The Great Game in Space

China's Evolving ASAT Weapons Programs and Their Implications for Future U.S. Strategy

Ian Easton

PROJECT 2049 INSTITUTE

The Project 2049 Institute seeks to guide decision makers toward a more secure Asia by the century's mid-point. The organization fills a gap in the public policy realm through forward-looking, region-specific research on alternative security and policy solutions. Its interdisciplinary approach draws on rigorous analysis of socioeconomic, governance, military, environmental, technological and political trends, and input from key players in the region, with an eye toward educating the public and informing policy debate.

www.project2049.net

If there is a great power war in this century, it will not begin with the sound of explosions on the ground and in the sky, but rather with the bursting of kinetic energy and the flashing of laser light in the silence of outer space. China is engaged in an anti-satellite (ASAT) weapons drive that has profound implications for future U.S. military strategy in the Pacific. This Chinese ASAT build-up, notable for its assertive testing regime and unexpectedly rapid development as well as its broad scale, has already triggered a cascade of events in terms of U.S. strategic recalibration and weapons acquisition plans. The notion that the U.S. could be caught off-guard in a "space Pearl Harbor" and quickly reduced from an information-age military juggernaut into a disadvantaged industrial-age power in any conflict with China is being taken very seriously by U.S. war planners. As a result, while China's already impressive ASAT program continues to mature and expand, the U.S. is evolving its own counter-ASAT deterrent as well as its next generation space technology to meet the challenge, and this is leading to a "great game" style competition in outer space.

Cover illustration:
www.defensetech.org.
Left: www.spyflight.com.uk

China's ASAT Weapons

The PLA has been developing ASAT weapons as a national priority since at least the early 1990s. The Pentagon first publicly disclosed that China was developing a direct-ascent ASAT missile in its annual report on Chinese military power in 2003. This report also pointed out that this type of ASAT weapon system was only one part of a larger spectrum of offensive capabilities aimed at vitiating U.S. dominance in space.[1] It was not long before the Department of Defense (DoD) report was proven correct. Starting in September 2004, the PLA reportedly began a series of three direct ascent ASAT tests, which led up to the fourth, this time successful, test that destroyed the FY-1C weather satellite on January 11, 2007.[2] Before the launch, Chinese aerospace engineers had conducted a series of ASAT simulations. Using the euphemism "space interceptor," results of these simulations indicate focus on a 100kg payload boosted by a solid-fueled vehicle on a specialized trajectory.[3]

China's direct-ascent, kinetic-kill ASAT launch vehicle appears to be a mobile, four-stage variant of the DF-21 medium range ballistic missile (MRBM), with a ground range of 1,700-2,500km. This ASAT missile, which has been designated SC-19 by U.S. intelligence,[4] is a variant of the Chinese *Kaituozhe*-1 (KT-1) or "Pioneer-1" solid-fuelled launch vehicle. This launch vehicle is developed by the China Aerospace Science and Industry Corporation (CASIC) mainly through its affiliated Space Solid Fuel Rocket Carrier Co. Ltd. (SSRC).[5] CASIC's development and manufacturing of KT-1, which occurred ostensibly for the commercial launch of small satellites, gave planning priority to the military demands of "speed(ing) up the pace of China's space-based weaponry construction."[6] The launch vehicle's guidance package is aided by ground based radars,[7] and unconfirmed Chinese sources suggest that the ASAT's kinetic-kill vehicle (KKV) is a modified HQ-19 warhead.[8]

The HQ-19 is the Chinese designation for the Russian SA-21 Growler surface-to-air missile (SAM) system, which was reported to be a joint development program with China.[9] The HQ-19 uses an inertial guidance with command updates and an active radar terminal seeker.[10] PLA Air Force Engineering Academy engineers involved in China's ASAT program have specifically mentioned using the latest Russian air-defense technology in outlining possible means to meet ASAT requirements.[11] However, the national-level effort to develop the means to make space intercepts, the 863-409 program, has also focused on an infrared seeker as the main element of the guidance system. It is possible that China

uses both multi-spectral radar and an infrared seeker in its KKV guidance package. According to a Chinese news website that focuses on military affairs, China has deployed up to 40 direct-ascent ASAT missiles.[12] China has also imported 8 battalions of S-300PMU2 SAMs which have limited ballistic missile interception capability, and with some modification could make ASAT intercepts as well.[13] Unconfirmed Chinese military reports indicate increasing interest in an integrated air and space defense system, with an emphasis on using SAMs for space control.[14] Such a system could be similar to the U.S. SM-3 program, which Chinese ASAT engineers have studied in detail.[15]

China's direct-ascent ASATs pose a serious challenge to U.S. photographic intelligence (PHOTINT), electro-optical (EO), synthetic aperture radar (SAR), and electronic intelligence (ELINT) satellites that operate in low-earth orbit (LEO). According to Desmond Ball, a stockpile of around 20 direct-ascent ASATs would be needed to guarantee the destruction of the six or seven EO/SAR satellites that are thought to currently constitute the bulk of classified U.S. national security space imaging.[16] A further 20 such weapons would be needed to guarantee the destruction of the four co-orbiting groups of three sub-satellite units (SSU) the U.S. Navy uses to locate enemy warships and ground-based air defense systems with which it can then target with its over-the-horizon, satellite-guided cruise missiles.[17] The loss of these EO/SAR/ELINT platforms, which are probably the main targets of China's direct-ascent ASAT weapons, would be a very serious blow to the U.S. at the outset of any conflict.

Left: http://news.xinhuanet.com

Right: www.defensetech.org

Aside from the direct-ascent KKV China has successfully tested, it is also possible that direct-ascent ASATs could be armed with the electro-magnetic pulse (nuclear or non-nuclear) warheads that the PLA is also developing for its anti-ship ballistic missile (ASBM) program, which is based upon similar technology as China's ASAT program.[18] Such

a weapons system would be serious (and rather indiscriminate) threat to a large number of civilian and military satellites in LEO, as well as those in highly elliptical orbits. China may feel that the use of such a device would be warranted in order to guarantee a survivable nuclear deterrent in the face of recent U.S. missile defense related infrared satellite deployments.

However, because DF-21-derived launch vehicles would not be able to reach satellites in low-inclination equatorial orbits, China is reported to be developing a submarine-launched launch vehicle for ASAT operations as a modified JL-2 submarine launched ballistic missile (SLBM). The JL-2 SLBM is deployed on China's type 094 Jin-class nuclear submarines, up to twenty of which may eventually be housed in an underground nuclear submarine base under construction at Sanya on Hainan Island in the South China Sea.[19] DoD estimates that China will have up to five Jin-class submarines with initial operating capability (IOC) by 2009-2010.[20] In principal, because the JL-2 has a ground range of only +7,200km, and China has limited radar satellite tracking capability, such a system could not threaten key U.S. military communications, early-warning, ELINT satellites in low-inclination equatorial, geostationary orbits (GEO), which are around 35,000km from Earth's surface. However, unsubstantiated reports indicate that China is currently developing an improved variant of its basic solid-fueled launch vehicle, designated the DF-25, that may eventually be able to use a larger first-stage motor based on DF-31 Intermediate Range Ballistic Missile/Intercontinental Ballistic Missile (IRBM/ICBM) technology, and an advanced guidance package to target U.S. satellites in GEO. In the interim, China is developing other ASAT technologies these GEO satellites may potentially be vulnerable to, such as radio frequency, cyber and laser weapons systems.[21]

China has been devoting significant resources to directed-energy weapons systems, particularly ground-based lasers, and have used them to target U.S. reconnaissance satellites.

China has been devoting significant resources to directed-energy weapons systems, particularly ground-based lasers, and have used them to target U.S. reconnaissance satellites. In August and September of 2006, China used high-powered, ground-based lasers to blind or "paint" U.S. reconnaissance satellites on several occasions as they passed over China. Reports stated that these were either ASAT tests or relatively "low-power" laser ranging devices intended to precisely determine satellite orbits for ASAT targeting purposes.[22]

According to one account, the "Chinese routinely turn powerful lasers skywards, demonstrating their potential to dazzle or permanently blind spy satellites." This report went on to quote Gary Payton, a senior Pentagon official who said "They let us see their lasers. It is as if they are trying to intimidate us."[23] According to a Hong Kong news website, China has at least one very large "ASAT laser artillery" weapon deployed

somewhere in its North Western territory, possibly somewhere high in Xinjiang's Tianshan Mountains where there would be far less atmospheric interference to deal with.[24]

China has also been developing (and in some cases fielding) cyber warfare units to hack into space control systems; co-orbital ASAT systems to covertly disable enemy satellites; radiofrequency weapons to jam satellite signals; and high-powered microwave weapons to destroy satellites from Earth. Some of these systems have been in development for over a decade, and the cyber warfare and laser programs are particularly mature.[25] In terms of co-orbital ASAT development, China's recent BX-1 micro-satellite test, which was carried out as a part of the manned Shenzhou-7 mission, demonstrated technology that can be used as a base for future covert satellite inspection missions, as well as co-orbital ASAT attacks. The BX-1 test was particularly notable for the fact that it pasted within 25 km of the International Space Station (ISS) in what may have been a simulated attack run.[26] In the near future, it is possible that China could use this technology to launch co-orbital, micro-satellite ASAT weapons from its Xichang Satellite Launch Center (or Base 27) to attack U.S. national security satellites in GEO. Looking longer term, such weapons could potentially be launched using road-mobile launchers as well. The summation of this broad and assertive Chinese ASAT weapons program is a clear challenge to U.S. space operations, and by way thereof, nearly all modern U.S. war fighting capabilities. This fact has not gone unnoticed, especially in the Pacific theater of operations, where the U.S. is especially reliant upon its space assets.

U.S. Vulnerability and Response to Chinese ASATs

From the American perspective, China is rapidly becoming a space-age superpower. In doing so, China is arguably altering the status quo in outer space, a realm that has been viewed as a domain of unchallenged U.S. dominance and defined by international cooperation since the end of the cold war. The U.S. is uniquely vulnerable to China's ASAT weapons. It operates nearly half of the 270-plus military satellites in orbit, as well as hundreds of civil, commercial and dual-use satellites that can be used for military operations. And while many of the details concerning the U.S. military space architecture are classified, a review of the open source literature is revealing.

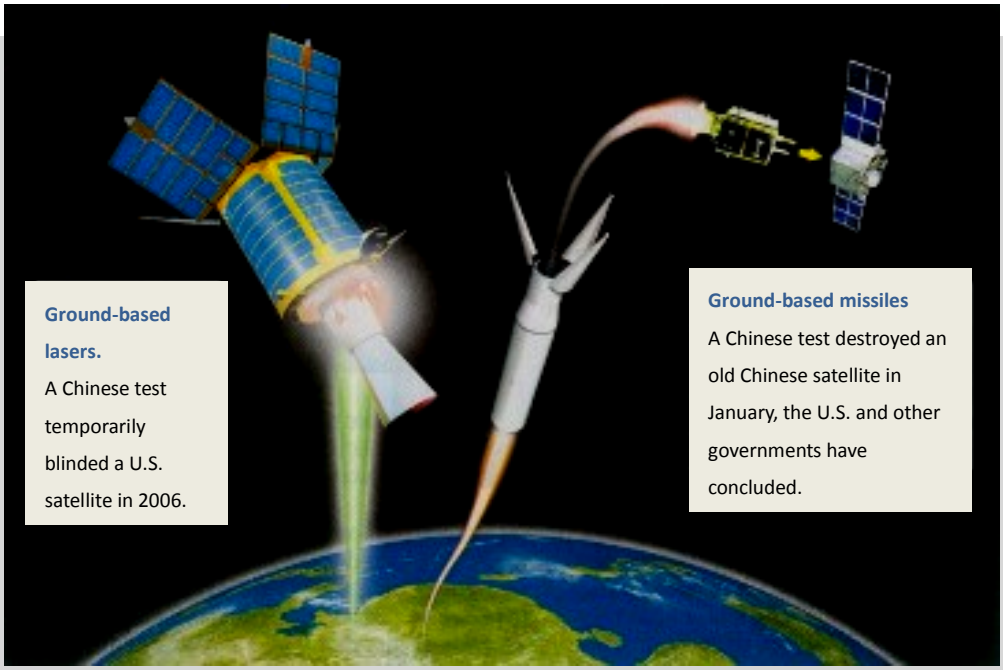
Electro-Optical Satellites. In terms of imagery intelligence (IMINT) assets, the U.S. is reported to have three operationally deployed 15 ton-plus "Improved Crystal" KH-12 EO reconnaissance satellites, which operate in LEO and are believed to be able to image

objects down to centimeters in width. These IMINT platforms are said to be further supplemented by an advanced version of the KH-12 reconnaissance imaging spacecraft codenamed "Misty." It is reported to utilize a unique stealth technology to evade detection and tracking. Like the KH-12 and other national security satellite platforms, Misty satellites (of which there are thought to have been two launched to date with one currently operational and a third scheduled for launch some time around 2009) are designed to be nuclear war, battle hardened spacecraft.

SAR Satellites. The U.S. also operates three "Lacrosse/Onyx" SAR imaging satellites in LEO that are all-weather (being able to use radar to see through cloud cover) and can image targets in the dark to resolutions less than 2 meters. Lacrosse/Onyx satellites are also reported to be able to image targets underground or underwater to an unknown depth.[27]

SIGINT Satellites. Aside from imagery, the U.S. military also relies on satellites for SIGINT, and is reported to have up to three giant "Mentor/Orion" satellites parked in GEO for the purpose of collecting radio emissions with radio reflecting dishes estimated to be 100 meters in diameter.[28]

Missile Early Warning Satellites. Also in GEO, four to five Defense Support Program (DSP) satellites utilize infrared sensors to provide worldwide coverage and early warning



Source: www.spyflight.com.uk

of missile launches and nuclear explosions. DSP satellites were used in the 1991 Iraq war to detect Scud missile launches and provided early warning to population centers as well as coalition forces, and are now sufficiently sensitive to detect short-range missile launches in real-time.[29]

Communications Satellites. In terms of communications, five "MILSTAR" communication satellites provide secure, jam resistant, worldwide communications for high priority military users,[30] and nine Defense Satellite Communications System (DSCS) Phase III spacecraft, which allow for high priority command and control communication, orbit in near GEO space over 35,000km out.[31]

GPS Satellites. Twenty-four (plus spares) Global Positioning System (GPS) satellites provide highly accurate positioning, navigation, velocity and timing information worldwide to both military and civilian users from Mid-Earth Orbits (MEO) 20,000km out. GPS spacecraft allow allied troops to navigate trackless desert, and guide Joint Direct Attack (JDA) munitions with pinpoint accuracy, allowing for the bombing of enemy targets with minimal collateral damage.[32] This combination of military space assets, which provide vital intelligence, secure communications, navigation, missile guidance, meteorology and, crucially, early warning and missile defense, gives the U.S. an unparalleled advantage in modern warfare, and is driving its military transformation. During the recent Iraq war, 68% of U.S. munitions were satellite guided, a massive increase from the merely 10% of satellite guided munitions used in the 1991 Iraq War.[33]

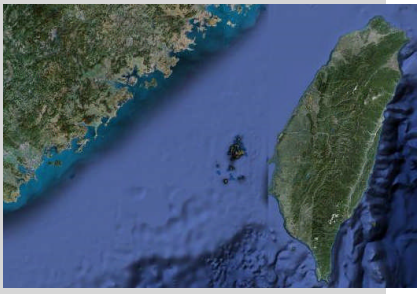
> …thanks to satellite technology the U.S. no longer fights in the fog of war, but in a "huge cloud of electrons."

One senior Air Force officer said that thanks to satellite technology the U.S. no longer fights in the fog of war, but in a "huge cloud of electrons." However, because four-fifths of America's military data is transmitted through unhardened commercial satellites, and a single Global Hawk unmanned surveillance drone flying over the Middle East can consume several times more bandwidth than was used in the whole of the 1991 war against Iraq, Air Force officers commonly describe space as being America's "Achilles Heel."[34] Referring to China's January 11, 2007 direct-ascent ASAT test, General Hamel of the Air Force's Space and Missile Systems Center said "if they take our asymmetric advantage in space, we go from an information age war machine to an industrial age war machine…shifting the balance; the edge will go to the adversary."[35]

Many specialists also argue that aside from the U.S. military dependency on orbital space, the U.S. economy, and in turn, much of the world economy, is also rapidly becoming dependent on space-based systems. They posit that, in effect, the U.S. is now a "space

faring" nation whose very way of life is tied to the myriad capabilities provided by the orbital space medium.

War games conducted as part of U.S. national security protocols, such as the Army-After-Next, Navy Global and Air Force Global Engagement series, Space Game 2 and Schriever 1 & 2, as well as the privately conducted "DEADSATS" war games, conducted from the late 1990s and the early 2000s, confirm this view. According to some space experts who were intimately involved with the war games, the exercises exposed "a critical national Achilles heel that politicians, economists and corporate CEOs have largely ignored…losses in space can quickly affect the economic, social, and national security fabric not only of the United States, but of the entire world." These experts further speculate that "large military powers," such as the United States, could "be held hostage by the unknowns inherent in a new kind of war."[36] These concerns are directly linked with China's ASAT weapons and their potential applicability in any future U.S.-Sino conflict. A more recent war game, "Pacific Vision," conducted by Pacific Air Forces (PACAF) underscored the vulnerability of the unprotected commercial communication satellite channels on which the Air Force relies, as well as its cyber and radar vulnerabilities to Chinese attack.[37]



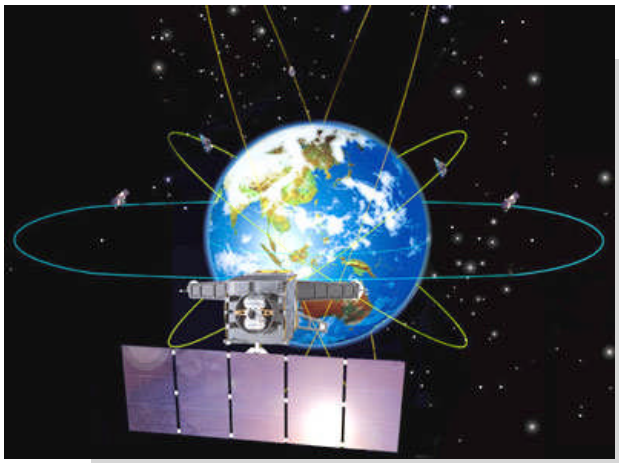
Source: Google maps.

Any possible U.S. military contingency around the Taiwan Strait would require secure satellites as the U.S. becomes ever more reliant upon its space systems. Moreover, reconnaissance satellites are thought to limit the risk inherent in the build-up of forces that both the PRC and the U.S. could be expected to deploy to the region in the event of a crisis. However, if the U.S. was blinded as the result of a preemptive Chinese ASAT attack, the conflict could quickly escalate to a dangerous level. According to two experts on the subject, "if there is a great-power war in the twenty-first century, our crystal ball says that it will be between the United States and China over Taiwan, with a very serious potential for a horrible escalatory process."[38] This underscores the gravity of the topic as well as the negative impact the Chinese shift towards fielding ASAT weapons could have.

While many of America's national security satellites are in GEO or highly- elliptical orbits and will not remain vulnerable to Chinese direct-ascent ASAT weapons like the one that destroyed FY-1C in the near-term, China's reported interest in jamming vulnerable GPS signals is causing the U.S. to set-up backup ground stations in case the main GPS control center outside Colorado Springs is disabled by cyber attacks.[39] The National Geospatial-intelligence Agency (NGA) has added at least 11 more shared monitor stations to strengthen the GPS land-based infrastructure as well.[40] The U.S. is also planning to deploy a new generation of GPS-III satellites with higher-power signals to make jamming

more difficult, and is developing laser communication systems, which can carry far more data and are much less prone to interference than radio waves.[41] The U.S. military is also expected to improve its surveillance and intelligence of space threats while further hardening its low-orbiting EO/SAR satellites with "passive defenses," such as lens shutters to shield from laser blinding such as those which occurred in August/September 2006. Other passive defenses may include satellite redundancy (having back-up satellites), as well as turn-off and maneuvering systems to avoid Chinese tracking and targeting.

It is also no coincidence that a little over four months after China's successful direct-ascent ASAT test, the U.S. Air Force established an Operationally Responsive Space (ORS) office at Kirtland Air Force Base in New Mexico. The mission of this office is to focus on assuring space power via the launching of smaller satellites on smaller boosters which could quickly reconstitute lost satellite capabilities and augment existing platforms in times of national emergency.[42] Two satellites have been launched to date as a part of to ORS effort, the TacSat-2 and TacSat-3. The TacSat-2 featured a low-power imagery sensor and SIGINT payload, and the TacSat-3 features a hyperspectral imaging sensor to penetrate camouflaged targets such as vehicles, buildings and landmines.[43] The U.S. Army Space and Missile Development Command (SMDC) has also created a constellation of four or more 4 kg (8.8 lb) communication satellites as part of the ORS effort. These nanosatellites were delivered in April, and are expected to have their launch schedule fixed by the end of June. Using some off-the-shelf components, the "SMDC-One" satellites are designed to demonstrate that operationally relevant satellites can be developed and readied for launch within a year.[44]



Source: http://spaceflightnow.com

The Air Force is also said to be investing heavily in a stealthy, supersonic unmanned aerial vehicle UAV which would combine high speed, high-stealth, high altitude and high persistence to fill any satellite gaps caused by increasingly problematic developmental delays or ASAT attacks.[45] The U.S. Air Force has already deployed two Space Based Infrared System (SBIRS) satellites in highly-elliptical orbits that will be difficult for China to target because of their high orbital speeds as they approach their perigee, and plans to launch a third SBIRS satellite into GEO late this year. Such satellites provide a revolutionary early warning system that is sensitive enough to detect and target mobile missile launchers from their engines' heat signatures and have a crucial role to play in missile defense.[46]

In terms of developing a counter-ASAT deterrent, the U.S. is looking at retaliating against any Chinese ASAT attack with "prompt global strike" weapons such as modified, non-nuclear ICBMs; stealth bombers armed with "bunker buster" bombs; and high-speed, long-range cruise missiles that could target Chinese ASAT missile sites very rapidly from modified Ohio-class nuclear submarines[47]. The Pacific island of Guam is playing a key role in the U.S. strategic recalibration, and is currently undergoing a massive construction effort to support a wide range of Air Force, Navy and Marine Corps missions. In terms of counter ASAT missions, these include housing and support facilities for Global Hawk UAVs, B-2 stealth bombers, fast-attack submarines, cruise missile submarines and an aircraft carrier strike group, all of which would play a role in responding to any Chinese ASAT attack. In particular, the Navy's two Pacific-based cruise missile submarines, the Ohio and the Michigan, can be armed with up to 154 cruise missiles to target Chinese ASAT missile sites.

New generations of supersonic and hypersonic cruise missiles and UAVs are also future payload possibilities. These modified boomers can stay on patrol off the Chinese coast for up to 400 days, surfacing in Guam in the middle of a deployment for 21 days to change crews, do maintenance and load fresh supplies. The Ohio and the Michigan deployed for operations in the Pacific in 2007 and 2008, respectively, and represent the front line of the U.S. military's evolving counter ASAT deterrent.[48]

Looking ahead, the Air Force is developing a Common Aero Vehicle (CAV), or space plane, that could deliver a range of conventional weapons at hypersonic speeds to counter ASAT launches. However, due to concerns that the use of such a system could escalate nuclear tensions, the CAV program now appears to be focusing more on providing for rapid worldwide delivery and deployment of space assets.[49] In any event, the CAV program, like the Navy's cruise missile submarines and a host of orbital and sub-orbital programs under development, will have an important role to play in a future threat environment increasingly defined by Chinese ASATs.

Conclusion

China is currently engaged in a large-scale ASAT weapons program that has profound implications for future U.S. military strategy in the Pacific. China successfully tested and has reportedly deployed enough direct-ascent ASAT missiles to threaten the destruction of

vital U.S. satellites in LEO. China has also apparently tested and deployed at least one large, ground-based ASAT laser weapon for use on a number of targets in LEO, and is developing a submarine-based ASAT missile with which it could eventually target U.S. national security satellites in GEO. Developments in China's co-orbital ASAT systems also pose a future risk to U.S. satellites, as do China's development of cyber warfare units, radiofrequency jamming devices and ground-based microwave weapons.

As a result, while China's expansive ASAT program continues to strengthen, the U.S. is developing its own counter-ASAT deterrent as well as its next generation space technology to meet the challenge, and this is leading to a "great game" style competition in outer space. This competition is likely to intensify over the coming decades as both nations attempt to further exploit the military high-ground space represents, while seeking to deny their opponents access to this increasingly vital theater of operations.

[1] Office of the Secretary of Defense, "Military Power of the People's Republic of China." *Department of Defense Annual Report to Congress*, 2003, p. 36.

[2] Ashley J. Tellis, "China's Military Space Strategy," *Survival* (Autumn 2007), p. 43.

[3] Yuan Liwei, Yang Jianjun, and Jin Fengjie, "A Study on Trajectory Optimization of Space Interceptor" (*Kongjian lanjie dandao youhua yanjiu*), *Journal of Ballistics* (*Dandao xuebao*), Vol. 19 No.1 (2007/03), pp. 5-8.

[4] "Transcript of Lieutenant General Michael Maples' Interview," February 8, 2008, http://www.dia.mil/publicaffairs/Press/trans01.pdf, accessed June 20, 2009.

[5] SSRC is also known as the CASIC Fourth Academy, which was formed in 2002 as part of a CASIC reorganization.

[6] Shi Fashu, "Kaituozhe-1 Solid Launch Vehicle Development Planning and Implementation," *China Aerospace* (*Zhongguo Hangtian*), August 1, 2003, pp. 13-16.

[7] See Desmond Ball, "Assessing China's ASAT Program," *Austral Special Report*, June 14, 2007, www.nautilus.org/~rmit/forum-reports/0714s-ball/, accessed March 1, 2008.

[8] "Exposing China's Secret NMD Exo-atmospheric Missile Defense, ASAT HQ-19 Missile" (*Jiemi zhongguo NMD daqicengwai fandao fanwei HQ-19 daodan*), http://bbs.tiexue.net/post_1981798_1.html, accessed June 19, 2009. Use of the "HQ" or "Hongqi" designation would imply a leading role by the CASIC Second Academy. The Second Academy is China's primary organization responsible for development and manufacturing of surface-to-air missile systems.

[9] "HQ-19 (S-400)(China)" *Jane's Strategic Weapons Systems*, December 23, 2008, www.janes.com/extracts/extract/jsws/jsws9067.html, accessed June 20, 2009. The HQ-19 is known by its NATO designation SA-21 Growler (or S-400 Triumph), and was formerly known as the S-300PMU-3.

[10] "SA-21 Growler," *Canada Space Reference*, http://reference.canadaspace.com/search/SA-21%Growler/, accessed June 20, 2009. See also Wikipedia's "SA-21 Growler" page, http://en.wikipedia.org/wiki/S-400_Triumf, accessed June 20, 2009.

[11] Yuan Liwei and Yang Jianjun, "Discussing ASAT Weapons Development" (*Fanweixing wuqi zhuangbei fazhan tantao*), *Missile Flight* (*Feihang daodan*), No. 12 (June 3, 2004), p. 46.

[12] "U.S. Says China has Deployed 40 KT-1 Anti-Satellite Missiles" (*Meiguo cheng zhongguo bushu 40mei KT-1fanweixing daodan*), *News Military Affairs* (*Dijiu junshi pindao*), http://milnews.com/Article/wyyc/700.html, accessed on May 27, 2009.

[13] Gordon Arthur, "A Comparison of China and India's Long Range Ground-to-Air Missiles," *Kanwa Asian Defense*, May 2009, p. 7.

[14] "Military Report: Informationalized Age, New Challenges Facing Air and Space Defense System" (Junbao: xinxihua shidai kongtian fangyu tixi mianlin xintiaozhan), *Xinhuawang*, May 21, 2009, http://news.xinhuanet.com/mil/2009-05/21/content_11411941.htm, accessed June 19, 2009.

[15] Lin Tao and Zhang Jianxin, "Analysis of Exo-atmospheric Infrared Imagery System Capabilities" (*Waiceng kongjian hongwai chengxiang xitong xingneng fenxi*), *2004 National Optic Electric Techniques Exchange Meeting* (2004nian quanguo guangdian jishu xueshu jiaoliuhui), 2004, http://www.lib2.com/A-%E4%BC%9A%E8%AE%AE%E8%AE%B0%E5%BD%95ID~6215194.html, accessed June 19, 2009.

[16] Ball, June 14, 2007.

[17] See Major A. Andronov, "The U.S. Navy's 'White Cloud' Spaceborne ELINT System," http://www.fas.org/spp/military/program/surveill/noss_andronov.htm, accessed on May 26, 2009.

[18] See "Qi Faren: Anti-Satellite Technology Can Be Used to Attack Aircraft Carrier," *Ming Pao*, March 5, 2007, p. A4. See also Mark Stokes, "The Evolving PRC Ballistic Missile Challenge to U.S. Maritime Operations in the Western Pacific," *Project 2049 Institute*, draft copy from author, p. 27.

[19] See "U.S. Deeply Concerned by China's Continued Increase in Anti-Satellite Ballistic Missile Technology," (*Mei guanqie zhongguo xu zengqiang fanweixing daodan jishu*), *Voice of America News* (*meiguo zhiyin*), January 18, 2008, http://www.voanews.com/chinese/archive/2008-01/w2008-01-18-voa29.cfm, accessed May 27, 2009.

See also Thomas Harding, "Chinese nuclear submarines prompt 'new Cold War' warning," *Telegraph.co.uk*, May 3, 2008,

http://www.telegraph.co.uk/news/newstopics/uselection2008/1920917/Chinese-nuclear-submarines-prompt-new-Cold-War-warning.html, accessed June 4, 2009.

[20] Office of the Secretary of Defense, "Military Power of the People's Republic of China," *Department of Defense Annual Report to Congress*, 2009, p. 48.

[21] See "Kaituozhe 1 (KT-1) Launch Vehicle," *sinodefense.com*, http://www.sinodefense.com/space/launcher/kaituozhe1.asp, accessed May 26, 2009. See also Mark Stokes, "The Evolving PRC Ballistic Missile Challenge to U.S. Maritime Operations in the Western Pacific," *Project 2049 Institute*, draft copy from author, p. 11. And Ball, June 14, 2007.

[22] See Ball, June 14, 2007.

[23] See "The Militarisation of Space: Dangerous driving in the heavens." *The Economist*, January 19, 2008, p. 26.

[24] See "Taiwan Publication: Mainland China has Already Deployed Anti-Satellite Laser Artillery," (*TaiKan: Dalu yibushu jiguang fanweixingpao*), *takungpao.com* (*dagong wang-xinwen*), April 26, 2009, http://www.takungpao.com/news/09/04/26/junshi03-1072048.htm, accessed May 27, 2009.

[25] Tellis, pp. 54-55.

[26] Brian Weeden, "China's BX-1 microsatellite: a litmus test for space weaponization," *The Space Review*, October 20, 2008, http://www.thespacereview.com/article/1235/1, accessed May 26, 2009.

[27] Bill Sweetman, "Spatial Awareness: Satellite Imaging Systems Span the Globe," *Jane's International Defence Review*, May 2007, pp. 46-48.

[28] "Jonathan's Space Report," No. 369, August 22, 1998, www.planet4589.org/space/jsr/back/news.369, accessed April 23, 2008. See also Wikipedia's page on Mentor satellites, http://en.wikipedia.org/wiki/Mentor_(satellite), accessed April 23, 2008.

[29] U.S. Air Force Fact Sheet, "Defense Support Program Satellites," *Air Force Space Command*, Peterson AFB, http://www.af.mil/factsheets/factsheetasp?id=96, accessed April 22, 2008.

[30] U.S. Air Force Fact Sheet, "MILSTAR Satellite Communications System," *Air Force Space Command*, Peterson AFB, http://www.af.mil/factsheets/factsheet.asp?fsID=118, accessed April 22, 2008.

[31] U.S. Air Force Fact Sheet, "Defense Satellite Communications System," *Air Force Space Command*, Peterson AFB, http://www.af.mil/factsheets/factsheet.asp?ID=95, accessed April 22, 2008.

[32] U.S. Air Force Fact Sheet, "Global Positioning System," *Air Force Space Command*, Peterson AFB, http://www.af.mil/factsheets/factsheet.asp?ID=119, accessed April 23, 2008.

[33] See "Military Uses of Space," *Parliamentary Office of Science and Technology*, December 2006, No. 273, http://se2.isn.ch/serviceengine/FileContent?serviceID=RESSpecNet&fileid=B2F8F49B-6175-D3F8-F6FE-7F04E44C164E&lng=en, accessed April 23, 2008.

[34] See *The Economist*, January 19, 2007, pp. 18-19.

[35] Richard Hughes and Jon Lowe, "We Need a Civil Reserve Space Fleet," *The Wright Stuff*, April 17, 2008, http://www.au.af.mil/au/aunews/archive/0307/Articles/CivilReserveSpaceFleet.html, accessed April 23, 2008.

[36] Michael J. Coumatos et al., *Space Wars: The First Six Hours of World War Three* (New York: Forge, 2007), p. 8.

[37] Richard Halloran, "PACAF's 'Vision' Thing," *Airforce-Magazine.com*, http://www.airforce-magazine.com/MagazineArchives/Pages/2009/January%202009/0109vision.aspx, accessed May 26, 2009.

[38] Richard Bush and Michael E. O'Hanlon, *A War Like No Other: The Truth about China's Challenge to America* (Hoboken: John Wiley & Sons, 2007), p. 114.

[39] See *The Economist*, January 19, 2007, p. 28.

[40] U.S. Air Force Fact Sheet, "Global Positioning System," *Air Force Space Command*, Peterson AFB, http://www.af.mil/factsheets/factsheet.asp?ID=119, accessed April 23, 2008.

[41] Jeremy Singer, "Laser Links in Space," *Airforce-Magazine.com*, January 2008, http://www.airforce-magazine.com/Magazine/Archive/Pages/2008/January%202008/0108laser.aspx, accessed May 26, 2009.

[42] Sheila Rupp, "Operational Responsive Space," *AF.mil*, May 22, 2007, http://kirtland.af.mil/news/story.asp?id=123054292, accessed May 26, 2009.

[43] See Jeremy Singer, "Downshifting in Space," *Airforce-Magazine.com*, April 2009, http://www.airforce-magazine.com/MagazineArchive/Pages/2009/April%202009/0409space.aspx, accessed May 26, 2009. See also "Team helps put tactical satellite in orbit," *AF.mil*, May 22, 2009, http://www.af.mil/news/story.asp?id=123150722, accessed May 26, 2009.

[44] Bill Sweetman, "Pint-Size Comsat," *Defense Technology International*, June 2009, p. 14.

[45] Vago Muradian, "A Stealthy, supersonic (and secret) UAV," September 1, 2004, http://militaryphotos.net/forums/archive/index.php/t-21934.html, accessed May 26, 2009.

[46] Jeremy Singer, "Downshifting in Space," *Airforce-Magazine.com*, April 2009, http://www.airforce-magazine.com/MagazineArchive/Pages/2009/April%202009/0409space.aspx, accessed May 26, 2009.

[47] Keir A. Lieber and Daryl G. Press, "Superiority Complex: Why America's growing nuclear supremacy may make war with China more likely," *The Atlantic* (July/August 2007), pp. 88-90.

[48] Richard Halloran, "Guam, All Over Again," *Airforce-Magazine.com*, January 2008, http://www.airforce-magazine.com/MagazineArchive/Pages/2008/January%202008/0108Guam.aspx, accessed May 26, 2009. See also "Ohio Class Submarine," *Wikipedia*, http://en.wikipedia.org/wiki/Ohio_class_submarine, accessed May 26, 2009.

[49] "X-41 Common Aero Vehicle (CAV) Hypersonic Technology Vehicle (HTV)," http://www.globalsecurity.org/space/systems/x-41.htm, accessed June 21, 2009.