Testimony before the U.S.-China Economic and Security Review Commission: Hearing on China's Advanced Weapons

Kevin Pollpeter

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Maryanne Kivlehan-Wise
Research Team Leader
CNA China Studies

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Kevin Pollpeter
Research Scientist, CNA
23 February 2017

China's military has identified outer space as a new domain described as a "new commanding height of war" which China must fight for and seize if it is to win future wars. Space now plays a more central role in China's plans to project power far from its shores and in its abilities to defeat high-tech adversaries, such as the U.S. military. To carry out this mission, the People's Liberation Army (PLA) has embarked on a comprehensive modernization effort involving a new concept of operations, technological modernization, and organizational reform that will allow it to better use space for military operations and to deny the use of space to adversaries.

Since 2004 the Chinese government and military have been placing increasing importance on space as a military domain. In 2004, the PLA issued its *New Historic Missions*, which called on its forces to defend China's interests, not only within its traditional boundaries of the land, airspace, and territorial waters, but also in the new domains of the distant oceans, outer space, and cyber space. In 2012, then-president Hu Jintao ordered the PLA to focus its efforts on defending the maritime domain, outer space, and cyber space. In China's 2015 defense white paper, *China's Military Strategy*, China for the first time officially designated outer space a domain.

These announcements have coincided with assessments in important PLA publications of the vital nature of space to military operations. For many years, Chinese writers have made the oft-repeated statement that "whoever controls space will control the Earth" and that outer space is the new high ground of military operations. They note that the center of gravity in military operations has transitioned from the sea to the air and is now transitioning to space.[1] According to a book published by the PLA's Academy of Military Science, *A Study of Space Operations*, "Whoever is the strongman of military space will be the ruler of the battlefield; whoever has the advantage of space has the power of the initiative; having 'space' support enables victory, lacking 'space' ensures defeat."[2] The authors of the 2013 *Science of Military Strategy* similarly conclude that space is the new high ground and that without space superiority one is at a disadvantage in all other domains.[3] The goal of space operations is to achieve space superiority (制天权), defined as "ensuring one's ability to fully use space while at the same time limiting, weakening, and destroying an adversary's space forces."[4] It includes not only offensive and

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[1] See Jiang Lianju and Wang Liwen (eds.), *Textbook for the Study of Space Operations* (空间作战学教程), (Beijing: Military Science Publishing House, 2013), p. 14.
[2] Ibid., p. 1.
[3] China Academy of Military Science, *Science of Military Strategy* (战略学), (Beijing: Military Science Press, 2013), p. 96; and Jiang and Wang, *Study of Space Operations*, p. 13.
[4] Jiang and Wang, *Study of Space Operations*, p. 6.

defensive operations in space against an adversary's space forces, but also air, ground, and naval operations against space assets.[5]

In fact, the authors of the 2013 *Science of Military Strategy* identify outer space as one of five major military threats facing the PLA, along with nuclear, conventional, cyber, and nuclear-conventional threats. *Science of Military Strategy* then goes on to recommend that the PLA must adapt to the "new forms of warfare and to the characteristics of new operational domains" and "closely track the world's strong powers in the development of military technologies, weapons and equipment, operational forces, and strike methods" by developing unmanned aerial vehicles, counter-stealth and cruise missile technologies, aircraft carrier strike units, counterspace platforms, as well as tactics for countering ISR, precision strike, cyber attack, space weapons, and other new attack methods.[6] Given the wide-range of rapid strike methods, "especially space and cyber attack and defense methods," the authors of *Science of Military Strategy* argue that China must prepare for an enemy to attack from all domains.[7] It predicts that future wars will likely begin in outer space and cyberspace and states that "achieving space superiority and cyber superiority are critical for achieving overall superiority and being victorious over an enemy."[8]

In addition to officially designating space as a military domain, the 2015 defense white paper also announced a change in the PLA's concept of operations from "local wars under informatized conditions" to "informatized local wars." More so than its predecessor concept, informatized local wars place emphasis on joint operations and the technology necessary to connect units, not only vertically through a chain of command but also horizontally across different combat arms and services fighting in different domains. An important component of informatized local wars is "system vs. system operations" (SvS operations). SvS operations are intended to "accelerate operational response times to enhance firepower and maneuver, particularly by shortening and streamlining decision making and sensor to shooter times to get inside an opponent's decision cycle." It will also "enable units to operate with greater independence in dispersed deployment in a nonlinear battlespace; yet synchronize operations within a centralized command structure with some allowance for initiative."[9] SvS operations "rel[y] on information systems…to unify and optimize force groupings, provide real-time information sharing and precision control of combat operations."[10] To carry out SvS operations, the PLA is required to make "advances in communications, satellite navigation, and reconnaissance capabilities that enable greater sharing of information, situational awareness, and a flatter command structure."[11]

This new way of war moves the PLA away from a platform-centric approach. Under this concept, warfighting is a contest between networks of systems where the operation of every system and subsystem affects the performance of the entire system. Together the synergistic qualities of this

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5 Ibid.
6 AMS, *Science of Military Strategy*, pp. 100, 118, 130.
7 Ibid., p. 102.
8 Ibid., p. 96.
9 Kevin McCauley, "System of System Operational Capability: Key Supporting Concepts for Future Joint Operations," *China Brief*, October 5, 2012, http://www.jamestown.org/single/?no_cache=1&tx_ttnews%5Btt_news%5D=39932#.VenjnWeFOh1.
10 Ibid.
11 Ibid.

system-of-systems configuration can yield a result greater than the sum of its parts, enabling joint operations through the use of networked information systems that provide each operational element with a real-time common operating picture of the battlefield and allowing units to be more flexible and adaptive.[12]

Space as a Component of System vs. System Operations

Chinese analysts portray space as a critical component of information warfare due to the ability of space technologies to better enable ground, air, and naval operations and the necessity to deny other countries the use of space. These analysts assert that space is the ultimate high ground and that whoever controls space controls the Earth. Explicit in these arguments is that space has become so vital to fighting modern war that no country can do without it. At the same time, Chinese military analysts regard space as a great vulnerability that if denied, can so debilitate an enemy that victory could be achieved.

Space-based C4ISR capabilities support military operations through a variety of national security applications, including reconnaissance, meteorology, missile early warning, communication, and navigation. These technologies provide critical capabilities to monitor the activities of potential adversaries, facilitate communication between far-flung forces, and provide navigation data to naval, ground, and air forces. Counterspace operations, in contrast, are intended to deny, degrade, disable, or destroy an opposing side's space capabilities. These can include attacks against both ground-based and space-based space assets through the use of kinetic and non-kinetic means. Space operations thus play a critical role in the PLA's ability to conduct antiaccess/area denial operations by enabling long-range precision strikes against land, air, and naval targets and in denying adversaries the use of their own space assets.

Operationally Responsive Space Capabilities

In order to achieve its goal of achieving space superiority, China appears to be developing an operationally responsive space force. Operationally responsive space contains two elements: assurance of capabilities and timely delivery. These include "reconstitution of lost capabilities, filling unanticipated gaps in capabilities, exploiting new technical or operational innovations, and enhancing survivability of space systems."[13] This requires two capabilities. The first is the capability to launch a variety of satellites into all orbits and to be able to rapidly reconstitute or plus-up satellite constellations. The second is the possession of satellites that enable the PLA to achieve its mission objectives while also ensuring survivability.

Road-mobile Launch Vehicles

A major component of an operationally responsive space capability is assured launch. In addition to its liquid-fueled Long March launch vehicles, China has also developed two solid-fueled rockets. Although not as powerful as their liquid-fueled counterparts, these solid-fuel rockets do not need to be fueled before launch and can be launched from sites other than China's four launch centers, enhancing responsiveness and survivability. The Long March 11 is reportedly based on the DF-31 ICBM and can carry a payload of 700 kilograms into orbit. The second of China's solid-fueled rockets is the Kuaizhou launch vehicle. The Kuaizhou is reported to be

[12] AMS, *Science of Military Strategy*, p. 125.
[13] Thomas Davis, *Operationally Responsive Space – The Way Forward,* http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=3213&context=smallsat.

based on the DF-21 medium-range ballistic missile and is advertised as being capable of launching 300 kg into orbit with just four hours of preparation.[14]

Space-based C4ISR

A robust, space-based C4ISR system is often described as a critical component of a future networked PLA. The need 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 for over-the-horizon attacks against land and naval targets requires the ability to locate, track, and target enemy installations and ships 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, provide strategic intelligence before a conflict begins, and help provide post-strike battle damage assessments. 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. These capabilities will also better integrate disparate services into a joint force by allowing one service to better support other services through better communications and by helping integrate intelligence functions through a shared battlefield picture.

Remote Sensing Satellites

China has made remarkable progress in space-based remote sensing capabilities and, by 2020, plans to establish a "high-resolution Earth observation system" capable of stable all-weather, 24-hour, multi-spectral, various-resolution observation. Since 2000, China has launched a number of new types of remote sensing satellites to accomplish this goal. These include satellites with electro-optical (EO), synthetic aperture radar (SAR), multispectral, hyperspectral, stereoscopic, staring camera, and electronic intelligence (ELINT) payloads. See Table 1 for a list of selected Chinese remote sensing satellites and their features.

Table 1: Selected Chinese Remote Sensing Satellites[15]

Satellite	Payloads	Resolutions	Number Operational
Yaogan	EO, SAR, ELINT	1-10 m	30+

[14] Kuaizhou Solid-Fueled Rocket Chief Designer (快舟固体运载火箭总设计师), http://liuqiankktt.blog.163.com/blog/static/121264211201442483039223/.

[15] Sources: S. Chandrashekar and Soma Perumal, "China's Constellation of Yaogan Satellites and the Anti-Ship Ballistic Missile: May 2016 Update, National Institute of Advanced Studies, http://isssp.in/wp-content/uploads/2016/05/Yaogan-and-ASBM-May-2016-Report.pdf, "Long March 3B lofts Gaofen-4 to Close Out 2015," nasaspaceflight.com, December 28, 2015, http://www.nasaspaceflight.com/2015/12/long-march-3b-gaofen-4-close-2015/; "China's Ocean Satellites" (中国海洋卫星), *Aerospace China* (中国航天), No. 372 (April 2009), 10–11; Wang Qiao, Wu Chuanqing, and Li Qing, "Environment Satellite 1 and Its Application in Environmental Monitoring," *Journal of Remote Sensing* 1 (2010): 104; Rui C. Barbosa, "China launches Jilin-1 mission via Long March 2D," nasaspaceflight.com, October 7, 2015, http://www.nasaspaceflight.com/2015/10/china-launches-jilin-1-mission-long-march-2d/; Stephen Clark, "Commercial Earth-observing Craft Recover From Off-target Launch," *spaceflightnow.com*, January 11, 2017, https://spaceflightnow.com/2017/01/11/commercial-earth-observing-craft-recover-from-off-target-launch/

Gaofen	EO, Staring camera	EO= <1m-2m, 800m; Staring camera=50m	5
Haiyang	EO and color scanners	EO=250m	1
Huanjing	EO	30m	3
Jilin	EO	0.72m	4
Tianhui	Stereoscopic	5m	3
Gaojing	EO	0.5 meters	2

Communications and broadcasting satellites

China has also launched a number of communications satellites. The Yatai and Zhongxing satellites cover China as well as major areas of the world. Tiantong-1, China's first mobile communications satellite, was launched in 2016. In addition to this is the Tianlian data relay constellation. Without these data relay satellites, China's remote sensing satellites would have to fly within line of sight of a ground receiving station to send their images to Earth. With these satellites, China can now cover 100 percent of the globe, greatly increasing the timeliness of the delivery of China's space-based ISR data.

Navigation Satellites

China's navigation and positioning system, Beidou, is currently comprised of 22-satellite constellation that provides coverage for China and most of Asia. By 2020 it will be expanded to a 35-satellite constellation to provide global coverage. The accuracy of Beidou-2 is currently better than 10 meters and can achieve sub-meter accuracy with the assistance of ground stations.

Smaller Satellites

China is also developing small, micro, nano, and pico satellites that are less capable than larger satellites but can be deployed more quickly to reconstitute lost satellites. The Jilin-1 mission launched on October 7, 2015, consisted of four satellites: one for high-definition images, two for videos, and one for technology development. The Jilin-1 satellite has a mass of 420 kg and can provide imagery with a resolution of 0.72 meters. The Lingqiao A and B satellites launched with the Jilin-1 satellite have a mass of just 95 kg and can provide videos with resolutions of 1.3 meters. According to the goals of the manufacturer, by 2020, sixty Jilin-1 satellites will be able to achieve revisit rates of 10 minutes and by 2030 one hundred thirty-eight satellites will be able to provide a 10-minute revisit rate.[16]

In September 2015, China's first launch of the Long March 6 launch vehicle carried 20 micro, nano, and pico satellites. These small satellites were mainly technology demonstrators, including electric propulsion, in-space communication links, new software, cameras, nanotechnology, and amateur radio relay.[17] The two pico-satellites accompanying the launch had masses of just 1.5 kg and entered orbit piggybacked on another satellite.[18]

Advanced Technology Testing

China has recently launched a number of projects to test cutting-edge technologies that appear to place it at the forefront of space technologies in some areas. These include quantum

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[16] Rui C. Barbosa, "China Launches Jilin-1 Mission via Long March 2D," *nasaspaceflight.com*, October 7, 2015, https://www.nasaspaceflight.com/2015/10/china-launches-jilin-1-mission-long-march-2d/.

[17] Stephen Clark, "Debut launch of Long March 6 deploys 20 satellites," *spaceflightnow.com*, https://spaceflightnow.com/2015/09/20/debut-launch-of-long-march-6-deploys-20-satellites/.

[18] Ibid.

communications and pulsar navigation satellites and electromagnetic (EM) drive. In each case, China has launched these technologies ahead of U.S. programs. If the reports of these tests are accurate, it may indicate that China is moving from simply copying or reengineering technology to conducting true original innovation.

Quantum Communications Satellite

In August 2016 China launched the world's first quantum communications satellite. Named Micius after a Chinese scientist who conducted the first optic experiments in the 5th century B.C., the satellite is designed to "establish 'hack-proof' quantum communications by transmitting uncrackable keys from space to the ground."[19] Quantum science is one of six "big ideas" identified by the U.S. National Science Foundation. Previous Chinese experiments only involved sending quantum communications over a fiber optic cable no more than 500 km. Quantum encryption works on the principle that due to the entanglement of quantum particles, any attempt to measure the particles will result in their destruction, rendering the message unreadable. Such a capability will render communications using quantum communications virtually impregnable to eavesdropping.

The reported $100 million project will attempt to distribute quantum keys between two sites on Earth through the Micius satellite. Tests will include transmissions of messages between Beijing and Urumqi, Xinjiang, and between sites in China and Vienna, Austria.[20] According to Pan Jianwei, the project's chief scientist, a global quantum communications network could be set up around 2030.[21]

Electromagnetic Drive

On December 10, 2016, China announced that it had developed a prototype electromagnetic (EM) drive that is currently being tested in orbit,[22] possibly on the Tiangong-2 space station.[23] Experimental testing of EM drive technologies started around 2001 by the UK company Satellite Propulsion Research Ltd., and in 2014 NASA researchers announced that they had successfully tested an EM drive in a laboratory on Earth. But China is the first country to have tested an EM drive in space.

EM drive technology is thought to be impossible by some. It involves the use microwaves instead of propellant to move a satellite through space. EM drives offer two benefits. Without the need to store propellant, the mass of a satellite can be greatly reduced, thereby saving launch costs. Further cost savings can be achieved if the satellite is launched into low Earth orbit and

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[19] "China Launches First-ever Quantum Communication Satellite," Xinhua, August 16, 2016, http://news.xinhuanet.com/english/2016-08/16/c_135601026.htm.

[20] "China Launches First-ever Quantum Communication Satellite," Xinhua, August 16, 2016, http://news.xinhuanet.com/english/2016-08/16/c_135601026.htm.

[21] "Xinhua Insight: China launches first-ever quantum communication satellite," Xinhua, August 16, 2016, http://news.xinhuanet.com/english/2016-08/16/c_135601064.htm.

[22] Cao Xiuying, "Electromagnetic Propulsion: Arabian Nights or Important Breakthrough" (电磁驱动：天方夜谭还是重大突破), *Science and Technology Daily* (科技日报), December 11, 2016, http://digitalpaper.stdaily.com/http_www.kjrb.com/kjrb/html/2016-12/11/content_357004.htm?div=-1.

[23] Mary-Ann Russon, "EmDrive: Chinese space agency to put controversial tech onto satellites 'as soon as possible,'" *International Business Times*, December 13, 2016, http://www.ibtimes.co.uk/emdrive-chinese-space-agency-put-controversial-tech-onto-satellites-soon-possible-1596328.

then reaches high Earth orbit under its own power. An EM drive can also propel a satellite to much greater speeds than regular propellant. A spacecraft traveling to Mars using an EM drive, for example, could make the trip in 70 days rather than the six months it would take using a normal propulsion system.[24]

Pulsar Navigation

In November 2016 China launched the XPNAV-1 satellite to test pulsar navigation technologies. NASA is expected to begin testing on-orbit pulsar navigation technologies onboard the International Space Station later this year. Pulsar navigation uses pulsars—rapidly rotating neutron stars that "pulse" by sending out regularly timed signals in the x-ray band. By using the pulse of these stars, which can be as fast as 30 times per second, as the timing function, navigation satellites can achieve better accuracies than those achieved through the use of atomic clocks. The XPNAV-1 will detect the signals of 26 nearby pulsars to create a pulsar navigation database so that their signals can be used for navigation.[25]

Pulsar navigation is most commonly thought of in reference to deep space navigation where GPS is no longer available and where it can take hours for ground signals to reach a satellite. By using pulsar navigation, a satellite can achieve more autonomy in executing its flight plan. Closer to Earth, satellites guided by pulsar navigation and star trackers can achieve positioning accuracies of a few meters or less, greatly enhancing control of a satellite for civil or military purposes.[26] Moreover, satellites using pulsar navigation can operate independently of legacy satellite navigation systems, such as GPS or Beidou, and thus eliminate the dependency of those satellites on those systems. Finally, pulsar navigation can also improve the accuracy of satellite navigation signals sent to ground receivers by improving the known location of the navigation satellites and reducing timing errors.[27] This feature could improve the precision of guided munitions and military navigation.

Counterspace

The second component of the PLA's goal to achieve space superiority is counterspace. Chinese analysts assess that the United States relies on space for 70–90 percent of its intelligence[28] and 80 percent of its communications.[29] Based on this assessment, Chinese analysts surmise that the loss of critical sensor and communication capabilities could imperil the U.S. military's ability to achieve victory or to achieve victory with minimal casualties.

According to the U.S. defense department, China is developing a wide range of counterspace technologies intended to threaten an adversary's space capabilities from the ground to high Earth

[24] Jose Rodal, Jeremiah Mullikin, and Noel Munson, "Evaluating NASA's Futuristic EM Drive," *nasaspaceflight.com*, April 29, 2015, https://www.nasaspaceflight.com/2015/04/evaluating-nasas-futuristic-em-drive/.

[25] "China launches pulsar test satellite," *Renmin Wang*, November 10, 2016, http://en.people.cn/n3/2016/1110/c90000-9139794.html.

[26] Taylor Dinerman, "X-ray pulsar navigation: the deep space solution?," *The Space Review*, December 11, 2006, http://www.thespacereview.com/article/762/1.

[27] See Dennis W. Woodfork II, "The Use of X-Ray Pulsars For Aiding GPS Satellite Orbit Determination," thesis completed for the Department of the Air Force Air University, March 2005.

[28] Jiang and Wang, *Study of Space Operations*, p. 150.

[29] Chang Xianqi, *Military Astronautics*(军事航天学) (Beijing: National Defense Industry Press, 2002), pp. 257–58.

orbit. For a summary of Chinese counterspace operations and tests and tests with counterspace implications, see Table 2.

Table 2: Chinese Counterspace Operations and Tests, and Tests with Counterspace Implications

Year	Technology
2006	Chinese laser paints U.S. satellite, though intent of action is unknown
2007	China destroys aging FY-1C meteorological satellite with direct-ascent kinetic-kill vehicle
2010	China conducts mid-course ballistic missile defense test
2010	Two Shijian satellites involved in close proximity operation, causing slight change in one satellite's orbit
2012	Cyber attack against Jet Propulsion Laboratory
2013	China conducts mid-course ballistic missile defense test
2013	Three satellites involved in close proximity operation to test space debris removal and robotic arm technologies
2013	China conducts "high-altitude science" mission with rocket reaching GEO
2014	China conducts direct-ascent KKV test
2014	Cyber attack against National Oceanic and Atmospheric Administration
2016	Aolong-1 space debris satellite launched

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 that created more than 3,400 pieces of debris.[30] China has also conducted a series of counterspace-related direct ascent tests. In 2010 and 2013 China conducted mid-course tests of a missile defense system, which have been widely regarded as having counterspace implications. In July 2014 China again conducted what it called a missile defense test. The U.S. defense department, however, characterized the test as a non-debris-producing ASAT test.[31]

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.[32] This claim was contradicted by a U.S. government assessment that the rocket "appeared to be on a ballistic trajectory nearly to geosynchronous Earth orbit (GEO)."[33] If so, the test would represent an expansion of China's ASAT capabilities. The 2007 ASAT destroyed a satellite at an altitude of 800 kilometers, demonstrating the ability to threaten satellites in low Earth orbit, such as remote sensing satellites. The May 2013 test, in comparison, would allow China to threaten satellites such as GPS and communication satellites in medium and high Earth orbits.

[30] "Fengyun-1C Debris Cloud Remains Hazardous," *Orbital Debris Quarterly News*, January 2014: 3–4.
[31] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2015*, p. 14.
[32] "China Again Conducts a High Altitude Science Mission: Higher Altitude and More Data" (中国再次高空科学探测试验：高度更高数据更多), *China News* (中国新闻网), May 14, 2013, http://www.chinanews.com/gn/2013/05-14/4817925.shtml.
[33] Brian Weeden, "Through a Glass, Darkly: Chinese, American, and Russian Anti-Satellite Testing in Space," *Space Review*, March 17, 2014, http://www.thespacereview.com/article/2473/1.

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 true intention of the test fueled concern that it was a cover for testing ASAT capabilities.[34]

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 that will be used on a future Chinese space station. As with the August 2010 tests, however, the dual-use nature of the test and the silence of the Chinese on the matter have only fueled speculation that China was also testing counterspace technologies.[35] In June 2016 the Aolong-1 debris removal satellite was launched. This satellite is equipped with a robotic arm to test space debris removal capabilities.[36]

China is also developing directed-energy weapons such as lasers, high-powered microwaves, and particle beam weapons for ASAT missions.[37] The U.S. defense department concluded in 2006 that China had "at least one…ground-based laser designed to damage or blind imaging satellites."[38] Lasers at higher power levels can permanently damage satellites and at lower power levels can temporarily blind the imagers of a remote sensing satellite. Lasers can be based on the ground, on aircraft, on ships, or in space. In 2006 it was reported that China 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.[39]

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 either overheating or short circuiting. RF weapons are thus useful in achieving a wide spectrum of effects against satellites in all orbits.[40] RF weapons employed on satellites may be detected since the satellite would need to be close to the target satellite for the weapon to be effective. A satellite armed with an RF weapon on a crossing orbit with the target satellite, however, may not

[34] Brian Weeden, "Dancing in the Dark: The Orbital Rendezvous of SJ-12 and SJ-06F," *Space Review*, August 30, 2010, http://www.thespacereview.com/article/1689/1.
[35] See Kevin Pollpeter, "China's Space Robotic Arm Programs," *SITC News Analysis*, October 2013, http://igcc.ucsd.edu/assets/001/505021.pdf.
[36] "China's New Orbital Debris Clean-Up Satellite Raises Space Militarization Concerns," June 29, 2016, http://spaceflight101.com/long-march-7-maiden-launch/aolong-1-asat-concerns/.
[37] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2012), p. 9.
[38] Office of the U.S. Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (2006), p. 35.
[39] Elaine M. Grossman, "Top Commander: Chinese Interference with U.S. Satellites Uncertain," *World Politics Review*, October 18, 2006.
[40] 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, pp. 66–67.

be recognized as a threat. RF weapons launched on rockets can detonate near the target satellites and thus may not be detected. Because RF weapons affect the electronics of satellites, evaluating the success of an attack might be difficult since no debris would be produced.[41]

China has also been involved in computer hacks against satellite computer systems. In 2012, NASA Inspector General Paul Martin stated in a report that cyber attacks from Chinese IP addresses had resulted in the perpetrators gaining "full access to key Jet Propulsion Laboratory [computer] systems and sensitive user accounts."[42] In November 2014 the National Oceanic and Atmospheric Administration (NOAA) reported that its agency's networks were hacked. The agency did not release information on which networks were compromised, and it did not identify China as the culprit. Then-congressman Frank Wolf, however, stated that NOAA had told him that China was behind the hack.[43]

China has also acquired foreign and indigenous jammers that give it "the capability to jam common satellite communications bands and GPS receivers."[44] 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.[45]

Organizational Reform

In December 2015 the PLA created a new organization, the Strategic Support Force（SSF/战略支援部队）. The Strategic Support Force commands elements of the PLA's space and cyber force[46] and its creation appears to be intended to move the PLA's space enterprise from the research and development-oriented General Armament Department to the operationally focused SSF. As such, the SSF appears to be a major part of the PLA's effort to structurally reform in order to better conduct joint operations through the use of information technologies. Nevertheless, much remains unknown about the SSF. Significant in this regard is the command structure for China's counterspace forces. PLA sources are clear that the SSF will operate China's constellation of satellites, but they make no mention of counterspace capabilities.

Conclusions

Whether it is the acquisition of intelligence or navigation information from space-based platforms to enable long-range strikes or the use of offensive space control measures, space plays a prominent role in China's efforts to establish an effective military capable of winning

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

[42] Statement of Paul K. Martin, Inspector General, National Aeronautics and Space Administration, "NASA Cybersecurity: An Examination of the Agency's Information Security," February 29, 2012, p. 5.

[43] http://www.washingtonpost.com/local/chinese-hack-us-weather-systems-satellite-network/2014/11/12/bef1206a-68e9-11e4-b053-65cea7903f2e_story.html.

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

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

[46] "The Reader for Chairman Xi Jinping's Important Expositions on National Defense and Military Reform (2016 Edition) on Resolutely Winning the Battle to Deepen National Defense and Military Reform – On Completely Implementing the Strategy on Reforming and Strengthening the Military" (习主席国防和军队建设重要论述读本（2016 年版）》坚决打赢深化国防和军队改革这场攻坚战 ——关于全面实施改革强军战略), *Liberation Army Daily*, May 26, 2016, p. 4.

informatized wars through an asymmetric strategy directed at critical U.S. military platforms. The PLA's development of a concept of operations, technologies, and organizations to carry out the space mission strongly suggests that the PLA has moved beyond just technology development to laying the ground work for operational and command and control concepts to govern their use.

These developments have important consequences for the U.S. military. The denial of critical space-based C4ISR capabilities integrated with cyber and kinetic attacks against non-space-based C4ISR nodes could greatly complicate the ability of the U.S. military to flow forces to the region and to conduct operations effectively, and acts as a force multiplier that greatly increases the PLA's its effectiveness against less capable militaries. This strategy gains more salience when pitted against the U.S. concept of air-sea battle, which emphasizes standoff weaponry enabled by information technologies.[47] China's space capabilities, when directed at less capable militaries, would have an even more salient effect on overall military operations. As a result, China's military may now see space systems in the same way that the U.S. military regards its space systems: as "an integral – not adjunct, not supporting, not auxiliary" part of its military.[48]

[47] David Fulghum, "Navy Aviation in the Crosshairs," *Aviation Week*, April 9, 2012: 49.
[48] Bob Butterworth, "Limit Command of Military Satellites: Butterworth," *Breaking Defense*, September 15, 2014, accessed http://breakingdefense.com/2015/09/limit-military-command-of-spy-satellites-butterworth/. Butterworth's comments were actually made about U.S. space systems.

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