DEVELOPMENTS IN BALLISTIC MISSILE DEFENCES

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Understanding key interrelationships between space and missile defences is an issue of growing importance. Space capabilities empower modern life in fundamental yet transparent and ubiquitous ways. During the Cold War, outer space was primarily the domain of the superpowers, but today space capabilities shape, and are shaped, by global politics among almost all actors ranging from individuals up through states. The role of missile defences in global politics has changed even more radically since the end of the Cold War, moving away from focusing on strategic stability between the superpowers and towards potential contributions to dissuading rogue actors from acquiring weapons of mass destruction and ballistic missiles and defending against those that do. Yet the role of missile defences in the structure and stability of the relationships among nuclear-armed states remains an issue of critical importance and growing complexity due to a number of factors, including declining numbers of offensive systems and the increasing potential of space systems to contribute to defences. This paper briefly examines these issues by describing the US space-enabled reconnaissance strike complex, reviewing the current state of US missile defence developments, and evaluating key dimensions of the interrelationships among these elements.

Empowered by a space-enabled, global reconnaissance, precision-strike complex, the United States and coalition forces achieved rapid and decisive conventional military successes during Operations Desert Storm in the Persian Gulf in 1991, Allied Force in Serbia in 1999, Enduring Freedom in Afghanistan in 2001 and Iraqi Freedom in 2003. These decisive victories in conventional combat illustrate how space capabilities have enabled transformation and created a new American way of war. The Department of Defense (DoD) is seeking to continue and accelerate this military transformation by developing even lighter and more easily deployable forces that can be defended globally and strike more precisely from greater distances. Space capabilities often provide the best, and sometimes only, way to pursue these ambitious transformational goals. There are, however,

Published in: *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty—Conference Report 2–3 April 2007*, Geneva, UNIDIR, 2007.

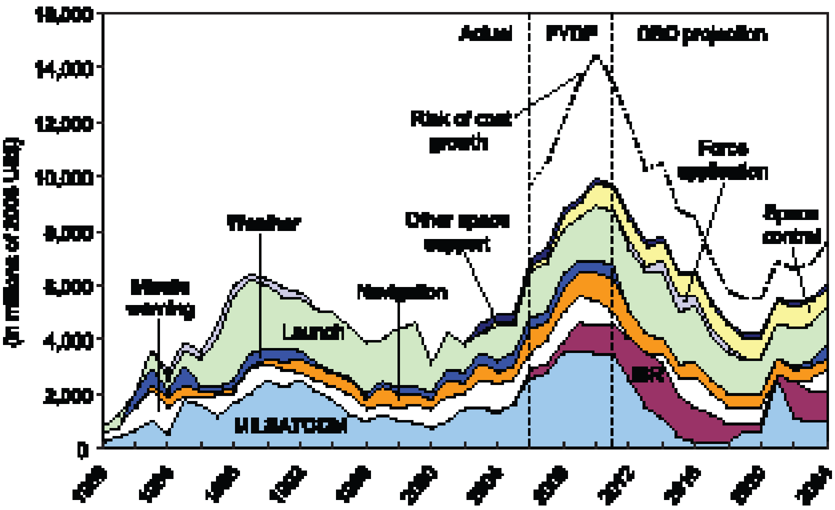
many difficult and fundamental issues related to space and missile defences, including the role of dual-use space capabilities in enabling the information revolution and modern life, the potential for space and missile-defence capabilities to dissuade and deter emerging military competitors and defend against new threats, and the proper place of diplomacy, spacepower, and missile defences in the changed geopolitical environment following the end of the Cold War and the 11 September 2001 attacks. These complex factors contribute to uncertainty about the utility of investments in space and missile defence capabilities versus other enabling military capabilities or diplomatic initiatives. The United States faces major challenges in its current plans to modernize, improve or replace almost all major military space systems because most of these acquisition programmes have encountered significant cost overruns and deployment delays. In addition, further development of missile-defence capabilities must contend with domestic and international political opposition, technological and testing challenges, and growing costs. It is not clear how the political support and opposition to these developments will evolve, whether the United States will be able to sustain the political will and resources required to continue these modernizations, if the technology required for these future systems can be developed and integrated on cost and on time, and how these new capabilities may accelerate military transformation and affect geopolitics. In short, the potential of space and missile-defence capabilities continue to grow much faster than our ways of thinking about them and it is unlikely that Cold War mindsets will be a sound foundation for building the conceptual frameworks needed for the future.

The US reconnaissance–strike complex and analytical frameworks

The US national security space (NSS) sector includes DoD programmes, conducted primarily by the Air Force, to enhance national security and National Reconnaissance Office (NRO) activities to collect intelligence data from outer space. The NSS sector is also divided sometimes into separate sectors known as the military or defence space sector and the intelligence space sector. Following implementation of one of the recommendations of the January 2001 Commission to Assess National Security Space Management and Organization (Space Commission) Report, the DoD now uses an accounting procedure known as the virtual Major Force Program (vMFP) to track NSS spending.[1] According to the Congressional Research Service, the total DoD request for space spending amounted to US$ 22.12 billion in 2005 and is US$ 22.66 billion for 2006.[2] A Congressional Budget Office

(CBO) study found that unclassified military space acquisition budgets grew from US$ 4.9 billion to US$ 6.9 billion, or more than 40%, between 2005 and 2006.[3] Overall trends in all planned major military space acquisition through 2024 are shown in Graph 1. The most important line on the graph, labelled Risk of Cost Growth, illustrates that space acquisition expenditures will peak at US$ 14.4 billion in 2010, or nearly triple present funding, if current programmes follow the historic trend of an average 69% rise in costs for space research, development, engineering and testing, as well as an average growth of 19% in space procurement costs.[4] Clearly, it will be very difficult for the United States to maintain the scope and timing for its currently planned, nearly simultaneous improvements and modernizations for almost all major NSS systems.

Graph 1. Investment in major unclassified military space programmes



Source: Congressional Budget Office, *The Long-Term Implication of Current Plans for Investment in Major Unclassified Military Space Programs*, Congressional Budget Office, 12 September 2005, p. 3.

Three major analytical frameworks shape most discussions about NSS capabilities—space activity sectors, military space mission areas and military space doctrines. There are four space activity sectors: civil, commercial, military and intelligence; many traditional space activities fall neatly into one of the sectors, although the growing number of dual-use space systems, digital convergence, and growth in the commercial space sector is making it increasingly difficult to delineate the sectors.[5] There are also four military space mission areas: space support, force enhancement, space control and force application.[6] Currently, force enhancement is the most important military space mission area; due to growth in the number and efficacy of space systems, many analysts believe these systems now produce effects that have moved beyond force enhancement and today enable a wider range of military missions to be undertaken or even contemplated. Table 1 shows the major divisions within force enhancement as well as the current and projected space systems to support these missions. Finally, building on the analysis of David Lupton, there are also four major military space doctrines: sanctuary, survivability, control and high ground.[7] The attributes associated with these doctrines—functions, operational characteristics and desired organizational structures—are shown in Table 2.

Almost all US space capabilities help to enable the reconnaissance–strike complex, but the discussion below focuses on the policies and capabilities most directly associated with these capabilities and missile defences. Currently, the Air Force maintains a constellation of geostationary Earth orbit (GEO) satellites, called the Defense Support Program (DSP), to provide warning of ballistic missile launches and some data on the type of attack and the missile's intended target. The most recent launch of a DSP satellite occurred in February 2004 and the launch of the last DSP satellite (DSP-23) has been delayed several times but is now scheduled to take place during the fourth quarter of 2007. DSP's successor is the Space-Based Infrared System (SBIRS), a programme designed to satisfy operational military and technical intelligence overhead non-imaging infrared requirements, provide improved detection, and supply foundational assessment capabilities for ballistic missile defence. Lockheed Martin is the prime contractor for SBIRS. The operational SBIRS constellation was envisioned originally to include four GEO satellites, two highly elliptical orbit (HEO) payloads on classified host satellites, and one spare GEO satellite. In addition, the Missile Defense Agency (MDA) is considering a Northrop Grumman system formerly known as SBIRS-Low and now named the Space Tracking and Surveillance System (STSS). MDA plans to launch two demonstration satellites in 2007. If these demonstrators work well in tracking missile launches and warheads, an operational STSS system could follow, with a first launch in the 2016–2017 timeframe.

Table 1. Force enhancement mission areas, primary orbits, and associated space systems[8]

Environmental Monitoring	Communications	Position, Navigation, and Time	Integrated Tactical Warning and Attack Assessment	Intelligence, Surveillance, and Reconnaissance (ISR)
Polar Low-Earth Orbit (LEO)	Geostationary Earth Orbit (GEO)	Semi-synchronous Orbit	GEO and LEO	Various
Current Defense Meteorological Support Program (DMSP)	**Current** Defense Satellite Communications System (DSCS) II, DSCS III, Ultra-High Frequency Follow-on (UFO), Milstar, Global Broadcast System (GBS), Iridium, commercial systems	**Current** Global Positioning System (GPS) GPS II GPS IIR GPS IIR-M	**Current** Defense Support Program (DSP), GPS	**Current** Imaging (IMINT) Satellites, Signals Intelligence (SIGINT) Satellites, commercial systems
Projected National Polar-Orbiting Operational Environmental Satellite System (NPOESS)	**Projected** Advanced Extremely High Frequency (AEHF), Wideband Gapfiller System (WGS), Mobile User Objective System (MUOS), Polar Military Satellite Communications System, Transformational Communications System (TSAT)	**Projected** GPS IIF GPS III	**Projected** Space-Based Infra-Red System (SBIRS), Missile Warning Satellite Systems Program, Space Tracking and Surveillance System (STSS)	**Projected** Future Imagery Architecture (FIA), Integrated Overhead SIGINT Architecture (IOSA), Space Radar

Table 2. Attributes of military space doctrines

	Primary Value and Functions of Military Space Forces	**Space System Characteristics and Employment Strategies**	**Conflict Missions of Space Forces**	**Appropriate Military Organization for Operations and Advocacy**
Sanctuary	Enhance Strategic Stability Facilitate Arms Control	Limited Numbers Fragile Systems Vulnerable Orbits Optimized for National Technical Means (NTM) verification mission	Limited	National Reconnaissance Office (NRO)
Survivability	Above functions, plus Force Enhancement	Terrestrial Backups Distributed Architectures	Force Enhancement Degrade Gracefully	Major Command or Unified Command
Control	Control Space Significant Force Enhancement	Autonomous Control Hardening On-Orbit Spares Crosslinks Manoeuvre Less-Vulnerable Orbits	Control Space Significant Force Enhancement Surveillance, Offensive, and Defensive Counterspace	Unified Command or Space Force
High Ground	Above functions, plus Decisive Impact on Terrestrial Conflict Ballistic Missile Defence	Stealth Attack Warning Sensors 5 Ds: Deception, Disruption, Denial, Degradation, Destruction Reconstitution Capability Active Defense Convoy	Above functions, plus Decisive Space-to-Space and Space-to-Earth Force Application Ballistic Missile Defence	Space Force

The first SBIRS HEO payload was delivered in August 2004 and the first GEO satellite is expected to launch in 2008. SBIRS is probably the most troubled NSS acquisition effort—a Defense Science Board report called it "a case study for how not to execute a space program."[9] Total cost estimates have jumped to nearly five times the original estimates, and the programme has triggered four required reports to Congress for breaching limits on cost overruns.[10] In December 2005, Under Secretary of Defense for Acquisition, Technology, and Logistics Kenneth Krieg and DoD Executive Agent for Space Ronald Sega restructured the programme significantly. Current plans call for no more than three GEO SBIRS spacecraft in the restructured programme and purchase of the third satellite will be contingent on performance of the first. In addition, the restructuring called for Krieg to retain milestone decision authority over the SBIRS programme and for Sega to develop alternative infrared satellite systems (now known as the AIRSS programme). The intent is to generate competition for SBIRS GEO 3, exploit alterative technologies and be ready for launch by 2015. Under the 2006 Future Years Defense Program (FYDP) and CBO's projection of its implications, investment spending for DSP and SBIRS would total about US$ 11 billion through 2024.[11]

Fundamental US policy goals for position, navigation and time (PNT) were reiterated by a Space-Based PNT Executive Committee Fact Sheet dated 15 December 2004. These objectives call for the United States to maintain uninterrupted PNT services for all user needs, remain preeminent in military PNT, provide civil services that exceed or are competitive with foreign PNT services and continue as an essential component of internationally accepted PNT services, and promote US leadership in PNT.[12] One of the most difficult challenges, mandated by Navigation Warfare requirements, is to operate the Global Positioning System (GPS) effectively despite adversary jamming; deny use to adversaries; not unduly disrupt civil, commercial or scientific uses outside an area of military operations; and identify, locate and mitigate interference on a global basis.[13] The Air Force acquires and operates the GPS constellation, which currently contains 30 satellites developed through a series of block upgrades. In September 2005 the Air Force began launching Lockheed Martin block IIR-M satellites, which incorporate two new military signals and a second civilian signal. It plans to start launching Boeing block IIF satellites, which will broadcast a third signal for civilian use, in 2007. The first block III satellites, originally scheduled for launch in 2013, will include improvements such as better anti-jam capability and satellite crosslinks for more accurate signals. As part of the "back-to-basics" approach to space acquisition, and as a result of current on-orbit GPS satellites exceeding their design lifetimes, Air Force Under Secretary Sega decided not to award a GPS III contract as originally planned during 2006 and indicated that the contract award may be delayed for more than one year.[14] Based on the 2006 Budget, the CBO projected that the total investment spending on the GPS would be US$ 12.5 billion through 2024.[15]

Space control capabilities are key enablers of all NSS activity. These programmes focus on developing ground- and space-based sensors to enhance space situational awareness (SSA, meaning knowledge of activity and events in, or that could affect, circumterrestrial space), improve capabilities to protect friendly space assets from enemy attack, and develop capabilities to negate enemy space capabilities. SSA programmes include Spacetrack, which is developing radar and optical sensors, and the Space-Based Surveillance System and other ground systems designed to track objects of interest in outer space. Other space control programmes—such as the Rapid Attack Identification, Detection, and Reporting System (RAIDRS) and the Counter Communications System (CCS)—focus on developing technology to protect friendly systems or to disrupt, deny, degrade or destroy enemy space capabilities. Joint Publication 3-14, *Joint Doctrine for Space Operations*, discusses ways to gain or maintain space control by providing freedom of action through protection and surveillance or to deny freedom of action through prevention and negation.[16] Air Force doctrine, by contrast, aligns space control doctrine, like air doctrine, as offensive counterspace (OCS) and defensive counterspace (DCS). OCS missions would disrupt, deny, degrade or destroy space systems, or the information they provide, if these systems are used for purposes hostile to US national security interests. DCS missions include both active and passive measures to protect US and friendly space-related capabilities from enemy attack, interference or use for purposes hostile to US national security interests.[17] Funding for the Orbital Deep Space Imager, a space-based system designed to track objects in GEO, was eliminated from the president's budget request in 2007. Under current plans, research, development, testing and evaluation funding for space control programmes would increase from US$ 195 million in 2006 to US$ 768 million in 2011.[18] SSA and space control are areas of particular concern in Congress, as indicated by the tasking of the Secretary of Defense in the 2006 National Defense Authorization Act (NDAA) to report to Congress about these topics in April and July 2006, respectively.[19] The overarching goals in the SSA Strategy and Roadmap report to Congress call for the development of a data-enabled user-defined operational picture and the ability to attribute all activity in circumterrestrial space to man-made or natural causes. The House Armed Services Committee (HASC) mark-up of House Resolution 1585 (the NDAA for 2008) calls for an additional US$ 130 million for SSA and space control programmes.

Development of systems with the potential to apply force to, in, or especially from, outer space is of even greater congressional, public and international concern. These concerns are exacerbated by significant difficulties in distinguishing between concepts and technologies being developed for ballistic missile defence, protection, space control and force application, as well as the development of some of these systems in classified programmes. Domestic groups opposed to space weaponization, such as the Center for Defense Information (CDI) and the Stimson Center, argue that momentum created by experiments testing space control and force application concepts in outer space will create "facts in orbit", driving US policy toward space weapons without debate by either Congress or the public.[20] The programmes of greatest concern to these groups include the MDA's Space-Based Interceptor Test Bed, and Near Field Infrared Experiment (NFIRE); as well as the Air Force's Experimental Satellite System (XSS) and Autonomous Nanosatellite Guardian for Evaluating Local Space (ANGELS).[21] It is difficult, however, to see how the United States could continue improving its space protection and ballistic missile defence capabilities without the data provided by conducting these relatively small-scale experiments, how the experiments could appreciably change any facts in orbit, or how they might lead to full-scale space weaponization without triggering significant public debate, especially given all the space acquisition woes the United States faces. Indeed, the cumulative effect of current NSS acquisition problems has contributed to a small but perceptible shift in priorities away from space control and force application. Comparison of the most recent Space Posture statements to Congress by the Under Secretary of the Air Force shows the greater emphasis that Peter Teets placed on assured access to and freedom of action in outer space while his successor, Ronald Sega, has not focused on this area but has emphasized consistently a "back-to-basics" approach to acquisition.[22]

The Common Aero Vehicle (CAV) programme is the primary effort by the United States to develop force application capabilities, but this programme is not very robust and it is doubtful whether it will result in any fielded hardware. Under the joint Air Force–Defense Advanced Research Projects

Agency (DARPA) programme office created in December 2002, the CAV programme was envisioned originally as a conventional warhead that would be launched from an intercontinental ballistic missile (ICBM), or potentially from an orbiting space platform, and was part of the Force Application and Launch from Continental United States (FALCON) programme. However, the FALCON portion of the CAV programme was restructured. Now known as Falcon (lower case), the programme is focused on the development and transition of more mature technologies into a future weapon system capable of delivering and deploying conventional payloads worldwide from and through outer space. Within the Falcon programme, CAV has been redesignated the Hypersonic Technology Vehicle and all weaponization activities have been excluded. The 2006 FYDP calls for total funding of less than US$ 100 million per year for those programmes through 2011. The CBO's projection assumes the limited deployment of 40 CAV-equipped ICBMs in about 2015, at which point the demand for investment resources would peak at US$ 600 million.[23]

US missile defence developments

The George W. Bush Administration publicly announced its policy on ballistic missile defence on 20 May 2003. This policy emphasizes that changes in the global security environment caused by the end of the Cold War and the 11 September 2001 attacks, as well as a growing number of missile and weapons of mass destruction (WMD) threats, "requires a different approach to deterrence and new tools for defense."[24] Among the most worrisome recent events are the North Korean Taepodong-2 launch in July 2006 and the nuclear weapon test in October 2006, continuing Iranian testing of a number of increasingly longer-range missiles such as the Shahab-3 and major efforts to develop nuclear weapons, and the close cooperation between these rogue actors in developing these systems.[25] Even more disturbing is Pyongyang's demonstrated willingness to sell every weapon it has developed to any actor able to pay. The Bush Administration also stresses the consistency of its policy with the National Missile Defense Act of 1999 which stated, "It is the policy of the United States to deploy as soon as it is technologically possible an effective National Missile Defense system capable of defending the territory of the United States against limited ballistic missile attack (whether accidental, unauthorized, or deliberate)".[26] In light of these changes in the geostrategic environment and its greater enthusiasm towards missile defences, the Bush Administration has taken several incremental but significant steps towards improving United States ballistic missile defence capabilities, including withdrawing from the 1972 Anti-Ballistic Missile (ABM) Treaty, increasing missile defence funding and fielding the first dedicated missile defence interceptors on US soil since the 1970s. The request for missile defence funding submitted to Congress in February 2007 for the 2008 budget is US$ 8.9 billion, a decrease of US$ 500 million from the amount appropriated the year before. "Within this budget, the Missile Defense Agency (MDA) has allocated $4 billion for the development of new capabilities, $2 billion for testing of new and existing capabilities, $2 billion for fielding of existing capabilities, and $900 million to sustain fielded assets."[27] To implement the policy, MDA is taking a three-part approach "[to m]aintain and sustain an initial capability to defend the U.S., allies, and our deployed forces against rogue attacks; close the gaps and improve this initial capability; and develop options for the future."[28]

MDA's plans call for a number of actions over the FYDP to maintain and sustain its initial capability to defend the United States, allies and deployed forces against rogue attacks. Continuing deployment of two interceptor missile systems, the Standard Missile-3 (SM-3) aboard Aegis cruisers and Ground Based Interceptors (GBI) in Alaska and California, is one of the most important steps to attain this initial capability. Plans call for taking delivery of up to 40 SM-3 and 30 GBI by the end of 2008. Additional planned actions to maintain and sustain initial capabilities include enhancing early warning radars in Alaska, California and the United Kingdom; fielding a sea-based X-band radar in the Pacific and a forward-transportable radar in Japan; and expanding command and control, battle management, and communications capabilities. To close gaps and improve its initial capabilities over the FYDP, MDA plans to add more Aegis interceptors, field four transportable Terminal High Altitude Area Defense (THAAD) units, introduce land and sea variants of the Multiple Kill Vehicle (MKV) programme, upgrade the early warning radar in Greenland, and establish a GBI site and corresponding radar capability in Europe. Finally, to create options for the future MDA plans to continue development of the Space Tracking and Surveillance System (STSS); maintain two programmes, the Kinetic Energy Interceptor (KEI) and the Airborne Laser (ABL), one of which is to be selected as the boost-phase missile defence element by 2010; and develop a Space Test Bed to examine space-based options for expanding the coverage and effectiveness for future missile defence systems.[29]

Many concepts and programmes associated with missile defences have been highly charged politically and strategically since before the Reagan Administration announced the Strategic Defense Initiative in 1983, and elements of the Bush Administration's programme are no exception. It is likely that reenergized political debates over the efficacy and wisdom of missile defences will arise following the capture of both houses of Congress by the Democrats in November 2006. Thus far, however, most Democratic critiques of missile defences in the 110th Congress have been somewhat restrained and centered more on technical issues such as cost and test performance rather than broader strategic issues. Among many controversial issues, several stand out including the third European site for the GBI and associated radar. Congress cut the funding for this site last year, and so far this year the HASC mark-up has eliminated the US$ 206 million requested for 2008 and would require the DoD to complete a comprehensive independent study on the implications of developing a third site. In addition, there have been numerous high-level objections raised by the Russians and there are political issues in Poland and the Czech Republic, the proposed host states for the 10 GBI and associated radar.

Another perhaps less politically charged but more technologically challenging programme is the ABL. The ABL has recently made some technical progress, including a successful airborne test of the target illuminator lasers in March 2007 that demonstrated an ability to track an airborne target and measure and compensate for atmospheric distortion, but the initial airborne attempt to intercept a boosting missile has been pushed back again and is now scheduled for late 2009. The ABL was fully funded at US$ 632 million in 2008 and the 2008 request is US$ 549 million, but the HASC mark-up has reduced this by US$ 250 million. There is also some controversy surrounding the Kinetic Energy Interceptor (KEI) and the MKV. Both programmes had funding cuts last year and it is not clear whether the KEI would offer a significant new capability such as boost-phase intercept capability or a mobile launcher. Testing issues have been a perennial concern for all missile defence systems and many elements of the current defence architecture have endured multiple test failures or only partial successes, even under less than stressful testing scenarios. Recently, many elements of the defence architecture have had far greater success, and MDA had 13 successful tests out of 14 attempts during 2006, but concerns remain, particularly among Democrats in Congress, about the breadth and scope of future testing and certification requirements. Finally, perhaps the most controversial issue of all directly relates to the interrelationship between space and missile defences and concerns the proposed Space Test Bed. Opponents argue this test bed is unnecessary, will weaponize space, and will destabilize relations with other major nuclear-weapon states such as China and Russia. Supporters believe the test bed is needed to subject space-based interceptors (that could be similar to the Brilliant Pebbles concept first discussed in the late 1980s) to testing under operational conditions and that such interceptors are required to build a capable global boost-phase intercept capability. They also point to China's 11 January 2007 anti-satellite (ASAT) test to show that threats are growing and that "space weapons" need not be stationed in outer space. The request for the Space Test Bed for 2008 is US$ 10 million and requested funding is projected to grow to US$ 15 million for 2009, but the HASC mark-up provided no funding for test bed.

Contentious space and missile defence issues

As outlined above, there are many controversial programmatic issues associated with space and missile defences. Unfortunately, however, these programmatic controversies pale in comparison to strategic and diplomatic contention over their proper role. Probably the broadest and most important point of contention concerns the quest to find a "sweet spot" where US missile defences are robust enough to assure allies and dissuade, deter and defend against rogue actors, without becoming powerful enough to have the potential to neutralize a significant portion of Chinese and Russian nuclear forces, thereby undermining concepts of strategic stability. These are complex and intangible values to be balanced and it is no surprise that sophisticated conceptual models capable of fully expressing this multidimensional problem have not yet emerged. Finding this balance is made more difficult by the growing number of nuclear- and missile-armed, and potentially rogue, actors, the decreasing numbers of deployed nuclear forces of the former superpowers, the growing accuracy of nuclear and conventional long-range strike systems, and the increasing potential of defensive systems and space-based defences in particular. Other analysts question whether it is possible or desirable to find this sweet spot because they do not wish to delay robust defences against rogue actors for a quixotic quest for balance and stability or to replicate Cold War paradigms based on mutual vulnerability with every emerging WMD actor. Given these difficulties, it seems unlikely that a balance acceptable to all major nuclear-weapon states can be found unless the number of potential rogue actors with WMD and ballistic missiles can be reduced or the perceived need for mutual vulnerability among nuclear-armed actors can be lessened.

A second set of highly contentious issues relates to the operational benefits and drawbacks of space-based, boost-phase missile defences versus concerns over weaponization of outer space and creation of space debris. Space basing would provide a number of potentially significant advantages for global boost-phase defence including always-deployed global coverage that precludes the need for crisis deployments into contested areas, rapid reaction times, and equal access to all potential launch sites. Boost-phase intercept allows engagement of missile targets during their slowest, most visible and most vulnerable phase of flight, and has the additional benefit that any WMD aboard the missile may fall back onto the territory of the attacker. Of course, there are also daunting technical and programmatic challenges associated with boost-phase defence including the requirement to engage targets very rapidly and the potential need to predelegate engagement authority to the defensive systems rather than being able to maintain human decision makers in the loop under certain conditions, the costs and technical capabilities of the defences, the absentee ratio of defences and the potential ability of attackers to saturate defences via salvo launches or other techniques, and the costs to boost, maintain and replenish such a system. At the strategic level, space-based defences raise concerns about weaponizing outer space due to the latent anti-satellite capability that any missile defence system is likely to have. Satellites are generally fragile and travel along predictable orbital paths; any defensive system capable of engaging missiles in the boost, post-boost or midcourse phases of flight will very likely have considerable latent ASAT capabilities and it is difficult to see how such capabilities could be engineered out of a defensive system. Moving towards resolution of this strategic-level concern will require balancing the costs and benefits of defences, especially against potential rogue actors or new and unexpected threats, with concerns about space weaponization and satellite vulnerabilities. As in the case of the sweet spot issue above, it is unlikely that major actors will value these concerns in the same ways or be able to resolve these issues easily. In addition, there is also the potential that testing or use of space-based defences could create space debris. The kinetics of interception for boost-phase defences are not likely to lead to orbital debris, and are especially unlikely to create long-lived debris, since neither the target nor interceptor is travelling on an orbital trajectory. Engagement of satellites or otherwise testing against objects with orbital velocities may create long-lived debris and the need for such actions should be balanced against the hazards to all space actors created by such debris.

A final set of contentious issues regarding space and missile defences concerns the definition of a space weapon and the potential utility of controlling or regulating such weapons versus the ability of a wide range of systems to produce significant weapons effects in outer space or against ballistic missiles, even if they are not based in outer space. Simply put, since so many systems in a variety of basing modes can have effects against ballistic missiles and especially space systems, it will be very difficult to define what a space weapon is or to control such systems. The United States is developing dedicated missile defence systems that are land-, sea- and air-based, and, as discussed above, the Bush Administration wishes to test space-based defensive systems. Are all of these systems space weapons? Does the basing mode matter and, if so, how? These issues are unclear, but the basing mode of a system does not seem to be nearly as important as the effects it can create and the ways in which it might be used. Of course, as illustrated by the 11 January 2007 Chinese ASAT test, the United States is not the only actor creating such dedicated capabilities. Probably even more significant are all the residual ASAT capabilities possessed by a wide range of systems that were not designed for this purpose. Every space object that can transmit or manoeuvre has some potential to interfere with, damage, or even destroy, other space objects by colliding with them. Problems in controlling residual ASAT capabilities would seem to be exacerbated by a number of trends, including rapid growth in the number of commercial assets in outer space, movement towards smaller satellites that are more difficult to find and track, and wider development of autonomous rendezvous and docking capabilities. In addition to all these problems, there are also numerous ways to cause interference with or disrupt satellite up- and downlinks or to attack or otherwise disrupt satellite telemetry, tracking and control facilities on the ground. Finally, even if all these definitional issues and problems with residual and latent ASAT capabilities could be addressed with some sort of controls, it is not clear that such controls would necessarily produce greater stability. In 1986, Ashton Carter explained the paradox of ASAT arms control—the idea that because space systems cannot be divorced from the strategic balance on Earth or the natural dialectic between offensive and defensive forces, an effective ban on ASAT weapons might make outer space safer for the development of major space-to-Earth strike systems and result in less strategic stability.[30] More recently, Michael O'Hanlon has questioned the need for space arms control and the desirability of granting sanctuary status to targeting systems that operate from outer space.[31] Cumulatively, these factors indicate that movement toward effective and stabilizing control of space weapons and missile defences will remain a daunting challenge and that it is an act of hubris to believe otherwise.

Notes

1 Unfortunately, programmes within the vMFP have not remained constant from year to year and have not always covered all major space systems, reducing the utility of this measure for tracking NSS expenditures over time.

2 Marcia S. Smith, *U.S. Space Programs: Civilian, Military, and Commercial*, Congressional Research Service, 9 August 2005.

3 Congressional Budget Office, *The Long-Term Implication of Current Plans for Investment in Major Unclassified Military Space Programs*, Congressional Budget Office, 12 September 2005, p. 1.

4 Ibid., p. 5.

5 Most US government documents list three rather than four space sectors. See, for example, the National Space Policy's discussion of civil, national security (defence and intelligence), and commercial sectors. Office of Science and Technology Policy, *Fact Sheet: National Space Policy*, the White House, 31 August 2006. For discussion emphasizing the four sectors see *Report of the Commission to Assess National Security Space Management and Organization*, Commission to Assess National Security Space Management and Organization, 11 January 2001, pp. 10–14.

6 Joint Staff, *Joint Doctrine for Space Operations*, Department of Defense, 9 August 2002.

7 David Lupton, *On Space Warfare: A Space Power Doctrine*, Air University Press, June 1988.

8 Satellites in low-Earth orbit (LEO) operate from less than 100 miles to several hundred miles altitude and complete each orbit in approximately 90 minutes. Polar LEO is ideal for many intelligence and weather applications because it covers all parts of the Earth several times each day as the Earth rotates and it also can be aligned in sun-synchronous orbits that arrive at the same location at the same time each day. Satellites in semi-synchronous orbit are located at approximately 12,500 miles altitude and complete an orbit every 12 hours. Geostationary Earth orbit (GEO) is located approximately 22,300 miles above the equator, a location where the satellites' orbital velocity matches Earth's rate of rotation and the satellite appears to

remain motionless above the same spot—a valuable attribute for communications and some signals intelligence satellites.

9 *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs*, Defense Science Board, May 2003, p. 6.

10 Government Accountability Office, *Assessments of Selected Major Weapon Programs*, 2006, pp. 101–2. Through the end of 2005, the SBIRS programme had triggered four reports to Congress under the Nunn–McCurdy Act; the programme breached its cost estimates by 25% in 2001, by 15% in 2004, and by 25% twice during 2005.

11 Congressional Budget Office, *Investment in Major Military Space Programs*, 2005, p. 12.

12 Office of Science and Technology Policy, *Fact Sheet: US Space-Based Positioning, Navigation, and Timing Policy*, the White House, 15 December 2004, p. 3.

13 Ibid., pp. 6–7.

14 Breanne Wagner, "Aerospace World", *Air Force Magazine*, vol. 89, no. 7, July 2006, pp. 21–2.

15 Congressional Budget Office, *Investment in Major Military Space Programs*, 2005, p. 9.

16 Joint Staff, *Joint Doctrine for Space Operations*, Department of Defense, 9 August 2002, pp. iv-5–iv-8.

17 US Air Force, *Counterspace Operations*, Doctrine Document 2-2.1, Air Force Doctrine Center, 2 August 2004, pp. 25–34.

18 Congressional Budget Office, *Investment in Major Military Space Programs*, 2005, p. 16.

19 Section 911 of the 2006 National Defense Authorization Act, "Space Situational Awareness Strategy and Space Control Mission Review".

20 Theresa Hitchens, Michael Katz-Hyman and Victoria Samson, *Space Weapons Spending in the FY 2007 Defense Budget*, Center for Defense Information, 8 March 2006.

21 Ibid. The NFIRE programme, in particular, has been the object of a great deal of attention and criticism after MDA revealed that the satellite would include a sensor-projectile that would approach and likely strike a target missile in space. This portion of the experiment was eliminated but Congress, in language accompanying the 2006 Defense Appropriations Act, encouraged the MDA to reconsider. MDA has said it will begin planning in 2007 to study the feasibility of adding a projectile to an NFIRE satellite. MDA requested US$ 10.8 million for NFIRE in 2007 and the 2006 budget for the effort was US$ 13.5 million.

[22] See the Space Posture statements presented to Congress by the two Under Secretaries of the Air Force in March 2005 and March 2006, respectively. Peter Teets resigned in March 2005 and was replaced by Ronald Sega in July 2005.

[23] Congressional Budget Office, *Investment in Major Military Space Programs*, 2005, p. 16.

[24] Office of the Press Secretary, *National Policy on Ballistic Missile Defense Fact Sheet*, the White House, 20 May 2003.

[25] Bruno Gruselle, "The Final Frontier: Missile Defence in Space?", *Disarmament Forum*, no. 1, 2007, pp. 53–7; and Independent Working Group, *Missile Defense, the Space Relationship, and the Twenty-First Century: 2007 Report*, Institute for Foreign Policy Analysis, 2006, pp. 2–4.

[26] Ibid.

[27] *Policy Outlook: Missile Defense Issues in the 2008 Budget Request—Issues and Background*, George C. Marshall Institute, February 2007.

[28] Ibid.

[29] Ibid.

[30] Ashton Carter, "Satellite and Anti-Satellites: The Limits of the Possible", *International Security*, vol. 10, no. 4, 1986, pp. 46–98.

[31] Michael O'Hanlon, *Neither Star Wars Nor Sanctuary: Constraining the Military Uses of Space*, Brookings Institution, 2004.