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China's Pursuit of Space Power Status and Implications for the United States

Alexander Bowe, Policy Analyst, Security and Foreign Affairs

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Executive Summary

- China seeks to become a peer in technology and status of the United States in space. Although China still lags behind the United States in some areas, given the fact that in at least one key area it is likely to accomplish in 20 years what took the United States 40 years to complete, it will likely achieve other important milestones more quickly than the United States did in the past.
- China's successful deployment of a lander to the moon's far side, the first in history, clearly demonstrates Beijing's ability and desire to achieve increasingly sophisticated milestones in space. It is likely a Chinese crewed lunar mission will launch by the mid-2030s.
- China's deliberate and comprehensive approach to its space program, backed by high levels of funding and political support, has allowed it to attain domestic legitimacy and international prestige. China will probably launch, assemble, and operate a long-term space station before 2025 and has invited international partners to participate in its use.

Introduction

China seeks to become an international leader in space, or what it terms a "space power in all respects." In this role, Beijing aspires to lead international space-related innovation and exploration and establish an advanced system of infrastructure to serve its space sector.[1] China has suffered some setbacks on projects crucial for the progression of program milestones, such as its heavy-lift launch vehicle program, and still lags behind the United States in its human spaceflight and space station program.[2] Nevertheless, China's space program is a source of national pride, and its consistent high level of political support and funding ensures progress toward establishing itself as a space power.[3] In 2003, China joined the United States and Russia as a member of the exclusive group of countries to have conducted human spaceflight, and since then it has nearly completed a new, rival global navigation satellite system (GNSS)—set for completion in 2020[4]—and demonstrated its willingness to undertake high-risk, high-reward missions, as reflected by its historic landing on the moon's far side in 2019.[5] China is likely to achieve future milestones in areas where it is lagging behind international standards on shorter timetables than when the United States accomplished similar missions.

This report examines China's space goals and national space strategy; its progress toward those goals, including an examination of China's progress in its advanced launch vehicle, long-term crewed space station, and lunar exploration programs; and the primary entities involved in setting and implementing its space policy. Finally, the report assesses the implications of China's space program for the United States and its continued leadership in space.

China's Space Strategy and Goals

China has clearly outlined its ambitions to be a global leader in space and is now competing with the United States in technology and status in such endeavors as robotic probe missions and international space cooperation.[6] According to Chinese President and General Secretary of the Chinese Communist Party (CCP) Xi Jinping, China's "space dream" is to "[unflaggingly pursue] exploring the vast universe, developing aerospace enterprises, and building a strong aerospace country."[7] Wu Yanhua, vice administrator of the Chinese agency responsible for raising the international profile of China's space program, claimed in January 2017 that China's goal is to be a major global space power by around 2030, and China's primary state-owned space contractor has stated China aims to be a global leader in space equipment and technology by 2045.[8] These goals are consistent with the important role China's leaders have assigned to China's space program as part of the country's attempts to advance its national interests and build up national strength.[9] Beijing's goal is to become the United States' peer in space militarily, diplomatically, commercially, and economically.[10] If China continues to meet its declared space goals, it may be the only country to have an active space station after U.S. government funding for the International Space Station

(ISS) ends in 2024, and it may begin to establish a research station on the moon by 2025.[*] [11] In May 2018, the military office overseeing China's human spaceflight program announced UN member countries will have the opportunity to use China's space station for scientific research, demonstrating Beijing's ability to benefit diplomatically from identifying and addressing potential gaps in the international community's space needs.[12]

Beijing consistently invests high levels of funding and political will to its space program, which has driven its steady progress in achieving important milestones.[†] [13] This support, along with a focus on improving and standardizing the quality of manufactured components, has helped create a mature space program whose development was previously constrained by poor infrastructure and less advanced technology.[14] Compared to the U.S. space program, China's program is also more connected to the "levers of power," meaning its goals more often draw support from top leaders and are interconnected with the overall priorities of China's industrial and foreign policies.[15] China's deliberate and comprehensive approach to its space program gives it opportunities to derive important economic, political, and diplomatic benefits, including domestic legitimacy, international prestige, and access to tasking information and observational data derived by international clients using its space platforms.[16] For example, China's Beidou GNSS is a vital component in the Belt and Road Initiative (BRI) as part of the Digital Silk Road.[17] According to one high-ranking government official overseeing information technology policy, the Digital Silk Road will help establish "a community of common destiny in cyberspace," invoking a slogan Beijing uses to describe a revised global order more accommodating to its political and economic system .[18]

Beidou does not directly compete with the U.S.-built Global Positioning System (GPS)—since both services are available for free and a majority of receivers can access multiple satellite constellations[‡]—but it is nevertheless a tool of geopolitical and diplomatic competition for China.[19] China is actively promoting the use of Beidou and other satellites among BRI participants, including for military use.[20] For instance, following a 2013 agreement, Pakistan was the first partner country to be granted access to Beidou's restricted high-precision signal for military use.[21] According to the *New York Times*, Pakistan's use of the system is intended to be a model for Beidou's expansion to other BRI participants.[§] [22] More recently, in addition to its promotion of Beidou, in January 2019 China

[*] It is still possible the ISS's use may be extended to 2030. Jeff Foust, "Cruz Plans to Try Again with Commercial Space Legislation," *Space News*, January 16, 2019. *https://spacenews.com/cruz-plans-to-try-again-with-commercial-space-legislation/*.

[†] The Organization for Economic Cooperation and Development estimated China's combined military and civil space budget in 2005 was $1.5 billion in purchasing power parity, the fourth-largest of any single country, compared to the U.S. space budget that year of $36.6 billion, the largest. China's budget increased to $6.1 billion and $10.8 billion in 2009 and 2013, respectively, the world's second largest in those years, after the U.S. budgets of $43.6 billion and $39.3 billion. Beijing does not release accurate cost data on military goods and services, so purchasing power parity conversions are not entirely reliable, however. Center for Strategic and International Studies, "What Does China Really Spend on Its Military?" 2018. *https://chinapower.csis.org/military-spending/*; Organization for Economic Cooperation and Development, "The Space Economy at a Glance 2014," October 23, 2014, 18. *https://www.oecd-ilibrary.org/docserver/9789264217294-en.pdf/*; Organization for Economic Cooperation and Development, "The Space Economy at a Glance 2011," July 22, 2011, 53. *https://www.oecd-ilibrary.org/docserver/9789264113565-6-en.pdf*; Organization for Economic Cooperation and Development, "The Space Economy at a Glance 2007," October 16, 2007, 37. *https://www.oecd-ilibrary.org/docserver/9789264040847-en.pdf*.

[‡] There are four dominant GNSS constellations: GPS, China's Beidou, Russia's GLONASS, and the EU's GALILEO. According to a 2018 report by the EU GNSS Agency, about 30 percent of all GNSS receivers are compatible with all four constellations, about 35 percent are compatible with either two or three constellations, and about 30 percent are compatible with GPS only. European GNSS Agency, *GNSS User Technology Report*, October 2018, 20. *https://galileognss.eu/wp-content/uploads/2018/10/gnss-user-tech-report-2018.pdf*.

[§] The Beidou network is expected to achieve global coverage with a total of 35 satellites by 2020, comprising a 27-satellite global constellation and a separate network of satellites providing redundant coverage over Asia. According to the Test and Assessment Research Center of the China Satellite Navigation Office, as of April 2019 there were 33 operational Beidou satellites, comprising 15 Beidou-2 and 18 Beidou-3, plus five Beidou-3 and Beidou-3S satellites in testing. Defense Intelligence Agency, *China Military Power: Modernizing a Force to Fight and Win*, January 3, 2019, 42. *http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/China_Military_Power_FINAL_5MB_20190103.pdf*; Test and Assessment Research Center of China Satellite Navigation Office, "System Basic Info." Translation. *http://www.csno-tarc.cn/system/constellation*; U.S.-China Economic and Security Review Commission, *2018 Annual Report to Congress*, November 2018, 178–179; Jordan Wilson, "China's Alternative to GPS and Its Implications for the United States," *U.S.-China Economic and Security Review Commission*, January 5, 2017, 3. *https://www.uscc.gov/sites/default/files/Research/Staff%20Report_China%27s%20Alternative%20to%20GPS%20and%20Implications%20for%20the%20United%20States.pdf*; Information Office of the State Council of The People's Republic of China, *China's BeiDou Navigation Satellite System*, June 16, 2016. *http://www.china.org.cn/government/whitepaper/node_7238634.htm*.

established a new remote sensing satellite data center in Fuzhou, Fujian Province that Beijing has billed as part of its Maritime Silk Road, the maritime component of the BRI.[23] China claims the new data center—which is able to receive, store, process, and distribute data from 26 Chinese Yaogan remote sensing satellites—will promote information integration between Fujian and Association of Southeast Asian Nations countries, provide services to BRI countries, and promote integration between Taiwan and the Chinese Mainland.[24]

The People's Liberation Army's (PLA) Strategic Support Force (SSF), a new service of China's armed forces established in late 2015, is responsible for most of the military's space warfare mission alongside its responsibility for cyber, electronic, and psychological warfare.[25] China's military—especially the SSF and the Central Military Commission Equipment Development Department (EDD)—plays an important role in organizing and overseeing China's space activities, meaning most of China's ostensibly civilian space activities have dual-use applications.[*] [26] China's space policy in effect allows Beijing to continue developing military space capabilities while publicly claiming to oppose militarization of space.[27] Both Beidou and GPS have capabilities that extend beyond civilian applications; for instance, Beidou has the potential to improve China's missile guidance and ultimately reduce its reliance on GPS.[28] China's activities with more direct military application include direct-ascent antisatellite missiles, which are capable of striking targets passing over China; co-orbital systems, or small space-based platforms that could be used for a variety of "rendezvous and proximity" counterspace missions; and advanced scramjet engines, which may be used in both hypersonic missiles and a future spaceplane.[†] [29]

Space white papers published by China's State Council, a civilian body, outline China's space ambitions and highlight its accomplishments, showing a clear progression as China attempts to catch up with established space powers, and then sets out its ambitions to actively compete in cutting-edge technological advances.[30] White papers published in 2000, 2006, 2011, and 2016 document China's definition of goals and achievements since 1956 including the expectation that the space program will follow a strategic plan and strengthen innovation leading to lunar exploration, space stations, and the establishment of China as a leading space power.[31] Specifically, China's 2011 space white paper announced China would conduct feasibility studies for a crewed lunar mission and retrieve lunar samples.[32] China's 2016 space white paper stated Beijing's intent to complete a "stable and reliable space infrastructure" by 2021, comprising improved satellite systems and a space-ground integrated information network as well as improving standards and measurements and removing bottlenecks to scientific advancements.[33] The 2016 space white paper also announced Beijing's intent to launch a probe to the far side of the moon in 2018 and to carry out feasibility studies of technological requirements for a robotic mission to the Jupiter system, though the latter program has not yet been officially approved.[34]

Approval Process for Space Programs

Beijing approves its space programs at the policy level only after identifying the precise technological components required for the project and completing a feasibility study.[35] State-owned defense contractors and official research institutions carry out feasibility studies, which can also take political justification into account.[36] For example, in the late 1980s, as Beijing grappled with a struggling economy and containing the fallout from the Tiananmen Massacre, political opponents of the expensive human spaceflight program argued resources would be better spent

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[*] The U.S. National Aeronautics and Space Administration (NASA) is a civilian agency, designed to be distinct from Department of Defense-run military space operations. Soon after the January 1958 launch of the first U.S. satellite, which was developed by the Army, President Dwight Eisenhower's intention to clearly separate civilian and military space activities as the United States entered the Space Age led to NASA's creation. National Aeronautics and Space Act § 20102, Pub. L. No. 111–314, December 18, 2010. *https://www.nasa.gov/sites/default/files/atoms/files/public_law_111-314-title_51_national_and_commercial_space_programs_dec._18_2010.pdf*; Patricia Moloney Figliola et al., "U.S. Space Programs: Civilian, Military, and Commercial," *Congressional Research Service*, June 13, 2006, 1. *https://fas.org/sgp/crs/space/IB92011.pdf*.

[†] For information on China's military space activities, see Tate Nurkin, "China's Advanced Weapons Systems," (prepared for the U.S.-China Economic and Security Review Commission), May 12, 2018. *https://www.uscc.gov/sites/default/files/Research/Jane%27s%20by%20IHS%20Markit_China%27s%20Advanced%20Weapons%20Systems.pdf*; U.S.-China Economic and Security Review Commission, Chapter 4, Section 2, "China's Pursuit of Advanced Weapons," in *2017 Annual Report to Congress*, November 2017.

elsewhere.[37] In some cases, policymakers plan a program and set national goals but withhold formal approval until researchers have proven the requisite technologies. For example, the 2016 space white paper declared China's intent to research technologies necessary for "low-cost launch vehicles, new upper stage [rockets], and [a] reusable space transportation system [to] low-Earth orbit (LEO)," which China views as necessary to achieve its stated goal of establishing a "stable and reliable space infrastructure."[38] It also describes the need to make breakthroughs in key technologies such as high-thrust liquid oxygen and kerosene engines before the Long March-9 (LM) heavy-lift launch vehicle program can be officially approved.[39]

Steady Progress in Key Programs

Several key programs are especially important for China's space power ambitions: the development of advanced launch vehicles, a long-term crewed space station, and a crewed lunar mission. Each of these projects has successfully met important milestones, although it remains to be seen whether each will be completed on schedule. New launch vehicles are crucial for the success of China's human spaceflight programs, including its planned space station and crewed lunar mission—potentially to include long-term research stations on the lunar surface—and China is determined to perfect new rockets despite encountering some difficulties. China's space station program has successfully overseen the launch and operation of several temporary labs, and its lunar exploration program has rapidly achieved important milestones, including landing an exploration rover on the far side of the moon—a technological achievement no other country has accomplished.

Advanced Launch Vehicle Program Moves Ahead Despite Delays

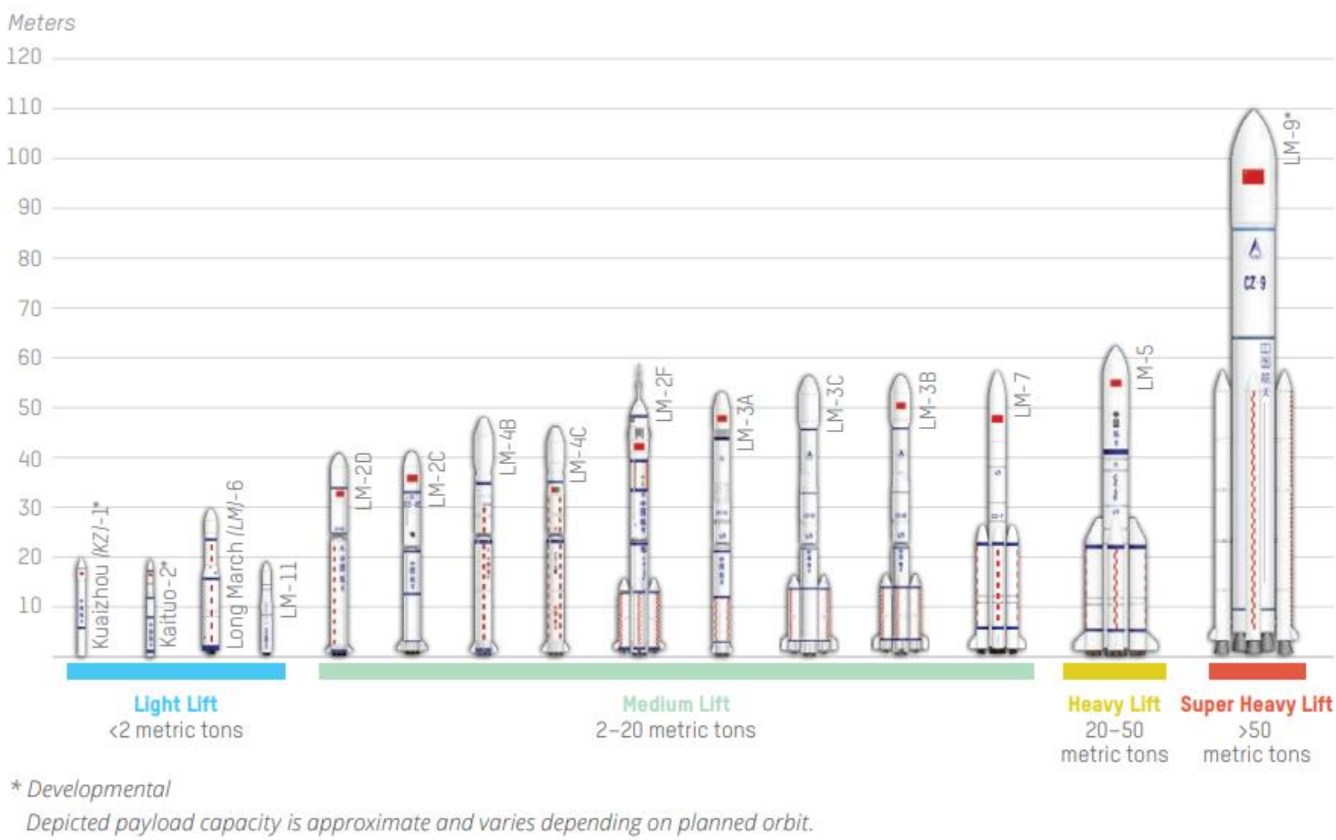
China is currently capable of launching space vehicles to any Earth orbit, but it has not yet perfected advanced launch vehicles necessary to achieve its most important space goals, such as launching crewed lunar missions.[40] New super heavy-lift launch vehicles rivaling the U.S.-made Saturn V, first launched in 1967 and still the most powerful ever to fly successfully, are especially crucial.[*] [41] China's 2016 space white paper identified the implementation of "new-generation launch vehicles" as a major task for the next five years, and according to the 2017 contractor's roadmap, Chinese rockets are planned to reach "international mainstream standards" by 2020 and thus begin to provide "diversified commercial launch services" globally.[42] China's future plans depend in part on the success of the crucial LM-5 heavy-lift launch vehicle, the lift capacity of which is 27.6 tons to LEO and 15.4 tons to geosynchronous orbit, more than doubling the maximum payload mass China can currently deliver to these altitudes.[43] According to Harvard University's Jonathan McDowell, the LM-5 is China's "flagship rocket" and is "key for [China's] ambitions.... They've got to get this right."[44]

The heavy-lift LM-5 and the future LM-9 super heavy-lift launch vehicles are China's most important launch vehicle projects and rely on new technologies, materials, manufacturing techniques, and equipment.[45] China is also working on technology for reusable rockets, which will debut with the LM-8 around 2021; once this technology is mature, other LM versions will likely also adopt it.[46] According to the lead designers of the LM-5, unlike previous LM rockets that reused proven technology from prior generations, almost all of the LM-5's design is new, and China will use this new technology to upgrade its other rockets.[47] Following a successful first launch in 2016, however, the July 2017 second LM-5 launch failed due to problems with the first-stage engine's exhaust system.[48] The planned launch of a key robotic lunar probe mission which requires the LM-5's lift capability was delayed until July 2019 because of this failure.[49] In 2018, the U.S. Department of Defense's annual report on China's military

[*] The United States has not had its own launch system for crewed spaceflight since the Space Shuttle program ended in 2011, and it currently relies on Russian Soyuz rockets to access the ISS. The forthcoming super heavy-lift Space Launch System (SLS), which has been in development since 2011 and is a priority of the Trump Administration, will eventually send U.S. astronauts to Mars by the late 2030s using the same RS-25 rockets that powered the Space Shuttle in the 1980s. The SLS will ultimately have a payload to LEO of 143 tons, compared to the Saturn V's payload to LEO of about 122 tons. *Economist*, "Why Does America Still Use Soyuz Rockets to Put Its Astronauts in Space?" October 16, 2018. *https://www.economist.com/the-economist-explains/2018/10/16/why-does-america-still-use-soyuz-rockets-to-put-its-astronauts-in-space*; Mike Wall, "Yes, NASA's New Megarocket Will Be More Powerful than the Saturn V," *Space*, August 16, 2016. *https://www.space.com/33691-space-launch-system-most-powerful-rocket.html*; National Aeronautics and Space Administration, "What Is the RS-25 Engine?" August 10, 2015. *https://www.nasa.gov/exploration/systems/sls/multimedia/rs-25-engine-infographic.html*.

power cited "key [Chinese] government officials" as saying this accident—along with the partial failure of an LM-3B launch as a result of faulty guidance, navigation, and control—created "significant delays" in China's national space program.[50] The LM-5 is also necessary for China's planned sixth moon probe in 2019, the first module of the long-term crewed space station beginning in 2020, a Mars probe mission in 2020, and a probe mission to Jupiter in the 2020s.[51] It remains likely China will complete a crewed lunar mission by the mid-2030s, using either an LM-9 or a similar rocket.[52] The LM-9 would be about six times more powerful than the LM-5, with a total thrust similar to that of the Saturn V that carried U.S. Apollo missions to the moon.[53] In March 2018, a Chinese aerospace official confirmed a demonstration version of a first-stage LM-9 engine was in progress, potentially to be completed by the end of 2018, though the full LM-9 program had yet to receive approval.[54] The LM-9 is currently undergoing feasibility studies and will likely not fly before 2030.[55] According to Andrew Jones, a reporter who covers China's space program, if a separate, currently unnamed heavy lift rocket which has been undergoing feasibility studies since 2016 is approved, this would be "a clear indication that China wants to speed up its apparent crewed lunar landing plans" to before the mid-2030s.[56]

Figure 1: Chinese Space Launch Vehicles



Source: *Defense Intelligence Agency*, Challenges to Security in Space, February 11, 2019, 16. http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf.

Ambitions for Long-Term Crewed Space Station before 2025

Since early in the Shenzhou spacecraft program, which saw its first launches in the late 1990s and early 2000s, the goal of China's human spaceflight project has been to establish a long-term crewed station, known as the China Space Station (CSS).[57] The U.S. Department of Defense assessed in 2018 China will probably "launch, assemble in-orbit, and operate" the CSS before 2025.[58] China's earliest space station designs during the mid-1990s depicted a station comparable to the Soviet Union's Salyut—the world's first space station, launched in 1971—and in 2000, Russia confirmed it was helping China design such a station.[59] Beijing planned to emulate the Soviet Union's model of occupying such a station temporarily and then permanently, and launched its first Tiangong space lab in 2011.[60]

According to Joan Johnson-Freese, professor at the U.S. Naval War College, the Tiangong space laboratories "are not space stations intended for long-term use, or to be permanently crewed, but form the basis for a small laboratory to test technologies ... including rendezvous, docking, and life support."[61] Beijing's 2016 space white paper said the fall 2016 rendezvous and assembly in space of Tiangong-2 and the crewed Shenzhou-11 spacecraft demonstrated China's mastery of these technologies as well as space extravehicular activity and long-term ground mission support.[62] Tiangong-2 is currently set to perform a controlled de-orbiting sometime after July 2019.[63]

China uses its human spaceflight programs to prove the technological feasibility for follow-on projects necessary for the eventual launch and operation of the CSS. Zhu Congpeng, chief designer of Tiangong-2, said in October 2016 Tiangong-2 would "make a breakthrough in providing fuel and supplies and medium-term residence for personnel."[64] For example, water and food sustainability design was taken into account in preparation for a 30-day crewed mission.[65] The space lab has tested life support, propulsion systems, orbital refueling, and docking tests; its experiments served as a basis for later development of a CSS that can support life for months.[66] According to the China Manned Space Agency, the initial CSS will weigh approximately 66 tons, or about one-seventh the mass of the ISS, and it will have a number of payload racks available for use by foreign partners.[67] The CSS, planned to initially comprise a core module plus two experimental modules, will accommodate three to six taikonauts[*] for up to three- to six-month intervals and will have a service life of at least ten years.[68] Tianhe-1, the 20 metric ton core module of the CSS, is currently scheduled to launch in 2020 on an LM-5B.[69] Two science modules are scheduled to launch by the end of 2022, completing the station, and the CSS will have the potential for further expansion; Yang Hong, chief designer of the CSS, said in October 2018 the CSS could accommodate up to three additional modules, eventually increasing its total mass to 160–180 metric tons.[70] In 2017, a high-level aerospace industry official said the CSS project—including cargo and crewed rendezvous missions after the station's assembly—will require more than a dozen launches.[71]

Crewed Lunar Mission Continues to Meet Milestones

Beijing has made substantial progress in its lunar exploration program by rapidly achieving increasingly sophisticated technological victories on the way to an eventual crewed lunar mission, which—according to the U.S. Air Force's National Air and Space Intelligence Center (NASIC)—is planned for 2036.[72] With its soft landing of a robotic probe on the moon's far side in January 2019, Beijing demonstrated clear progress in its space program and the ability to achieve milestones no other country has.[73] China's lunar exploration program has proceeded by launching increasingly advanced robotic probes to demonstrate every major step Beijing originally established in 2004 as prerequisites for a crewed mission to the moon: launch and orbit of a lunar probe, landing of a robotic lunar rover, and lunar sample return.[74]

China's lunar probes have been part of a logical progression designed to culminate in a crewed lunar mission and a planned research station on the lunar surface. Chang'e-4, the most recent and advanced of China's robotic lunar probes and the first in history to land on the far side of the moon, demonstrated China's ability to land and communicate with equipment on the moon's far side, which is necessary for China's future lunar exploration goals.[75] Ye Peijian, chief designer of China's lunar exploration program, argues the far side is scientifically significant because it is possible to conduct electromagnetic research there without interference from radio waves emitted from Earth, since the moon acts as a shield.[76] The official newspaper of the Ministry of Science and Technology, *Science and Technology Daily*, likened the far side to the "holy grail" of locations for a future research base for this reason.[77] Zhao Xiaojin, Party Secretary of the China Academy of Space Technology, a state-owned aerospace research institution, said in March 2018 China hopes to begin construction of such a lunar research station

[*] While functionally the terms astronaut (U.S. usage), cosmonaut (Russian usage), and taikonaut (Chinese usage) may refer to the same profession, each title refers to people trained and certified by different space agencies, each of which has different operational philosophies, knowledge areas, and skill sets. Each term is effectively a specific job title, not just a translation or interchangeable word for a trained professional technician who travels into space and operates a spacecraft. Robert Frost, "What Are the Differences between an Astronaut and a Cosmonaut?" *Forbes*, May 11, 2017. *https://www.forbes.com/sites/quora/2017/05/11/what-are-the-differences-between-an-astronaut-and-a-cosmonaut/#66d4502c3fa7*.

around 2025 and then send taikonauts to the lunar surface around 2030.[78] Finally, China plans to establish a lunar research and development (R&D) base around 2050 that will be primarily robotic but that humans will be able to visit.[79]

Chang'e-4's successful autonomous landing on the far side of the moon was one of the most technologically impressive feats China's space program has accomplished to date, given the uneven landscape in the target location and the need for a relay satellite to facilitate communication with Earth.[80] Dr. Ye also identified the long lunar nights that restrict access to solar power as a major challenge for the mission: due to the lunar night and the inability to provide long-term heating, a mini-biosphere experiment that was part of the mission froze after only a few days, though *Xinhua* cited Chinese researchers as saying it provided data for future attempts to grow food on the moon.[81] China deployed its relay satellite, Queqiao, in May 2018 to a strategically important location[*] above the moon's far side.[82] According to *Xinhua*, Queqiao carries equipment to perform laser ranging experiments to study gravitational waves, and its "umbrella" antenna is the largest ever deployed for deep space exploration.[83] Jeff Gossel, a senior intelligence engineer at NASIC, said in October 2018 Queqiao could potentially function as a relay for an attack spacecraft or weapon to circle around the moon and strike U.S. military satellites in geosynchronous orbit with little to no warning.[84] He added, however, that although the actual threat from Queqiao is probably small, it is important to consider unlikely threat scenarios.[85]

Technologies developed for the Chang'e program will benefit future missions both to the moon and to other celestial bodies, such as Mars. In 2015, Dr. Ye likened the moon and Mars to the Senkaku Islands and the Spratly Islands, respectively, and warned not exploring them may result in a failure to protect China's "space rights and interests," revealing how geopolitically important these milestones are by comparing them to China's self-professed territorial "core interests."[86] According to Dr. Ye, research in preparation for Chang'e-4 will function as a stepping stone for the next probe and China's future lunar and deep space exploration milestones.[87] The Chang'e-5 sample return mission will launch in 2019.[88] Chang'e-6, developed as a backup, will have 10 kilograms of payload capacity available to international partners for sample return and is tentatively scheduled to launch in the early-mid 2020s, targeting the lunar south pole.[89] These probes both require China to perfect technologies necessary for lunar sampling, lunar surface liftoff, lunar orbit docking, and high-speed re-entry to Earth.[90] Chang'e-7 will study the terrain around the lunar south pole, according to Wu Yanhua, and Chang'e-8 will prepare for the construction of the planned research base, which he suggested may be undertaken by China along with other countries.[91] In addition to progress on lunar exploration, Dr. Ye claimed in 2015 Chinese researchers had achieved breakthroughs necessary to explore Mars and asteroids, and he contends China's first Mars probe will streamline the lunar program's earlier discrete goals into one by "orbiting, landing, and roving" in the same mission.[92] Another senior official said China's mission to send a robotic probe to Mars was formally approved by the central government in January 2016 after eight years of preliminary research, and a mission to capture an asteroid had been discussed by senior officials but not yet formally approved.[93] According to NASIC, China intends to launch missions to return samples from an asteroid and from Mars around the mid-2020s.[94]

Key Actors in China's Space Program

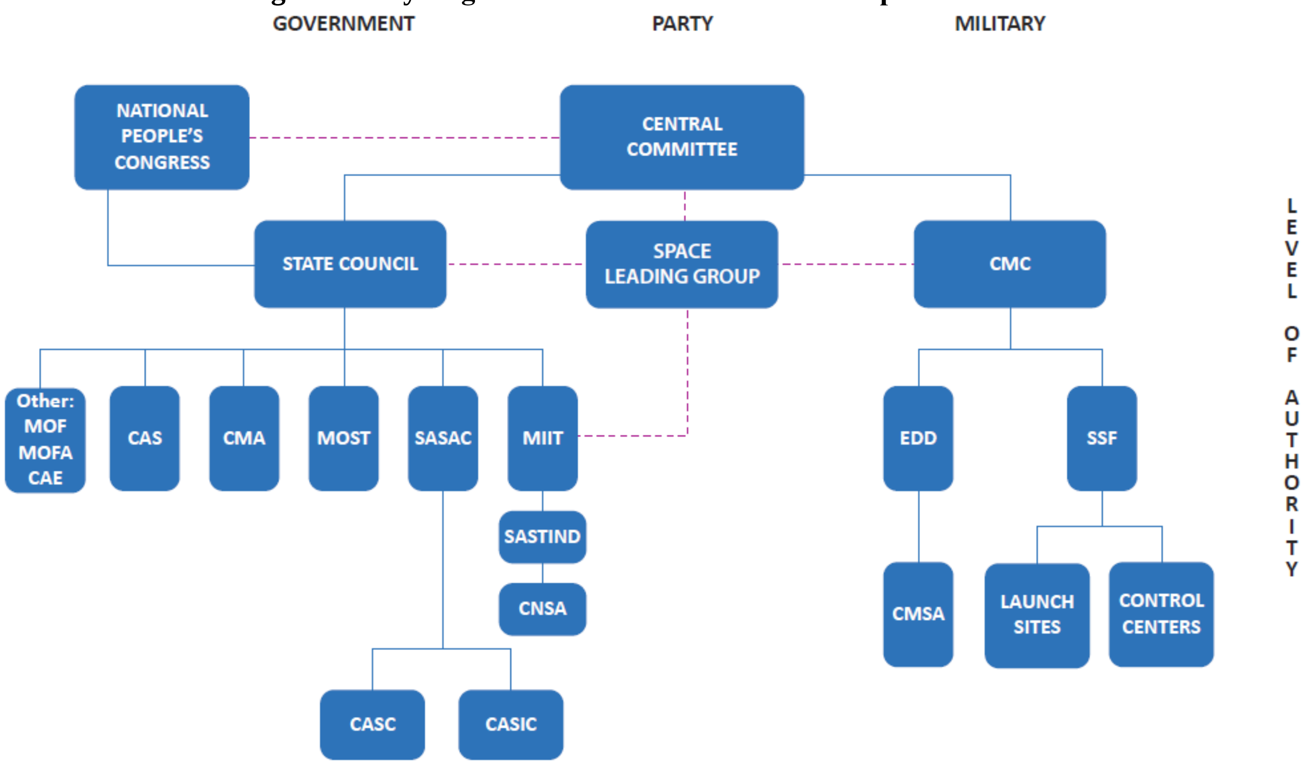
The State Council formally adopts long-term science and technology policies and strategies and approves programs and funding, although the military is also involved at the highest levels in formulating, executing, and managing these programs.[95] In the 1960s, China formed the still-active ad hoc Central Special Committee—comprising

[*] The satellite orbits L2, a Lagrangian point. Lagrangian points are "parking spots" in space where a small mass can maintain a relatively stable position due to the combined effect of its own centripetal force and the gravitational pulls of two larger celestial bodies nearby. Dr. Ye and coauthors argue L2—the Lagrangian point on the other side of the moon from Earth—is "ideal for long-term, continuous moon-earth communication." Ye Peijian et al., "An Overview of the Mission and Technical Characteristics of Chang'e-4 Lunar Probe," *Science China Technological Sciences* 60:5 (2017): 2–3; National Aeronautics and Space Administration, *Home on Lagrange*, July 26, 2012. *https://www.nasa.gov/missions/solarsystem/f-lagrange.html*; National Aeronautics and Space Administration, *The Lagrange Points*, July 2012. *https://map.gsfc.nasa.gov/mission/observatory_l2.html*.

powerful civilian, military, scientific, and engineering leaders—which reports to the State Council, the CCP Politburo Standing Committee, and the Central Military Commission.[96] The Committee coordinates China's strategic R&D, almost certainly including the space domain.[97] The State Council also formed a Space Leading Group in 1989 comprising high-level science, industry, foreign affairs, and state planning officials to coordinate the planning among the key stakeholders involved.[98] The military plays a role in planning space policy, as well. For example, in 2004 the State Council and the Central Military Commission, China's highest-ranking military body, formed a joint leading small group for the lunar probe project which convened at least 14 times from 2004 to 2015.[99] In addition to lunar exploration, China reportedly has formed leading small groups for human spaceflight, Earth observation satellites, and heavy-lift launch vehicles, which have also likely included military participation and reflect the importance Beijing ascribes to those programs.[100]

Several Chinese government entities play key roles in planning, implementing, and coordinating official space policy and research, a process that spans the civil, military, academic, and commercial sectors.[101] Military entities are even heavily involved in China's ostensibly nonmilitary space projects.[102]

Figure 2: Key Organizations Involved in China's Space Activities



Source: Adapted from Marco Aliberti, *When China Goes to the Moon…* Springer International Publishing, 2015, 10.

Acronyms from top to bottom, left to right: Central Military Commission; Ministry of Finance; Ministry of Foreign Affairs; China Academy of Engineering; China Academy of Sciences; China Meteorological Administration; Ministry of Science and Technology; State-owned Assets Supervision and Administration Commission; Ministry of Industry and Information Technology; Equipment Development Department; Strategic Support Force; State Administration of Science, Technology, and Industry for National Defense; China National Space Administration; China Manned Space Agency; China Aerospace Science and Technology Corporation; China Aerospace Science and Industry Corporation.

Civil Government Entities

In 2014, the Chinese government opened the space industry to the private sector, allowing non-state-owned companies to build and launch satellites for the first time as part of Beijing's push for military-civilian fusion, a strategy to leverage key dual-use industries such as aerospace, aviation, and automation to give China an edge in its competition with the United States.[103] Several companies have achieved suborbital launches—usually rockets carrying scientific experiments that complete less than one full orbit before falling back to Earth[104]—but in October 2018, China's first attempted orbital private satellite launch failed.[105] According to Landspace, the developer, the first and second stages of the rocket were successful, but "something abnormal happened" that prevented the satellite from reaching orbit.[106] Still, given time and the Chinese government's continued support for the private space sector, private launch companies in China will likely continue to make progress.[107]

Ministry of Science and Technology (MOST): MOST, an agency directly subordinate to the State Council, takes the lead in establishing and overseeing the implementation of science and technology plans and policies.[108] It formulates and promulgates major long-term strategies for the development of science and technology, including updating and pursuing space-related R&D objectives.[109]

Chinese Academy of Sciences (CAS): CAS, also directly subordinate to the State Council, describes itself as China's "foremost science and technology advisory body" and has a primary academic focus on "long-term scientific challenges related to national strategic needs."[110] In addition to contributing to research, CAS scientists often participate in proposing, setting, and implementing space policy, including mission planning and implementation of projects such as the human spaceflight program, the Mars orbiter program, astronomy, remote sensing, and space science.[111] CAS also participates in feasibility studies of technology for space projects and the commercial-scale production of space-related technology such as hypersonic engines.[112]

State Administration of Science, Technology, and Industry for National Defense (SASTIND): SASTIND, China's main administrative and regulatory agency of science, technology, and industry for national defense, falls under the Ministry of Industry and Information Technology (MIIT) and issues and monitors the implementation of regulations and standards concerning China's defense and space industries.[113] It also allocates R&D funds through programs and is responsible for regulating procurement and supply of the defense and aerospace industries.[114] As part of China's military-civilian fusion strategy, SASTIND provides some support to new private space companies.[115]

China National Space Administration (CNSA): CNSA is subordinate to SASTIND and is the public-facing government agency responsible for managing China's civilian space activities and international space cooperation.[116] This management includes issuing regulations as well as capitalizing on space technology's dual-use nature by coordinating between relevant government agencies and industry.[117] CNSA is the agency ostensibly responsible for implementing China's space policy and monitoring the progress of China's space program in meeting its objectives.[118] In reality, however, it is more of a figurehead organization designed to raise awareness of China's space program through high-profile agreement signings and participation in international conferences, and to liaise between SASTIND—which CNSA administrator Zhang Kejian directs, in addition to being vice-minister of the MIIT[119]—and China's military aerospace industry entities.[120]

PLA Entities

Equipment Development Department: The EDD, which replaced the former PLA General Armaments Department in 2016, is responsible for the research, development, and acquisition of China's satellites, launch vehicles, spacecraft, counterspace weapons, and national-level engineering programs.[121] One of its subordinate organizations, the China Manned Space Agency, is responsible for China's human spaceflight program.[122] The EDD appears to have retained control over space organizations and R&D entities the General Armaments Department previously oversaw, while the SSF took over China's launch facilities, control centers, and their associated research programs.[123] Indicating the importance of the space mission to the PLA, since September 2017 the EDD has been led by Lieutenant General Li Shangfu, an aerospace engineer and former deputy commander of the SSF and director of China's Xichang Satellite Launch Center.[124]

Figure 3: Chinese Space Launch Sites and Key Satellite Control Centers

Source: Defense Intelligence Agency, Challenges to Security in Space, February 11, 2019, 17.
http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf.

China Aerospace Science and Technology Corporation (CASC): CASC, a subordinate of the State-owned Assets Supervision and Administration Commission of the State Council, is the most important state-owned contractor in China's space program; it is heavily involved in key research, such as for the lunar exploration program, and it carries out most Chinese government contracts for space launches, spacecraft, and satellites, and oversees strategic ballistic missile programs.[125] CASC's subordinate academy, the China Academy of Launch Vehicle Technology, is China's most important organization for research, development, and production of space launchers, including the Long March family of rockets, which are produced by state-owned Tianjin Long March Launch Vehicle Manufacturing Company.[126] The China Academy of Space Technology, which develops space technology such as satellites and spacecraft, also helps formulate national space technology development plans and facilitates foreign exchanges and cooperation.[127] The China Academy of Space Technology and the China Great Wall Industry Corporation are two especially important CASC subsidiaries involved in space projects.[*] [128] In addition to launching satellites within China, China Great Wall Industry Corporation is China's sole provider of commercial satellite and launch services for international clients.[129]

China Aerospace Science and Industry Corporation (CASIC): Following CASC, CASIC is China's other primary state-owned defense industrial corporation supporting space technology.[130] Until 1999, CASC and CASIC were part of the same company, China Aerospace Corporation, which was broken apart to promote competitiveness in China's space industry.[131] CASIC is also a key advisory body for the PLA and State Council.[132] CASIC develops solid rockets and other space products, and it is involved in building security and support systems for crewed spaceflight, lunar exploration, and other major national space projects.[133] CASIC is also China's primary missile designer and manufacturer, and it plans and oversees China's direct-ascent antisatellite weapons programs.[134]

Implications for U.S. Policymakers

[*] For more detailed information on the responsibilities of CASC's subordinate academies and firms, see Kevin Pollpeter et al., "China Dream, Space Dream: China's Progress in Space Technologies and Implications for the United States," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), March 2, 2015, 102–104. *https://www.uscc.gov/sites/default/files/Research/China%20Dream%20Space%20Dream_Report.pdf*.

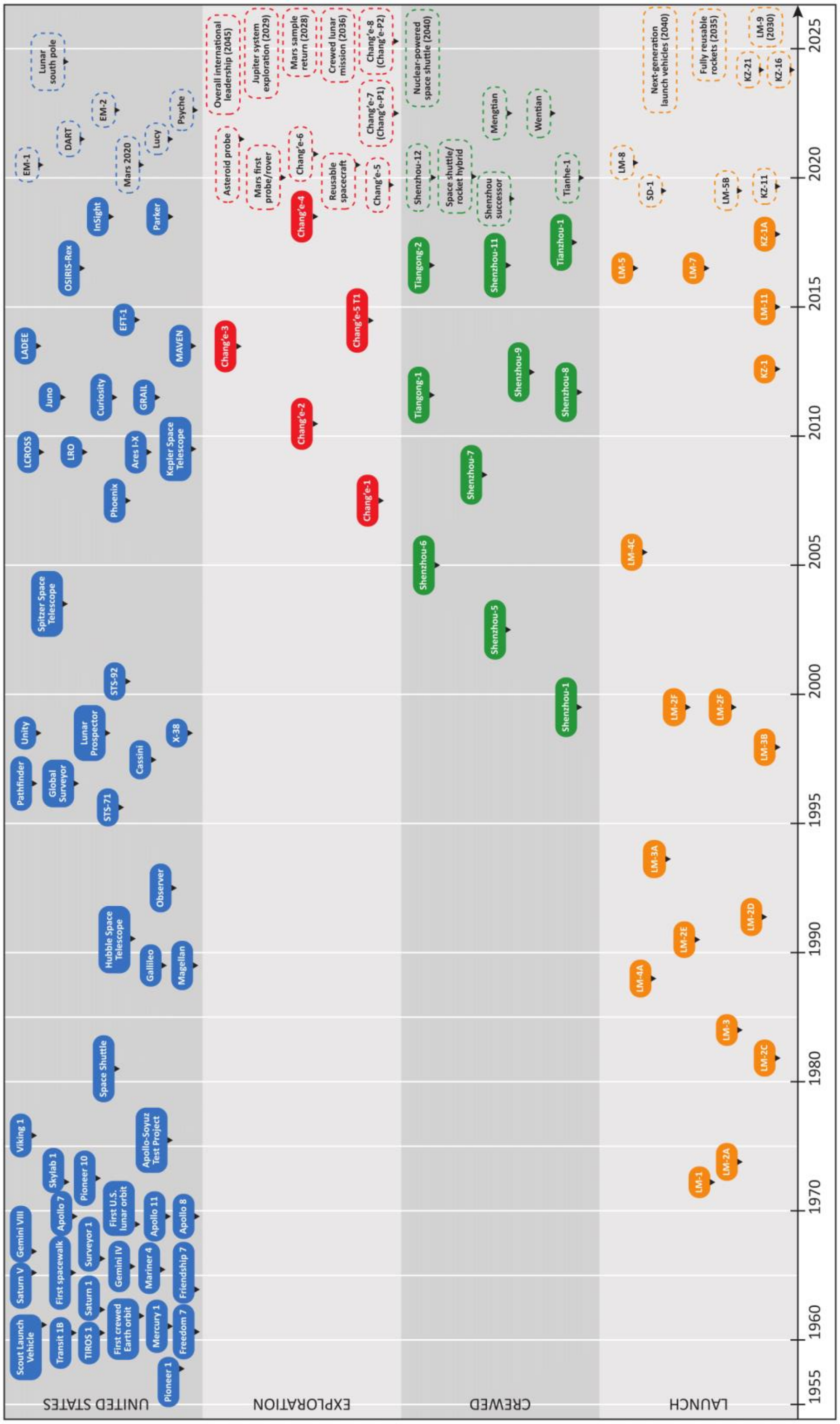
Each of China's successful space launches has demonstrated considerable technological advancements and China's determination to catch up with the United States and other global space leaders despite lagging behind in some technologies and research areas.[135] For example, the United States launched its first crewed spaceflight mission in 1961 and its first temporary space lab, Skylab, in 1973.[136] The U.S. National Aeronautics and Space Administration's (NASA's) first long-term ISS module launched two and a half decades later in 1998.[137] In contrast, China launched its first crewed spaceflight mission in 2003, but only eight years later launched its first temporary Tiangong space lab in 2011.[138] If plans hold to launch its first long-term space station module, Tianhe-1, in 2020, it will have matched NASA's nearly 40-year progression from first human spaceflight to first space station module in less than 20 years.[139] Given China's technological approach, along with strong political and funding support, U.S. policymakers should not expect China's space program to remain significantly behind the United States' indefinitely, especially as the CCP increasingly attempts to leverage military-civilian fusion to jumpstart innovation in its space industry with the goal of leapfrogging the United States.[140]

Recent developments suggest the United States is committed to both significant new civil space exploration programs and a new Space Force in the Department of Defense; Heather Wilson, Secretary of the U.S. Air Force, said in March 2019 the United States "will continue to be the best in the world at space, and establishing a dedicated space force strengthens our ability to deter, compete, and win in space."[141] In February 2018, the Trump Administration released its *Presidential Memorandum on Reinvigorating America's Human Space Exploration Program*, calling for the United States to "lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."[142] In March 2019, invoking a "space race" with China and Russia, Vice President Mike Pence, who leads the National Space Council, announced the Administration is committed to returning U.S. astronauts to the moon for the first time since 1972 by 2024 "by any means necessary."[143] Major new projects such as the Space Launch System (SLS) rocket, the Orion capsule, and the Lunar Gateway—a small crewed space station planned for lunar orbit that will be able to support a maximum of four crew members for 30–90 day tours[144]—are funding priorities for the Administration, although NASA is open to commercial alternatives if the SLS is not ready in time.[145] According to NASA, the Gateway is "central to advancing and sustaining human space exploration goals" and will provide crewed missions a common jumping-off point to space on the near side of the moon, for robotic and human lunar surface access, and for missions to Mars; it is designed to "offer astronauts longer stays on the lunar surface, easier crew returns, safe haven in the event of an emergency, and the ability to navigate to different orbits around the Moon."[146] Canada has announced a 24-year commitment to cooperate on the Gateway, and potential additional partners include Japan, Russia, and the European Space Agency.[147] If the Gateway is delayed and the ISS is not extended beyond 2024, however, retiring the ISS before alternatives for low-gravity research are deployed could result in a gap in U.S. space access, potentially grounding U.S. astronauts until NASA develops new space flight vehicles.[148]

China appears to have both the financial resources and political will to continue to make progress in establishing the CSS and potentially a lunar base, positioning Beijing to assume a greater leadership role in an era of renewed global interest in deep space exploration.[149] According to Representative Ted Yoho (R-FL), then Chairman of the House Foreign Affairs Subcommittee on Asia and the Pacific, Beijing may outpace the United States in this new round of space competition simply because it has "the cash to do it."[150]

Appendix

Figure 4: Key Chinese and U.S. Past and Projected Space Milestones



Source: Commission research.

Table 1: Key U.S. Space Milestones

Milestone	Significance	Milestone	Significance	Milestone	Significance
Apollo 7	First piloted *Apollo* flight	GRAIL	Gravity Recovery And Interior Laboratory probe to study lunar interior	Phoenix	Lander that studied the history of water in the Martian arctic
Apollo 8	First lunar orbit	Hubble Space Telescope	First major optical telescope in space	Pioneer 1	NASA's first spacecraft
Apollo 11	First crewed lunar landing	Juno	Jupiter orbiter	Pioneer 10	First flyby of Jupiter
Apollo-Soyuz Test Flight	First U.S./Soviet space flight, Apollo and Soyuz systems docked	Kepler Space Telescope	Planet-hunting telescope	Psyche	Probe designed to rendezvous with a metallic asteroid
Ares I-X	First launch of next-generation crewed launch vehicle	Lucy	Flyby probe to observe seven asteroids	Saturn 1	First test of the Saturn 1 launch vehicle (9,000 kg to LEO)
Cassini	Saturn probe	Lunar south pole	Planned crewed landing in lunar south pole	Saturn V	Largest launch vehicle (122 tons to LEO)
Curiosity	Mars Science Laboratory, large to explore past/present Martian life	Lunar Prospector	Lunar polar probe	Scout Launch Vehicle	Workhorse launch vehicle f launching a 385-pound satellite into a 500-mile orbit
DART	Double Asteroid Redirection Test to change an asteroid's orbit	LCROSS	Lunar Crater Observation and Sensing Satellite	Skylab 1	First U.S. orbital workshop
EFT-1	Orion crewed capsule flight test	LRO	Lunar Reconnaissance Orbiter	Space Shuttle	First flight of *Columbia*, the first Space Shuttle
EM-1	First SLS/Orion test mission	Magellan	Probe to map Venus	Spitzer space telescope	Largest infrared telescope ever launched into space
EM-2	First crewed SLS/Orion mission to lunar vicinity	Mariner 4	First probe to photograph Mars at close distance	STS-71	Space shuttle *Atlantis* docks with Russian *Mir* space station
Friendship 7	First U.S. crewed Earth orbit	Mars 2020	Rover to search for signs of past microbial life	STS-92	100th Space Shuttle mission and 100th U.S. spacewalk
Freedom 7	First piloted Mercury spacecraft	MAVEN	Mars Atmosphere and Volatile Evolution mission	Surveyor-1	First U.S. spacecraft to land on the moon
Galileo	Jupiter probe	Mercury 1	Mercury-Redstone capsule-launch vehicle combination	TIROS 1	Television InfraRed Observational Satellite, first successful weather satellite
Gemini IV	First U.S. spacewalk	Observer	Orbiter that studied the climate and geology of Mars	Transit 1B	Experimental orbital navigation system
Gemini VIII	U.S. astronauts perform the first orbital docking	OSIRIS-Rex	Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer sample return	Unity	First U.S. ISS module
Global Surveyor	Mars probe equipped with magnetometer	Parker	Orbiter designed to study the sun's corona and solar wind	Viking 1	Mars lander
		Pathfinder	Mars lander with small rover as technology demonstration	X-38	First test flight of ISS "lifeboat" spacecraft

Source: Various.[151]

Table 2: Key Chinese Space Milestones

Milestone	Significance	Milestone	Significance
Asteroid probe	Undetermined mission to study an asteroid	LM-4B	Medium-lift launch vehicle
Chang'e-1	Probe designed to validate lunar orbiter technology	LM-4C	Medium-lift launch vehicle
Chang'e-2	Lunar orbiter to select site for future lander	LM-5	Heavy-lift launch vehicle
Chang'e-3	Lunar lander with rover	LM-5B	LM-5 designed to launch CSS modules
Chang'e-4	Probe to lunar far side	LM-7	Medium-lift launch vehicle
Chang'e-5	Lunar sample return mission	LM-8	First reusable launch vehicle
Chang'e-5 T1	Test flight to validate Chang'e-5 atmospheric re-entry design	LM-9	Future Saturn V-class super heavy-lift launch vehicle
Chang'e-6	Sample return mission to lunar south pole	LM-11	Light, quick-reaction launch vehicle
Chang'e-7	First mission to lunar pole to study surrounding terrain	Mars first probe/rover	First Mars lander with rover
Chang'e-8	Second mission to lunar pole; will prepare for construction of research base	Mars sample return	Undetermined mission to return Mars sample
Crewed lunar mission	First crewed landing on lunar surface	Mengtian	CSS scientific module
Fully reusable rockets	Fully reusable launch vehicles	Next-generation launch vehicles	Space transport system able to conduct multiple interplanetary trips
Jupiter probe	Undetermined mission to study Jupiter	Nuclear shuttle	Nuclear-powered space shuttle
KT-2	New light-lift launch vehicle	Overall international leadership	China will have the capability to conduct human-machine collaborative exploration of space at scale, equipment and technology to be among overall international leaders, and the ability to support comprehensive realization of the aerospace power goal.
KZ-1	Kuaizhou-1, first "quick reaction" solid propellant light launch vehicle	Reusable spacecraft	Plane-like spacecraft capable of reaching orbit
KZ-1A	Solid-propellant launch vehicle, can launch 300 kg satellites	SD-1	Smart Dragon 1, first Dragon commercial rocket (150 kg payload to sun-synchronous orbit)
KZ-11	Future solid-propellant launch vehicle, will be able to launch 1.5-ton payload to LEO	Shenzhou-1	First uncrewed test launch of Shenzhou program
KZ-16	Future solid-propellant launch vehicle, will be able to launch 4-ton payload to LEO	Shenzhou-5	First crewed spaceflight
KZ-21	Future solid-propellant launch vehicle, will be able to launch 20-ton payload to LEO	Shenzhou-6	First "multi-person and multi-day" crewed spaceflight
LM-1	First LM launch vehicle	Shenzhou-7	China's first spacewalk
LM-2A	Early light-lift launch vehicle	Shenzhou-8	Validated technology for space docking
LM-2C	Medium-lift launch vehicle	Shenzhou-9	China's first crewed space docking
LM-2D	Medium-lift launch vehicle	Shenzhou-11	China's longest crewed space mission
LM-2E	Medium-lift launch vehicle	Shenzhou-12	First crewed mission to Tianhe-1
LM-2F	Medium-lift launch vehicle used to launch Shenzhou spacecraft	Shenzhou successor	New version of crewed spacecraft
LM-3	Light-lift launch vehicle	Tianhe-1	CSS core module
LM-3A	Medium-lift launch vehicle	Tianzhou-1	First launch of cargo spacecraft
LM-3B	Medium-lift launch vehicle	Tiangong-1	China's first space lab
LM-4A	Medium-lift launch vehicle	Tiangong-2	China's second space lab
LM-4B	Medium-lift launch vehicle	Wentian	CSS scientific module

Source: Various.[152]

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