.

So to each of you on the panel, we have heard about the importance to U.S. leadership of returning our astronauts to the surface of the Moon and doing so before China lands taikonauts there. What are the likely impacts should the U.S. not return humans to the Moon before China?

So please answer with a quick yes or no. No. 1, is NASA on track to return humans to the Moon before taikonauts set foot there? We will start with Mr. Cheng.

Mr. CHENG. I am very pessimistic about our ability, so, no.

Mrs. FOUSHEE. OK.

Mr. Swope?

Mr. SWOPE. Worried.

Mrs. FOUSHEE. OK.

Mr. Besha?

Dr. BESHA. You are not going to like it. Maybe. Maybe.

Mrs. FOUSHEE. Dr. Griffin?

Dr. GRIFFIN. No possible way is NASA on track to return astronauts to the Moon with the present plan.

Mrs. FOUSHEE. And lastly, if trying to beat China to the Moon with humans means committing massive resources that jeopardizes and sets back U.S. space science, aeronautics, low-Earth orbit activities, and space technology, where does that leave the United States, NASA, and the health of our civil space program?

Dr. GRIFFIN. I will start. NASA was created in the late 1950s to pioneer spaceflight. Many other activities become—space science, space applications become possible when your goal is to pioneer a new frontier. Many follow on activities are possible, but if you don't have the central mission goal that the United States will be pre-eminent on the space frontier, then the other things don't follow and they don't matter.

Mrs. FOUSHEE. Thank you.

Dr. BESHA. I think one way to think about the space agency is not so much just as a monolith but as—80 percent of NASA's funding goes to things like small businesses. It goes to universities, scientists, engineers. And so when you cut that budget, you may be cutting that agency, but you are really cutting this broad industrial base. You are trimming some of the American industry and some of our competitiveness. That money is going to researchers and things like that.

Mr. SWOPE. I think I would add just that I have confidence that NASA can execute on the Artemis mission, which is a long-term sustained presence on the Moon as a steppingstone beyond to for Mars. I think Mr. Cheng mentioned that. So to me I do have confidence in that, and I don't think we should take our focus on that.

So if it takes more resources just to beat China before Artemis III, I don't know if it is worth it, but I do have confidence in the long run we are going to execute on that Artemis mission.

Mr. CHENG. Because China confronts us with a whole-of-society challenge, I would really hope to see that NASA integrates itself more broadly into our terrestrial efforts. Why hasn't NASA sent a team of astronauts on a good-will tour of Africa, of South America, to bring home the achievements of American space capabilities?

NASA has one of the best brand recognitions out there. Coca-Cola would kill to have NASA's reputation. But they don't seem to have integrated themselves into that broader component, which the Chinese absolutely do.

Mrs. FOUSHEE. Thank you, Mr. Chairman. I yield back.

Chairman HARIDOPOLOS. Thank you.

The Representative from Georgia, Mr. McCormick, you are recognized for 5 minutes.

Mr. MCCORMICK. Thank you, Mr. Chair.

First of all, I love that idea, Mr. Cheng, on the way NASA goes out there and markets itself. I, too, would love, as a pilot and a physician, I would like to get out into outer space myself. They market it quite well to me.

Mr. Swope, you in your writings have talked about the fractured regulatory burden on our companies and how it kind of makes us noncompetitive. Meanwhile, China has been basically getting rid of all the burdens. They can do that because they are kind of top-down driven. They don't have any balance in their government.

What could we do that would put us in a more advantageous position so that we can actually be competitive in this future market rather than—for example, we have regulations on every single launch. If you change something, even for safety, to make it more safe, you have to go back and reapply—I am just going to give you one example—for that right to launch the next time. Ridiculous because you did something safe and now you are getting punished for that by saying you are not safe enough to launch again. That is one example.

But give me some examples of what we could do here in Congress to make sure that we become—we continue to be the most competitive market, encourage people to stay here, launch here, and excel here in the greatest Nation of the world rather than become an afterthought in the space race.

Mr. SWOPE. Thanks for the question. I really think you nailed it there. One thing about the U.S. space ecosystem that is based on free market principles to thrive, less regulation, less red tape, less bureaucracy is probably what we need to inject in that system to get the outcome that we want.

Three areas to think about—and in some cases folks in the Administration and past Administrations have looked to try to optimize this. So I am not saying we are not doing it now. But definitely spectrum. How are spectrum rules aligned so that they encourage innovation and they don't encourage the status quo?

When it comes to launch and reentry, I think I would put a little focus on reentry. I looked at one U.S. company that tried to do reentry the first time to a U.S. Federal range. They had a lot of trouble and since then they have been going to Australia. So I think

right there, where is that? Is that a regulatory burden? Is that a coordination burden? Is that a prioritization burden that is not happening? I don't know, but we should look at that because there is a lot of growth probably for reentry.

And then the third area we should highlight is export controls, ITAR (International Traffic in Arms Regulations), issues where companies want to sell technology to other countries, allied governments. Specifically, thinking of things on synthetic aperture radar. If you can't get it from a U.S. company, I am going to go to a French company. And that is what happens because those rules are a barrier and a paperwork barrier.

So I think in all those areas we can improve the regulations that we have now. I don't think it is time for more red tape, more paperwork for space companies. So if I hear anything about adding a regulatory burden or rules, even if it is a light touch approach, that is still paperwork. I don't think the industry needs that.

Mr. McCORMICK. That is such a great point you just made, and, first of all, I want to point out that every company that is trying to put spaceships out there and retrieve them has a reputation that they exist on. If you fail, if you are unsafe, their business is done. There is nobody who wants to be more safe than those companies. They can regulate themselves probably better than we ever could and be competitive only when we get out of their way.

And to your point, our ability to get in the way of selling our products to other countries only encourages us to be supplanted by China as the industry standard. And that is not just in space, by the way. That is in computer chips or anything else. We have to be very careful not to limit our ability.

And by the way, we just had a dissemination bill last year that was overseen by the Secretary that we withdrew that boundary that the Biden Administration put on us before and has made us competitive again in the market. But we lost shares during that time. We lost our industry standard.

So I just want to encourage people—and thank you so much for putting a very succinct outline of that—to not limit our ability to produce and disseminate and actually flourish in our Nation as competitors. The government is not the solution. We are the problem. Thank you for outlining that. Thank you.

And with that, I yield.

Chairman HARIDOPOLOS. Thank you.

I want to thank each of the witnesses for coming in today. This has been very insightful and thought-provoking, and we appreciate that very much. I also appreciate the thoughtful questions of the Members as well. This is a race we must win, and I think you've all given us a nice roadmap to which to work from, especially, as the latest line of questioning, trying to reduce some of those barriers to entry.

And with that, the record will remain open for 10 days for additional comments and written questions from Members.

This hearing is now adjourned.

[Whereupon, at 11:28 a.m., the Subcommittee was adjourned.]

Appendix

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Dean Cheng
U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

“Strategic Trajectories: Assessing China’s Space Rise and the Risks to U.S. Leadership”

Mr. Dean Cheng, Senior Fellow, The Potomac Institute for Policy Studies

Questions submitted by Chairman Mike Haridopolos

1. Over the last decade, the PRC has sought to develop and mature its commercial space industry.

In part, this is intended to develop commercial capabilities for global markets. Advancing its space exports has become a national priority for China, and it recently established a dedicated space export promotion agency to help facilitate this objective. To what extent can the Chinese private space sector compete with American companies? In what specific areas is the competition most intense? And, in which sectors do you anticipate competition between the U.S. and Chinese space industries will be most intense in the future?

A: We should expect the Chinese to develop a private space sector capable of competing with American companies, at a minimum on price, but also on coverage and, in the longer term, on technology. This will be the result of at least two distinct elements of general Chinese industrial policy:

- A. The widespread use of subsidies and facilitated financial support;*
- B. The general policy of “dual circulation.” This is the strategy by which the Chinese internal market is protected from foreign competition, but domestic producers are encouraged to compete with each other to generate innovation and efficiencies. The winners will then be unleashed on global markets, sometimes with additional subsidies.*

The Chinese are likely to push private companies in all relevant sectors, including space launch, satellite manufacturing, satellite broadband, earth-imaging, space data analysis, space situational awareness.

At the current time of 2026, satellite broadband is likely to be most intense, as the American SpaceX/Starlink is already in operation, while China is promoting several different commercial and state-owned companies (Guowang, Thousand Sails/Qianfan, Honghu-3) in competition. The Chinese are competing for satellite bandwidth in part to ensure that foreign operators cannot

access the broader Chinese public (by essentially bypassing the Great Firewall of China), and in part in order to secure maximum global marketshare.

2. The U.S and the PRC have at times engaged in exchanges and cooperation on space issues. Between 2015 and 2016, for example, the two sides convened two rounds each of a U.S.-China Civil Space Dialogue and a U.S.-China Space Security Exchange. Some experts have called for a renewed dialogue with the PRC about space, particularly about the challenges posed by orbital debris. Others have suggested starting with a U.S.-PRC working group on joint astronaut rescue operations, building on the UN Rescue and Return of Astronauts Agreement. What is your opinion of proposals to renew U.S.-PRC dialogue and/or exchanges on space topics?

A: I believe that the United States needs to be extremely careful in any cooperative effort with the PRC, including in any aspect of science. American scientists tend to see science as borderless, and cooperation as a natural good. They often fail to recognize that their counterparts from authoritarian countries operate in a different environment. Even if a Chinese scientist sees the world that way (and they might), those same scientists operate at the sufferance of the Chinese Communist Party (CCP), who see the world quite differently.

*The experience with COVID-related information, where Chinese doctors and health officials did **not** routinely and promptly share information, and may have even destroyed key samples, should warn us that the PRC sees science, even public health, very differently.*

*In the space domain, Chinese behavior is even more problematic. China is right now generating orbital debris, with rocket bodies and components. The CCP does not seem to care¹ where LM-5B bodies (complete with their engines intact) land.² Parts of the Long March-6A have repeatedly³ disintegrated into orbital debris.⁴ This is **not** a matter of educating the Chinese, who have repeatedly launched multi-stage rockets with an excellent track record. This is a matter of Chinese choices. It should not be in the American interest to promote or countenance such*

¹ <https://www.bbc.com/news/science-environment-62333546>

² <https://www.space.com/china-long-march-5b-rocket-falls-into-pacific-ocean>

³ <https://www.space.com/china-rocket-disintegrates-space-junk-cloud>

⁴ <https://spacenews.com/chinese-rocket-stage-breaks-up-into-cloud-of-more-than-700-pieces-of-space-debris/>

irresponsible behavior. At a minimum, the Chinese should improve their operational standards before the US should engage in any kind of cooperation.

This, of course, leaves aside the reality that the PRC's space industrial complex is tightly linked to the Chinese People's Liberation Army and the PRC's military industrial complex—including the manufacturers of ICBMs, whose products were on prominent display in the September 2025 military parade in Beijing.

As for human spaceflight, this is widely seen as the "crown jewel" of each nation's space programs. To undertake discussions in this area, without any kind of foundation of discussion in unmanned spaceflight, general space exploration, or even general data exchanges, would seem to be extraordinarily premature, and would open the door to misunderstanding on both sides.

Questions submitted by Full Committee Chairman Brian Babin

1. China's Military-Civil Fusion development strategy has permeated through the CCP's space programs. Can you describe how Military-Civil Fusion strategy has benefited and/or expedited China's space activities? Additionally, what organizational links between the CCP's civil and military space programs exist today? And, to what extent do the People's Liberation Army's goals influence which civil or commercial programs the CCP chooses to pursue or fund?

A: Space systems are inherently dual-use; that is, most space systems (e.g., communications, earth observation, meteorology, data relay) can be used for both military and civilian purposes. For the PRC, this is a key driver for leveraging Chinese space-related investments to allow them to satisfy both civilian and military demands. Through Military-Civil Fusion (MCF), Chinese satellite and launch advances will redound to the benefit of both the broad economy and the PLA.

In this regard, it is important to recognize that the PLA manages all PRC space facilities. The mainstay of the Chinese space industrial complex, the two state-owned enterprises (SOEs), produce both military and civilian products. Consequently, advances in civilian and commercial space endeavors, whether more efficient satellite and rocket production, gains in satellite capability, better space situational awareness, will help the military.

At the same time, the military's emphasis on developing Chinese space capabilities means there is a steady customer for Chinese space products and services (much as the US Department of War and intelligence community are key customers for American space products and services).

Questions submitted by Rep. Keith Self

1. Lagrange regions, especially L1 and L2, are prime real estate for persistent lunar communications relay and navigation support, and as cislunar space becomes contested, showing up occasionally will not hold terrain. The advantage will go to whoever fields reliable, interoperable services that others plug into, including communications relay, positioning navigation and timing beacons, and space domain awareness, built quickly enough to matter and procured in a way that pulls in private capital rather than waiting on slow bespoke government builds. L1 and L2 are prime real estate for lunar communications and navigation relay, and the cislunar theater is becoming contested. What is the minimum architecture the United States should deploy at or near L1 through L5 including relay, positioning navigation and timing beacons, space domain awareness sensors, and data transport, and what is the fastest procurement model to do it?

A: Broadly speaking the US should prioritize being the foremost provider of position, navigation, and timing (PNT) and space situational awareness (SSA) information in the cis-lunar domain. The PRC has given indications it wants to be a foremost supplier of both, and it is in the American interest that other space-faring parties (e.g., Europe, Japan, India, Middle East) choose American rather than Chinese resources. The advantage accrued to the United States of being the foremost supplier of terrestrial PNT data has been significant.

Similarly, the United States should strive to be the foremost provider of cis-lunar data relay capacity, as the US in particular, but also its allies, should not be dependent on the PRC in this category, any more than it should be dependent on the PRC for 5G service terrestrially.

In this regard, I am not qualified to address the fastest procurement model for the enumerated services. A review of historical acquisition trends, however, would suggest that the fastest procurement method is probably NOT through the US government, with the Federal Acquisition Regulations (FAR) and Defense Federal Acquisition Regulations (DFAR) more likely to be impediments than facilitation.

2. China is increasingly shifting from one off missions to durable cislunar infrastructure. The difference is decisive because persistent logistics and continuous communications and navigation coverage create real operating advantage and let the first mover shape standards, norms, and access in ways that disadvantage competitors and constrain allied operations. What's your estimate for when China can sustain (a) continuous crewed presence, (b) continuous robotic operations, and (c) continuous logistics and communications coverage in cislunar space, and what indicators should Congress watch?

A: From a policy perspective, if the CCP makes establishing a lunar presence, whether human, robotic, or mixed, a priority, then the PRC will make a maximum effort to achieve that goal. The PRC is already reportedly working on establishing a PNT and communications network for the Moon. Consequently, Chinese logistics/communications/PNT capabilities may predate all Chinese efforts on the lunar surface.

The PRC will continue to land robotic probes on the lunar far side and lunar poles. The first Chinese human landing may not be at one of the lunar poles, but subsequent landings will probably be aimed at those strategic regions.

I am not technically qualified to provide an estimate of precisely when the PRC is likely to deploy missions and systems for each of the enumerated objectives.

3. China's civil military fusion collapses any neat separation between commercial capability and state capability, so dual use transfer risk is structural, not hypothetical. As China advances in these capabilities, what targeted export controls should the United States implement to protect the most sensitive rendezvous, proximity, and servicing enablers while preserving the competitiveness of legitimate U.S. commercial space industry?

A: With regards to export controls, the International Trade in Arms Regulations (ITAR) are already in place. They need to be monitored and updated as needed. The Committee on Foreign Investment in the United States (CFIUS), and the Foreign Investment Risk Review Modernization

Act of 2018 (FIRRMA) addresses potential PRC acquisition of more mature companies and technology. What arguably requires review are the less visible lines of approach, such as Chinese funded venture capital and minority shareholding (w/ board rights), which can allow access to CUI without full-blown acquisition. The Chinese interaction with the company Global IP is a prime example of how the Chinese have sought to circumvent both ITAR and CFIUS regulations.⁵

*Nonetheless, at the end of the day, it is important to recognize that the PRC's "around, under, over, through" strategy of acquiring foreign technology means nothing can be made absolutely secure and airtight. The United States, at best, can slow down illicit PRC acquisition of advanced technology and raise the cost of doing so. (One reason why cooperation with China on "scientific" and other ventures is problematic is that it potentially **lowers** the cost for the PRC of acquiring data and technology.)*

In the longer term, then, the United States needs to promote innovation, shorten the innovation cycle, and also bring new technologies and products to market faster, in order to stay ahead of the PRC. This arguably requires fewer regulations, fewer restrictions, in order to maximize the freedom for small start-ups to blossom and to facilitate the transition from innovating technology to producing them at scale.

4. In your view, have we lost sight of building sustainable lunar infrastructure and drifted back toward a flags and footprints approach rather than creating a sustained presence?

A: As the United States has built neither sustainable lunar infrastructure nor succeeded in planting a new US flag and leaving new footprints, it would seem that it is premature to argue that the US is favoring one or the other approach. We would seem to be failing at both.

5. If we know we still have work to do to perfect crewed lunar landing capability, why are we not using the intervening years to pre position and stockpile critical supplies and infrastructure on the lunar surface now so a sustained presence becomes inevitable rather than aspirational?

⁵ <https://www.wsj.com/articles/china-maneuvers-to-snap-top-secret-boeing-satellite-technology-1543943490>

A: I do not know why we are not prepositioning critical supplies and infrastructure, or deploying consumables (e.g., water, oxygen) on the Moon, or on Mars. It should be incumbent upon NASA to answer these important questions.

6. The Administration says the United States must dramatically increase launch cadence by 2030 and has directed agencies to streamline commercial space licensing. We should be able to point to measurable changes in processing time, predictability, and throughput. The Administration has directed the streamlining of commercial space licensing to increase cadence by 2030. What changes are actually happening on the ground, and where is it still performative?

A: I am not qualified to answer this question.

7. While we slept, China executed a decades-long plan to become the world's leader in critical materials. We are finally waking up, and taking the first steps to catch up. But I want to look at a critical material that many people have not yet focused on: helium-3. It's an isotope of helium that is extremely rare on Earth, and is necessary for cooling some kinds of quantum computers almost to absolute zero so they can operate. If you believe, as I do, that quantum computing will revolutionize national security and the economy, then we have to have a steady supply of helium-3. Helium-3 is so rare on Earth that it makes sense to go to the Moon to get it. The bad news is that China is planning to do just that, but the good news is that we don't have to give them a head start. We can add helium-3 missions to the Artemis program and ensure that we have the critical material we need to drive the quantum revolution. Do you think we should pursue this or should we let China add to its critical material advantage?

A: I am not familiar with the cooling requirements associated with either quantum computing or AI-related data centers. I would note that the more proximate challenge would seem to be

ensuring that there is a stable American power grid, able to withstand weather and other natural events, as well as the growing demand from industry, urban development, etc. Given American reliance on China for manufacturing transformers and other parts of our grid, there are a number of steps that are necessary to insulate ourselves from potential Chinese pressure. He-3 is arguably a real, but somewhat longer-term, concern.

*Responses by Mr. Clayton Swope***Responses to Member Questions for the Record from Clayton Swope**

For the Committee on Science, Space, and Technology hearing titled, “Strategic Trajectories: Assessing China’s Space Rise and the Risks to U.S. Leadership,” on December 4, 2025

Questions submitted by Chairman Mike Haridopolos

1. In order to enable both of its landings on the far side of the Moon, the CCP deployed a communications relay satellite into cis-lunar space. This first step represents only the beginning of the CCP’s interest in deploying satellites and other capabilities into cis-lunar as well as other deep-space destinations. In fact, the CCP has proposed developing comprehensive communications and positioning, navigation, and timing, or PNT, capabilities for the cislunar domain. What progress has the CCP made in developing cislunar communications and PNT capabilities? How do the PRC’s assets and capabilities compare to the systems the U.S. operates in lunar orbit? And, what are the national security implications of the CCP possessing and expanding its cislunar communications and PNT capabilities?

Answer: The PRC operates two Queqiao communications satellites in cislunar space. Both satellites are intended to support PRC activities on the Moon, including uncrewed and crewed missions. These two satellites are a first-generation lunar communications network that will be followed by a more advanced system providing cislunar communications, PNT, and remote sensing capabilities. China has already launched technology demonstrator satellites in support of this future constellation. The United States is looking to develop lunar communications and PNT systems, turning to companies to help provide lunar infrastructure, in some cases as a commercial service. The United States recognizes the importance of cislunar infrastructure – but the PRC has a lead in operationalizing its vision. The Moon undeniably holds strategic value. Just as communications and accurate navigation capabilities were essential for sea power, they will also be essential for projecting national space power to the Moon and beyond.

2. Over the last decade, the PRC has sought to develop and mature its commercial space industry. In part, this is intended to develop commercial capabilities for global markets. Advancing its space exports has become a national priority for China, and it recently established a dedicated space export promotion agency to help facilitate this objective. To what extent can the Chinese private space sector compete with American companies? In what specific areas is the competition most intense? And, in which sectors do you anticipate competition between the U.S. and Chinese space industries will be most intense in the future?

Answer: China is positioning its companies to compete with U.S. space companies for international business in three main areas: launch services, satellite broadband, and remote sensing. While China has made strides in its commercial aerospace sector, it is largely still building up its capacity to mass-produce satellites and provide reliable launch services. It

remains to be seen if PRC companies can truly compete with U.S. companies in these areas because of the deep mistrust between the West and China and security lessons learned from the West's experience with Huawei and ZTE. It is doubtful that a company who wants to do business with the government of the United States, a NATO member, Australia, Japan, New Zealand, or South Korea, among others, let alone a government agency in these countries, would buy a space service provided by a PRC company. Other than domestic customers in China and potentially Russia and Global South countries, there are no obvious markets for space services sold by Chinese companies. Given that India is promoting its own domestic space industry, it is also not clear India would be a strong customer of PRC space companies. For China, its space companies may be a money-losing investment because business in the Global South will have to be subsidized by Beijing – but the PRC may be looking to them more for a strategic and less for a business purpose.

3. The U.S and the PRC have at times engaged in exchanges and cooperation on space issues. Between 2015 and 2016, for example, the two sides convened two rounds each of a U.S.-China Civil Space Dialogue and a U.S.-China Space Security Exchange. Some experts have called for a renewed dialogue with the PRC about space, particularly about the challenges posed by orbital debris. Others have suggested starting with a U.S.-PRC working group on joint astronaut rescue operations, building on the UN Rescue and Return of Astronauts Agreement. What is your opinion of proposals to renew U.S.-PRC dialogue and/or exchanges on space topics?

Answer: Reflecting on the Apollo-Soyuz mission, George Low, NASA administrator from 1969 to 1976, observed that, “We live in a rather dangerous world. Anything that we can do to make it a little less dangerous is worth doing.” However, it is hard to envision a joint project in space between the United States and China anytime soon. Peaceful space cooperation, oriented around human spaceflight safety, mirroring the goals of the Apollo-Soyuz mission, may one day be possible – but that day is not today. That does not mean there is no room for engagement when that engagement suits U.S. interests. Rather than cooperation with China in space, it might be sensible to start with coordination or simply consultation, particularly with regards to upcoming lunar plans. The U.S. interest for such consultation would be human spaceflight safety of the Artemis astronauts and ensuring the successful execution of Artemis, reducing the risks of an unintentional accident arising from a lack of awareness of each other's plans. Such consultations should not involve technical or engineering information that could be used by the PRC to further their space technologies and operations.

Questions submitted by Full Committee Chairman Brian Babin

1. China's Military-Civil Fusion development strategy has permeated through the CCP's space programs. Can you describe how Military-Civil Fusion strategy has benefited and/or expedited China's space activities? Additionally, what organizational links between the CCP's civil and military space programs exist today? And, to what extent do the People's Liberation Army's goals influence which civil or commercial programs the CCP chooses to pursue or fund?

Answer: Unlike the U.S. system, which is based on free-market principles, the PRC is governed top down. Beijing wields all elements of its national power – governmental, industrial, and academic resources – to meet its goals. This framework has enabled Beijing to stick to its space vision over decades and make rapid progress in space. For the PRC, space power is national power, with elements of that power anchored in both civilian and military uses of space. The state-owned enterprises that have historically formed the backbone of China's space power support both civilian and military uses of space – the same research institutes, factories, scientists, engineers, and technicians undoubtedly support both applications. It is not possible to segregate PRC civil space technologies from military ones. Programs with scientific aims may produce technologies with military purposes. Governmental funding supports efforts to develop dual-use space technologies and bolster China's domestic space supply chains. The China Manned Space Agency, which leads PRC human spaceflight initiatives, is a military organization. I am not aware of the specifics for how PLA requirements shape civilian and commercial programs in China, though it would be safe to say they probably shape the direction of PRC investments in companies and basic research and technological development goals.

2. China has made clear its intent to overtake the U.S. and become the global leader in space. While lunar exploration stands as a top priority for the PRC, it's among a growing range of national space projects and programs. The expansion of China's space activities highlights its interest in leading not only on the Moon, but in all aspects of space. How does lunar exploration fit into China's broader space exploration goals, and what role does it play in supporting the PRC's space leadership ambitions?

Answer: For China, its lunar ambitions fit within a broader narrative about its space achievements that it uses domestically and internationally to show that China is a world-class power. Domestically, this narrative is used to ensure the Chinese people remain supportive of the regime. Internationally, the narrative is used to recruit allies, mostly from among the ranks of the Global South. China also sees the Moon through a strategic lens, aiming to establish itself there as a stepping stone for future activities in space. The PRC likely assesses, correctly, that the Moon will provide strategic long-term benefits to nations who are able to operate there.

Questions submitted by Rep. Haley Stevens

1. While the Chinese Communist Party uses civil-military fusion to tightly direct its quasi-commercial sector to reliably meet its space goals on accelerated timelines, the United States follows a strategic and deliberative approach, that includes science-community decadal surveys to help shape NASA's science portfolio and that are implemented by civil government, academic, and private and international partners. However, we have seen the Trump Administration disregard the decadal surveys and long-term strategy in favor of short-term, politically-motivated decision making. I worry that if NASA is not trusted to maintain a constancy of purpose and follow through on its word with its partners, then the United States' ability to collaboratively enable the space sector to achieve our broad national goals will be severely limited, which risks significantly diminishing our capacity to respond to emerging threats, including advancements by the CCP. The fundamental advantage that our own robust free market systems give us may depend on sending a clear demand signal to generate investment.

- a. As we seek to advance long-term space leadership, why is it important to maintain both reliance on the decadal surveys to guide NASA's science mission and research priorities and also NASA's focus on its mission as a civil space agency?

Answer: The decadal surveys are an important tool for obtaining expert consensus and justification for NASA's science vision, providing a long-term rationale for why certain missions are important and worth the investment. The surveys serve as an anchor to explain why NASA prioritizes certain missions over others.

- b. As we seek to collaboratively shape the direction of the American space industry, what are the long-term considerations for short-term, politically-motivated programmatic changes without long-term agreements?

Answer: For NASA, the success of nearly everything it does is measured over many years, sometimes over decades. If we are to compete (and win) with China in space, the United States must have a long-term vision and strategy. Proverbs says is best: "Where there is no vision, the people perish."

Questions submitted by Rep. Bill Foster

1. Are you aware of any investigations into the implications of an explosion during refueling of a starship-like vehicle in low-earth orbit, in terms of orbital debris and potential damage to planned constellations of satellites in LEO including the Golden Dome satellite deployment? If so, what did those studies find?

Answer: I am not aware of any study on that issue.

Questions submitted by Rep. Keith Self

1. Lagrange regions, especially L1 and L2, are prime real estate for persistent lunar communications relay and navigation support, and as cislunar space becomes contested, showing up occasionally will not hold terrain. The advantage will go to whoever fields reliable, interoperable services that others plug into, including communications relay, positioning navigation and timing beacons, and space domain awareness, built quickly enough to matter and procured in a way that pulls in private capital rather than waiting on slow bespoke government builds. L1 and L2 are prime real estate for lunar communications and navigation relay, and the cislunar theater is becoming contested. What is the minimum architecture the United States should deploy at or near L1 through L5 including relay, positioning navigation and timing beacons, space domain awareness sensors, and data transport, and what is the fastest procurement model to do it?

Answer: The Earth-Moon Lagrange points provide unique opportunities for lunar communications systems to maintain continuous connectivity with Earth and for monitoring activities in cislunar space. While the United States is investing in these areas, it should consider accelerating work, leaning on industry as much as possible to come up with innovative solutions, to build out cislunar infrastructure. Such infrastructure will be important not only for U.S. activities on the Moon, but also to support future activities beyond Earth in other parts of the Solar System.

2. China is increasingly shifting from one off missions to durable cislunar infrastructure. The difference is decisive because persistent logistics and continuous communications and navigation coverage create real operating advantage and let the first mover shape standards, norms, and access in ways that disadvantage competitors and constrain allied operations. What's your estimate for when China can sustain (a) continuous crewed presence, (b) continuous robotic operations, and (c) continuous logistics and communications coverage in cislunar space, and what indicators should Congress watch?

Answer: China already operates lunar communications relays and, over the next few years, will likely expand that network to include more robust communications, PNT services, and remote sensing capabilities. This will likely support efforts by the PRC to maintain a continuous robotic presence on the Moon by the early 2030s. At this point, it is not clear whether the PRC is planning for a continuous human presence on the Moon, rather than a semi-regular human presence supported by a robotic lunar base. Congress should watch Chang'e 7 and Chang'e 8. Do these missions launch on time? Do they go as planned?

3. China's civil military fusion collapses any neat separation between commercial capability and state capability, so dual use transfer risk is structural, not hypothetical. As China advances in these capabilities, what targeted export controls should the United States

implement to protect the most sensitive rendezvous, proximity, and servicing enablers while preserving the competitiveness of legitimate U.S. commercial space industry?

Answer: For decades, China has mostly copied the U.S. playbook in space. The problem now is that the PRC is innovating on its own. The United States should maintain robust export controls on space technologies, recognizing, however, that China now has an ability to produce the technologies required for RPO and servicing missions and has demonstrated that it can perform such operations in space.

4. In your view, have we lost sight of building sustainable lunar infrastructure and drifted back toward a flags and footprints approach rather than creating a sustained presence?

Answer: NASA is committed to the long-term vision, as represented by the concept of Moon to Mars and the role of a sustained lunar presence in that framework. It is worth emphasizing the strategic value of that long-term vision as we are about to embark on the Artemis II mission.

5. If we know we still have work to do to perfect crewed lunar landing capability, why are we not using the intervening years to pre position and stockpile critical supplies and infrastructure on the lunar surface now so a sustained presence becomes inevitable rather than aspirational?

Answer: I do not have first-hand familiarity with the types of materials or supplies that could be stockpiled now at the Moon and would hope another expert may be able to better address this thoughtful question.

6. The Administration says the United States must dramatically increase launch cadence by 2030 and has directed agencies to streamline commercial space licensing. We should be able to point to measurable changes in processing time, predictability, and throughput. The Administration has directed the streamlining of commercial space licensing to increase cadence by 2030. What changes are actually happening on the ground, and where is it still performative?

Answer: The administration has made clear its intention to improve space licensing processes, identifying ways to streamline launch licensing. The FCC is also proposing an overhaul of its licensing process for space systems. These reforms will meaningfully impact the U.S. space industry. Beyond FAA and FCC licensing reforms, the administration should be cautious in how it approaches adding new paperwork for space companies as part of a mission authorization framework. Non-specific text in the Outer Space Treaty of 1967 is not a sufficient reason alone, in my view, to impose new red tape on U.S. space companies. Ironically, it is the PRC that has criticized the United States for not meeting this treaty provision.

7. While we slept, China executed a decades-long plan to become the world's leader in critical materials. We are finally waking up, and taking the first steps to catch up. But I want to look at a critical material that many people have not yet focused on: helium-3. It's an isotope of helium that is extremely rare on Earth, and is necessary for cooling some kinds of quantum computers almost to absolute zero so they can operate. If you believe, as I do, that quantum computing will revolutionize national security and the economy, then we have to have a steady supply of helium-3. Helium-3 is so rare on Earth that it makes sense to go to the Moon to get it. The bad news is that China is planning to do just that, but the good news is that we don't have to give them a head start. We can add helium-3 missions to the Artemis program and ensure that we have the critical material we need to drive the quantum revolution. Do you think we should pursue this or should we let China add to its critical material advantage?

Answer: The U.S. government should be funding basic research and development that supports technologies that could be used to extract and use space resources, including helium-3. Such technologies, and the operational methods to conduct resource extraction and use in space, are fundamental to the future space economy.

Responses by Dr. Patrick Besha

Dr. Patrick Besha
 Founder
 Global Space Group
 Responses to Questions for the Record
 January 26, 2026

Questions submitted by Chairman Mike Haridopolos

1. The U.S and the PRC have at times engaged in exchanges and cooperation on space issues. Between 2015 and 2016, for example, the two sides convened two rounds each of a U.S.-China Civil Space Dialogue and a U.S.-China Space Security Exchange. Some experts have called for a renewed dialogue with the PRC about space, particularly about the challenges posed by orbital debris. Others have suggested starting with a U.S.-PRC working group on joint astronaut rescue operations, building on the UN Rescue and Return of Astronauts Agreement. What is your opinion of proposals to renew U.S.-PRC dialogue and/or exchanges on space topics?

Response

Historical exchanges and cooperation on space issues including the State Department-led US-China Civil Space Dialogue and the NASA-led Earth and Space Science Working Groups yielded important insights and stabilized space relations between the two nations. In other areas of advanced science and technology, the US and China continue to maintain bilateral government dialogues on a variety of topics. Pragmatic engagement and dialogue between the US and China on space issues should be re-started.

Within the realm of possible topics conducive to stabilizing relations while steering clear of sensitive subjects, building on the UN Rescue and Return of Astronauts Agreement may be a useful initiative. It is an area in which both sides are incentivized to cooperate for the safety of their crew. However, astronaut safety and joint rescue operations requires a very high level of trust and transparency that is not currently manifest in the bilateral space relationship. My recommendation would be to initiate bilateral dialogue on cooperative activities such as scientific data and material exchanges in Earth and space science. Next, advance discussion on broad topics of global concern and general benefit such as slowing the profusion of space debris in orbit, aligning planetary defense efforts, and coordinating satellite observatory measurements. Progress can be made by individual nations acting of their own accord toward mutually agreed upon goals (thereby limiting any exchange of technology). In addition, as part of any dialogue, the US and China should establish a hotline that facilitates direct communication between key space operators to reduce the risk of miscalculation in orbit.

NASA's bilateral cooperation is significantly constrained by the Wolf Amendment.¹ Since enactment, this legislation has had at least two major effects. First, it shut down direct American access to Chinese science data, while preserving Chinese access to American data which is freely available worldwide. Second, it reduced the strategic role of NASA in international relations and provided China a diplomatic advantage because they are able to cooperate in space with any

¹ First enacted in 2011 as Section 539 of the Commerce, Justice, Science, and Related Agencies Appropriations Act, 2012 (P.L. 112-55, Division B). It is been repeated each year since then in appropriations bills.

nation. Congress should carefully consider the pros and cons of continuing to support this legislation.

Questions submitted by Rep. Keith Self

1. Lagrange regions, especially L1 and L2, are prime real estate for persistent lunar communications relay and navigation support, and as cislunar space becomes contested, showing up occasionally will not hold terrain. The advantage will go to whoever fields reliable, interoperable services that others plug into, including communications relay, positioning navigation and timing beacons, and space domain awareness, built quickly enough to matter and procured in a way that pulls in private capital rather than waiting on slow bespoke government builds. L1 and L2 are prime real estate for lunar communications and navigation relay, and the cislunar theater is becoming contested. What is the minimum architecture the United States should deploy at or near L1 through L5 including relay, positioning navigation and timing beacons, space domain awareness sensors, and data transport, and what is the fastest procurement model to do it?

Response

A core issue with maintaining space domain awareness in the cislunar environment is the enormous volume of space. This compels developers to initially focus monitoring efforts on smaller regions that are likely to become transit corridors to lunar and other valuable orbits. To travel from low-Earth orbit to cislunar space, there are high-energy direct transfers with discernable trajectories (such as those used by Apollo) and there are also low-energy, long-duration and deep space transfers that may be challenging to track.

In terms of existing assets, NASA maintains the Lunar Reconnaissance Orbiter, as well as the CAPSTONE smallsat in lunar orbit. China deployed the Queqiao 1 and Queqiao 2 lunar communications relay satellites in Earth-Moon L2 and a frozen lunar orbit, respectively. China also maintains a Chang'e 5 orbiter in distant retrograde orbit, along with a smallsat constellation. Other countries currently operate orbiters in lunar orbit as well.

To articulate the minimum architecture would require an in-depth analysis based on current and planned mission needs, from the perspective of NASA robotic and human spaceflight cislunar missions and defense/IC interests in cislunar space. I conducted this analysis in my previous position at NASA, and could do so again as an independent consultant with the Global Space Group if there was a funded opportunity.

In terms of the fastest procurement model, this would depend on the design of the architecture. However, I suggest there may be a trade-off between fastest and best if the intention is to build a long-term and sustainable presence in cislunar space. While we should support private and commercial space when it presents an advantage (and it often does for smaller, high-risk missions), in some cases a hybrid government-industry approach is more optimal.

To develop shared infrastructure, such as for Lagrange region communication and navigation support, a hybrid build out may be the best approach. A single commercial company is unlikely to require such extensive infrastructure for its own missions or realize profitability. For this

reason, private capital is unlikely to materialize at the levels needed for development. However, government-funded basic comms/nav infrastructure for US Government and allied customers could provide the necessary de-risking to attract private capital for follow-on commercially-operated space domain awareness or other commercial activities.

2. China is increasingly shifting from one off missions to durable cislunar infrastructure. The difference is decisive because persistent logistics and continuous communications and navigation coverage create real operating advantage and let the first mover shape standards, norms, and access in ways that disadvantage competitors and constrain allied operations. What's your estimate for when China can sustain (a) continuous crewed presence, (b) continuous robotic operations, and (c) continuous logistics and communications coverage in cislunar space, and what indicators should Congress watch?

Response

China is unlikely to maintain a continuous crewed presence in cislunar space until at least the 2040's and beyond. The country currently has only notional plans related to a Gateway-type crewed orbiting platform in the 2030's, and such a platform would be capable of sustaining only intermittent crewed presence for most of its initial deployment. Furthermore, sustaining a continuous human presence on the lunar surface would require significant infrastructure, as well as cargo logistics and crew launch capability exceeding what will be available at least until the late 2030's.

However, China *currently* maintains continuous robotic operations in cislunar space. For example, the Queqiao 1 and Queqiao 2 communications and navigation relay satellites, and the Chang'e 5 orbiter in distant retrograde orbit are operational. In addition, the Yutu-2 rover that was deployed as part of the 2018 Chang'e 4 mission is reportedly still operating at a very low level of performance. Upcoming missions such as Chang'e 7 and 8 will deploy orbital, lander and rover assets that may also operate well past their design lifetimes, expanding the number of Chinese operational assets in cislunar space and on the lunar surface.

China presently maintains some continuous communications coverage in cislunar space. An initial logistics or supply chain operation capable of regular cargo and mission launches to cislunar space is likely to be realized by the mid-2030's, when China ramps up its efforts to build out the International Lunar Research Station. Key indicators include the serial production of the LM-10 launch vehicle (early 2030's) and the initial demonstration flight of the super-heavy LM-9 launch vehicle (mid-2030's). The development of a multi-node lunar communications network to provide full coverage of the lunar surface would also be an indicator to watch. Ultimately, transporting cargo from a lunar surface landing site to the main base of operations may require a hub-and-spoke or similar distributed approach. Indicators may include surface logistics routes, cargo vehicles, and power distribution facilities.

3. China's civil military fusion collapses any neat separation between commercial capability and state capability, so dual use transfer risk is structural, not hypothetical. As China advances in these capabilities, what targeted export controls should the United States implement to protect the most sensitive rendezvous, proximity, and servicing enablers while preserving the competitiveness of legitimate U.S. commercial space industry?

Response

The existing export controls related to rendezvous proximity operations (RPO) are likely sufficient. I am not aware of any specific export control issues requiring remediation. China's advances in RPO surpass the capabilities of the US commercial space industry and appear to be the result of targeted domestic investment in R&D and their significant prioritization within the space program.

4. In your view, have we lost sight of building sustainable lunar infrastructure and drifted back toward a flags and footprints approach rather than creating a sustained presence?

Response

Yes

5. If we know we still have work to do to perfect crewed lunar landing capability, why are we not using the intervening years to pre-position and stockpile critical supplies and infrastructure on the lunar surface now so a sustained presence becomes inevitable rather than aspirational?

Response

NASA and the Administration have not signaled support for Artemis missions beyond Artemis 5, so there is no impetus to pre-position and stockpile critical supplies, or build out infrastructure for a sustained presence. Support for later missions would provide an indication whether we intend to pursue a sustained presence on the lunar surface, whether we will continue flying the SLS rocket or shift to a commercial alternative, and insight into planning for crewed missions to Mars.

6. The Administration says the United States must dramatically increase launch cadence by 2030 and has directed agencies to streamline commercial space licensing. We should be able to point to measurable changes in processing time, predictability, and throughput. The Administration has directed the streamlining of commercial space licensing to increase cadence by 2030. What changes are actually happening on the ground, and where is it still performative?

Response

The Administration moved to change commercial space licensing with the intention to become more streamlined and efficient. The FCC issued a Notice of Proposed Rulemaking ("Space Modernization for the 21st Century") intended to create a more rapid and efficient licensing assembly line. In addition, the White House issued Executive Order 14335 which seeks to eliminate or expedite the Department of Transportation's environmental reviews for, and other obstacles to the granting of, launch and reentry licenses and permits. These changes are very recent and their effectiveness is unclear. In some cases, such as the FCC NPRM, the comment period is still open and no rules have gone into effect.

In my opinion, it is unlikely that the most significant impediment to improving launch cadence is the regulatory licensing process. Far more critical is healthy competition and investment in the launch vehicle sector, to include commercial space ports and associated launch infrastructure. R&D funding, contracts and other procurement efforts can grow the variety of launch providers

and vehicles, improve capabilities, and drive costs down. Support for building and maintaining launch pads can also increase launch cadence.

7. While we slept, China executed a decades-long plan to become the world's leader in critical materials. We are finally waking up, and taking the first steps to catch up. But I want to look at a critical material that many people have not yet focused on: helium-3. It's an isotope of helium that is extremely rare on Earth, and is necessary for cooling some kinds of quantum computers almost to absolute zero so they can operate. If you believe, as I do, that quantum computing will revolutionize national security and the economy, then we have to have a steady supply of helium-3. Helium-3 is so rare on Earth that it makes sense to go to the Moon to get it. The bad news is that China is planning to do just that, but the good news is that we don't have to give them a head start. We can add helium-3 missions to the Artemis program and ensure that we have the critical material we need to drive the quantum revolution. Do you think we should pursue this or should we let China add to its critical material advantage?

Response

There are several challenges with securing He-3 on the lunar surface. First, we do not currently have an accurate characterization of He-3 on the lunar surface, including its relative abundance (parts per billion) or the sites with densest concentrations. As a first step, NASA and commercial lunar payload services providers could field instruments and/or conduct survey missions to perform resource characterization (e.g., VIPER or similar). The results of these investigations could help determine a mining and refinement strategy, if any. Notably, at a theoretical concentration of several grams per ton of lunar regolith, mining and refinement may require large scale operations far beyond the capabilities of any planned lunar missions. A key comparison to consider before significantly funding such efforts will be the cost of building out large scale He-3 lunar mining facilities versus the cost of expanding the production of He-3 on Earth.

Questions submitted by Rep. Haley Stevens

1. Over the last decade, we have seen many nations in Latin America, Africa, Asia, and the Middle East begin to recognize the importance of establishing their own sovereign space capabilities. Such emerging space countries often rely on partnerships with established space powers to help develop indigenous space capabilities and access the low Earth orbit economy. At the same time, we have seen the Chinese Communist Party (CCP) adopt a long-term lunar strategy that relies on their Tiangong space station and other elements of shared space infrastructure to leverage new opportunities to engage in space diplomacy and attempt to establish the norms and standards for the next frontier of space, including in-space manufacturing, engineering, and research. And yet, the President's FY2026 Budget Proposal for NASA would have the United States walk away from many existing and planned international partnerships.

a. What is the strategic value to the United States of pursuing partnerships and investments with emerging space countries? What risks are associated with such partnerships?

Response

The strategic value of pursuing partnerships with emerging space countries is significant. Such partnerships:

- 1) Improve NASA's missions, from conducting additional data analysis to in-kind contributions of instruments and hardware. Such contributions can enable NASA to avoid the cost of developing critical hardware. With the diffusion of advanced space capabilities worldwide, some emerging space programs can now provide sophisticated, valuable and mutually beneficial contributions to major NASA missions.
- 2) Enhance US soft power through space diplomacy. Cooperation on NASA missions generates significant good will in emerging space nations, which in turn helps to advance US strategic goals in space and other areas. China similarly partners with nations to advance its own goals.
- 3) Create normative coalitions and alignment with our allies. As we partner with countries, we also encourage a number of important norms such as free and open exchange of scientific data, transparency in space operations and, utilizing space for peaceful purposes. All of these norms reflect core democratic ideals that are in the US interest to strengthen worldwide.

Placing a partner in the critical path on a mission can introduce risk. International partnerships can deepen mission complexity and introduce schedule slip. However, a 2016 NASA OIG examination international collaboration found reduced cost growth in comparison to NASA-only and US interagency missions.²

b. The President's FY2026 Budget Proposal proposes the cancellation of several NASA – European Space Agency (ESA) partnerships, including those under the Lunar Gateway program and the Mars Sample Return program. If ESA moves beyond its traditionally strong ties with NASA and focuses on new collaborations, what repercussive consequences might it have on the ability of both the CCP and the United States to engage other non-European partners?

Response

The European Space Agency has historically been one of NASA's most important and steadfast partners. Only a small handful of nations and supranational organizations can cooperate with NASA at the highest levels of technical sophistication and mission complexity across the spectrum of activities from space observatories to human spaceflight. Any further degradation of the relationship due to the cancellation of core joint projects may have far-reaching consequences for NASA's ability to lead the world in spaceflight. Rather than strengthening an allied group of like-minded democracies, it could lead to a splintering with the Europeans, Americans and Chinese vying for engagement with other nations. This would likely provide some net benefits to emerging nations, which would gain advantage in negotiations to join missions on favorable terms. However, future missions would likely be smaller in nature, and more limited in scale. The assembly of the International Space Station was a monumental diplomatic effort that could not easily be achieved in a fractured or contested multi-polar global environment.

² IG-16-020. "NASA's International Partnerships: Capability, Benefits, and Challenges"

Questions submitted by Rep. Bill Foster

1. Are you aware of any investigations into the implications of an explosion during refueling of a starship-like vehicle in low-earth orbit, in terms of orbital debris and potential damage to planned constellations of satellites in LEO including the Golden Dome satellite deployment? If so, what did those studies find?

Response

I am not aware of any investigations into the implications of an explosion during refueling of a Starship-like vehicle in low-Earth orbit. A key concern related to satellites and crewed platforms in LEO would be the refueling altitude and whether an over-pressurization event could cast debris into higher orbits.

On March 14, 2024, during the flight phase of the IFT-3 mission, SpaceX conducted an internal transfer of thousands of pounds of cryogenic propellant between internal tanks. This in part fulfilled a NASA-sponsored technology demonstration related to cryogenic propellant management.³

³ Sources: NASA ESDMD: <https://www.nasa.gov/directorates/esdmd/artemis-campaign-development-division/human-landing-system-program/nasa-artemis-mission-progresses-with-spacex-starship-test-flight/>, NASA Tipping Point: <https://techport.nasa.gov/projects/116764>

Responses by Dr. Michael D. Griffin

House of Representatives
Committee on Science, Space and Technology

Hearing
on

Strategic Trajectories: Assessing China's Space Rise and Threats to U.S. Leadership

4 December 2025

Witness
Michael D. Griffin

Questions for the Record

Questions submitted by Chairman Mike Haridopolos

1. In order to enable both of its landings on the far side of the Moon, the CCP deployed a communications relay satellite into cis-lunar space. This first step represents only the beginning of the CCP's interest in deploying satellites and other capabilities into cis-lunar as well as other deep-space destinations. In fact, the CCP has proposed developing comprehensive communications and positioning, navigation, and timing, or PNT, capabilities for the cislunar domain. What progress has the CCP made in developing cislunar communications and PNT capabilities? How do the PRC's assets and capabilities compare to the systems the U.S. operates in lunar orbit? And, what are the national security implications of the CCP possessing and expanding its cislunar communications and PNT capabilities?

I do not know what progress China has made in developing cislunar comms and PNT capabilities, and I do not know how it compares to what we have in lunar orbit.

The national security implication of Chinese development of lunar comms and PNT in cislunar space when we have no comparable capability is that they will set the *de facto* standards for the future of those systems in cislunar space. As other nations begin to engage in cislunar and lunar operations, human or robotic, they will inevitably adopt the easiest course of action, which will be to adopt Chinese standards and in many cases to use Chinese hardware. This cannot possibly be good for the United States and the West.

2. The U.S. and the PRC have at times engaged in exchanges and cooperation on space issues. Between 2015 and 2016, for example, the two sides convened two rounds each of a U.S.-China Civil Space Dialogue and a U.S.-China Space Security Exchange. Some experts have called for a renewed dialogue with the PRC about space, particularly about the challenges posed by orbital debris. Others have suggested starting with a U.S.-PRC working group on joint astronaut rescue operations, building on the UN Rescue and Return of Astronauts Agreement. What is your opinion of proposals to renew U.S.-PRC dialogue and/or exchanges on space topics?

I would always prefer to talk with a potential or actual adversary than to opt for isolation. Because we are a largely free and open society, our thinking and capabilities are generally known to others. We know less about a regimented, closed society such as the Chinese Communist Party (CCP) imposes on the Chinese people. It will be to our advantage to work with them on projects of mutual interest because we will always gain more knowledge about how they think and what their capabilities are than they can gain from such interactions. It is also the only way we have to influence them and their choices on technology and standards. Yes, there is a risk to such engagements but in my view we risk less than we gain. Knowledge of PRC power structures, communications, decision making, etc., may also help to lessen tensions. Avoiding open conflict, where it can be avoided, is a worthy goal that is supported by communication and collaboration in non-threatening areas.

3. Given Chinese operational and planned space planes, is there an increasingly urgent need for comparable or superior U.S. capabilities?

Yes, but not just for spaceplanes. It is of fundamental importance to the future of our nation and its position in global power politics that we do not allow China to possess any capability in the space, air, and maritime domains that we do not possess and which is inferior to that which they have. China as governed by the CCP is a self-declared adversary of the U.S. Despite their adversarial stance, it is desirable to avoid open war between the U.S. and the PRC. This goal is best served by being so dominant in all relevant domains that the PRC will continue to decline to engage militarily because they know they cannot win.

Questions submitted by Full Committee Chairman Brian Babin

1. The Chinese Communist Party appears to be making steady progress on its work to enable a crewed lunar landing by the end of the decade. The CCP has tested key systems required for a crewed lunar landing, including a test of its lunar landing and ascent capabilities this past August. This suggests that China could be ready to carry out such a mission by the end of the decade. Can you speak to the specific milestones that China still has to meet before it can attempt a crewed lunar landing, and on what timeline do you anticipate the CCP will complete these milestones? What events (such as uncrewed launch vehicle tests, crewed Lunar flybys, or uncrewed landings) should we be watching for to measure if they are on track for a 2030 landing? When would we expect those events to take place, and what impact would delays to those events have on their overall schedule?

I cannot speak to the “specific” milestones the CCP must meet before attempting a manned lunar landing, because the selection of such milestones depends critically on the level of risk they are willing to take and other factors not known and potentially not knowable. I will say that all of the various elements that are required for such a mission are either demonstrated or in work, e.g., heavy lift launch, lunar lander, lunar surface suits, lunar rover and Earth return vehicle. The Chinese have not hidden their plans or their progress in tests. I suggest that we can learn what we need to know by studying publicly released material. The problem for the U.S. is not that we do not know what the CCP is doing; the problem is that we do not seem to care.

2. China has made clear its intent to overtake the U.S. and become the global leader in space. While lunar exploration stands as a top priority for the PRC, it's among a growing range of national space projects and programs. The expansion of China's space activities highlights its interest in leading not only on the Moon, but in all aspects of space. How does lunar exploration fit into China's broader space exploration goals, and what role does it play in supporting the PRC's space leadership ambitions?

In my opinion, lunar exploration and settlement fits into China's broader goals not solely because of what space offers militarily, but because at this point it is so clearly beyond what the U.S. can do and so technically and organizationally impressive that it presents the world's lesser powers with a choice we would rather they did not have: aligning with the U.S., or with China. In a world consisting of three major nuclear powers and many smaller nations, it can never be in our interest for those nations to decide that their future lies with China. Like the U.S., China views space through military, economic, and "soft-power" lenses and the strategic advantage it offers in all of those (just as they do other domains).

Questions submitted by Rep. Daniel Webster

1. Would one way to ensure dominance be for the United States to promote voluntary, consensus-based standards that are developed by the private sector?

It is probably best to have standards developed in the manner exemplified by the work of professional society standards bodies such as AIAA, ASME, IEEE, 3GPP, etc. But what matters is not who develops them, but that they be promulgated into cislunar space and beyond by the United States and Western nations and not the CCP. The only way to ensure that U.S. standards become world standards is to be present on the space frontier. The standards will be determined by those who are there, not by those who stay home.

The other point that should be made is that the CCP completely understands the importance of setting global standards. It is the case that standards bodies such as IEEE and 3GPP have significant Chinese presence and influence. To the point made in my testimony, competition in this arena also has no finish line.

2. Would this cornerstone of America's standardization system work to counter the Chinese Communist Party's attempts to reset international norms and standards?

Yes.

Questions submitted by Rep. Bill Foster

1. Are you aware of any investigations into the implications of an explosion during refueling of a starship-like vehicle in low-earth orbit, in terms of orbital debris and potential damage to

planned constellations of satellites in LEO including the Golden Dome satellite deployment? If so, what did those studies find?

No, I am not aware of such a study.

Questions submitted by Rep. Keith Self

1. Lagrange regions, especially L1 and L2, are prime real estate for persistent lunar communications relay and navigation support, and as cislunar space becomes contested, showing up occasionally will not hold terrain. The advantage will go to whoever fields reliable, interoperable services that others plug into, including communications relay, positioning navigation and timing beacons, and space domain awareness, built quickly enough to matter and procured in a way that pulls in private capital rather than waiting on slow bespoke government builds. L1 and L2 are prime real estate for lunar communications and navigation relay, and the cislunar theater is becoming contested. What is the minimum architecture the United States should deploy at or near L1 through L5 including relay, positioning navigation and timing beacons, space domain awareness sensors, and data transport, and what is the fastest procurement model to do it?

I do not know what the “minimum architecture” is that the U.S. should deploy, but regarding the type of assets to be deployed, I think the question itself contains the answers: PNT beacons, space domain awareness sensors, and comms transport would be high on my list. Whether they should be positioned at one or more of the Lagrange points is a matter for study; I would caution against an automatic assumption that those are the most advantageous orbital positions. Also, it is not so much a matter of “holding terrain” in cislunar space – it is an enormous region with plenty of room for all – as it is that we make certain that our standards and protocols and hence our systems are the infrastructure of choice in this domain.

2. China is increasingly shifting from one off missions to durable cislunar infrastructure. The difference is decisive because persistent logistics and continuous communications and navigation coverage create real operating advantage and let the first mover shape standards, norms, and access in ways that disadvantage competitors and constrain allied operations. What’s your estimate for when China can sustain (a) continuous crewed presence, (b) continuous robotic operations, and (c) continuous logistics and communications coverage in cislunar space, and what indicators should Congress watch?

Your first two sentences are the essence of my testimony! For schedule estimates, I will offer that Items (a)-(c) could reasonably be accomplished at present or in the near term. I do not believe there is an early need for crewed cislunar presence, and I doubt the CCP would deploy a manned station in cislunar space anytime soon, but they could do it if they determined it to be advantageous for some reason that I am missing. Items (b) and (c) could be done at any time they wish; these items do offer an obvious and significant warfighting advantage, and I would not want to guarantee that the CCP is not already doing them. Such activities cannot be easily monitored from Earth, and possibly not at all, as far as I know we do not have any deployed space domain awareness systems in cislunar space, and I do not

believe there are “indicators” the Congress can “watch” on this topic. With luck, our intelligence apparatus might be able to provide information as to what China is doing to prepare for conflict on Earth by storing warfighting reserves in cislunar space. However, I have no personal knowledge of this matter and, if I did, could not comment on it in an open hearing.

3. China’s civil military fusion collapses any neat separation between commercial capability and state capability, so dual use transfer risk is structural, not hypothetical. As China advances in these capabilities, what targeted export controls should the United States implement to protect the most sensitive rendezvous, proximity, and servicing enablers while preserving the competitiveness of legitimate U.S. commercial space industry?

In my opinion, none. Export controls are not, in general, an effective long term means of stifling adversary activity in a given area. For short periods of time, e.g., a few years, yes, export controls can work. Over longer time scales, adversaries will simply learn to replicate what we are trying to prevent them from obtaining. Export controls also prevent us from promulgating to others the standards and practices that we find beneficial. As a canonical example of this point, the relaxation of export controls on commercial encryption has enabled the U.S. to benefit more from e-commerce than any other country. Bottom line: we should play the long game, emphasizing and enhancing our industry’s ability to compete on the world market. The way to stay ahead of an adversary like China is not to try to constrain their behavior – there is no effective way to do that – but to do what winners do: work harder and smarter and rely on the free-market capitalism that got us to the position we occupy in the world economy.

4. In your view, have we lost sight of building sustainable lunar infrastructure and drifted back toward a flags and footprints approach rather than creating a sustained presence?

Knowledgeable space professionals understand that Apollo did not have to be about “flags and footprints”. As pointed out in my testimony, Apollo missions to the Moon and the buildup of lunar infrastructure to support a sustained presence could have been continued even through the low point of NASA’s budget in the 1970s. The “flags and footprints” program that we look back on, where \$21 B in then-year dollars was spent to develop a new-to-the-world capability and only \$4 B was spent to use it before the capability was summarily destroyed, did not have to occur. A variety of factors contributed to the abandonment of lunar exploration in the Apollo era, but as pointed out in my testimony, one of the most significant of those was the view at the time that we were in a race with the Soviet Union and, having won the race, there was no reason to continue. For a great nation, pioneering the frontiers of its time is not a “race”, it is a lifestyle. It is my hope that this point will come to be more broadly understood, that the next step in space exploration is to pioneer the Moon, meaning to go there again and begin the long and arduous challenge of settling and extracting economic benefit from it.

But with that said, and again per my testimony, the most urgent problem that we must solve is that we are going about that task in the wrong way. Those in charge of the task believe their approach will work; it will not. Until and unless we adopt more appropriate tactics for

the exploration and development of cislunar space and the Moon, the strategic importance of sustained presence cannot be realized.

5. If we know we still have work to do to perfect crewed lunar landing capability, why are we not using the intervening years to pre-position and stockpile critical supplies and infrastructure on the lunar surface now so a sustained presence becomes inevitable rather than aspirational?

You are repeating what I have advocated for decades that the U.S. should do. The United States should have a rational program for returning to, exploring, exploiting, and pioneering the Moon as a first step on the road to bringing the resources of the Solar System into mankind's economic sphere. We could and should be doing these things now, and we are not. If they were the priority that I think they should be, we would be doing them.

However, you are not asking what we should do; you are asking why we are not doing what is obviously necessary. I cannot explain why people are not pursuing the obvious.

6. The Administration says the United States must dramatically increase launch cadence by 2030 and has directed agencies to streamline commercial space licensing. We should be able to point to measurable changes in processing time, predictability, and throughput. The Administration has directed the streamlining of commercial space licensing to increase cadence by 2030. What changes are actually happening on the ground, and where is it still performative?

I am not part of the Administration, do not know what they are doing to streamline commercial launch licensing, and have no ideas as to whether it has proved or is proving to be more effective than past practice. I hope this is the case, as there was, and likely still is, much improvement to be made. But I cannot answer your question.

7. While we slept, China executed a decades-long plan to become the world's leader in critical materials. We are finally waking up, and taking the first steps to catch up. But I want to look at a critical material that many people have not yet focused on: helium-3. It's an isotope of helium that is extremely rare on Earth, and is necessary for cooling some kinds of quantum computers almost to absolute zero so they can operate. If you believe, as I do, that quantum computing will revolutionize national security and the economy, then we have to have a steady supply of helium-3. Helium-3 is so rare on Earth that it makes sense to go to the Moon to get it. The bad news is that China is planning to do just that, but the good news is that we don't have to give them a head start. We can add helium-3 missions to the Artemis program and ensure that we have the critical material we need to drive the quantum revolution. Do you think we should pursue this or should we let China add to its critical material advantage?

I do not believe, as you do, that quantum computing will "revolutionize national security and the economy" in the near term. Whether it will in the longer term is still an open question; although progress is being made, there is significant hype in this domain. Nor, granting your assumption, do I believe that Helium-3 will be critical to the development and deployment of quantum computers, should they ultimately prove to be effective at important tasks. But if I again grant your assumption that it will, and that mining it from the Moon will be cheaper than, say, obtaining it from subsurface helium vents, there is plenty of it to go around on the

Moon. Extracting it from the lunar regolith will be a significant engineering challenge, but it can certainly be done if there is an economic incentive to do so. We do not need to compete with China to obtain Helium-3 from the Moon.

