Developments in Military Space: Movement toward space weapons?[1]

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Introduction

There is no question that outer space is already militarized. Indeed, from the dawn of the space age, the two Cold War superpowers were already focusing on developing space assets for military uses: from early warning to strategic communications to verification of arms control treaties and even to efforts to build anti-satellite (ASATs) weaponry.

In recent decades, as the inevitable march of technology and the spread of information has quickened, it would be fair to say that the militarization of space has become more profound and embedded. While according to U.S. Air Force officials there are only eight to 10 countries routinely applying space capabilities to their military operations, there are another 40 or so nations with civil space capabilities that could eventually be applied to military uses. The trend line seems clear: the coming decades will see more and more nations able to harness the advantages of space-based assets to improve their military command, control and communications, strategic and battlefield surveillance, weapons targeting, and perhaps even missile defenses.

What remains unclear is if this increased militarization of space will inevitably lead toward the actual weaponization of space. The answer to that question, however, lies less in the progress of technological know-how and more in the realm of geo-political calculations outside the scope of this paper. At the same time, there are ongoing technology and political developments that may lead some countries to seek this path – sooner rather than later.

This paper will review major technology development efforts among today's space-faring powers that bear relevance to the possibility of elevating the battlefields of the future to the heavens. One caveat: it must be remembered that despite the ongoing research into weapons-related technology, there are no formal programs in any country to procure or deploy space weapons. This is in large part due to the fact that the technologies necessary to do so remain immature and costly to pursue.

[1] A condensed version of this paper was presented to a workshop on "Outer Space and International Security: Options for the Future," sponsored by The Space Policy Institute, George Washington University, on Oct. 29, 2003.

The United States

There is no question that the United States is the world leader in military exploitation of space. According to the Stockholm International Peace Research Institute, the United States at the end of 2001 had nearly 110 operational military-related satellites, compared to 40 for Russian and 20 for the rest of the world combined.[2] The United States outspends the rest of the world by vast amounts in the military space arena, accounting for almost 95 percent of global military space spending in 1999, according to the French space agency CNES.[3]

The U.S. military uses satellites – both dedicated military satellites and those owned by private firms – for weather prediction; strategic and tactical communications including ship-to-ship; Earth imaging; surveillance and reconnaissance (including optical, infrared and radio frequency systems); and tracking and monitoring objects in space, including potentially dangerous debris. Since the early 1990s, the military has used the Global Positioning System (GPS) satellite navigation network to time and synchronize operations, as well as increasingly to target precision-guided munitions. Also since the Information Revolution of the 1990s, the U.S. military has exponentially increased its use of satellite communications, not only for voice but also for transmission of imagery to the battlefield and Internet communications. According to a senior Army official, some 380 megabits of bandwidth were used by the U.S. military during Operation Iraqi Freedom (as compared to 99 megabits in Operation Desert Storm) for both communications and imagery transmission, with about 80 percent of it supplied by commercial not military assets.

Suffice to say that space assets are now critical to the American way of war, providing rapid global power projection and ever-greater precision war-fighting. This fact has led to growing concerns within the U.S. military about protecting its own space assets, and about the ability to, in future warfare, keep opponents from using space assets in a similar manner to increase their military effectiveness and erode the U.S. military edge. It is also driving a renewed push toward the weaponization of space by the faction of the U.S. political/military spectrum who believe that space weapons are required to maintain U.S. military dominance into the next century. Currently, the United States is the country most capable, both technically and economically, to undertake a serious space weapons program, and the country most clearly starting to move in that direction – both from a technology development viewpoint and a policy perspective.

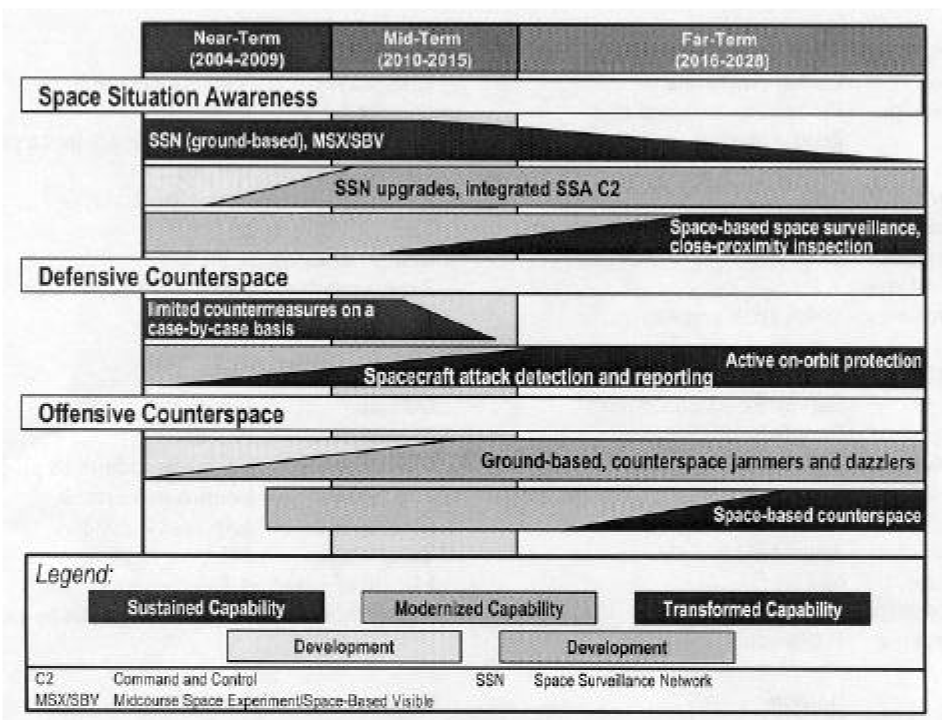
Besides ramping up programs to, for want of a better word, "passively" protect U.S. space assets – such as the planned improvements to the Global Positioning System to better protect it against jamming or degradation – current long-term planning and budget documents envision a number of programs to develop so-called "active" defenses as well

[2] John Pike, 2002, Chapter 11 summary, in SIPRI, "SIPRI Yearbook 2002: Armaments, Disarmament and International Security," Oxford University Press, http://editors.sipri.se/pubs/yb02/ch11.html

[3] Centre Natinal d'Eturdes Spatiales (CNES), "2001-2005 Strategic Plan," p. 13, http:www.cnes.fr/enjeux/2frame_index_enjeux.html

as offensive capabilities against enemy space assets, some eventually to be based in space.

Offensive systems are are defined as "counterspace operations" in the Air Force Space Command's most recent long-term planning document, "Strategic Master Plan FY04 and Beyond" published in November 2002.[4] As the chart below explains, "defensive counterspace" operations not only include attack detection and reporting, but in the roughly 2016-2028 timeframe, the deployment of "active on-orbit protection" – which one must assume includes "shooting back" in some fashion at a potential or ongoing attack from another space-based object, although the Master Plan is less than clear on what exactly is being considered. According to the Master Plan, the desired capabilities in "offensive counterspace" are first concentrated on three ground-based systems: the mobile Counter-Coummunications system to jam uplinks and downlinks of enemy satellites; the Counter-ISR system to blind optical sensors; and the Counter-Navigation system to prevent adversaries from using space-based navigation signals. However, in the 2016-2028 timeframe, the plan envisions the availability of "space-based counterspace" systems, which most of us would probably define more simply as anti-satellite weapons (ASATs). The plan elaborates intentions to field "full-spectrum, space-based OCS systems capable of preventing unauthorized use of friendly space services and negating adversarial space capabilities from LEO to GEO altitudes."



[4] U.S. Air Force Space Command, "Strategic Master Plan FY04 and Beyond," pp. 12-13, http://www.peterson.af.mil/hqafspc/library/AFSPCPAOffice/Final%2004%20SMP--Signed!.pdf

At least some of these counterspace programs already have made an appearance in the DoD fiscal year 2004 (FY 04) budget request. Overall, the Pentagon asked for $82.6 million for counterspace technologies (at the engineering, manufacturing and development level of so-called 6-4 funding) in FY 04, and a total of $325.2 million between FY 04 and FY 09.[5] Included under that line are: the Counter Satellite Communications System at $9.6 million in FY 04 and a total of $42.3 million from FY 04-FY 09, and the Counter Surveillance Reconnaissance System (referred to in the Master Plan as the Counter-ISR system) funded at $66.4 million in FY 04 and a total of $152.5 million over the FYDP.

While Air Force Space Command officials have not said much about these programs, except for maintaining that the goal of both programs is develop temporary, reversible and/or non-destructive methods of accomplishing the counterspace mission.[6] While, as noted above, both these programs are being designed as ground-based systems, there is no reason to believe that there is not interest in miniaturizing laser and other jamming technologies – indeed, the Air Force has a number of ongoing efforts at miniaturization of such technologies, especially lasers.

The Air Force budget request also included another $138.6 million over the FYDP in Space Control Technologies, aimed at technology development, demonstration and prototyping.[7] Somewhat confusingly, Space Control is defined by the Air Force as including Space Situational Awareness, Defensive Counterspace and Offensive Counterspace – but the budget breaks out counterspace technologies separately, with the exception of the Kinetic Energy Anti-Satellite (KE-ASAT) program, which is funded under Space Control Technologies. However, the small amount of money included in the Air Force budget for KE-ASAT was inserted by Congress; the Pentagon did not ask for it. This is in keeping with the KE-ASAT's long history – its development, began in 1989 as a technology demonstration, is primarily due to the championship of former Sen. Bob Smith of New Hampshire, who for many years pushed funds for the program on the Army, the program's original owner. While senior Air Force officials in the past have expressed concerns about the use of kinetic energy weapons in space due to the creation of space debris – and there has been a long-running argument about the debris-creating potential of KE-ASAT itself -- there are currently rumors that the service is looking at asking for money in the FY 05 budget to flight test at least one of the three KE-ASAT prototypes.

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[5] Jeffrey Lewis, "Lift Off for Space Weapons: Implications of the Department of Defense's 2004 Budget Request for Space Weaponization," July 2003, Center for International and Security Studies at Maryland, University of Maryland, College Park, Md., p. 15, http://www.cissm.umd.edu/documents/spaceweapons.pdf

[6] Amy Butler, "USAF Pursues Technology To Block Enemy Access to SATCOM, Imagery," *Inside the Air Force*, June 27, 2003, p.1.

[7] Lewis, p. 12.

Besides KE-ASAT, the other key U.S. Air Force programs that seem to be at least partially aimed at developing future space-based ASAT capabilities are clustered in a group of microsatellite technology projects. Microsats are usually described as those weighing less than 100 kg. The Air Force long has been interested in reducing the size of satellites due to potential benefits in reducing launch costs – still the major expense in any space program, hovering between $11,000 per kg and $22,000 per kg. In fact, microsats are not new at all, in that the first military communications satellites in the 1960s, the Defense Satellite Communications System, weighed about 45 kg.[8] Since that time there have been at least 20 U.S. military on-orbit microsat tests; however, there are only few examples of microsats actually performing operational missions.[9]

In recent years, however, as technology has improved, there has been more interest from the U.S. military (as well as commercial satellite firms) in microsat technology. The latest U.S. Air Force Space Command study on microsats, "The 1999 Microsatellite Technology Requirements Study," concluded that microsat development should be pursued as rapidly as possible.[10]

For the three major Air Force microsat activities – known as MightySat, TechSat21 and the XSS Experimental Satellite series – there is $68.1 million in the FY 04 budget request, and a total of $502 million over the FYDP. With regard to possible future weapon applications, the XSS program is the most interesting. The first of the series, XSS-10, was launched Jan. 29, 2003. Weighing 28 kg, the XSS-10 successfully maneuvered autonomously around another space object (a Delta II upperstage) and took images.[11] A follow-on, XSS-11, is to be launched in late 2004 and is expected to remain on orbit for a year, with the experiment involving "navigating larger distances and performing more extreme maneuvers" with a more specific sensor payload.[12]

While the XSS experiments so far have involved only maneuvering and imaging, the Air Force has envisioned possible future ASAT uses and the technologies being demonstrated – particularly the capability to maneuver into a near-by orbit and move

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[8] Matt Bille, Robyn Kane, Maj. Mel Nowlin, "Military Microsatellites: Matching Requirements and Technology," presented to the AAIA Space 2000 Conference and Exhibition, Long Beach, Calif., Sept. 19-21, 2000, p. 1

[9] Matt Bille, Robyn Kane, Drew Cox, "Microsatellites and Improved Acquisition of Space Systems," presented at the 14 Annual AIAA/Utah State University Conference on Small Satellites; published by the American Institute of Aeronautics and Astronautics, Inc., 2000; www.sdl.usu.edu/conference/smallsat/proceedings/14/tsiv/iv-7.pdf

[10] Bille, Kane, Nowlin, p. 1.

[11] Theresa Hitchens and Jeffrey Lewis, "Arms Race in Space? U.S. Air Force Quietly Focuses on Space Control," *Defense News*, Sept. 1, 2003.

[12] Ibid; Jane M. Sanders, "The Little Engine That Could: Small, low-cost satellite demonstrates autonomous operations," *Research Horizons*, Georgia Institute of Technology, Altanta, Ga., Spring/Summer 2003, pp. 8-9.

closely around another on-orbit object -- have applicability to such missions. The 1999 Microsatellite Technology Requirements Study done for Air Force Space Command strongly called for "the deployment, as rapidly as possible, of XSS-10-based satellites to intercept, image, and if needed, take action against, a target satellite."[13] There is apparently on-going discussion within the Air Force about melding KE-ASAT technology into the XSS program; there also has been discussion of equipping XSS-like satellites with a kind of ink-jet like system to blind a target satellite. However, exact plans for this program remain somewhat opaque, with Air Force officials downplaying their possible role as ASATs.[14]

The United States could also acquire space weapons and/or ASATs through the ongoing Missile Defense Program. There are three programs that if successfully deployed would be technically capable, provided slight modifications, of an ASAT mission. At the same time, the three programs are technically challenging and costly; thus there remains some question about their future viability.

Space-Based Boost-Phase Interceptors. The Missile Defense Agency (MDA) currently has tentative plans under its boost-phase interceptor development program to orbit a "test bed" of space-based boost-phase interceptors sometime in the 2007/08 timeframe. There is $14 million in the FY 04 budget for a concept study, and $119 million in 2005 for granting design contracts.[15] Congressional cuts to the overall pot of money slated for boost-phase intercept programs have made the fate of the space-based interceptor effort somewhat unclear, however. MDA announced in August that due to immature technology and cost issues, its plans for the program were on hold.[16]

Space-Based Laser. The Space-Based Laser program officially was canceled in 2002 due to technical and cost challenges, there remains in the MDA budget a line item for exploring laser technologies.

Airborne Laser. The ABL was budgeted at $345 million in FY 04. MDA has been planning to conduct its first lethality demonstration in 2004-05, but the development effort has been plagued by cost and weight issues and the program was heavily criticized by the General Accounting Office in a July 2002 report.[17]

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[13] Bille, Kane and Nowlin, p.9.

[14] Hitchens and Lewis.

[15] MDA Budget Justifications for the PE 06038863C Ballistic Missile Defense System Interceptors, http://www.defenselink.mil/comptroller/defbudget/fy2004/budget_jutificaion/pdfs/rdtande/MDA_RDTE.pdf

[16] Kerry Gildea, "Missile Defense Agency's Space-Based Boost Phase Program Put On Hold," *Defense Daily*, Aug. 1, 2003.

[17] General Accounting Office, "Missile Defense: Knowledge-based Decision Making Needed to Reduce Risks in Developing Airborne Laser,: GAO-02-631, July 12, 2002.

Lastly, there has been some consideration in military and space circles in the United States about the possibility of basing kinetic energy weapons in space designed to destroy hardened and deeply buried targets, weapons sometimes referred to as "Rods From God." Indeed, such ground-strike weapon systems have been looked at for many years – but there remains a serious question about the technical and cost viability of such weapons, as the engineering required to overcome the physics challenges are large.

China

China is the only other nation whose political/military establishment seems to be having an ongoing debate on the potential value of space weapons, especially ASATs. This is despite the fact that official Chinese policy is in support of a space weapons ban, and the fact that China is less dependent on satellites than the United States. China's military does have communications satellites, remote sensing satellites, and weather satellites; in addition two Bei Dou navigation satellites out of a planned four have been launched.[18]

According to the latest Pentagon report on Chinese military capabilities, "China's leaders probably views ASATs – and offensive counterspace systems, in general – as well as space-based missile defenses as inevitabilities. In addition to passive counterspace measures – such as denial and deception – China is said to be acquiring a variety of foreign technologies which could be used to develop an active ASAT capability."[19]

Indeed, there are increasing signs that the United States and China are poised at the edge of a potentially destabilizing space arms race. Both countries are increasingly suspicious of each other's ambitions in space and perhaps convinced that they need to prepare for a future space war.[20] Chinese media reports and official statements have also expressed concern about the U.S. use of space for global power projection. In a July 2000 article, Chinese defense analyst Wang Hucheng posited that: "For countries that can never win a war with the United States by using the method of tanks and planes, attacking the U.S. space system may be an irresistible and most tempting choice. Part of the reason is that the Pentagon is greatly dependent on space for its military action"[21] From the U.S. side, China's excessive secrecy about its space program, especially its military projects, spurs concerns.

China just became the third nation to put a man in orbit. While it is inevitable that the manned program is having, and will have, technology spin-offs for military capabilities –

[18] Joan Johnson-Freese, "China's Manned Space Program: Sun Tzu or Apollo Redux?" Navy War College Press, Summer 2003, http://www.nwc.navy.mil/press/Review/2003/Summer/art2-su-3.htm

[19] U.S. Department of Defense, "Report to Congress Pursuant to the FY2000 National Defense Authorization Act, Annual Report On The Military Power Of The People's Republic Of China," July 28, 2003, p. 32. (Referenced in Future as Annual Report on Chinese Military Power.)

[20] William C. Martel and Toshi Yoshihara, "Averting a Sino-U.S. Space Race," The Center for Strategic and International Studies and the Massachusetts Institute of Technology, *The Washington Quarterly*, Autumn 2003, pp. 19-35.

[21] Wang Hucheng, "The US Military's 'Soft Ribs' and Strategic Weaknesses," Beijing Xinhua Hong King Service, July 5, 2000.

indeed it is believed that the orbital module left behind by the Shenzou V launched Oct. 14 is carrying an imaging payload – it is not China's ambitious manned space effort that is of the most direct concern to U.S. military officials (although the program is managed by the PLA). Rather it is suspected Chinese efforts to develop a number of satellite jamming technologies and ASAT weapons. According to the Pentagon report, China may be developing Global Positioning System jammers and may already have the "capability to damage, under specific conditions, optical sensors on satellites that are very vulnerable to damage by lasers."[22] The report goes on to assert that China may have acquired laser technology that "probably" could be used to develop ground-based laser ASATs. China has made laser research a high priority, and independent experts also believe that "ground-based laser technology is well within China's reach."[23]

Hong Kong newspapers in January 2001 also claimed that China had developed a "parasitic" microsatellite (presumably a kinetic energy or explosive device that could attach itself to a target satellite) – a claim the Pentagon report says still "is being evaluated." China is actively pursuing microsat and nanosat technology and small launchers for then, ostensibly for communications, earth imaging and other civil uses. Beijing (along with a number of other countries) has worked with the U.K. University of Surrey, a leading developer of microsatellites.[24] For example, China's Tsinghua University participated in a Surrey Space Centre experiment in 2000 with a co-designed 50 kg microsatellite called Tsinghua-1. In addition, the university's majority owned company, Surrey Satellite Technology Ltd., intends to launch in 2005 a disaster monitoring satellite for China with a 4 meter resolution as part of a larger international constellation.[25]

However, many independent experts have cast doubt on the idea that China has developed a microsat ASAT. There has been little in the scientific research to support the idea that actual work on such a system is ongoing, and no obvious on-orbit testing.[26] In addition, several scientists have noted that development of such a weapon would require space capabilities (such as sophisticated orbital maneuvering) that even the United States has yet to demonstrate.

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[22] Annual Report on Chinese Military Power, p. 32.

[23] Phillip Saunders, Jing-dong Yuan, Stephanie Lieggi, and Angela Deters, "China's Space Capabilities and the Strategic Logic of Anti-Satellite Weapons," Center for Nonproliferation Studies, Monterrey Institute of International Studies, July 22, 2002, http://www.cns.miis.edu/

[24] Tom Wilson, "Threats to United States Space Capabilities," prepared for the Commission to Assess United States National Security Space Management and Organization (known as the Space Commission), Jan. 11, 2001, p.30.

[25] University of Surrey Press Release, "Launched – the world's first disaster monitoring service in space," Sept. 27, 2003.

[26] Saunders, et al.

China also lacks some key capabilities that would make a space weapons program currently possible. These include limited tracking and launch capabilities. Another issue is costs, given China's extensive domestic development problems.[27] And given China's vocal public support of a space weapons ban, it may be that China would be reluctant to be the first nation to pursue space weapons options – instead more likely to hedge its bets while hoping to avoid such an expensive undertaking.

India

India, too, has a sophisticated space program, building and launching its own satellites since 1980, now in both LEO and GEO orbits. Primarily, India is focused on using satellites for communications and remote sensing – but New Delhi also has said it is considering planetary exploration and possibly even a manned mission to the moon.[28] In addition, India hopes to sell its launch services to other nations.

India is an active proponent of the rights of developing countries to use space, with keen interest in things like telemedicine. India is also officially a proponent of a space weapons ban and active in pushing for such negotiations at COPUOS in Geneva.

However, India too may be researching options for disrupting or destroying enemy satellites in wartime. Just prior to arch-rival China's launch of an astronaut Oct. 15, the chief of the Indian Air Force, S. Krishnaswamy, told reporters that India was planning a new aerospace force command that would eventually develop space weapons. Krishnaswamy claimed that the Indian Air Force already has "started work on conceptualizing such weapon systems and its operational command system," arguing that this was necessary because "advanced countries are already moving toward laser weapon platforms in space and killer satellites."[29]

India also has been working on laser technologies for military applications since the mid-1990s. A recent story in *Bharatvarsha 1947* maintains that India's chiefs of staff have asked for a feasibility study of space-based lasers, and that the Indian defense research organization, DRDO, is already doing research on a system called Durga (directionally unrestricted ray-gun array) as well as on a "kinetic attack loitering interceptor" known as Kali.[30] The credibility of this report may be somewhat doubtful, however, as the author seems to be mixed up on the differences between laser and kinetic energy weapons.

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[27] Martel and Yoshihara.

[28] Spacetoday web site, http://www.spacetoday.org/India/IndiaSpaceSatellites.html; Agence France-Presse, "India, China turn traditional rivalry into space race," Oct. 12, 2003, http://www.spacedaily.com/2003/031012013635.6p1w7a9u.html

[29] PTI, "IAF enters space age, starts work on laser weapons, killer satellites," Oct. 6, 2003, http://www.newindipress.com/news.asp?id=IEL20031006070831

[30] R. Prasannan, "Fast forward Defence: India enters the cruise missile race; hyperplane Avatar reaches planning stage," Bharatvarsha 1947, Feb. 15, 2003, http://www.geocities.com/bharatvarsha1947/Feb_2003/avatar.htm

Considering India's current state of technology development, and official tendencies to "hype" military research and development progress, it is somewhat unlikely that India has made much real technical progress on this front. The political impetus to spend money and effort on space weapons, however, would be present if China were to develop and deploy such weaponry.

Other Nations

There is no body of evidence indicating that any other nation is seriously interested in space weapons. However, a number of countries have, or are developing, capabilities that could be applied to ASAT programs. In addition, progress in a number of key technology areas indicates that this trend could speed.

Russia.

Since the launch of Sputnik, Russia has built and maintained a sophisticated civil and military space program, and, as noted, in the past has pursued ASAT capabilities. From 1968 to 1971, the then-Soviet Union successfully tested a radar-guided co-orbital ASAT system. Another set of tests took place between 1976 and 1982, when Moscow unilaterally suspended testing – despite the failure of negotiations with the United States on an ASAT ban.[31]

Like the United States, Russia maintains a full spectrum of military-dedicated satellite systems for early warning, communications, navigation, optical reconnaissance and signals intelligence. Its Glonass navigation system is the only other in the world besides the U.S. GPS. The Russian space industry is large, well entrenched and technically capable.

Thus, Russia would certainly have the technical capability to pursue space weapons if it so chose. In particular, Russia is researching and development microsat technology and has also worked with Surrey, with many Surrey satellites launched on Russian rockets. Russia also has a long history of work on laser programs.

However, the Russian military space program is currently suffering from disarray, both in its management and in the fact that it is being starved of funding. None of its military programs are functioning at full operational level – for example, Glonass is supposed to comprise a network of 24 satellites but at the moment only eight are operational.[32] Several other programs are thought to be practically non-functional, and others are being phased out.

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[31] Lt. Col. Peter L. Hays, USAF, "United States Military Space Into the Twenty-First Century," INSS Occasional Paper 42, Institute for National Security Studies, U.S. Air Force Academy, Col., September 2002, pp. 103-104.

[32] Pavel Podvig, "Russian Military Space Program –An Overview," presented to the CISSM/ISKRAN Workshop on Outer Space and International Security, Sept. 29, 2003, http://www.russianforces.org/podvig/eng/publications/space/20030929washdc.shtm

Officially, the Russians, like the Chinese, are strong backers of a space weapons ban – the two countries have jointly introduced draft treaty language to the UN Committee on Peaceful Uses of Outer Space. And the 2001-2002 *Jane's Space Directory* characterizes the Russian ASAT program as "inactive."

That said, Russian military officials have expressed concerns similar to those of their Chinese counterparts regarding the intentions and directions of the U.S. military space program. Upon his appointment as commander of the new Russian Space Forces in April 2001, Col.-Gen. Anatoliy Perminov warned that the international community "should be on guard regarding the American policy of the military utilization of outer space" – citing in particular U.S. doctrine "reserving the right to employ force to conduct military operations in space, through space and from space."[33]

Thus it seems logical to assume that while Russia would not welcome a space arms race that would further tax their struggling space program, Moscow might feel the need to purse space weaponry if other nations did so – and given enough funding, such a Russian program would be technically feasible.

United Kingdom

While there is little or no evidence that Britain has interest in space weapons per se, as noted the University of Surrey is a leading producer of microsatellites and nanosatellites. According to a university press release, Surrey has launched 23 small satellite missions for international customers over the last 22 years. It also designed and launched one of the first advanced nanosatellites, the 6.5 kg SNAP-1, in June 2000. SNAP was able to take images of other on-orbit objects and to maneuver into a docking orbit with Tsinghua-1, and use GPS to determine its on-orbit position.[34] According to an annex to the U.S. Space Commission, Surrey has cooperated with Russia, China, Pakistan, Chile, Thailand, Portugal, Singapore and Malaysia on microsatellite research and development.[35] Surrey also is building a 120 kg Earth observation satellite with a 2.5 meter resolution for the U.K. Ministry of Defense.[36]

Other microsat work

Other nations said by the Space Commission to be researching microsatellites include Israel, Canada, Australia and Sweden.[37] For example, Israel -- which maintains its own

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[33] Alexander Dolinin, "Space Forces commander outlines priorities," *Krasnaya Zvezda,* translated by Worldwide Monitoring, April 27, 2001.

[34] Surrey Satellite Technology Ltd. Press Release, "Surrey Satellite Technology's SNAP-1 Nanosatellite Snaps Satellites in Orbit," Oct. 1, 2000, http://www.spaceref.com/news/viewsr.html?pid=1181

[35] Wilson, p. 30.

[36] Surrey Satellite Technology Ltd. Press Release, "SSTL Supplies TerraSAR Antennas," March 17, 2003, http://www.spacedaily.com/news/antenna-03b.html

[37] Ibid.

military surveillance satellite program, Ofeq; commercial communications satellites; and a launch vehicle program (Shavit) – also has been working on microsatellites since the mid-1990s, primarily out of Technion Israel Institute of Technology. Its first successful launch of a microsatellite was on July 10, 1998, with the 48 kg Gurwin-II Techsat shot out of Baikonur in Kazakhstan on a Russian Zenith.[38]

In particular, Canada's Ministry of Defense is researching the use of observational microsatellites in support of military operations. The high Earth orbit space surveillance project is planned to begin in April 2004, with a request for proposals going out in 2005 and a planned launch in 2006. The current plan is to use these microsats for space surveillance of other spacecraft and debris and then send the data recorded to the U.S. Space Surveillance Network which supports North American Aerospace Defense Command (NORAD). The two 70-kilogram microsatellites are planned to be launched on the same rocket and hoped to cost a little over $9 million. As project leader Canadian Air Force Maj. Frank Pinkney explained, "My goal is to show you can do real missions with smaller, cheaper satellites that will be affordable." These two microsatellites are hoped to be place-holders until Canada can field a larger space observation satellite in 2007 (the Sapphire system, thought to cost $75 million).[39]

Japan, another developed space power capable of launching and building its own satellites, on Dec. 14, 2002, successfully launched three microsats as piggybacks to the Advanced Earth Observing Satellite-11 – the Micro-LabSat developed by Japan's National Space Development Agency, FedSAT developed by Australia, and the Whale Ecology Observation Satellite (WEOS) developed by the Chiba Institute of Technology in Japan. Each weighed about 50 kg.[40]

France, Europe's largest military and civil space power, similarly has been working with microsatellites since the 1990s. Cerise, designed to undertake broadband radiometric measurements, designed by SSTL, was launched for Alcatel Espace and France's Defense Ministry in July 1995. The follow-on Clementine was launched Dec. 3, 1999. France continues to work with Surrey on further microsatellite projects.[41]

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[38] Technion web site, "Transforming Idea Into Reality," http://www.technion.ac.il/ASRI/techsate/techsat_history.htm; Avhavat Eretz Israel, "The Technion-Israel Institute of Technology," http://www.ahavat-israel.com/ahavat/eretz/technion.asp

[39] David Pugliese, "Canada Aims To Prove Value of Microsatellites for Military Use," *Space News*, Sept. 1, 2003, p8.

[40] NASDA Press Release, "Separation Status of Three Microsatellites," Dec. 14, 2002, National Space Development Agency of Japan web site, http://www.nasda.go.jp/press/2002/12/piggy_20021214_e.html; NASDA Information Sheet, "H-11A Launch Vehicle No. 4 – First Polar Orbit Satellite Launch," http://www.nasda.go.jp/rockets/h2a/documents/f4/sheet/h2af4_01_e.html

[41] SSTL Press Release, "Space Debris Collides with Cerise Microsatellite in Low Earth Orbit at 31,000 Miles Per Hour?" Aug. 15, 1996, http://satobs.org/seesat/Aug-1996/0110.html; SSTL Press Release, "Clementine microsatellite officially accepted in orbit by French Government," May 24, 2000, http://www.ukspace.com/press/press63.htm

Other Threats

It must also be remembered that a nation need not have a sophisticated space program to possess capabilities that could threaten the space assets of others. Any nation with an intermediate range ballistic missile and access to a nuclear warhead could launch a nuke into LEO, knocking out satellites in the line of site with a High Altitude Electromagnetic Pulse (HEMP), and over time corrupting all satellites in LEO due to the increase in ambient radiation caused by the blast. Damage from this elevated radiation would be "enough to severely damage nearby satellites and shorten the lifetimes of satellites in LEO from years to months or less."[42] Similarly, any nation with an intermediate range ballistic missile could instead equip its missiles with payloads of sand or gravel to be released in LEO, causing clouds of damaging debris. However, as more and more nations become dependent on space assets for their daily business, it remains unclear whether any nation would have the incentive to conduct such a "scorched Earth" operation. While satellites in LEO are most vulnerable to direct ascent attack, those in GEO are less so – as it is more difficult and more expensive to reach GEO orbit and only a few nations now possess that capability.

Conclusion

In sum, technological progress shows capabilities for conducting space warfare are moving out of the realm of science fiction and into reality – perhaps over the next 20 years or so. The march of technology is unlikely to stop, although it must be stressed again and again that all space programs are highly challenging and costly. Many of the technologies necessary for actual conduct of space warfare remain either on paper or in the laboratory. In particular, maintaining on-orbit populations of weaponry would require a breakthrough in rapid, inexpensive space launch capabilities – a Holy Grail pursed for more than two decades with little success. Space launch costs remain exorbitant (around $22,000 per kg), and successful launches can take weeks, months and sometimes years to pull off.

At the same time, there are competing political pressures. Among some countries, the seeds for a potential arms race in space have already been planted. Yet, there remain strong international norms and deep-seated public opinion around the world against space weaponization. Finally, the global reliance on space for commerce, economic development, disaster monitoring and other critical civil services is growing – making the risks that would emanate from a future war in space even higher. At the end of the day it will be political choices by governments, not technology, that determines if the nearly 50 year taboo against arming the heavens remains in place.

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[42] Wilson, P. 23.