Testimony before the U.S.-China Economic and Security Review Commission for the hearing on "China's Space and Counterspace Programs"

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China is a nation on a quest for wealth and power. It seeks increased influence and independence from foreign powers with the ultimate goal of preserving China's sovereignty, independence, territorial integrity, and political system. Over the long term, China seeks to transform the international system to better suit its interests, but seeks to integrate itself into the existing international system over the short term with the goal of reshaping the Asia-Pacific political environment into one in which it is dominant.

China's pursuit of space power is intended to carry out this strategy. China views the development of space power as a necessary move for a country that wants to strengthen its national power. Indeed, China's goal is to become a space power on par with the United States and to foster a space industry that is the equal of those in the United States, Europe, and Russia. China takes a comprehensive, long-term approach to its space program that emphasizes the accrual of the military, economic, and political benefits space can provide. By placing much of its space program in a 15-year development program and providing ample funding, the Chinese government provides a stable environment in which its space program can prosper. Although China is probably truthful when it says that it is not in a space race, such statements mask the true intent of its space program: to become militarily, diplomatically, commercially, and economically as competitive as the United States is in space.

China's efforts to use its space program to transform itself into a military, economic, and technological power may come at the expense of U.S. leadership. Even if U.S. space power continues to improve in absolute terms, China's rapid advance in space technologies will result in relative gains that challenge the U.S. position in space. At its current trajectory, China's space program, even if not the equal of the U.S. space program, will at some point be good enough to adequately support modern military operations, compete commercially, and deliver political gains that will serve its broader strategic interest of again being a major power more in control of its own destiny.

Military Benefits

China's space program assists the People's Liberation Army (PLA) in its efforts to achieve information superiority, defined as the ability to freely use information and the ability to deny the use of information to an adversary. Based on their analysis of U.S. military operations, Chinese military researchers view space as a critical component in making the PLA into a force capable of winning "informatized" wars and recognize the role space plays in the collection and transmittal of information and the need to deny those capabilities to an adversary.

Indeed, nearly every Chinese source describes space as the "ultimate high ground," leading many Chinese analysts to assess that space warfare is inevitable. Because of the preeminence of the space battlefield, analysts writing on space argue that it will become *the* center of gravity in future wars and one that must be seized and controlled. In fact, these analysts argue that the first condition for seizing the initiative is to achieve space supremacy.

Space Technologies
China has made impressive progress in space technologies since 2000. China now has nearly a full range of satellites to accomplish a variety of missions. These include remote sensing satellites with various resolutions and covering various spectrums, a satellite navigation system, communication satellites, and robust human spaceflight and lunar exploration programs.

Space-based C4ISR Technologies
A robust, space-based C4ISR system is often described as a critical component of a future networked PLA. The necessity to develop space-based C4ISR systems is based on the requirement to develop power-projection and precision-strike capabilities. The development of long-range cruise missiles and ballistic missiles requires the ability to locate and target enemy ships and bases hundreds of kilometers away from China's shores, as well as the ability to coordinate these operations with units from multiple services. In doing so, remote sensing satellites can provide intelligence on the disposition of enemy forces and provide strategic intelligence before a conflict begins. Communication satellites can provide global connectivity and can facilitate communications between far-flung forces. Navigation and positioning satellites can provide critical information on location and can improve the accuracy of strikes.

Satellite Navigation
China's Beidou satellite navigation system is planned to provide a global service by 2020. Designed to be similar to the U.S. Global Positioning System (GPS), Beidou will consist of 35 satellites in medium Earth and geosynchronous orbits that will provide positioning accuracies of less than 10 meters. With the use of a nation-wide system of differential Beidou, accuracy will be improved to one meter. Unlike GPS, Beidou has a short messaging service in which messages as long as 120 characters can be sent to other Beidou receivers. Beidou is increasingly used by the Chinese military at the regiment level and above and is reportedly being integrated into weapon guidance systems.

Remote Sensing
The stated purpose of China's satellite remote sensing project is to build an all-weather, 24-hour, global Earth remote sensing system by 2020 capable of monitoring the ground, atmosphere, and oceans. China has a variety of remote sensing satellites, including four new series introduced since 2000: the Gaofen, Yaogan, Huanjing, and Tianhui satellites. This is in addition to legacy satellite series such as the Ziyuan Earth remote sensing satellite and the Fengyun meteorological satellite.

With these satellites, China can serve a variety of remote sensing needs. Chinese imagers have stated resolutions of one to thirty meters and can image in the visible, infrared, and multispectral ranges. The Yaogan and Huanjing satellites also use synthetic aperture radar (SAR) to be able to image through cloud cover or at night. Certain Yaogan satellites are also rumored to have electronic intelligence capabilities.

Accessing information from these satellites is facilitated by a network of three satellites, designated Tianlian, that relay communications and data between satellites and ground stations anywhere on the Earth regardless of the position of the satellite in orbit or the location of the unit on the ground.

Counterspace Technologies

The PLA also recognizes that it must deny the use of information to its opponents. Chinese analysts assess that the employment of space-based C4ISR capabilities by potential adversaries, especially the United States, requires the PLA to develop capabilities to attack space systems. According to the U.S. Defense Department, China has a broad-based development program for counterspace technology that consists of jammers, direct-ascent kinetic-kill vehicles, directed-energy weapons, and co-orbital spacecraft.[1] China's development of counterspace weapons appears to be aimed at developing an all-around capability to threaten satellites with a variety of weapons at all orbits.

Direct Ascent Counterspace Technologies

The most prominent demonstration of China's counterspace technologies was the 2007 destruction of a defunct FY-1C meteorological satellite with a direct-ascent kinetic-kill vehicle. In 2010, 2013, and 2014, China conducted mid-course tests of a missile defense system that are believed to be de facto ASAT tests.

In addition to missile defense tests, China conducted a "high altitude science mission" in 2013 using a sounding rocket. According to the Chinese Academy of Sciences, the rocket reached an altitude of more than 10,000 kilometers and released a barium cloud to study the dynamic characteristics of the Earth's magnetosphere.[2] This claim appeared to be contradicted by a U.S. government assessment that the rocket "appeared to be on a ballistic trajectory nearly to geosynchronous Earth orbit (GEO)," which could refer to a distance of 30,000 kilometers.[3] If so, the test would represent an expansion of China's ASAT capabilities and could help enable China to threaten satellites such as GPS and communication satellites in medium and high Earth orbits.

Directed Energy Counterspace Technologies

China is also developing directed-energy weapons such as lasers, high-powered microwave, and particle beam weapons for ASAT missions.[4] The Defense Department concluded in 2006 that China had "at least one…ground-based laser designed to damage or blind imaging satellites."[5] Lasers at higher power levels can permanently damage satellites and at lower power levels can temporarily blind the imagers of a remote sensing satellite. In 2006 it was reported that China

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[1] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2012), 9.

[2] "中国再次高空科学探测试验：高度更高数据更多" [China Again Conducts a High Altitude Science Mission: Higher Altitude and More Data], 中国新闻网 [*China News*], May 14, 2013, accessed September 2, 2014, http://www.chinanews.com/gn/2013/05-14/4817925.shtml.

[3] Brian Weeden, "Through a Glass, Darkly: Chinese, American, and Russian Anti-Satellite Testing in Space," *Space Review*, March 17, 2014, accessed September 2, 2014, http://www.thespacereview.com/article/2473/1.

[4] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2012), 9.

[5] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2006), 35.

had fired a laser at a U.S. satellite. According to U.S. officials, the intent of the lasing is unknown and did not damage the satellite, suggesting that China could have been determining the range of the satellite rather than trying to interfere with its function.[6]

China is also researching radio frequency (RF) weapons that could be used against satellites. Radio frequency weapons using high power microwaves can be ground-based, space-based, or employed on missiles to temporarily or permanently disable electronic components through overheating or short-circuiting. RF weapons are thus useful in achieving a wide spectrum of effects against satellites in all orbits.[7] Because RF weapons affect the electronics of satellites, evaluating the success of an attack may be difficult since no debris would be produced.[8]

Co-orbital Counterspace Technologies

Chinese researchers also discuss the use of co-orbital counterspace technologies. As one researcher states, the "ample use of the superiority and characteristics of modern small satellites, ingeniously applied to space attack and defense, will cause small satellites to become a space weapon assassin's mace."[9] Co-orbital satellites are those satellites that come within a close distance to another satellite to interfere with, disable, or destroy the target satellite. Co-orbital satellites do not have to be dedicated to the counterspace role and can also serve legitimate peacetime functions.[10]

According to the U.S. Defense Department, China has "conducted increasingly complex close proximity operations between satellites."[11] During the Shenzhou-7 mission the Banxing-1 flew around Shenzhou-7 at a distance of several tens of meters to several hundred meters. After the astronauts departed for Earth, BX-1 orbited Shenzhou-7 at a distance of one to two hundred kilometers. BX-1 was equipped with two cameras that took images of Shenzhou-7. The stated reason for the BX-1 was to test the orbiting of a spacecraft with the Shenzhou 7 to prepare for an eventual docking mission with a space station.[12]

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[6] Elaine M. Grossman, "Top Commander: Chinese Interference With U.S. Satellites Uncertain," *World Politics Review*, October 18, 2006, accessed September 2, 2014,

[7] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2006), 34; and Office of Technology Assessment, *Anti-Satellite Weapons, Countermeasures, and Arms Control*, September 1985, 66–67.

[8] David Wright, Laura Grego, and Lisbeth Gronlund, *The Physics of Space Security: A Reference Manual* (Cambridge, MA: American Academy of Arts and Sciences, 2005), 133.

[9] Lin Laixing, "Study on the Overseas Microsatellite Application in Space Attack-Defense (国外微小卫星在空间攻防中的应用研究)," *Journal of the Academy of Equipment Command and Technology* (装备指挥技术学院学报), 2006/6, 49.

[10] See, for example, Huang Siyong and Xu Peide, "空间武器平台潜伏轨道分布模型研究" [Study of Distributed Model of Hidden Orbits for Space Weapons Platforms], 航天控制 [*Aerospace Control*], June 2007; and Ma Wendi, 小卫星编队与反卫星卫星 ["Small Satellite Formations and ASAT Satellites"], 中国航天 [*Aerospace China*], April 2006.

[11] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2012), 9.

[12] "伴飞小卫星将"追赶"分离后的神七轨道舱" [Small Companion Satellite Will Chase After the Shenzhou 7 Orbital Capsule After Separation], Xinhuanet, September 24, 2008, accessed February 18, 15, http://news.xinhuanet.com/newscenter/2008-09/24/content_10104787.htm; "Shenzhou-7 Launches Small Monitoring Satellite," Xinhuanet, September 27, 2008, accessed February 18, 15, http://news.xinhuanet.com/english/2008-09/27/content_10123015.htm; "伴飞小卫星将给神七 '照相'" [Small

The BX-1 mission was involved in some controversy when it passed within 45 kilometers of the International Space Station, leading some to conclude that the mission was also a test of a co-orbital ASAT capability[13] or that it was testing satellite inspection capabilities.[14] The proximity of the BX-1 did not present a hazard to the International Space Station.[15]

In August 2010 it was reported that after conducting a series of maneuvers the Shijian-12 (SJ-12) satellite had most likely bumped into the Shijian 6F (SJ-6F), causing it to drift slightly from its original orbit. The maneuvering could have been practice for docking the Shenzhou space capsule with the Tiangong-1 space station, but Chinese silence on the intention of the test fueled concern that it was a cover for testing ASAT capabilities.[16]

In August 2013 China conducted a test of robotic arm technologies involving the Chuangxin-3, Shiyan-7, and Shijian-15 satellites where one of the satellites acted as a target satellite and another satellite, most likely equipped with a robotic arm, grappled the target satellite. As with the August 2010 test involving the SJ-12 and SJ-6F, the test could have been for a legitimate peaceful purpose: the testing of robotic arm technologies to be used on future Chinese space stations. As with the August 2010 tests, however, the dual-use nature and silence by the Chinese on the matter have only fueled speculation that China was also testing counterspace technologies.[17]

Cyber Operations

Many Chinese writings describe cyber operations as a new type of warfare which holds the potential to change the face of war as we know it by being able to greatly affect an adversary's political, economic, and military capabilities.[18] China may have been involved in computer hacks against satellite computer systems. In October 2007 and July 2008, a computer attack against the command and control system of Landsat-7, a remote sensing satellite operated by the USGS and NASA, resulted in 12 or more minutes of interference on each occasion. The attacks did not result in the perpetrator achieving the ability to take command of the satellite. In June and October 2008, the command and control system for the Terra EOS (Earth Observation System) was hacked into, resulting in two or more minutes and nine or more minutes of interference, respectively. In both cases, the perpetrator had the ability to command the satellite, but refrained

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Companion Satellite Will Take Photographs of Shenzhou 7], Xinhuanet, September 24, 2008, accessed February 18, 15, http://news.xinhuanet.com/newscenter/2008-09/24/content_10104656.htm.

[13] "Closer Look: Shenzhou-7's Close Pass by the International Space Station," International Assessment and Strategy Center, October 9, 2008, accessed February 18, 15, http://www.strategycenter.net/research/pubID.191/pub_detail.asp.

[14] "China's BX-1 Microsatellite: A Litmus Test for Space Weaponization," *Space Review*, October 20, 2008, accessed February 18, 15, http://www.thespacereview.com/article/1235/1.

[15] Tianlian satellites are discussed in further detail later in the paper.

[16] Brian Weeden, "Dancing in the Dark: The Orbital Rendezvous of SJ-12 and SJ-06F," *Space Review*, August 30, 2010, accessed September 2, 2014, http://www.thespacereview.com/article/1689/1.

[17] See Kevin Pollpeter, "China's Space Robotic Arm Programs," *SITC News Analysis*, October 2013, accessed September 2, 2014, http://igcc.ucsd.edu/assets/001/505021.pdf.

[18] Lu Yunsheng and Liu Haifeng, "Jisuanji wangluo gongji tixi gouxiang" (A Vision for Computer Network Attack), *Wangluo anquan jishu yu yingyong* (Network Security Technology and Application), No. 108 (December 2009), p. 43.

from doing so.[19] The attacks have not been attributed and China has denied responsibility for the attacks.[20]

Electronic Warfare

China has acquired foreign and indigenous jammers that give it "the capability to jam common satellite communications bands and GPS receivers."[21] GPS, in particular, can be easily jammed due to the attenuation of the signal over the 12,500-mile distance between the satellites and Earth.[22] As a result, even low-power jammers can achieve effects over long distances. According to the Defense Science Board, "modest (few watt) jammers can deny acquisition [of the GPS signal]" at ranges up to hundreds of kilometers.[23]

Nuclear Weapons

China could detonate a nuclear weapon in space to destroy and disable satellites through both the blast and the electromagnetic pulse generated by the explosion. The use of a nuclear weapon in space, however, would also affect China's satellites, as well as those of third parties.[24]

Manned Platforms

Chinese analysts also see a role for manned platforms in space warfare. Manned platforms are described as more responsive than unmanned platforms and able to employ a variety of weapons.[25] Other authors write that manned platforms are "the best space weapon for attacking satellites in low earth orbit, synchronous orbit, and high orbit."[26]

Manned space platforms include space capsules, space stations, and space planes. Space capsules and space planes can transport goods and people between ground and space, carry out space rescue missions, and conduct reconnaissance and surveillance against targets.[27] According to an article written by the current director of the China Manned Space Agency, space stations can service military satellites in orbit, including repair, maintenance, fueling, and replenishment of ammunition, as well as serve as platforms for kinetic and directed energy weapons.[28]

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[19] U.S.-China Economic and Security Review Commission, *2011 Report to Congress of the U.S.-China Security and Economic Review Commission,* November 2011, 216.

[20] Sui-lee Wei, "China Denies It Is Behind Hacking of U.S. Satellites," Reuters, October 31, 2011, accessed September 9, 2014, http://www.reuters.com/article/2011/10/31/us-china-us-hacking-idUSTRE79U1YI20111031?feedType=RSS&feedName=scienceNews&utm_source=dlvr.it&utm_medium=twitter&dlvrit=309301.

[21] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2011), 37.

[22] Congressional Budget Office, "The Global Positioning System for Military Users: Current Modernization Plans and Alternatives," October 2011, 4.

[23] Defense Science Board, "Report of the Defense Science Board Task Force on Tactical Air Warfare," November 1993, 12.

[24] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2011), 37.

[25] Li Yiyong, Li Zhi, and Shen Huairong, "临近空间飞行器发展与应用分析" [Analysis on Development and Application of Near Space Vehicle]," 装备指挥技术学院学报 [*Journal of the Academy of Equipment Command and Technology*], 2008/2, 64 and Chang, *Military Astronautics*, 118–19.

[26] Li, Cheng, and Zheng, *Integrated Aerospace Information Operations*, 218.

[27] Chang, *Military Astronautics*, 123, 145.

[28] Wang Zhaoyao, "军事航天技术及其发展" [Military Space Technology and Its Development], 航天器工程 [*Spacecraft Engineering*] 1 (2008): 17.

Launch Vehicles
China is developing a new generation of launch vehicles capable of launching China's large space station and larger satellites. The new rockets are designed to meet China's launch needs for the next 30–50 years and offer increased reliability and adaptability and will be powered by "nonpoisonous" and "nonpolluting" engines that will provide more thrust than the current generation of launch vehicles. [29] The new generation of rockets will be divided into light, medium, and heavy-lift versions that will be able to send 1 to 25 metric ton payloads into low Earth orbit and 1 to 14 metric ton payloads into geosynchronous Earth orbit.[30] This presents a significant increase in payload capacity. China's current heaviest launch vehicle, the LM-2F, can lift eight metric tons into low Earth orbit.

This new generation of Long March vehicles has been designated the Long March 5, 6, and 7. The Long March 5 will be used to launch the heaviest payloads into orbit, such as China's planned large space station, and larger communication and remote sensing satellites. The Long March 7 will be a medium-lift rocket that will be used to ferry supplies to the space station. The Long March 6 is a light launch vehicle intended to launch payloads of up to one metric ton into orbit.

Additionally, China is developing operationally responsive space capabilities that will allow it to replace depleted or destroyed satellites quickly. Its development of the Kuaizhou and Long March-11 launch vehicles, both solid-fueled rockets, provide China with the capability to launch relatively small satellites rapidly if other satellites were to be destroyed or degraded. Although not as capable as larger satellites, these smaller satellites would be "good enough" to meet the needs of the Chinese warfighter. Moreover, the ability to launch these rockets from road-mobile launchers will also provide the Chinese military with the capability to replenish or augment its satellite architecture when its launch centers have been damaged or destroyed and would be less susceptible to U.S. prompt global strike capabilities.

Ground-based Infrastructure
China has four launch centers, including its newest launch center in Wenchang, Hainan Province and a network of telemetry, tracking, and control (TT&C) stations.

Launch Centers
Jiuquan Satellite Launch Center (中国酒泉卫星发射中心)
The Jiuquan Satellite Launch Center is China's oldest and largest, and conducts launches of spacecraft into low, medium, and high Earth orbits. It is the only launch center that has conducted human space flight launches.[31] The launch center is composed of a northern launch pad and a southern launch pad. The northern launch pad launches LM-2C and 2D rockets while the southern

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[29] Zhang Feng, "中国的长征五号运载火箭" [China's Long March 5 Launch Vehicle], 卫星应用 [*Satellite Application*], 2012/5, 29.
[30] Sun Zifa, "中国未来 5 年实现"长征"五号六号七号火箭首飞" [In 5 Years China Will Realize the First Flights of the 'Long March' 5, 6, and 7], sohu.com, accessed September 2, 2014, http://news.sohu.com/20130301/n367552968.shtml.
[31]解放军总装备部:中国军工系统核心 ["PLA General Armament Department: China Defense Industry System Core"], accessed Feb. 5, 2012, www.360doc.com/content/11/1214/11/5575132_172141966.shtml*; and http://www.cgwic.com/LaunchServices/LaunchSite/JSLC.html.*

launch pad launches LM-2E and 2F rockets. In addition to the launch pads, the launch center has a command and control center, a rocket fuel storage area, a tracking station, a satellite and launch vehicle assembly station, a solid fuel rocket assembly station, and other support facilities.[32]

Taiyuan Satellite Launch Center **(**中国太原卫星发射中心*)*

The Taiyuan Satellite Launch Center is located near Taiyuan, Shanxi Province. Construction of the Taiyuan Satellite Launch Center began in 1967. The launch center conducts launches of satellites into sun synchronous and low Earth orbits, including meteorological, remote sensing, and communications satellites. The center consists of a launch site, a command and control center, and a technology testing area. The launch site consists of a single launch pad.[33]

Xichang Satellite Launch Center (中国西昌卫星发射中心)

The Xichang Satellite Launch Center is located 60 kilometers north of Xichang, Sichuan Province. Construction on the launch center began in 1970. This launch center launches satellites into geosynchronous orbits, including communication, broadcast, and meteorological satellites. The launch center is composed of a headquarters department, a launch site, a communication station, a command and control center, a technology testing station, and three tracking stations. The technology testing station has a launch vehicle testing facility, a satellite assembly and testing facility, and a rocket engine assembly, testing, and flaw detection facility.[34]

Wenchang Satellite Launch Center (文昌卫星发射中心)

The Wenchang Satellite Launch Center on Hainan Island was approved in 2007 and was reportedly completed in October 2014. The launch center's closer proximity to the equator than China's three other launch centers can increase launch payloads by 10–15 percent and satellite life by 2–3 years, a factor important for developing the commercial launch market. Launches will also be directed over the ocean, which will permit debris from launches to land safely out to sea. Wenchang will be the new launch center for China's manned space flights.

TT&C Network

China's improving TT&C network allows it to support China's human spaceflight and lunar exploration programs and enables China to better control its own satellites and to monitor the satellites of potential adversaries. China operates two satellite control centers at Xi'an and Beijing, and a network of 20 domestic TT&C stations based in China and three stations in Pakistan, Namibia, and Kenya, as well as three operational tracking ships. China built two dish antennas: a 50-meter diameter antenna near Beijing and a 40-meter diameter antenna near Kunming, Yunnan Province. The European Space Agency has also assisted China in its tracking efforts by allowing it to track a European lunar spacecraft launched in 2003.[35] In addition, ESA also provided TT&C support for China's lunar missions at its stations in Maspalomas, Canary Islands, and Kourou, French Guiana.[36]

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[32] Zhang, *China Military Encyclopedia (Second Edition): Introduction to Military Equipment*, 434–36.
[33] Ibid., 438–39.
[34] Ibid., 436–38.
[35] Ibid.
[36] "Chang'e-1 (Lunar-1 Mission of China)," eoPortal Directory, accessed February 18, 15, https://directory.eoportal.org/web/eoportal/satellite-missions/c-missions/chang-e-1.

The TT&C requirements for the Chang'e missions, for example, are described as the most difficult challenge. The Chang'e-1 controllers, for example, had to follow a careful balancing act in which the spacecraft's sensors had to face the moon to collect data, its antennas had to face the Earth to communicate with ground control, and its solar panels had to face the sun.[37] In August 2011, Chang'e 2 traveled to the L2 La Grange point to test China's deep space TT&C network. China is just the third country behind the United States and Europe to have sent a satellite to L2.[38] After completing its mission at L2, in April 2012 Chang'e-2 went to image an asteroid, Toutatis, passing within two miles of the object. [39]

China's Space Program to 2030

If the current trajectory of China's space program continues, by 2030 China will have a new line of advanced launch vehicles, a robust, space-based C4ISR network made up of imagery satellites with resolutions well below one meter, and more capable electronic intelligence communication satellites all linked together by data-relay satellites, in addition to a global satellite-navigation system that may gradually approach current GPS standards. At this point, China could also likely have made operational a number of advanced counterspace capabilities, including kinetic-kill, directed-energy, and co-orbital ASAT capabilities as well as some form of missile defense system.

Although China is probably truthful when it says that it is not in a space race, such statements mask the true intent of its space program: to become militarily, diplomatically, commercially, and economically as competitive as the United States is in space. Despite Chinese statements that it is not in a space race, China's space program has generated concern both in the United States and in Asia. As Clay Moltz writes, "There is a space race going on in Asia, but its outcome—peaceful competition or military confrontation—is still uncertain." He concludes that although "there are still reasonable prospects for avoiding negative outcomes in space…Asia is at risk of moving backward, motivated by historical mistrust and animosities and hindered by poor communications on security matters."[40] As a result, China's progress in space technologies, whether in relative or absolute terms, has implications for the United States and its neighbors. As China's space program increases in capability, it can be expected to wield this power in ways that, according to Bonnie Glaser, not only "persuade its neighbors that there is more to gain from accommodating Chinese interests" but also "deter countries from pursuing policies that inflict damage on Chinese interests."

There are several actions the United States can take to ameliorate the effects of China's rise as a space power.

First, if the United States is to remain the leading space power then it must continue to invest in both its civilian and military space programs. Although innovation is affected by many factors,

[37] Bradley Perrett, Frank Morring, Jr., and Craig Covault, "Spacefarers," 26–28.
[38] "Chang'e-2 Moon Orbiter Travels Around L2 in Outer Space."
[39] Liu Jianun, Ren Xin, Mou Lingli, Zhang Liyan, Feng Jianqing, Wang Xiaoqian, and Li Chunlai, "嫦娥二号卫星有效载荷与科学探测"[Chang'e-2's Payload and Scientific Surveying], 生命科学仪器 [*Life Science Instruments*], January 2013, 37; Chinese Spacecraft Flies by Asteroid Toutatis," Space.com, December 17, 2012, accessed February 18, 15, http://www.space.com/18933-chinese-probe-asteroid-toutatis-flyby.html.
[40] James Clay Moltz, *Asia's Space Race: National Motivations, Regional Rivalries, and International Risks* (New York: Columbia University Press, 2012), 191.

nothing can get done without adequate funding. This fact has not been lost on the Chinese government, which is taking a broad-based, well-funded approach to its space program.

Second, the most valuable resource of any industry is its people. The United States must continue to invest in its space workforce and in science, technology, engineering, and math (STEM) education. China's space industry workforce is young, with 55 percent the industry's employees aged 35 years or younger. The U.S. space industry workforce, on the other hand, is older, with nearly 60 percent of its workforce 45 years of age or older. Over the long-term, China's relatively young workforce will gain valuable experience that could provide an edge in innovating while the U.S. workforce loses high quality workers through retirement.

Third, the United States should enhance its space situational awareness capabilities to better able to better monitor the space and counterspace activities of other countries. Adequately defending the U.S. space-based architecture requires having a good picture of the operational environment and the threat it may pose.

Fourth, the United States could invest in smaller and more distributed satellite capabilities. Although smaller satellites would not be as capable and robust as larger satellites, the distribution of greater numbers of satellites would make the loss of any one satellite less catastrophic to the architecture as a whole. Owing to their lower cost, these satellites would provide a "good enough" capability that could be more quickly replenished.