



NATIONAL INSTITUTE FOR PUBLIC POLICY

FOREIGN SPACE CAPABILITIES: IMPLICATIONS FOR U.S. NATIONAL SECURITY

STEVE LAMBAKIS



Foreign Space Capabilities: Implications for U.S. National Security

By

Steve Lambakis

September 2017

For additional information about this publication or other publications by the National Institute Press, contact: Editor, National Institute Press, 9302 Lee Highway, Suite 750 • Fairfax, VA 22031 • (703) 293-9181 • www.nipp.org.

© National Institute Press, 2017

Foreign Space Capabilities: Implications for U.S. National Security

Acknowledgements

The author wishes to thank Matt Costlow, of the National Institute for Public Policy, for his excellent research contributions and graph-making skills. He would also like to recognize and thank the senior reviewers of this monograph. Their insights and contributions to the development of this work without question improved its quality. Special thanks to Dr. Kathleen Bailey, Ambassador Henry F. Cooper, Dr. Colin Gray, Ambassador Robert Joseph, Dr. Susan Jane Koch, Dr. Keith Payne, and Dr. Mark Schneider. Last, but not least, the author is grateful to Amy Joseph of the National Institute for Public Policy for her professional support throughout the entire project—simply put, without her, nothing gets done. Finally, the author would like to express his appreciation to the Smith Richardson Foundation for generously funding this work.

Steve Lambakis is a policy thought leader in U.S. ballistic missile defense and protection of our U.S. space systems. I worked with Steve at the Missile Defense Agency for many years when I was the Director there and found him to be the consummate professional delivering well-researched and thoughtful policy insights. He has made significant contributions in two areas: 1) development of a credible deterrence strategy to convince other states that they need to refrain from attacks on U.S. space systems; and 2) deployment of a space-based interceptor layer to significantly enhance U.S. Ballistic Missile Defense System effectiveness and to protect U.S. government, commercial, and allied/partner satellite assets from direct-ascent anti-satellites. Steve continues his great work in his new piece entitled *Foreign Space Capabilities: Implications for U.S. National Security*.

--Henry A. Obering III, Lieutenant General, USAF (ret)
Director of the U.S. Missile Defense Agency (2004-2009)

Table of Contents

Executive Summary	xi
Introduction	1
Chapter 1: Expanding Exploitation of Space	7
Chapter 2: Foreign Space and Counter-Space Developments.....	17
Chapter 3: Protecting and Exercising U.S. Space Power	41
Chapter 4: Implications for U.S. Defense Policy	59
Chapter 5: Recommendations.....	79

Executive Summary

Space utilities support the way of life in the United States in peacetime and provide critical warfighting capabilities. Capabilities for attacking space systems before and during conventional conflicts are spreading to other nations along with the proliferation of capabilities to exploit information derived from or processed by satellites. This report considers the current and emerging national security realities in space, examines the implications for U.S. defense policy, and offers policy recommendations for mitigating the threat.

More than 170 countries have access to space capabilities and 11 countries have indigenous space launch infrastructure and capabilities. Satellites accomplish critical communications, positioning and navigation, timing, early warning, space object tracking, earth surveillance, earth reconnaissance, and intelligence-gathering functions. Space usage has gradually evolved to take on critical military force enhancement functions in the armed forces of a growing number of countries.

The proliferation of space technologies offers foreign governments and non-state entities unparalleled opportunities to enhance military effectiveness over the United States and, over time, will enable them to strike with strategic effect. Russia and China continue to improve the capabilities of their military and intelligence satellites and grow more sophisticated in the integration of these capabilities into their military operations. Today's combatant commanders must now anticipate that adversaries will be watching or tracking the activities of U.S. armed forces, to include watching U.S. force movements and communicating with their own forces with very high levels of efficiency and accuracy.

In addition to increasing investments in their own space systems and capabilities and increasingly integrating them into their warfighting operations, foreign nations are also acquiring counter-space capabilities, which is of even greater concern to the United States given its reliance on space assets for its economy and national security. Yet the risk to U.S. space activities is growing faster than the U.S. ability or effort to mitigate it. The collection and distribution of information derived from space or processed in space may be denied, disrupted or degraded using tactics such as jamming of radio transmitters or blinding of satellite sensors using lasers. Satellite functions also could be denied or degraded through physical attack using an anti-satellite weapon (ASAT), which in effect takes out an element of a node in the information network, which, depending on the resilience of the network, may or may not have a catastrophic effect.

With their development of counter-space weapons and practice with counter-space operations, potential adversaries of the United States have indicated that their leaders believe that space is an extension of the battlefield on Earth. Both China and Russia are on record stating that they are developing counter-space capabilities, to include capabilities for jamming GPS signals and satellite communications, dazzling satellite sensors with ground-based lasers, and developing ground-based guided missiles and orbital systems to destroy satellites. Experts say that with as little as two dozen anti-satellite missiles, Russia or China could do significant damage to U.S. intelligence, navigation, and communications capabilities. North Korea and Iran are regional powers, but because we are dealing with the space and cyber domains, the counter-space threats they may pose could quickly become global in nature. The space activities of all four countries

are addressed in this report in greater detail. This report also takes a brief look at the growing risk to U.S. space systems posed by cyber intrusions and nuclear-generated electro-magnetic pulse.

Within this changing environment, the reliance by U.S. military forces on force multiplying effects of space services continues to grow. Since 2014, the U.S. Department of Defense has experienced what some have called a “counter-space awakening,” essentially a response to recent Chinese and Russian anti-satellite activities, which has led to an internal assessment that the United States had been moving too slowly to address the new challenges. Air Force Space Command is taking steps to reorient thinking to take threat into account and not assume a benign environment and to develop a more resilient U.S. space architecture to achieve improved space mission assurance. This report looks at the importance of improving situational awareness capabilities, ensuring reliable access to space, improving space control technologies and operations, and developing a robust capability to counter reversible and permanent space denial efforts by potential adversaries.

There are several policy considerations as the United States works to address the impacts of counter-space proliferation. Space threats are not highly salient to the public, nor are they visible because of classification and the reality that space activities take place out of sight. Not only is there little awareness of the developing anti-satellite capabilities worldwide, there is perhaps a perception by many that space war would be non-lethal and have limited impact on everyday life. Additionally, debates about space often are politically charged, with some viewing any preparation for war as a provocation.

There are a number of approaches the nation may take to address its vulnerabilities in space, the effectiveness of each are the subject of current policy discussions.

Alternatives to Space Capabilities: Should access to space be diminished or lost, it has been suggested that the United States could look to alternative capabilities to perform functions typically performed by space systems, such as unmanned aerial vehicle sensors and processing, Enhanced LORAN, terrestrial radio and microwave towers, and fiber-optic cabling. These substitutes may make sense, of course, when it comes to supplementing space services, yet they cannot come close to replacing what satellites have to offer. The nation is in space for a reason, and that is because space provides unparalleled advantages that an adversary would happily take away.

Deterrence: The current U.S. approach to deterrence of attacks in space is to deny the adversary victory by introducing passive space defense measures (disaggregation, proliferation of assets, etc.), thereby reducing the likelihood of an adversary’s success, which, accordingly, would induce the adversary to decide not to attack at all. A strong case can be made that another approach is needed to supplement the deterrence-by-denial strategy. The nation does not have but needs a credible and effective deterrence-by-punishment approach. The aggressor must perceive and fear that unacceptable costs would be imposed following a hostile action, or the aggressor must believe that it would not gain anything of consequence by aggressive action and that there would be costs involved. Regardless of the domain, understanding deterrence is about understanding the behavior and decision-making behavior of the potential adversary. The potential attacker on U.S. space systems should be made to fear U.S. deterrence strategies and see them as credible; it must understand that the United States is able to attribute provocations to the source and will hold that source accountable.

Dealing with Provocations in Space: Prevention of war in space is of course a desirable goal. Yet an adversary, especially one that is at a conventional disadvantage with the United States, may look upon the disruption or denial of U.S. space systems during a crisis as a risk worth taking. Certainly it would appear to be easier and less provocative to use temporary or reversible effects to counter space weapons (such as jammers or dazzlers) than it would be to use destructive kinetic weapons or turn off the satellite using cyber warfare. It is important to remember that not all satellites are created equal – disruption of commercial satellite operations may not have the same effect as the disruption of GPS or early warning satellites. Also, what is happening on earth is a key determining factor in a response to such a disruption. There will always be factors that are open to interpretation, and pressing timelines for making decisions may be expected to further complicate matters. This should underscore the importance of space situational awareness capabilities for general crisis stability, to include stability in space. If potential adversaries are truly interested in avoiding a situation that could escalate into a larger conflict, then improved communications and education are good steps to take. More importantly, it is important not to handcuff U.S. agencies responsible for responding militarily to possible aggression against U.S. space interests.

Arms Control: It is also the case that other nations may use diplomacy to manipulate arms developments in other countries, as Russia and China are attempting to do with the United States. The danger of declaring or negotiating agreements for peacetime moratoriums on direct-ascent ASATs, for example, is that it would impede the development of capabilities required for space control and limit the development, testing, and potentially the operation of ballistic missile defenses. Moreover, there are very serious definitional and verification problems associated with an ASAT agreement. ASAT weapons can be tested without the target vehicle actually being in orbit. In response to the relative strategic restraint demonstrated by the United States, both Russia and China continue to build up and modernize their ballistic missile and counter-space capabilities. Iran and North Korea, in defiance of international sanctions, have developed ballistic missiles and have leveraged their respective space programs to improve missile programs. The United States has a significant stake in promoting a space environment that is secure and free to operate in since it deploys significant space assets to support national security, but this does not mean that by refraining from steps to defend its interests through force that space will not somehow become more armed.

Recommendations

- The Administration should undertake a comprehensive space threat study.
- The Administration should develop national policies and strategies to guide the development and execution of space protection efforts.
- The Department of Defense must develop a credible comprehensive deterrence strategy.
- Officials in the White House and the Department of Defense should develop a strategic messaging plan.
- The Defense Department should request that the U.S. Congress provide the necessary resources and programs to improve space system protection and defense.
- The Department of Defense should invest in additional situational awareness sensors in space and on earth.
- The Defense Department should develop the capabilities to exercise positive space control.

- The Department of Defense should work to move missile defense intercept capabilities to space and consider steps to improve missile defenses against threats from southern trajectories.
- The nation should continue to integrate allies and partners into space operations, share situational awareness, and exercise together.
- The nations should continue to shape the international laws, regulations and codes affecting military space activity.
- The Department of Defense should revisit the 2001 Report of the Commission to Assess United States National Security Space Management and Organization.

Introduction

“Prosperity of the United States depends upon its largely uncontested ability to access and use the global commons, which consist of those areas that ‘belong to no one state and that provide access to much of the globe.’” So states a report issued by the U.S. Joint Chiefs of Staff, which declares that, in two decades time the United States will “find itself challenged in parts of the global commons as states and some non-state actors assert their own rules and norms within them.”¹ This is noteworthy because the unrestricted use of the air, sea, and space environments allows the nation to connect with allies and international partners and supports its economy as well as its global commitments to enhance security. The United States traditionally has invested significantly in military resources and political influence to keep these global commons free, open, and stable. The Joint Chiefs conclude that U.S. leaders should expect an increasing number of states to try to deny the operation of satellites and restrict U.S. freedom of access to space to isolate the United States from its allies and partners around the world and inhibit its ability to project power globally.²

Lieutenant General David Buck, Commander of Joint Functional Component Command for Space, puts military refinement on this observation: “space underpins our Nation’s way of life in peacetime and provides critical warfighting capabilities during conflict. It’s no surprise that potential adversaries have taken notice and are working to counter our operational advantages in space.”³ The general was, of course, referring to the significant force enhancement effects that satellites provide to U.S. military forces. Given recent counter-space developments among several potential adversary nations, the national security advantages enjoyed by the United States in space appear to be diminishing. Or to put it another way, the risks of operating in the space domain are growing.

Indeed, over the past few years, threats have evolved to the point where defense officials are now deeply concerned about the U.S. ability to operate freely in space and deliver “space effects.” According to the Joint Chiefs of Staff:

It is very unlikely that future adversaries will allow U.S. forces to move through the commons to forward positions and await a set-piece U.S. onslaught, as for example, the Serbs or Iraqis did in the past. The next two decades will see adversaries building the capacity to control approaches to their homelands through the commons, and later, translating command of the nearby commons into the connective architecture for their own power projection capabilities.⁴

According to a 2015 Defense Intelligence Agency report, “Chinese and Russian military leaders understand the unique information advantages afforded by space systems and are developing

¹ Joint Chiefs of Staff, *Joint Operating Environment: The Joint Force in a Contested and Disordered World* (Washington, D.C.: Joint Chiefs of Staff, July 14, 2016), p. 30, available at http://www.dtic.mil/doctrine/concepts/joe/joe_2035_july16.pdf.

² *Ibid.*, p. 30.

³ David J. Buck, “Statement of Lieutenant General David J. Buck, Commander, Joint Functional Component Command for Space,” *114th U.S. Congress*, House Armed Services Committee, March 15, 2016, p. 2, available at <http://docs.house.gov/meetings/AS/AS29/20160315/104620/HHRG-114-AS29-Wstate-BuckD-20160315.pdf>.

⁴ Joint Chiefs of Staff, *Joint Operating Environment: The Joint Force in a Contested and Disordered World*, op. cit., p. 33.

capabilities to deny U.S. use of space in the event of a conflict.”⁵ U.S. defense officials are watching the growth in counter-space programs within potential adversary nations, especially Russia and China, whose leaders are expanding their abilities to defend, attack, and control space. As the then-Air Combat Command Commander General noted: “Our adversaries are sinking massive resources into denying our forces access to tools such as Position Navigation and Timing (GPS) data links, communication networks and radars.”⁶ This is highly disconcerting, according to the former Commander of Air Force Space Command and current Commander of U.S. Strategic Command, General John Hyten, who holds that “[s]pace is critical to everything that we do in the military.”⁷

In addition to acquiring counter-space capabilities, foreign nations are increasing investments in their own space systems and capabilities to further their national security aims. The U.S. Air Force predicts “[a] doubling of foreign satellites on orbit by 2033 will provide new challenges in space.”⁸ A growing number of foreign governments and non-state entities, such as terrorist organizations,⁹ are able to use space to enhance diplomatic and military influence over the United States and plan attacks. This proliferation represents a significant change from just a couple decades ago.

Space represents a militarily, economically and commercially burgeoning global enterprise that is growing in each of these sectors with each passing year. Space systems are integral to today’s global information infrastructure.¹⁰ With more than \$330 billion invested in 2014 in the global space economy, the economic impact of loss of space would be very significant.¹¹ Space systems are essentially nodes in a larger information network to collect, process, and distribute information for: communication; intelligence, surveillance, and reconnaissance (ISR); and positioning, navigation, and timing (PNT). Space-reliant national security activities and functions include the execution of combat operations, command and control of forces and critical nuclear and missile defense systems, targeting and offensive operations, and logistics and humanitarian support.

⁵ Lt. General Vincent R. Stewart, “Worldwide Threat Assessment Armed Services Committee,” (Washington, D.C.: Defense Intelligence Agency, February 3, 2015), available at <http://www.dia.mil/News/SpeechesandTestimonies/tabid/7031/Article/13225/worldwide-threat-assessment.aspx>.

⁶ “General Michael Hostage III Commander, USAF Air Combat Command, ‘Future of the Combat Air Force’ AFA - Air & Space Conference and Technology Exposition 16 September 2014,” available at <http://www.af.mil/Portals/1/documents/af%20events/Speeches/16SEP2014-Gen-Michael-Hostage-Future-of-the-Combat-AF-AFA-Conference.pdf>.

⁷ As quoted in Phillip Swarts, “Space Wars: The Air Force Awakens,” *Air Force Times*, February 15, 2016, available at <https://www.airforcetimes.com/story/military/2016/02/15/space-wars-air-force-awakens/79804228>.

⁸ U.S. Air Force, *Global Horizons: United States Air Force Global Science and Technology Vision* (Washington, D.C.: Air Force, July 3, 2013), p. 2, available at <http://www.af.mil/Portals/1/documents/news/GlobalHorizons.pdf>. “The increasing proliferation of technologies as well as the increasing availability of commercial components for innovative or traditional use in systems, will shorten the foreign research, development, acquisition, and deployment timelines, meaning advanced capabilities will be reaching military systems in a reduced time frame. In addition, low tier threat countries with access to proliferated technologies or low cost commercial off the shelf (COTS) components may develop capabilities in niche applications that will cause an increasing threat to the US,” (p.7).

⁹ Terrorist organizations and Iraqi insurgents have access to satellite position, navigation, and timing signals and satellite phones and have used commercially available imagery to support their operations. See for example, Kelly Hearn, “Terrorist Use of Google Earth Raises Security Fears,” *National Geographic News*, March 12, 2007, available at <http://news.nationalgeographic.com/news/2007/03/070312-google-censor.html>; and Emily Wax, “Mumbai Attackers Made Sophisticated Use of Technology,” *Washington Post*, December 3, 2008, available at <http://www.washingtonpost.com/wp-dyn/content/article/2008/12/02/AR2008120203519.html>.

¹⁰ For a brief look at how innovations and the spread of intelligent devices is leading the expansion of space infrastructure, see Editors, “Brave new worlds,” *The Economist*, August 27, 2016, available at <http://www.economist.com/news/leaders/21705825-new-discoveries-intelligent-devices-and-irrepressible-dreamers-are-once-again-making-space>.

¹¹ Doug Lamborn, “Time to get serious about space threats,” *The Hill*, May 14, 2015, available at <http://thehill.com/opinion/oped/241933-time-to-get-serious-about-space-threats>.

Satellites and satellite-derived data are indispensable to emergency management operations by enabling responders to act faster and smarter.¹² Other activities of society dependent on space include trade and commerce, banking, financial transactions, food production and distribution, communications, transportation, power and water infrastructure, and weather monitoring and assessment. According to a study by the National Academies of Sciences, Engineering, and Medicine, “were the world to suddenly be ‘without space,’ these would all seriously degrade or shut down entirely.”¹³

While space provides critical support functions to the warfighter, no nation has yet to experience combat in space. This lack of battle practice includes missile defense, which may involve a clash between reentry vehicles launched by ballistic missiles and kinetic kill vehicles launched by ground- or sea-based interceptors to collide with and destroy them above the atmosphere.¹⁴ Despite the lack of battle experience in space, U.S. leaders continue to understand space systems to be essential to warfighting and a critical element of both conventional and nuclear deterrence. Indeed, the United States should anticipate that any future war will involve, in some form or another, war in space. It is a mistake to think of war on earth without anticipating it will involve military actions in space for the simple reason that space is so integrated into U.S. warfighting that any adversary seeking an advantage will naturally look to space to defeat a U.S. asymmetric advantage.

Roughly 60 years ago the United States and the Soviet Union pioneered the exploitation of the space domain and were the main operators in that environment through the 1980s. The United States once could take for granted the strategic, operational, and tactical advantages it enjoyed in space. Today U.S. defense officials believe that an adversary can “impose multiple domain impacts by denying or degrading space effects.”¹⁵ American citizens (and the citizens of other nations) are increasingly taking space for granted in their personal and professional lives, treating access to space much like they do the availability of “lifeline” services such as water or electricity—they expect it to be there for their travels, their work and play lives, and their daily communications. Warfighters also expect this space “utility” to be there, just like it is in their off-duty lives.

Since the first Gulf War and the impressive military display by U.S. armed forces, the rest of the world has been watching the United States very closely. In Desert Storm, it became apparent that space assets and space control would become ever more critical to U.S. conventional warfighting.¹⁶ Unlike during the Cold War when attacks on space systems (command and control and early warning systems) potentially meant crossing the line to nuclear war, the idea that space systems may be attacked before and during conventional conflicts is spreading. Potential

¹² Joseph Nimmich, *Written testimony for a Joint House Armed Services, Subcommittee on Strategic Forces; and, House Homeland Security, Subcommittee on Emergency Preparedness, Response and Communications*, “Threats to Space Assets and Implications for Homeland Security,” March 29, 2017, available at <https://armedservices.house.gov/legislation/hearings/threats-space-assets-and-implications-homeland-security>.

¹³ National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report* (Washington, D.C.: The National Academies Press, 2016), p. 2, available at <https://www.nap.edu/catalog/23594/national-security-space-defense-and-protection-public-report>. The National Academies report provides an excellent comprehensive look at the transformation of the space environment, especially as it has become more integral to the commercial sector, a sector the authors believe will lead space developments in the future.

¹⁴ U.S. forces have engaged in short-range missile defense actions in combat during Operation Desert Storm and Operation Iraqi Freedom, which involved intercepts by PATRIOT systems inside the atmosphere.

¹⁵ Buck, “Statement of Lieutenant General David J. Buck, Commander, Joint Functional Component Command for Space,” *op. cit.*, p. 3.

¹⁶ Steven Lambakis, “Space Control in Desert Storm and Beyond,” *Orbis*, Vol. 39, No. 3 (Summer 1995), pp. 417-433.

adversaries have taken steps to counter the U.S. advantages in space, so much so that today “there is not a single aspect of our space architecture, to include the ground architecture, that isn’t at risk.”¹⁷

This dependence on space is precarious, according to then-Deputy Secretary of Defense, Bob Work. Space systems, he said:

[C]ontribute in every aspect of the Joint multi-national battle networks we assemble to fight and prevail over any opponent.... Space capabilities are an absolutely essential part of our sensor grids, providing exquisite information on what is happening in an area of operations. They are an essential part of our C3I grids, providing us with the ability to operate forces over global and theater ranges in a coherent fashion. And they are an essential part of our effects grid, providing information that makes our application of force more precise and lethal.”¹⁸

How disruptive an attack on satellite systems would be for the nation depends on the type of satellite that is destroyed and the redundancy in the space system network. The collection and distribution of this information may be denied, disrupted or degraded using tactics such as jamming of radio transmitters or blinding of satellite sensors using lasers. Satellite functions could also be denied or degraded through physical attack using an anti-satellite weapon (ASAT), which in effect takes out an element of a node in the information network, which, depending on the resilience of the network, may or may not have a catastrophic effect.¹⁹ In the national security sector, the National Academies study authors point out that the loss or degradation of space capabilities supporting key functions “would increase the risk that a crisis would escalate into an unnecessary or unintended conflict.”²⁰

U.S. policy makers and defense planners also must grapple with a truly 21st century question: What is a space threat and what can we do about it? An enemy of the United States could use space in two different ways: 1) use proliferating counter-space capabilities to impede freedom of action; or 2) use space systems to positively further their own strategic and military objectives by exploiting data collected or processed by satellites. These developments impact important national security activities, to include the viability of deterrence.

The growing activities in space spurred on by relentless technological advances and growing demand for space-enabled information products has quickly outpaced existing policies and strategies for coping with strategic and military challenges presented in that arena. This monograph will put forth the case that, as the United States continues to place more and more investment and trust into space infrastructure, it needs to pay increasingly close attention to developing a credible deterrence strategy, bolstering defensive measures to protect those assets, developing loss-mitigation strategies should deterrence fail, and potentially exercising active “control” over parts of this domain to deny the enemy exploitation of space.

¹⁷ Buck, “Statement of Lieutenant General David J. Buck, Commander, Joint Functional Component Command for Space,” op. cit., p. 4.

¹⁸ Bob Work, *Remarks at the Space Symposium*, *Defense.gov*, April 12, 2016, available at <https://www.defense.gov/News/Speeches/Speech-View/Article/723498/remarks-at-the-space-symposium>.

¹⁹ National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report*, op. cit., p. 8.

²⁰ *Ibid.*, p. 2.

Put simply, the risk to U.S. space activities is growing faster than the U.S. ability or effort to mitigate it.²¹ As the *2011 National Security Space Strategy* recognizes, space is becoming increasingly congested, contested, and competitive.²² How should the United States prepare to maintain its access to space and prevail over another country's possible hostile use of space against us? Space also is an environment exploited by an increasing number of nations. Some nations, China in particular, are making considerable investments to develop military space capabilities.²³ What can the United States do to address this trend? There are many policy, strategy and deterrence challenges to face. This monograph considers the current and emerging realities in the world of space national security, examines the implications for national security, and offers policy recommendations for mitigating the threat.

²¹ General John E. Hyten, *Hearing on the Nomination of General John Hyten to be Commander of U.S. Strategic Command*, 114th U.S. Congress, Senate Armed Services Committee, September 20, 2016, p. 20, available at https://www.armed-services.senate.gov/imo/media/doc/16-70_9-20-16.pdf.

²² Robert M. Gates and James R. Clapper, *National Security Space Strategy: Unclassified Summary* (Washington, D.C.: Office of the Director of National Intelligence, January 2011), available at https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_nationalsecurityspacestrategy.pdf.

²³ U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China 2015* (Washington, D.C.: Department of Defense, April 2015), pp. 13-15, 33-35, 51, 69-71, available at https://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf.

Chapter 1: Expanding Exploitation of Space

Essentially, space power is the competitive use of space for national purposes and advantage. What transpires in space is a continuation of the struggles that occur on earth. The idea that a state would consider exerting influence in space or using space to exert influence on earth should not be a surprise. It is happening today and it will happen in the future.

The first uses of space involved force application. There have been significant changes since the military space age began during the Second World War, when 1,400 German V-2 rockets (designed to travel through space on a ballistic trajectory) rained down on England, Belgium, and France. The V-2s did not only damage targets, they also terrified the public and highlighted the revolutionary potential of space weapons, in this case space weapon attacks initiated by launches from earth. Today the use of vastly more effective rockets and missiles is commonplace.

Military satellites, as conduits of information, have been in orbit for nearly 60 years and today space is a common operating environment for about 60 nations. Roughly 1,400 active military, civil, commercial and research satellites circle the earth today providing a variety of services. More than 170 countries have access to space capabilities and 11 countries have indigenous space launch infrastructure and capability.²⁴ These world-circling platforms accomplish critical communications, positioning and navigation, timing, early warning, space object tracking, earth surveillance, earth reconnaissance, and intelligence functions.²⁵ (See figures below.) Space usage has gradually evolved to take on critical military force enhancement functions.

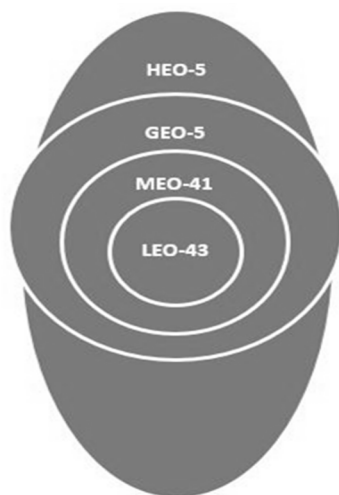


Figure 1. Number of countries and international organizations in each orbit in 2016²⁶

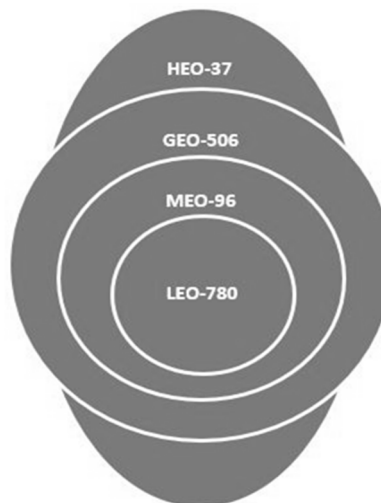


Figure 2. Number of satellites in each orbit in 2016²⁷

²⁴ General John E. Hyten, "Statement of John E. Hyten, Commander, United States Strategic Command," *115th U.S. Congress, House Armed Services Committee*, March 8, 2017, p. 11, available at <http://docs.house.gov/meetings/AS/AS00/20170308/105640/HRG-115-AS00-Wstate-HytenUSAFJ-20170308.pdf>.

²⁵ Steven Lambakis, *On the Edge of Earth: The Future of American Space Power* (Lexington, KY: University of Kentucky Press, 2001).

²⁶ Union of Concerned Scientists, "UCS Satellite Database," *UCSUSA.org*, accessed February 2017, available at http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WNWC8m_yvct.

²⁷ *Ibid.*

Geo-synchronous orbits (GEO) match the earth's rotation at an altitude of 42,164 km (26,199 mi) and may swing north or south at that altitude to expand the coverage area. Satellites in geostationary orbit remain 35,786 km (22,236 mi) over a single location on earth. GEO satellites allow for continuous monitoring for national security purposes, communications, data exchange activities, and weather forecasting. Satellites in medium earth orbit (MEO) most commonly circle the earth at 22,200 km (13,670 mi) altitude, which is where you will find Global Positioning System satellites. MEO orbits may range from 2,000 km to 35,786 km. GPS satellites (as well as other global navigation services) provide critical navigation, positioning, and timing services for military and civilian purposes. Low earth orbit (LEO) satellites, which operate between 160 km (100 mi) and 2,000 km (1,242 mi) altitude, are used for reconnaissance and earth and ocean resource measurements, which may be used by the military, for example, to prepare for battle field deployments. Weather and mobile communications satellites (i.e., Iridium, Globalstar, and ORBCOMM) also operate in LEO. There are also highly elliptical orbits (HEO) used by intelligence and communications satellites that have an extremely low perigee and a very high-altitude apogee that allow satellites to dwell for a long period of time over a targeted region.

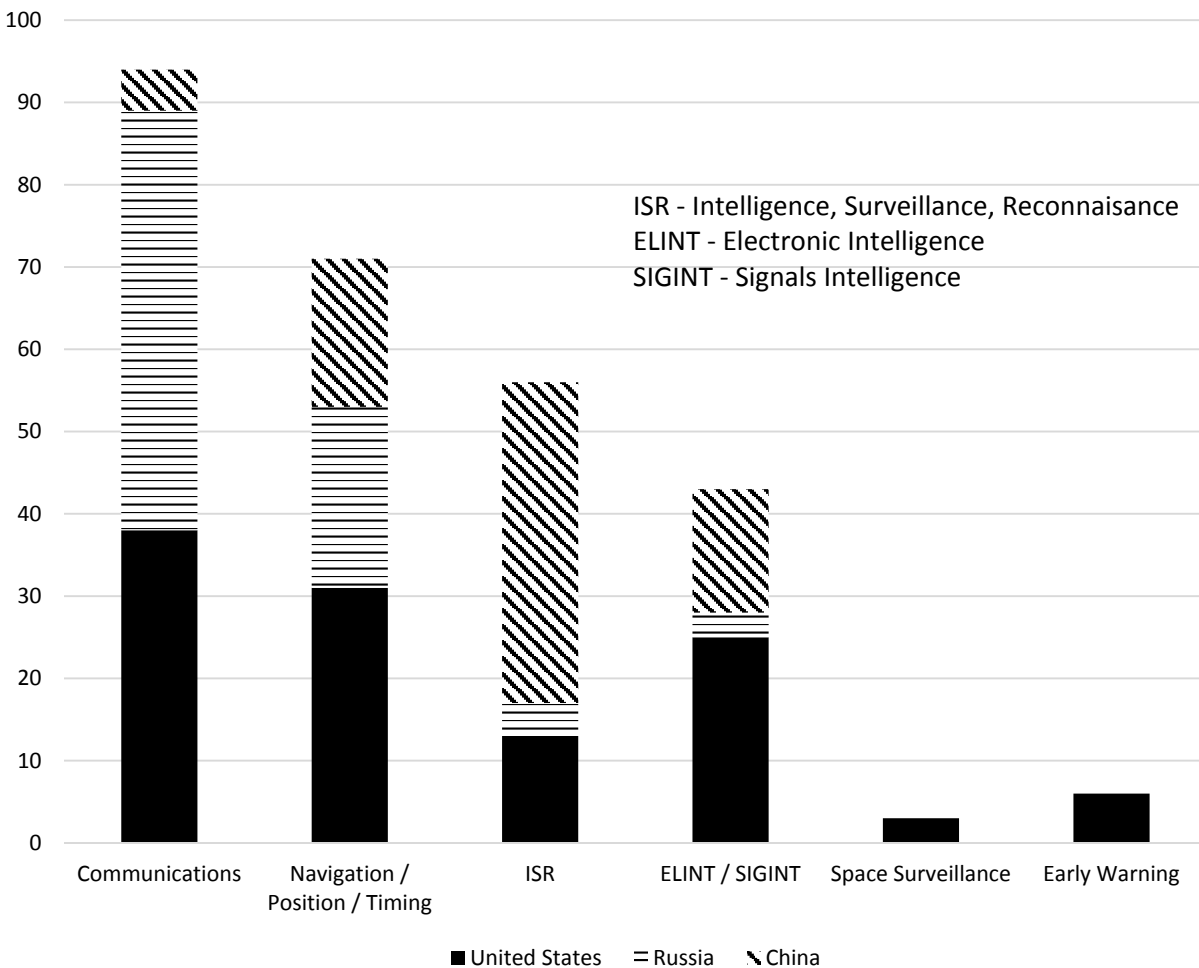


Figure 3. Satellite Capabilities by Country

The United States today has more than 500 military and civilian orbiting platforms, Russia more than 130, and the United Kingdom about 40. China reportedly has more than 140.²⁸ Other nations are making technological strides to close the space gap with the United States. This is a trend that is likely to continue. Competitive launch markets and improvements in space technology miniaturization have assisted many nations with ambitions to leverage the benefits of space. The figure above shows current comparative space capabilities of the United States, Russia, and China.

Russia and China continue to improve the capabilities of their military and intelligence satellites and grow more sophisticated in their operations. Russian military officials publicly tout their use of imaging and electronic-reconnaissance satellites to support military operations in Syria and have revealed increasingly sophisticated military uses of space services. According to U.S. defense officials, “not all space faring nations view space as a peaceful domain,” as “we have witnessed intent and ability to conduct hostile operations in this arena.”²⁹ This is an important observation because foreign governments are expanding their use of space services and beginning to rival the advantages space-enabled services provide the United States.

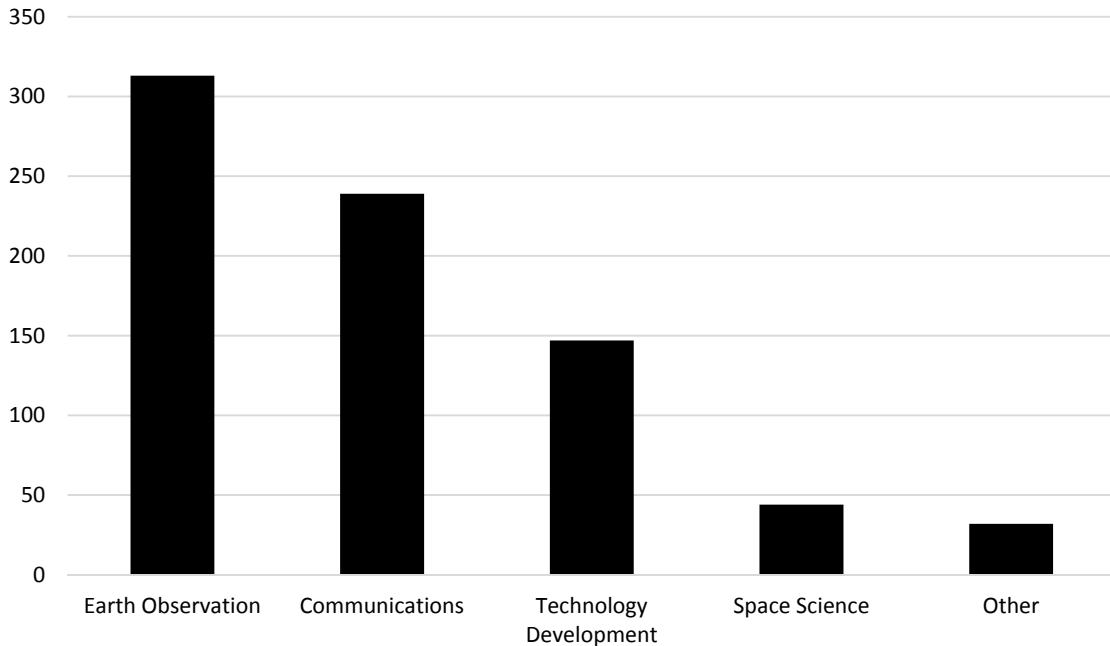


Figure 4. LEO Satellite Purposes and Numbers³⁰

²⁸ Malcolm Ritter, “How Many Man-Made Satellites Are Currently Orbiting Earth,” *TPM*, March 28, 2014, available at <http://talkingpointsmemo.com/idealab/satellites-earth-orbit>. A STRATFOR report from 2016 has slightly different numbers. “The Real Danger From Space Weapons,” *Stratfor*, February 22, 2016, available at http://www.realcleardefense.com/articles/2016/02/22/the_real_danger_from_space_weapons_109061.html.

²⁹ David J. Buck, “Statement of Lieutenant General David J. Buck, Commander, Joint Functional Component Command for Space,” *114th U.S. Congress, House Armed Services Committee*, March 15, 2016, p. 3, available at <http://docs.house.gov/meetings/AS/AS29/20160315/104620/HHRG-114-AS29-Wstate-BuckD-20160315.pdf>.

³⁰ Breakdown of LEO: Total: 780; composed of: Algeria-1, Argentina-9, Austria-1, Belarus-1, Belgium-3, Brazil-2, Canada-15, Chile-1, China-125, China/Brazil-1, Denmark-3, ESA-13, ESA/USA-1, France-5, France/Belgium/Sweden-2, France/Italy-1, France/Italy/Belgium/Spain/Greece-2, France/USA-1, Germany-22, Germany/USA-2, India-15, India/Canada-1, India/France-2, Indonesia-3, Iran-1, Iraq-1, Israel-8, Italy-5, Japan-35, Japan/USA-1, Kazakhstan-1, Morocco/Germany-1, Multinational-7, Netherlands-2, Nigeria-2, Norway-2, Peru-1, Russia-73, Russia/USA-2, Saudi Arabia-11, Singapore-9, South Africa-2, South Korea-6, Spain-6, Sweden-1, Switzerland-2, Taiwan-1, Taiwan/USA-5, Thailand-1, Turkey-3, Ukraine-1, UAE-2, United Kingdom-8,

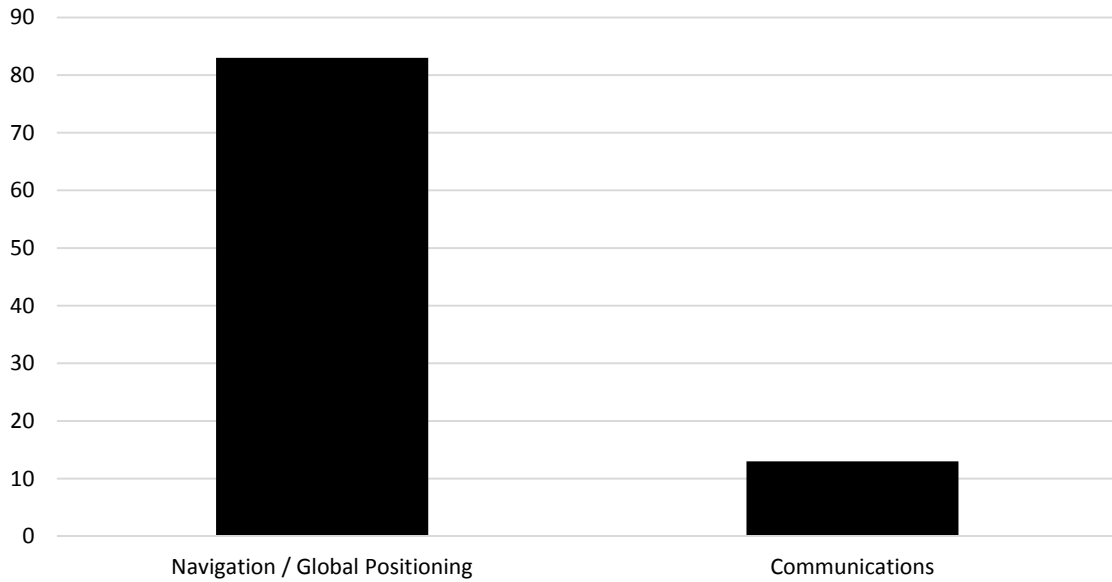


Figure 5. MEO Satellite Purposes and Numbers³¹

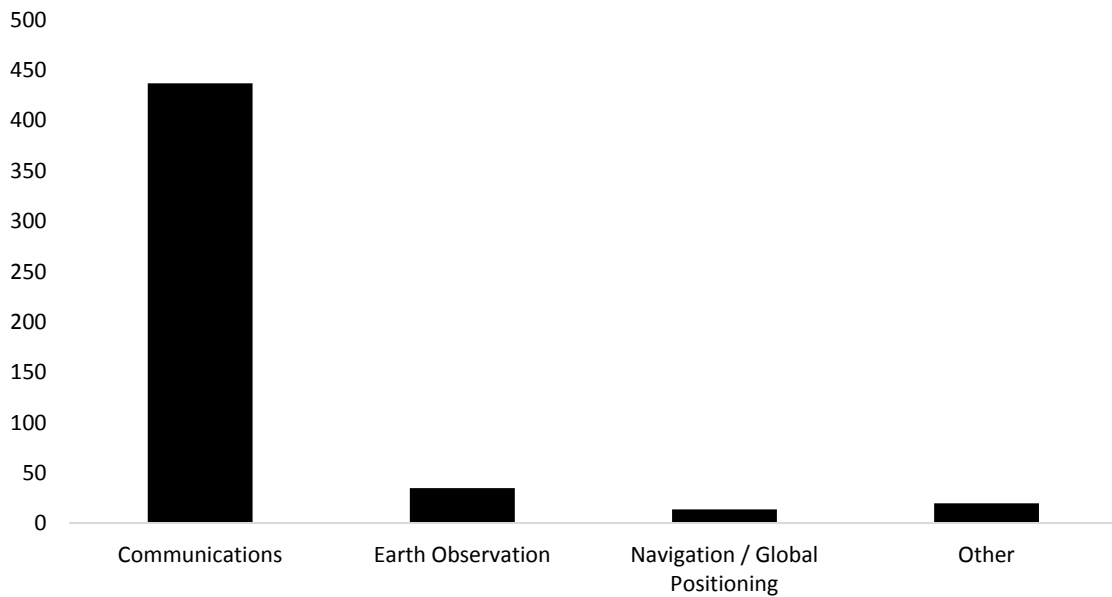


Figure 6. GEO Satellite Purposes and Numbers³²

Uruguay-1, USA-333, USA/Argentina-4, USA/Canada/Japan-1, USA/France-2, USA/Japan-2, USA/Japan/Brazil-1, US/UK/Italy-1, Vietnam-1, Venezuela-1. Union of Concerned Scientists, "UCS Satellite Database," *UCSUSA.org*, accessed February 2017, available at http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WNWC8m_yvct.

³¹ Breakdown of MEO: Total: 96, composed of: China-8, ESA-14, Russia-31, UK-12, USA-31. Union of Concerned Scientists, "UCS Satellite Database," *UCSUSA.org*, accessed February 2017, available at http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WNWC8m_yvct.

³² Breakdown of GEO: Total: 506; composed of: Argentina-2, Australia-7, Azerbaijan-1, Belarus-1, Bolivia-1, Brazil-7, Canada-13, China-46, Egypt-2, ESA-1, France-2, France/Italy-2, Germany-2, Greece-1, India-23, Indonesia-5, Indonesia/Philippines/Thailand-1, Israel-4, Italy-2, Japan-21, Kazhakstan-2, Laos-1, Luxembourg-18, Malaysia-4, Mexico-4, Multinational-56, Netherlands-8, Nigeria-

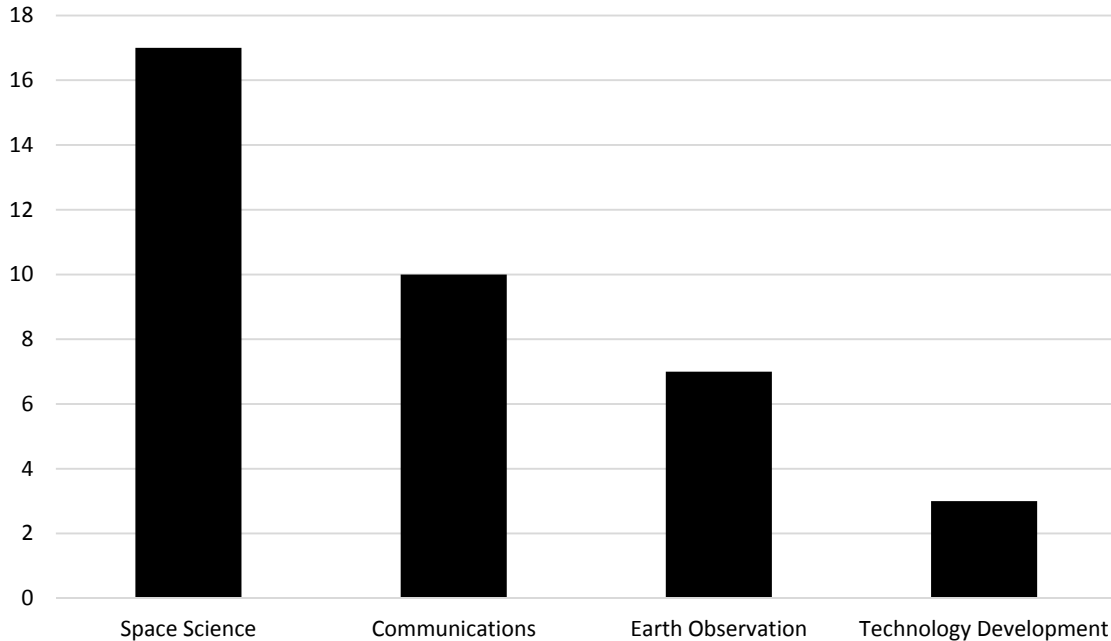


Figure 7. HEO Satellite Purposes and Numbers³³

The proliferation of space technologies offers foreign governments and non-state entities unparalleled opportunities to enhance diplomatic influence (perhaps giving them “eyes” to see otherwise unknown events in a remote part of the world) and military effectiveness over the United States and, over time, will enable them to strike with strategic effect. Potential enemies of the United States today have improved “vision” over the U.S. homeland and battlefield activities, a better sense of direction and geographic position, greatly improved long-range precision strike weapons which utilize GPS-like guidance, and an improved ability to mobilize forces and coordinate activities. No longer can the United States expect to conduct large-scale operational activities on the ground or at sea outside the view of other nations or even private organizations without using camouflage, concealment, and deception techniques to defeat enemy surveillance and reconnaissance satellites.³⁴

The United States clearly remains the dominant space power in the world today with its technical and manufacturing infrastructures and its ability to leverage space assets to support national security, civilian, and commercial activities, yet the space power gap between the United States and other nations is closing.³⁵ While military space power no longer belongs solely to the major powers, when it comes to monitoring space threats, we must look primarily at two major state

1, Norway-4, Pakistan-1, Russia-28, Russia/Multinational-1, Singapore/Taiwan-1, South Korea-3, Spain-9, Sweden-1, Thailand-4, Turkey-3, Turkey/France-1, Turkmenistan/Monaco-1, UAE-4, United Kingdom-21, UK/ESA-1, USA-178, USA/Canada-2, US/Japan-2, Venezuela-1, Vietnam-2. Union of Concerned Scientists, “UCS Satellite Database,” *UCSUSA.org*, accessed February 2017, available at http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WNWC8m_yvct.

³³ Breakdown of HEO: Total: 37; composed of: European Space Agency-6, France-2, Japan-2, Russia-5, USA-22. Union of Concerned Scientists, “UCS Satellite Database,” *UCSUSA.org*, accessed February 2017, available at http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WNWC8m_yvct.

³⁴ For a good summary of this new environment see, Robert M. Gates and James R. Clapper, *National Security Space Strategy: Unclassified Summary* (Washington, D.C.: Office of the Director of National Intelligence, January 2011), available at https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_nationalsecurityspacestrategy.pdf.

³⁵ Today the United States is dependent on Russian engines for heavy lift access to space, which is potentially a serious vulnerability.

powers, China and Russia, and two lesser powers that nonetheless command world attention, North Korea and Iran.³⁶ There are also states that are friendly toward the United States, such as France, that are becoming more proficient in using space power. France, with cooperation from the United States, made extensive use of satellite navigation and communications for its expeditionary operations in Mali to defeat its Islamist enemies.

The cost for development of space capabilities is going down as nations leverage the pioneering advances made by the United States and the Soviet Union, using that knowledge base to break through market barriers and jump relatively quickly into the space game. The requirement to operate far from their own countries and the need to remain interoperable with the United States has pushed them to exploit more advanced and less expensive technologies to have access to space. The technical difficulties and financial burdens mean space access remains cost prohibitive for most countries, yet there are several nations that are striving aggressively to exploit the space environment to further their national interests.

Growing space prowess is giving nations access to greater offensive (wartime or peacetime) and defensive capabilities. Moreover, the inherent friction in interstate politics will mean war in space or conflict involving space assets will remain a possibility. Today's combatant commanders must now anticipate that adversaries will be watching or tracking the activities of U.S. military forces—watching ships load or off load at ports, tracking aircraft as they arrive at bases in-theater, observing troop maneuvers, and communicating with their own forces with very high levels of efficiency and accuracy.

Proliferating Space Launch Capabilities

The baseline measure of space power is the country's ability to integrate space capabilities with other national activities and manage the rapid and immense flow of information—the ability to own and apply space capabilities and possess the requisite skills to exploit them. A growing number of countries and international organizations have the ability to launch satellites into orbit (United States, Russia, China, European Space Agency, France, United Kingdom, Ukraine, Israel, India, South Korea, North Korea, and Iran). The availability of smaller satellites not only makes it less expensive to build orbiting platforms, it can also lower the cost of launch and allow the launch of more satellites on a single launcher. Ownership of launching capabilities is a critical measure of a country's space power, which means that not all countries with satellites in orbit carry equal weight. Because of the skill-sets, technical know-how, and experience with advanced space systems involved, we need to pay particular attention to countries that have the ability to launch and deploy manned and robotic spacecraft. A country with the capability to launch payloads into orbit also has the ability to fly reentry vehicles through space and attack satellites using direct-ascent missile boost technology.

Space Force Application

Today primitive space force application capabilities exist in the form of ballistic missiles capable of carrying a reentry vehicle into space on a ballistic trajectory. Married to a nuclear weapon, long-range strike capabilities could pose a catastrophic threat to the United States and a threat to the nation's way of life if not existence. Fractional orbital bombardment systems (FOBS) leverage

³⁶ North Korea and Iran are developing much improved capability, but they do not have much capability right now. They can launch small satellites, but they do not have significant military potential except for the possible use of nuclear weapons.

ballistic missile launch technology to deliver a payload at suborbital velocities part way around the world to its target. An orbital nuclear weapons capability is also possible, potentially, for North Korea and Iran. Military space planes may also be used to deliver a payload from space to destroy targets on earth.

China and Russia continue to make considerable investments in ballistic missile systems, improving range, accuracy, payload lethality, and capability. Space-based guidance technology has been exploited by China to achieve a regional precision and near-precision strike capability.³⁷ There is reportedly great interest in Russia and China in developing payloads that evade missile defenses, to include technologies for multiple reentry vehicles, maneuvering reentry vehicles, cruise missiles, and midcourse countermeasures, such as decoys. Regional powers such as Iran and North Korea continue investments in ballistic missile and satellite launch vehicle technologies, and they are continuing with the development and acquisition of systems that may be used to deliver highly lethal or mass destruction payloads to targets in the United States. North Korea has accelerated its space program with the development and successful launches of long-range ballistic missiles and did have a successful launch in 2016 of its Musudan intermediate-range ballistic missile. In 2010 Iran introduced the larger Simorgh space launch vehicle, indicating that it will likely continue to pursue more capable space launch vehicles, which could lead to the deployment and launch of an ICBM system. India and Pakistan continue to develop new short- and long-range ballistic missiles.

Space Intelligence, Surveillance and Reconnaissance

Beginning with the late 1990s declassification activities, and the subsequent rise in commercial satellite services, imagery once available to a few governments with reconnaissance satellites has been made available to the general public. Today, satellite observations are integrated into everyday life. Applications like Google Maps that combine space, aerial, and ground-based imagery are able to put together a compelling picture of what is taking place on earth. What this means is that all people and all nations will have available multiple source imagery, to include new commercial satellite imagery with details approaching those provided by military spy satellites. All nations will have at their disposal tools to distinguish between trucks and tanks, expose the movements of large groups such as troops, and identify the locations of ships and aircraft. This will make it more difficult for countries to hide their activities.

The trend, in other words, is towards transparency, and nations will have to learn to manage the negative consequences of this. There are also positive consequences. Satellite imagery can provide credible evidence, for example, that another country is not mobilizing for attack, although like any information, imagery is subject to misinterpretation. Armed forces and other actors have learned to obscure their activities from overhead viewing. Indeed, many military research facilities, for example, have been built underground to evade detection and observation. The ability to accurately interpret imagery often depends on the availability of others sources of information.

³⁷ Rui C. Barbosa, "China opens 2010 with BeiDou-2 satellite launch," *NASASpaceFlight.com*, January 16, 2010, <http://www.nasaspaceflight.com/2010/01/china-opens-2010-with-beidou-2-satellite-launch/>; Mark B. Schneider, "The Nuclear Doctrine and Forces of the People's Republic of China," *Comparative Strategy*, July 1, 2009, p. 258, <http://www.tandfonline.com/doi/pdf/10.1080/01495930903025276>; Department of Defense, *Annual Report To Congress: Military and Security Developments Involving the People's Republic of China 2016* (Washington, D.C.: U.S. Department of Defense, 2016), p. 36, available at <https://www.defense.gov/Portals/1/Documents/pubs/2016%20China%20Military%20Power%20Report.pdf>.

Another consequence of this proliferation of widely available satellite imagery is that it can devalue national reconnaissance assets. The head of the French Joint Space Command, for example, believes the proliferation of high-resolution earth observation imagery has undermined the diplomatic value of France's own Helios surveillance satellites.³⁸ Yet the possession of space reconnaissance systems gives the owner a degree of flexibility and agility in their use. Tasking of satellites to cover a particular region can happen on a timeline that may be significantly shorter than what can be accomplished by tapping into commercial providers.

Nations too are investing in expanding the use of imagery satellites. Synthetic Aperture Radar satellites available to other countries have improved, which means more nations will have the capability to see U.S. activities at night or in poor weather conditions. In 2015, Russia launched 17 satellites to expand its remote sensing and intelligence collection capabilities. Reconnaissance capabilities in the Middle East are expanding. Common goals and perspectives have led to opportunities between nations to share intelligence from these imaging satellites, to include an agreement between Turkey and Qatar. Turkey has an active capability (projected to have three birds by the 2020s), while Qatar has not yet achieved one. Qatar's end of the bargain involves granting Turkey the right to base military personnel in Qatar.³⁹

Space-based Communications

Communications satellites are ubiquitous, essential to the internet, and serve all nations and people, to include incidentally terrorist organizations. Since the first LEO, MEO, and GEO communications satellite networks of the early to mid-1960s, space-based communications capabilities have expanded to the point where they are globally available. Given the country's northern location, the Soviet Union—Russia today—was not interested in GEO platforms. Instead it has invested in communications satellites that use highly elliptical orbits (Molniya orbits), which allow satellites to dwell over a targeted territory for an extended period of time. The Middle East and Asia/Pacific are two regions where the satellite industry is growing the most. Private communications services have expanded and consortia such as Intelsat own and operate global networks providing voice, video, and data services through leasing or sales, spreading space-based communications capabilities worldwide. Other international communications satellite organizations have formed a cooperative, such as Eutelsat, providing regional communications services for Europe. Intersputnik and the Express-A series of satellites cover the region over Russia. The growth in communications satellites has led to the expansion in the number of transponders, which in turn has put a high demand on radio frequency bandwidth. This growing congestion in space will lead to a greater probability of frequency interference, which will continue to make efforts to minimize this interference a challenge.

Some nations are purchasing commercial off-the-shelf communications satellites to build their own global information infrastructure. In the early 1990s, with the advent of microelectronics and an expanding and strengthening space launch industry, LEO communications satellite constellations providing mobile communications services were given new life. Many different satellite systems offering fixed and mobile communications capabilities mean that the ready availability of satellite communications networks will allow potential adversaries of the United

³⁸ Peter B. de Selding, "Imagery Proliferation has Diplomatic Cost for France," *Space News*, July 8, 2015, available at <http://spacenews.com/imagery-proliferation-has-diplomatic-cost-for-france/#sthash.oLJMk861.dpuf>

³⁹ John Sheldon, "The Turkish-Qatari plot thickens," *Space Watch Middle East*, April 4, 2016, available at <https://spacewatchme.com/2016/03/the-turkish-qatari-plot-thickens/>.

States to communicate more reliably with forces in the field. Foreign military forces, especially those forces with access to mobile communications devices, will be better able to synchronize operations. We must also assume that news from future battle fields will travel quickly, if not instantaneously.

Positioning, Navigation and Timing

Satellite navigation is also available routinely to all nations and people, free of charge. Following the success of the U.S. NAVSTAR Global Positioning System (GPS) of satellites and the Russian Global Navigation Satellite System (GLONASS), other nations have invested in orbiting constellations. China has its BeiDou system of navigation satellites and Europe has invested in the Galileo system. Other nations are able to choose among the global navigation satellite systems (GPS, GLONASS and Galileo) and incorporate small receivers capable of interoperating with all three constellations, giving them access to highly accurate positioning, navigation, and timing data. China is in the process of expanding its BeiDou system into a global capability. The ability of the operators to degrade the signals of these systems has encouraged other nations, such as Japan (Quasi-Zenith Satellite System) and France (DORIS), to consider investments in regional satellite navigation systems. Nations also may use satellite-based augmentation systems to further enhance the accuracy of these systems.⁴⁰ Satellite navigation systems allow for the use of precision weapons, which can greatly increase the lethality of the weapons and reduce the risk of collateral damage. Forces also may use these systems to synchronize ground, sea, and air operations and keep track of their locations.

To summarize, the proliferation of space technologies has opened up new opportunities for many other nations, including nations unfriendly to the United States and terrorist organizations that may wish to exploit space for military or diplomatic purposes or deny U.S. access to its space systems. Moreover, potential adversaries are learning from one another to advance their understanding of the space environment.⁴¹ This proliferation represents a dramatic change in the security environment from just a couple decades ago.

Agility in the exploitation of the space environment also means that other nations will be able to do damage to U.S. interests and counter U.S. power. No longer can U.S. defense leaders move into battle with their forces hidden from the eyes of the enemy (without adopting camouflage, concealment, and deception tactics to hide from the eyes in the sky) or with a monopoly on precise navigation signals. Tactics for denial and deception will necessarily change and evolve. Planning for battle, especially involving large-scale military operations, will be affected. Enemy combat units and special forces also will be able to move about with precision and tightly coordinate force operations. We ought to expect the enemy to become increasingly proficient in the use of space-based communications to aid enemy battlefield operations and force maneuvers. This new reality is impacting U.S. strategy-making, defense planning, military doctrine, weapons and military equipment development, and warfighting tactics. U.S. defense leaders must plan for the new reality that those who plan to damage U.S. interests and kill Americans will be able to leverage space to operate with ever greater efficiency and effectiveness.

⁴⁰ Satellite-based augmentation systems use additional satellite-broadcast messages and multiple ground stations to accurately locate points.

⁴¹ John E. Hyten, *Statement of John E. Hyten, Commander, U.S. Strategic Command Before The Senate Armed Services Committee*, April 4, 2017, p. 4.

Chapter 2: Foreign Space and Counter-Space Developments

U.S. space systems are among the most fragile and vulnerable assets operated by the U.S. military. This vulnerable communications and data collection, processing, and distribution infrastructure is worth billions of dollars and is vital to nearly every activity of the United States and, increasingly, the armed forces of U.S. allies. For decades this country has operated without having to worry about threats to its space systems because the technologies for attacking satellites were essentially restricted to a few nations and, it may be argued, because U.S. space systems were so closely tied to its nuclear operations (command and control and early warning satellites) and thereby protected by its nuclear deterrent strategy.⁴²

Foreign counter-space developments pursued by potential adversaries who understand the unique and asymmetric advantage space systems give the United States are increasingly worrisome and starting to get the (public) attention they deserve. Now attention must be paid not only to how a potential adversary may use space against the country, but also the steps it may take to deny the United States the free use of space. Thus, according to the Joint Chiefs of Staff:

Competition in orbit (even during peacetime) will be intense, highlighted by satellites maneuvering to hinder the operation of other satellites, co-orbital jamming, and the use of ground-based lasers to dazzle or destroy imaging sensors. Future adversaries will also have the capability to deploy blockers and grappers to impede the free operation of commercial and military satellites, and they will use ASAT weapons launched at space assets from the ground as well as from other satellites. Ultimately, this may generate space debris leading to a runaway chain reaction which destroys other satellites and threatens the integrity of many important orbits.⁴³

According to a former Commander of U.S. Strategic Command, counter-space operations would “deny U.S. forces the advantages of space, which have enabled us to favorably shape events in all corners of the globe.”⁴⁴ Satellite jamming activities are on the rise, with incidents of interference against satellites rising from 5% in 2010 to 15% in 2013, with a significant amount of jamming activity occurring over the Middle East and Africa regions. According to Air Force Space Command, U.S. forces should expect to face pervasive satellite jamming and dazzling threats when involved in a conflict with a major power.⁴⁵ Low-power GPS satellite jammers have proliferated to such an extent that they are now available on-line, and nations have invested in the development of higher power jammers that would increase the size of the jammed area with

⁴² Since the beginning of military space in the 1960s it may be argued that there has been less and less willingness by the United States to use nuclear weapons. Today our current formulation for a response to nuclear use is “overwhelming and effective.” Does this mean nuclear? To be sure, it makes the response ambiguous. And to some extent the United States still relies on deterrence to protect these space assets today. The proliferation of anti-satellite technologies to several actors, some of whom may not be easily deterred, means these same satellites operate today at greater risk.

⁴³ Joint Chiefs of Staff, *Joint Operating Environment: The Joint Force in a Contested and Disordered World*, July 14, 2016, p. 33, available at http://www.dtic.mil/doctrine/concepts/joe/joe_2035_july16.pdf.

⁴⁴ Admiral Cecil D. Haney, “Statement of Admiral C.D. Haney, Commander, United States Strategic Command,” *114th U.S. Congress*, House Armed Services Committee, February 24, 2016, pp. 17-18, available at <http://docs.house.gov/meetings/AS/AS29/20160224/104588/HHRG-114-AS29-Wstate-HaneyC-20160224.pdf>.

⁴⁵ Written responses provided by Air Force Space Command, March 31, 2017.; U.S. Air Force, *Global Horizons Final Report* (Washington, D.C.: U.S. Air Force, June 21, 2013), p. 7, available at http://www.airforcemag.com/DocumentFile/Documents/2013/GlobalHorizons_062313.pdf.

the potential for a substantial degradation of U.S. accuracy in GPS-guided weapons. Radar satellites may also be jammed and imagery satellites are vulnerable to both dazzling and, because of their low orbiting altitude, destruction by ground-based ASAT weapons (with launch-to-kill in as few as 10 minutes). With respect to communications satellites, which are no longer protected by their high orbital altitude, the loss of one satellite, either through jamming or destruction, would “open a geographic hole in a constellation, preventing normal communication in that region.”⁴⁶ Thus far, all that has been done to make the jammers pay the consequences of their interference is “naming and shaming.”⁴⁷ Ground stations for transmitting data to and from satellites are also vulnerable to kinetic and cyber attack as well as interference.

Without a doubt, the United States has the most to lose and the most to gain in space. U.S. adversaries have seen the significant advantage space provides the U.S. military and have been looking for ways to neutralize that advantage by disrupting, denying, or destroying satellite capabilities. According to the U.S. Air Force:

Superiority in the space domain can be affected in the near term by increasingly capable and widespread (i.e., available) SATCOM jamming. In terms of counterspace capabilities, by the 2030 time frame, multiple countries will have the ability to hold all US space services at risk via both physical and cyber attacks. Physical attacks via both direct-ascent interceptors and orbital anti-satellite systems can destroy our space assets. Foreign telemetry, tracking, and control (TT&C) and C2 threats can interfere with, disable, or destroy space assets that are vital to US space-based navigation, C2, and intelligence collection capabilities.⁴⁸

With their development of counter-space weapons and practice with counter-space operations, potential adversaries of the United States have indicated that their leaders believe that space is an extension of the battlefield on earth. Both China and Russia are on record stating that they are developing counter-space capabilities, to include capabilities for jamming GPS signals and satellite communications, dazzling satellite sensors with ground-based lasers, and developing ground-based guided missiles to destroy satellites in orbit. Repeated attacks using lasers, for example, to achieve temporary, reversible disruption of a satellite’s performance may also have the unintended effect of damaging that same satellite.

The countries discussed below are in competition with the United States on the national security stage. While the United States is not at war today with China, Russia, Iran, or North Korea, neither are relations entirely peaceful and without strain. General Paul Selva, at his confirmation hearing for the position of Vice Chairman of the Joint Chiefs of Staff, stated he “would put the threats to

⁴⁶ General William L. Shelton, USAF (Ret), *Statement before the House Armed Services Subcommittee on Strategic Forces and House Homeland Security Subcommittee on Emergency Preparedness, Response and Communications*, “Threats to Space Assets and Implications for Homeland Security,” March 29, 2017, pp. 4, 5, available at <https://armedservices.house.gov/legislation/hearings/threats-space-assets-and-implications-homeland-security>.

⁴⁷ Peter B. de Selding, “Eutelsat Blames Ethiopia as Jamming Incidents Triple,” *Space News*, June 6, 2014, available at <http://spacenews.com/40818eutelsat-blames-ethiopia-as-jamming-incidents-triple/>.

⁴⁸ U.S. Air Force, *Global Horizons: United States Air Force Global Science and Technology Vision* (Washington, D.C.: Air Force, July 3, 2013), p. 8, available at <http://www.af.mil/Portals/1/documents/news/GlobalHorizons.pdf>. “Foreign offensive efforts in the electronic warfare area include threats from digital radio frequency memory (DRFM) jamming, GPS jamming, and spoofing; defensive efforts include reconfigurable jammers, low probability of intercept/detection signals, and counter-DRFM. The source of the jammer is often difficult to identify, and thus counter, making this a challenge for all future military forces. Furthermore, we currently operate under an antiquated industrial-age reprogramming process that affects our ability to quickly respond to EW threats. This is complicated by the number and disparate types of foreign EW techniques expected in the future.” (p. 10).

this nation in the following order: Russia, China, Iran, North Korea...⁴⁹ All have space, ballistic missile, and counter-space programs as well as nuclear and weapons of mass destruction programs that could produce systems that would allow each to engage in activities that are detrimental to U.S. security. All four have issued political declarations indicating that there may be instances where they might oppose U.S. forces or undercut U.S. interests. While it may be possible to look at the strategic aims, military programs, and political declarations of Russia and China and declare them potential adversaries, the United States has complex relationships with both. China and Russia have been more aggressive at the regional levels. Experts say that with as few as two dozen anti-satellite missiles, Russia or China could do significant damage to U.S. intelligence, navigation, and communications capabilities.⁵⁰

Relations with Iran have been compromised by Iran's aggressive pursuit of ballistic missiles and its perceived desire to develop nuclear weapons. North Korea's bellicosity toward the United States and its allies has been expressed in its words and demonstrations, but has yet to reach the level of conflict. Both Iran and North Korea are more explicit in their aim of threatening destruction of the United States and harming U.S. interests. Although North Korea and Iran are regional powers, because we are dealing with the space and cyber domains, the threats they may pose can quickly become global in nature. For these reasons, it is important to consider the counter-space activities of each of these countries.

China

China's military modernization program is designed to improve its capability to prevail in regional conflicts, to include conflicts involving Taiwan and in the East and South China Seas. China has made expansive territorial claims in the South China Sea while building, seizing, and militarizing islands in disputed sea areas. China also has been steadily building up air, sea, and space capabilities to succeed in operational environments that are not necessarily adjacent to Chinese territory, to include combat insertions, island landing operations, humanitarian operations, and evacuations. These capabilities (e.g., increasingly sophisticated space-based sensors, ASAT capabilities, attack submarines, large cargo aircraft and fueling ships, and amphibious transports) also will strengthen China's traditional warfighting capabilities.⁵¹ Military modernization and the ability to challenge U.S. information supremacy have been high on China's priority list, and space assets clearly have contributed to the realization of both.⁵² A critical part of the anti-access/area denial strategy pursued by China is the ability to oppose other military forces from a distance, which would not be possible without the aid of space. Space allows China to identify and target distant forces and communicate with its forces.

⁴⁹ Morgan Chalfant, "Top Pentagon Generals Deem Russia Largest 'Existential Threat' to U.S.," *The Washington Free Beacon*, July 15, 2015, <http://freebeacon.com/national-security/top-pentagon-generals-deem-russia-largest-existential-threat-to-u-s/>.

⁵⁰ Robert K. Ackerman, "Space Vulnerabilities Threaten U.S. Edge in Battle," *Signal*, June 2005, available at <http://www.afcea.org/content/?q=space-vulnerabilities-threaten-us-edge-battle>; See also the Director of National Intelligence stated that "the highest level of ASAT and cyber threats comes from Russia and China." James R. Clapper, "DNI Clapper Opening Statement on the Worldwide Threat Assessment before the Senate and House Armed Services Committee," 114th U.S. Congress, February 26, 2015, available at <https://www.dni.gov/files/documents/2015%20WWTA%20As%20Delivered%20DNI%20Oral%20Statement.pdf>.

⁵¹ Dennis C. Shea, et al., *2016 Report to Congress of the U.S.-China Economic and Security Review Commission* (Washington, D.C.: Government Printing Office, 2016), pp. 218-221, 270-271, available at https://www.uscc.gov/sites/default/files/annual_reports/2016%20Annual%20Report%20to%20Congress.pdf.; Bill Gertz, "Report: China's Military Capabilities Are Growing at a Shocking Speed," *The National Interest*, November 7, 2016, available at <http://nationalinterest.org/blog/the-buzz/report-chinas-military-capabilities-are-growing-shocking-18316?page=show>.

⁵² Shea, et al., *2016 Report to Congress of the U.S.-China Economic and Security Review Commission*, op. cit., p. 272.

Though not nearly as advanced as the United States, China's space capabilities are advancing and expanding to aid military modernization and drive economic and technological advances, all of which would allow China to challenge U.S. information superiority. According to the U.S. Department of Defense, "China is seeking to utilize space systems to establish a real-time and accurate surveillance, reconnaissance, and warning system, and to enhance command and control in joint operations."⁵³ China's People's Liberation Army also have at their disposal China's civilian and commercial satellite systems to do reconnaissance, communications, and command and control. China reportedly has been developing a cheap and mobile launch capability based on its ICBM and MRBM technology that would allow it to replace satellites in orbit during an armed conflict.⁵⁴ In light of China's "underground great wall" tunnels for ballistic missiles and the survivability of mobile missiles once deployed, a replace capability is certainly possible. China has recently deployed a large mobile ICBM, the DF-41.⁵⁵ This missile could be adopted for space launch if China desires to do so. China also has an evolving manned space program. China values international collaboration because it gives it a leg up in the development of advanced space systems. According to Wang Chi of the National Space Science Centre, Chinese Academy of Sciences, "international collaborations are the shortcut for China to catch up with the world."⁵⁶

From the perspective of China's leaders, dependence on foreign satellite capabilities has enabled foreign domination and must not be permitted. China addressed this with the development of a comprehensive space program, especially in the areas of rocket launch and satellite development for telecommunications, remote sensing, meteorology, and navigation. China has 19 BeiDou navigation satellites today for expanding its global presence and enhancing precision strike capability, and it plans to expand the constellation worldwide for a total of 35.⁵⁷ Its decision not to rely on the U.S. GPS satellites apparently stems back to the 1996 Taiwan Crisis, when China claimed that the GPS interfered with missile launching, which a retired Chinese colonel stated was "a great shame for the PLA."⁵⁸

Attention to space and counter-space activities is a critical element in their strategy. For the same reason that the United States requires space assets to operate within the vast Asia-Pacific battlefield, so does China. China has roughly 875,000 nautical square miles that it aspires to monitor and exercise control over, an area that expands to 1.5 million nautical square miles when the Philippine Sea is included.⁵⁹ China's anti-access/area denial strategy (called by China "Active Defense"), restricting enemy access to certain strategic locations, is dependent on space

⁵³ U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China 2015* (Washington, D.C.: Department of Defense, April 2015), p. 35, available at https://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf.

⁵⁴ Vasily Kashin interview with Sputnik China, "New Reality: Future Space Weapons Will Be Able to Destroy Enemy Satellites," *Sputnik News*, October 26, 2016, available at <https://sputniknews.com/world/201610261046758894-russia-united-states-satellites-development/>.

⁵⁵ "Reported DF-41 Deployment: China 'Responding to US Missile Defense in Asia'," *Sputnik News*, January 24, 2017, available at <https://sputniknews.com/military/201701241049956101-china-us-df41/>; "Dongfeng-41 will bring China more respect," *Global Times*, January 23, 2017, <http://www.globaltimes.cn/content/1030353>.

⁵⁶ Stuart Clark, "China: the new space superpower," *The Guardian*, August 28, 2016, available at <https://www.theguardian.com/science/2016/aug/28/china-new-space-superpower-lunar-mars-missions>.

⁵⁷ Anthony H. Cordesman and Joseph Kendall, "How China Plans to Utilize Space for A2/AD in the Pacific," *The National Interest*, August 17, 2016, available at <http://nationalinterest.org/blog/the-buzz/how-china-plans-utilize-space-a2-ad-the-pacific-17383?page=show>.

⁵⁸ Cordesman and Kendall, "How China Plans to Utilize Space for A2/AD in the Pacific," op. cit.

⁵⁹ Ibid.

capabilities and infrastructure, although China reportedly is able to monitor sections of seas and ocean using sensors mounted on cheap high-altitude balloons attached to fiber-optic cables.⁶⁰

Anti-access/area denial strategies are designed to limit the ability of the United States to introduce and employ forces within a region by emphasizing denial of command, control and communications as well as the operability of airbases and ports.⁶¹ A key strategic objective for China is to deny the United States access to the Indo-Pacific theater. These operations would likely start with disruption and destruction of C4I capabilities with cyber and kinetic attacks on satellites and ground assets in support of other Chinese kinetic capabilities. This would be followed by large raid size ballistic missile attacks on regional bases and potentially on carrier battle groups.

The strategy of denying access requires counterforce targeting, which includes target detection, delivery of weapons precisely on target, and tracking and conducting hit assessment (understanding what is happening on the battlefield). This requires a significant command, control, communications network and intelligence, surveillance, and reconnaissance capabilities, much of which is reliant on space systems. China's control over the Asia-Pacific region requires an integrated system of real-time satellite imagery and target location (including mobile targets) and data fusion. China's ballistic missile development program is also tied to a space presence, as space capabilities are necessary to ensure launch warning and precision targeting, to include reportedly precision targeting against U.S. carriers and other naval assets in the Asia-Pacific region.⁶² China operates a space-tracking facility in Argentina, which provides a southern hemisphere node to communicate with satellites and download images.⁶³

Reportedly, China has launched a "quantum satellite," which it claims will provide "hack-proof" experimental communications between space and ground.⁶⁴ In June 2017, in a quantum satellite demonstration, China reportedly succeeded in transmitting "entangled photons" to earth station, which would alert the Chinese to any attempts to intercept and read the communications while simultaneously destroying the information, making it impossible for an adversary to decode and read.⁶⁵ This is a major development. These communications are said to be impossible to wiretap, intercept or crack, and any attempt to do so would be detected by the operators. Chinese official news sources say that the satellite is intended to explore new scientific principles, but in fact such a capability would have clear military applications and a network of secure communications. Such a capability, consisting of as many as 20 such satellites, would allow China to operate in a degraded communications environment.⁶⁶

⁶⁰ David P. Goldman, "China Leapfrogs U.S. in Critical Strategic Technology," *PJmedia.com*, June 19, 2017, available at <https://pjmedia.com/spengler/2017/06/19/china-leapfrogs-us-in-critical-strategic-technology/>.

⁶¹ U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China 2015* (Washington, D.C.: Department of Defense, April 2015), p. 33, available at https://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf.

⁶² It is rumored that China is developing experimental early warning satellites for missile defense purposes. Rui C. Barbosa, "Long March 3B launches second TJSW spacecraft for China," *NASA Spaceflight*, January 5, 2017, available at <https://www.nasaspaceflight.com/2017/01/long-march-3b-with-second-tjsw/>.

⁶³ Shea, et al., *2016 Report to Congress of the U.S.-China Economic and Security Review Commission*, op. cit., p. 221.

⁶⁴ Tom Phillips, "China launches quantum satellite for 'hack-proof' communications," *The Guardian*, August 16, 2016, available at <https://www.theguardian.com/world/2016/aug/16/china-launches-quantum-satellite-for-hack-proof-communications>.

⁶⁵ David P. Goldman, "China Leapfrogs U.S. in Critical Strategic Technology," *PJmedia.com*, June 19, 2017, available at <https://pjmedia.com/spengler/2017/06/19/china-leapfrogs-us-in-critical-strategic-technology/>.

⁶⁶ R.C. Porter, "China To Launch 'Unbreakable' Quantum Spy Satellite This Month—First Step In Building An Unbreakable Network Of Communications—Based on Cutting-Edge Physics; What Are The Implications For The United States," *Fortuna's Corner*, August

Following decades of investment in the development of space capabilities, a national priority for Beijing, China has become one of the world's leading space powers. Says one billboard outside China's remote space city Jiayuguan (home of the Jiuquan Satellite Launch Center), "Exploring the vastness of the universe, developing the space industry and constructing space power is our unceasing pursuit of the space dream!"⁶⁷ China has launched an increasing number of space launch vehicles in 2016 and is pressing ahead with the development of more advanced systems, such as the Long March 7. This new SLV is designed to help place a multi-module space station in orbit, the Tiangong 2, which is a replacement for the pioneering space station, Tiangong 1. It has the potential to support deployment of weapons, both offensive and defensive, because of its large payload capability. The Long March 7 will also be launched out of a new space launch complex currently under construction called the Wenchang launch complex. China's military is said to launch 15 to 20 percent of China's space missions.⁶⁸

Although in its public declarations China consistently attempts to persuade other nations that it believes in the peaceful uses of space, PLA Air Force Commander General Xu Qilang is on record as stating his belief that the militarization of space is a "historic inevitability."⁶⁹ China understands the importance of space in pursuing strategic objectives and has learned from the lessons of wars and conflicts fought by the United States. Signaling the importance of space to the People's Liberation Army, China recently established the Strategic Support Forces as a separate military service that is also responsible for cyber and electronic warfare.

China's People's Liberation Army "regard[s] the ability to use space-based systems and deny adversaries access to the same as central to enabling modern, 'informationized' warfare."⁷⁰ China is developing and has demonstrated a wide range of counter-space technologies. According to two analysts for the People's Liberation Army, "[a]nti-satellite weapons can be developed at low cost and that can strike at the enemy's enormously expensive yet vulnerable space systems will become an important option...to deter...powerful enemies...."⁷¹ China will increasingly be able to hold at risk U.S. satellites in all orbits and is developing a multi-dimensional ASAT capability supporting its anti-access/area denial strategies, with its most recent ASAT activities appearing to be focused on the refinement of its kinetic space weapons.⁷² A paper published by the U.S.-China Economic and Security Commission reports that China also may have tested a high altitude ASAT aimed at attacking GPS satellites.⁷³ It is believed to be

4, 2016, available at <http://fortunascorner.com/2016/08/04/china-to-launch-unbreakable-quantum-spy-satellite-this-month-1st-step-in-building-an-unbreakable-network-of-communications-based-on-cutting-edge-physics-what-are-the-implications-for-the/>.

⁶⁷ Bloomberg News, "The Remote Military Base Is Where China Blasts Humans Into Space," *Bloomberg*, November 28, 2016, available at <https://www.bloomberg.com/graphics/2016-asia-space-race/chinasidebar.html>.

⁶⁸ Stuart Clark, "China: the new space superpower," *The Guardian*, August 28, 2016, available at <https://www.theguardian.com/science/2016/aug/28/china-new-space-superpower-lunar-mars-missions>.

⁶⁹ U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, op. cit., p. 35.

⁷⁰ *Ibid.*, p. 35.

⁷¹ PLA Analysts Li Hechun and Chen Youong "Sky War - A New form of War That Might Erupt in the Future," *Liberation Army Daily* (online), 17 January 2001, available at <http://dialog.proquest.com/professional/login>.

⁷² Haney, "Statement of Admiral C.D. Haney, Commander, United States Strategic Command," op. cit., p. 5.

⁷³ Craig Murray, "China Missile Launch May Have Tested Part of a New Anti-Satellite Capability," (Washington, D.C.: China Economic and Security Review Commission, May 22, 2013), http://origin.www.uscc.gov/sites/default/files/Research/China%20Missile%20Launch%20May%20Have%20Tested%20Part%20of%20a%20New%20Anti-Satellite%20Capability_05.22.13.pdf.

developing co-orbital proximity capabilities to potentially use ASATs in space to destroy U.S. systems (attacking satellites from space).⁷⁴

China reportedly has two deployed mobile ground-launch ASAT interceptor systems and may be fielding two additional larger third generation ASAT systems, which may be based on four-stage mobile space launch vehicles or ICBMs.⁷⁵ China reportedly uses a variant of the DF-21 missile to perform the anti-satellite mission; the DF-21 also is a land-attack maneuvering missile that can be used as an anti-ship weapon.⁷⁶ China's destruction in 2007 of a defunct Chinese weather satellite sparked international outrage when the ASAT launched from earth created thousands of pieces of space debris. China's most recent hit-to-kill and direct-ascent ASAT tests took place in January 2010, January 2013, July 2014, and October 2015 using the same tracking, targeting, and guidance systems as the interceptor tested in 2007. This string of tests did not create orbital debris but has been evaluated as having contributed to China's knowledge of its SC-19 ASAT system.⁷⁷ With this range of direct-ascent ASAT capabilities, China may be capable of using hit-to-kill technologies to target and destroy surveillance satellites in low earth orbit, GPS satellites in medium earth orbit, and early warning satellites in geosynchronous orbit. Use of a single nuclear warhead in an ASAT role has the potential to decimate low altitude satellites. A 2005 report in a Hong Kong website (owned by China's official news agency) quoted an unidentified Chinese official as saying that China might not only stage two EMP attacks against Taiwan, but also might "conduct an announced nuclear EMP 'test' 1,200 km east of Taiwan to keep US forces at bay."⁷⁸ A secondary impact of such a "test" would be to destroy large numbers of low altitude satellites.

In May 2013, China launched an object into space on a ballistic trajectory that took it near geosynchronous orbit where the United States operates critical early warning, intelligence, and communications satellites. It is possible, according to the U.S. Department of Defense, that this was a test of counter-space technologies in geostationary orbit.⁷⁹ Such a system also could place a kinetic kill vehicle in the path of satellites in medium earth orbit (where GPS satellites operate) or in highly elliptical orbit (where U.S. infrared missile detection and warning satellites operate).

China has experimented with maneuvering satellites. In 2008, it reportedly maneuvered a nano-satellite close enough to the International Space Station to cause alarm. China reportedly has three ASAT-capable vehicles currently orbiting in space.⁸⁰ Future ASAT systems could include

⁷⁴ U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, op. cit., p. 35; William A. Reinsch, et al., *2015 Annual Report to Congress* (Washington, D.C.: U.S.-China Economic and Security Review Commission, November 17, 2015), p. 292, available at http://www.uscc.gov/Annual_Reports/2015-annual-report-congress. "China is pursuing a broad and robust array of counterspace capabilities, which includes direct-ascent antisatellite missiles, co-orbital antisatellite systems, computer network operations, ground-based satellite jammers, and directed energy weapons. China's nuclear arsenal also provides an inherent antisatellite capability."

⁷⁵ Bill Gertz, "China Prepares for Anti-Satellite Missile Test," *Washington Free Beacon*, December 9, 2016, available at <http://freebeacon.com/national-security/china-prepares-satellite-missile-test/>.

⁷⁶ Bill Gertz, "China Flight-Tests 10 DF-21 Missiles," *Washington Free Beacon*, December 2, 2016, available at <http://freebeacon.com/national-security/china-flight-tests-10-df-21-missiles/>.

⁷⁷ Eric Heginbotham, et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996-2017* (Santa Monica, CA: RAND Corporation, 2015), p. 248, available at http://www.rand.org/content/dam/rand/pubs/research_reports/RR300/RR392/RAND_RR392.pdf.

⁷⁸ Dr. Mark Schneider, *The Emerging EMP Threat to The United States* (Fairfax, VA: National Institute Press, November 2007), available at <http://www.nipp.org/wp-content/uploads/2014/12/EMP-Paper-Final-November07.pdf>.

⁷⁹ U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, op. cit., p. 35.

⁸⁰ Leonard David, "Mysterious Actions of Chinese Satellites Have Experts Guessing," *Space.com*, September 9, 2013, available at <http://www.space.com/22707-china-satellite-activities-perplex-experts.html>.

jammers, robotic arms based on space planes or satellite platforms, kinetic kill vehicles, lasers, and explosive satellites.

China is making progress with radio-frequency jammers and directed energy weapons that could pose risks to GPS and U.S. communications satellites. Chinese researchers, according to the Director of National Intelligence, are investigating enhanced robust jamming capabilities to attack commonly used frequencies in communications and global navigation satellite systems.⁸¹ China has fired lasers at U.S. reconnaissance satellites, which operate in low earth orbit. Such an incident occurred in 2006; China claimed that it was merely conducting laser ranging-finding (or “illuminating”) and not attempting to blind the satellite. In any case, the satellite’s sensors apparently suffered no permanent damage.⁸² China’s research into these and related areas is continuing. China has fixed laser ranging lasers at five locations, which are used mainly to establish satellite flight parameters, data it shares with 23 other countries within the International Laser Ranging Service network. It may be possible for China to scale up the power at these sites to the point where it could dazzle or do damage to satellite optics.⁸³ These laser rangers could be used to locate and precisely target orbiting satellites. China continues to modernize its space program to achieve near-real-time tracking of objects in space, improve command and control of deployed forces, and strike targets with precision.⁸⁴

China is also engaged in human spaceflight missions, which could be used to support counter-space missions as well as conventional and nuclear military capabilities. Its second experimental space laboratory, Tiangong 2, was launched in September 2016. China has the goal of operating its first space station by 2022.⁸⁵ The ability to track and identify satellites is enhanced by technologies developed for the manned and lunar programs. There are also reports that China is developing and using a small spacecraft, the stated mission of which is to clean up space junk. The Roaming Dragon craft uses a robotic arm to pick up large debris, to include old satellites.⁸⁶ This spacecraft, of course, also has potential military applications as an active, on-orbit ASAT weapon. It may be used as a deterrent or an active offensive capability, one which could also result in gaining insight into the technical capabilities of opponents’ satellites. The benefit of such a weapon is that it is “clean,” when compared to the debris-generating capacity of a kinetic-kill ASAT missile, meaning that its use in a counter-space role might not carry the same level of international opprobrium as the direct-ascent weapon.

⁸¹ Daniel R. Coats, *Worldwide Threat Assessment of the US Intelligence Community*, Before the Senate Select Committee on Intelligence, May 11, 2017, available at <https://www.dni.gov/index.php/newsroom/congressional-testimonies/item/1757-statement-for-the-record-worldwide-threat-assessment-of-the-u-s-intelligence-community-before-the-ssci>.

⁸² Glenn Kessler, “Bachmann’s claim that China ‘blinded’ U.S. satellites,” *The Washington Post*, October 4, 2011, available at https://www.washingtonpost.com/blogs/fact-checker/post/bachmanns-claim-that-china-blinded-us-satellites/2011/10/03/gIQAHvm7IL_blog.html?utm_term=.b425569bd9a0.

⁸³ Heginbotham, et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996-2017*, op. cit., p. 247.

⁸⁴ David J. Buck, “Statement of Lieutenant General David J. Buck, Commander, Joint Functional Component Command for Space,” *114th U.S. Congress*, House Armed Services Committee, March 15, 2016, p. 5, available at <http://docs.house.gov/meetings/AS/AS29/20160315/104620/HHRG-114-AS29-Wstate-BuckD-20160315.pdf>.

⁸⁵ Bloomberg News, “China Sends Astronauts Into Space for Longest Mission Yet,” *Bloomberg News*, October 16, 2016, available at <https://www.bloomberg.com/news/articles/2016-10-16/china-sends-astronauts-into-space-with-plans-for-longest-mission>.

⁸⁶ Stephen Chen, “Is China militarizing space? Experts say new junk collector could be used as anti-satellite weapon,” *South China Morning Post*, June 28, 2016, available at <http://www.scmp.com/news/china/diplomacy-defence/article/1982526/china-militarising-space-experts-say-new-junk-collector>. The European Space Agency reportedly has a similar project underway, as does the U.S. Defense Advanced Research Projects Agency (2020 launch anticipated). The United States once had this capability with the Space Shuttle program, which was terminated. Clark, “China: the new space superpower,” op. cit.

With respect to space force application, China continues to make large investments in ballistic missile systems, improving range, lethality, and capability for evading U.S. missile defense systems. Russia and China already have payloads that evade missile defenses, to include technologies for multiple reentry vehicles, maneuvering reentry vehicles, hypersonic glide vehicles,⁸⁷ cruise missiles, and midcourse countermeasures, such as decoys.

The modernization of China's strategic forces has been intense, with the development of new intermediate-range and long-range systems as well as submarines that can strike targets from the open water some 5,000 miles away. China's ballistic missile force is growing and its nuclear weapon modernization programs have been steady. China reportedly has 20 nuclear armed, liquid-propellant CSS-4 (DF-5) ICBMs capable of reaching the United States. China has deployed MIRV warheads on the CSS-4 Mod 3 (DF-5B).⁸⁸ It is also modernizing its nuclear forces by adding more survivable, road-mobile delivery systems. China has deployed the road-mobile CSS-10 Mod 1 and 2 ICBMs (DF-31 and DF-31A).⁸⁹ China is developing a new generation of mobile missiles and is undertaking efforts to maintain the viability of its offensive forces in the face of U.S. strategic intelligence, surveillance, reconnaissance, precision strike, and missile defense capabilities. The People's Liberation Army has deployed new command, control and communications capabilities for its nuclear ICBM forces. China has just deployed an advanced ICBM, the DF-41, that would have a range of up to 14,500km, capable of striking the United States in around 30 minutes time.⁹⁰ This ICBM would be deployed on easy-to-conceal rail cars.⁹¹ China is also producing the JIN-class SSBN, with three delivered and up to two under construction to carry the JL-2 submarine launched ballistic missile (7,400 km range).

China reportedly will continue to work on a range of technologies to counter U.S. ballistic missile defense systems, including maneuverable reentry vehicles (MaRVs), MIRVs, decoys, chaff, jamming, thermal shielding, and anti-satellite weapons.⁹² It also reportedly is working on a hypersonic craft that appears designed to be launched atop one of its ICBMs and then glide and maneuver at speeds of up to 10 times the speed of sound from near space towards the target.⁹³

⁸⁷ For an extensive review of China's hypersonic glide vehicle program, see Guy Norris, "China Takes Wraps Off National Hypersonic Plan," *Aviation Week*, April 10, 2017, available at <http://aviationweek.com/technology/china-takes-wraps-national-hypersonic-plan>.

⁸⁸ *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2016*, op. cit., p. 25.

⁸⁹ *Ibid*,

⁹⁰ "Reported DF-41 Deployment: China 'Responding to US Missile Defense in Asia,'" op. cit.; "Dongfeng-41 will bring China more respect," op. cit.

⁹¹ Minnie Chan, "China's top new long range missile 'may be deployed this year,' putting the US within striking distance, report says," *South China Morning Post*, March 30, 2016, available at <http://www.scmp.com/news/china/diplomacy-defence/article/1931652/chinas-top-new-long-range-missile-may-be-deployed-year>.

⁹² U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China 2013* (Washington, D.C.: Department of Defense, 2013), pp. 29-31, available at http://archive.defense.gov/pubs/2013_China_Report_FINAL.pdf; National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat* (Washington, D.C.: Office of the Director of National Intelligence, 2013), p. 18, 19, available at https://fas.org/programs/ssp/nukes/nuclearweapons/NASIC2013_050813.pdf. China has acknowledged the existence of a new ICBM capable of carrying multiple nuclear warheads, the DF-41. *AFP*, "China Says It Has Intercontinental Missile Capability of Carrying Nukes to US," *Firstpost*, August 1, 2014, available at <http://www.firstpost.com/world/china-says-it-has-intercontinental-missile-capable-of-carrying-nukes-to-us-1644559.html> Anti-satellite weapons and ballistic missile defense systems utilize similar technologies to achieve the destruction of the target using kinetic kill mechanism (hit-to-kill and blast fragmentation technologies) or directed energy.

⁹³ For an extensive review of China's hypersonic glide vehicle program, see Guy Norris, "China Takes Wraps Off National Hypersonic Plan," *Aviation Week*, April 10, 2017, available at <http://aviationweek.com/technology/china-takes-wraps-national-hypersonic-plan>. Bill Gertz, "Hypersonic arms race: China tests high-speed missile to beat U.S. defenses," *The Washington Times*, January 13, 2014, available at <http://www.washingtontimes.com/news/2014/jan/13/hypersonic-arms-race-china-tests-high-speed-missile/>; "China military affairs specialists said the hypersonic vehicle test is a significant milestone and appears to be part of China's development of asymmetric warfare weaponry that Beijing calls 'assassin's mace' weapons—high-technology arms that would assist China's overall weaker military forces to defeat the more technologically advanced U.S. military." Franz-Stefan Gady,

Beijing successfully flight tested new maneuvering warheads seven times as of April 2016 using the DF-ZF hypersonic glide vehicle atop a ballistic missile.⁹⁴ The glide vehicle, capable of extreme maneuvers, reportedly has been detected traveling between 4,000-7,000 miles per hour and would make for a very challenging target for current U.S. missile defenses, which would be our last line of defense against such a force application attack from space. Couple these modernization efforts with China's strategy of access denial, and it is clear that the risks to the U.S. homeland and interests in Asia-Pacific could increase quickly to an unacceptable, perhaps unmanageable, level.

Russia

With its modernization efforts and growth in nuclear, ballistic missile, and other military forces, coupled with its nuclear threats, one may conclude that Moscow has nuclear ambitions that are significantly opposed to those held in Washington.⁹⁵ Russian Defense Minister, General Serge Shoigu, observed that "[t]he rivalry for global leadership and resources is escalating." He took note of the "growing role of military force as an instrument of pursuing national interests."⁹⁶ Recent Russian military actions, most notably against Ukraine and in Syria, point to the continued role military domination plays in its foreign and defense strategies, strategies that are again at odds with those of the United States.

Russia is committed to investing in advanced technologies to improve its reconnaissance satellite capabilities, and possibly even match the resolution on the intelligence satellites operated by the United States. Historically, Russia has had a very strong manned space program and surveillance and reconnaissance program. According to the Joint Chiefs of Staff, although the United States possesses an advantage when it comes to the deployment of platforms used for sensing and command and control, "Russia, China, and other nations have developed increasingly capable space-based C3/ISR systems."⁹⁷

There are reports that Russia plans to launch three Hrazdan satellites between 2019 and 2024 that are technologically more advanced than the current Persona satellites in orbit, which reportedly have a resolution of 31 centimeters (which compares to the seven centimeters achieved by the best U.S. imagery satellites).⁹⁸ Russia uses the reconnaissance satellites to prepare the battlefield and support long-distance deployments, such as the current deployment of Russian armed forces to Syria. The satellites provide important targeting data that are exploited by Russian bombers and cruise missiles to strike targets in Syria with precision.⁹⁹ Today, Russia

"Russia Test Fires Nuclear-Capable Hypersonic Glider Warhead," *The Diplomat*, October 28, 2016, available at <http://thediplomat.com/2016/10/russia-test-fires-nuclear-capable-hypersonic-glider-warhead/>.

⁹⁴ Bill Gertz, "China Successfully Tests Hypersonic Missile: Seventh test of new DF-ZF glider tracked over northern China," *The Washington Free Beacon*, April 27, 2016, available at <http://freebeacon.com/national-security/china-successfully-tests-hypersonic-missile/>.

⁹⁵ Colin S. Gray and Keith B. Payne, "America's nuclear deterrence holiday," *The Washington Times*, December 22, 2016, available at <http://www.washingtontimes.com/news/2016/dec/21/americas-nuclear-deterrence-holiday/>.

⁹⁶ *Interfax.com*, January 12, 2017, available at <http://www.dialog.com/proquestdialog/>

⁹⁷ Joint Chiefs of Staff, *Joint Operating Environment: The Joint Force in a Contested and Disordered World*, July 14, 2016, http://www.dtic.mil/doctrine/concepts/joe/joe_2035_july16.pdf, p. 32.

⁹⁸ David Axe, "Vladimir Putin Plots a New Fleet of Spies in Space," *The Daily Beast*, August 8, 2016.

⁹⁹ Russia reportedly deployed 10 satellites at the end of 2015, including "civilian" remote-sensing satellites, and adjusted orbits to facilitate coverage over the conflict zone. The satellites reportedly accelerated the identification of targets and increased targeting accuracy by providing coordinates. "Spooky world of military satellites," *Russian Space Web*, February 2017, http://www.russianspaceweb.com/spacecraft_military.html

is reportedly making extensive use of space assets, especially reconnaissance and mapping satellites, to prosecute the war in Syria, to include fielding and deploying advanced equipment that leverages space for the execution of precision long-range strikes.¹⁰⁰

Moscow also has invested significantly in space-control and force application capabilities. Russian counter-space efforts may be traced back to the 1960 Soviet shoot-down of a high altitude American U-2 spy plane, which compelled Washington to consider the benefits of space for reconnaissance. Russia expanded its ASAT development and testing in the 1960s and 1970s, a commitment the United States did not fully understand until the 1980s, when the Soviet Union devoted significant resources to the development of ASATs, space strike complexes, manned military space shuttles, anti-ballistic missile forces, and directed energy systems.

Russia's ASAT program lapsed with the fall of the Soviet Union, so much so that Moscow struggled to hold together degenerating capabilities. Russia today is experiencing a counter-space revival. Moscow views space as critically important for deterrence and warfighting, and it intends to increase the number of its operational satellites to 150 by 2025.¹⁰¹ As part of its modernization efforts, Russia is expanding its space capability, spending roughly \$5 billion per year. Moscow has doubled its on-orbit advanced space assets (early warning and geosynchronous signals intelligence collection platforms) since 2014. Russia is also a leader in space launch, to include heavy lift capacity to geosynchronous orbit and human spaceflight, and it has the facilities to control these launches within Russia.¹⁰²

According to a 2015 Defense Intelligence Agency report to Congress, "Russia's military doctrine emphasizes space defense as a vital component of its national defense. Russian leaders openly assert that the Russian armed forces have anti-satellite weapons and conduct anti-satellite research."¹⁰³ In fact, one Russian military expert described an anti-satellite weapon "as a new reality which one should consider when planning a possible military operation."¹⁰⁴ Then-President Dmitri Medvedev announced in November 2010 the integration of missile warning and tracking and its air and missile defense systems.¹⁰⁵ Russia is developing and deploying improved capabilities to track and inspect orbiting space objects, increasing its abilities to detect and possibly sabotage American intelligence satellites. Moscow is committed to improving its space situational awareness and satellite tracking capability, a critical element of maturing space

¹⁰⁰ David Axe, "Russia Is Using Space Power in Its Attack on Syria," *The Daily Beast*, December 16, 2015, <http://www.thedailybeast.com/articles/2015/12/16/russia-is-using-space-power-in-its-attack-on-syria.html>. Russia claims to have placed 10 satellites over Syria to map terrain, conduct targeting surveillance, gather intelligence, and relay radio signals among air, land, and sea forces. James Clapper, *Worldwide Threat Assessment of the US Intelligence Community* (Washington, D.C.: Director of National Intelligence, February 9, 2016), p. 9, available at https://www.armed-services.senate.gov/imo/media/doc/Clapper_02-09-16.pdf. "Russia and China continue to improve the capabilities of their military and intelligence satellites and grow more sophisticated in their operations. Russian military officials publicly tout their use of imaging and electronic-reconnaissance satellites to support military operations in Syria—revealing some of their sophisticated military uses of space services."

¹⁰¹ Interview with Dr. Mark Schneider, January 13, 2016.

¹⁰² Lt. Gen David J. Buck, *Testimony before the House Armed Services Subcommittee on Strategic Forces on Fiscal Year 2017 National Defense Authorization Budget Request for Space Programs*, March 15, 2016.

¹⁰³ Bill Gertz, "Russia Flight Tests Anti-Satellite Missile: Launch took place as Air Force held space war game," *The Washington Free Beacon*, May 27, 2016.

¹⁰⁴ Vasily Kashin interview with Sputnik China, "New Reality: Future Space Weapons Will Be Able to Destroy Enemy Satellites," op. cit.

¹⁰⁵ Russia reportedly plans to deploy 10 new satellites and five radars to upgrade its missile attack warning and combat control system by 2020 and integrate all air and space operations by 2021. "Russia to launch ten missile attack warning satellites by 2020," TASS, December 20, 2016, available at <http://tass.com/defense/920880>.

capability.¹⁰⁶ The construction of new phased array radars is improving the country's capability to track space objects, with plans in place to build more advanced space tracking capabilities using laser optics and radars. According to the Director for National Intelligence:

Russia's senior leadership probably views countering the US space advantage as a critical component of warfighting. Its 2014 Military Doctrine highlights at least three space-enabled capabilities—"global strike," the "intention to station weapons in space," and "strategic non-nuclear precision weapons"—as main external military threats to the Russian Federation. Russia and China are also employing more sophisticated satellite operations and are probably testing dual-use technologies in space that could be applied to counterspace missions.¹⁰⁷

In March 2009, the First Deputy Defense Minister, General of the Army Vladimir Popovkin, announced that Russia was developing an ASAT system. In 2011, General Popovkin stated that aerospace defense was a Russian priority, and in January 2012, then-Chief of Russian General Staff Nikolay Makarov stated that Russia must be ready for war in space. Moreover, senior Russian military officials are on record stating the importance of being ready to achieve dominance in outer space and disrupt enemy attacks from space, while engaging in activities to ensure the survival of their own military-space facilities.¹⁰⁸

Russia is investing significantly in a full range of capabilities, to include ASAT kinetic weapons, lasers, jammers, and cyber weapons.¹⁰⁹ Public mention of Russian counter space forces (the development of "inspection and strike weapons") appeared in 2009 and 2010. The S-300 surface-to-air missile is said to be capable of targeting objects in "near earth space."¹¹⁰ The S-400 and S-500 SAM systems are also said to have such a capability, with the S-500 "mobile air and space defense complex," which ranges out to 600 km, set to enter service in 2018 with five units deployed by 2020.¹¹¹ While Russia has been short on details concerning the scope of its kinetic ASAT programs, Lieutenant General Ostapenko said that the S-500 will be able to intercept "low-orbital satellites and space weapons."¹¹²

As recently as December 2016, Russia reportedly tested a direct-ascent anti-satellite missile called the Nudol. This apparently was the third successful test of this system. This system is probably linked to Russian missile defense systems and would be capable of targeting satellites

¹⁰⁶ Gareth Jennings, "Russia to Activate Three New Ballistic Missile Warning Radars by End of 2016," *Jane's Defense*, January 13, 2016.

¹⁰⁷ James Clapper, *Worldwide Threat Assessment of the US Intelligence Community* (Washington, D.C.: Director of National Intelligence, February 9, 2016), p. 9, available at https://www.armed-services.senate.gov/imo/media/doc/Clapper_02-09-16.pdf.

¹⁰⁸ Author interview with Mark Schneider of the National Institute for Public Policy, January 13, 2016. See also Bill Gertz, "Russia Conducts Fifth Test of New Anti-Satellite Missile," *Washington Free Beacon*, December 21, 2016, available at <http://freebeacon.com/national-security/russia-conducts-fifth-test-new-anti-satellite-missile/>.

¹⁰⁹ "Russian defense officials acknowledge that they have deployed radar-imagery jammers and are developing laser weapons designed to blind US intelligence and ballistic missile defense satellites." Clapper, *Worldwide Threat Assessment of the US Intelligence Community*, 2016, op. cit., p. 10.

¹¹⁰ "New missiles for S-400 systems able to destroy targets in near-Earth space - Russian Aerospace Forces deputy commander," *Interfax*, April 8, 2017, available at http://dialog.proquest.com/professional/docview/188542327_0?accountid=155509 & CIS General Newswire.; Russian S-300 missile systems capable of targeting near space 'enter service', *Russia Today*, March 12, 2015, available at <http://rt.com/news/239961-near-space-missile-defense/>.

¹¹¹ "Russia's future S-500 SAM 'hypersonic', no warhead ('direct hit')," *BBC Monitoring Former Soviet Union*, April 8, 2017, <http://dialog.proquest.com/professional/docview/1885008438?accountid=155509>.

¹¹² Doug Lamborn, "Time to get serious about space threats," *The Hill*, May 14, 2015, available at <http://thehill.com/opinion/oped/241933-time-to-get-serious-about-space-threats>.

that pass over Moscow. According to Russian analyst Pavel Podvig, the missile manufacturer “is making an argument that an [anti-satellite] system might be useful to hold U.S. assets at risk.”¹¹³

In 2014, Russia reportedly launched four satellites into orbit, one of which was dissimilar to the other three. The Pentagon noticed that the fourth satellite conducted maneuvers, which means the Russians may be developing a capability to maneuver satellites to inspect or jam other satellites or put objects on a destructive path toward an adversary satellite and destroy it. In May 2017, it was reported that two of those satellites, after being idle for months, began to move, apparently on a mission to draw close to a defunct Chinese weather satellite; these satellites could be demonstrating a satellite inspection function. Of course, inspection satellites might also be armed with lasers or explosives and do damage to nearby satellites.¹¹⁴

There are also other counter-space programs to consider. Russian officials reportedly recommended resumption in research and development of an airborne ASAT missile to “intercept absolutely everything that flies from space.”¹¹⁵ An apparent revival of the Soviet-era Kontakt program, a Russian MiG-31BM platform, is said to be capable of releasing a large missile at a high altitude to deploy an ASAT weapon to destroy targets in near-space, including satellites.¹¹⁶ Moscow also continues to test an airborne laser system, which dates back to the 1970s. The A-60 aircraft reportedly has been upgraded and is ready for flight testing in the new configuration. The purpose of the aircraft is space counter warfare, to blind the sensors of enemy satellites. It was tested in this role in 2009 against a Japanese satellite at 1,500 km.¹¹⁷ Russia also reportedly has conducted testing of a high-altitude EMP weapon in April 1999, which would incapacitate all space systems (on the ground and in space) that are not hardened to withstand an EMP.¹¹⁸

While Russia is making strong technical strides toward having weapons capable of damaging or destroying U.S. satellites, it is using its foreign policy to try to hobble potential U.S. space weapons. For example, Russia (along with China) has advocated for a treaty preventing the placement of weapons in outer space and the threat or use of force against space-based assets. Russia is fully aware that there are no known technologies or capabilities to verify compliance with such a treaty. The purpose in pursuing such arms control agreements is to hobble U.S. weapons and technology development, because of the domestic political opposition such rhetoric might generate and because the United States will comply with any arms control agreement that it signs. The Russians do not have the same constitutional and political constraints in place as

¹¹³ Gertz, “Russia Conducts Fifth Test of New Anti-Satellite Missile,” op. cit.; Bill Gertz, “Russia Flight Tests Anti-Satellite Missile: Launch took place as Air Force held space war game,” *The Washington Free Beacon*, May 27, 2016, available at <http://freebeacon.com/national-security/russia-flight-tests-anti-satellite-missile/>.

¹¹⁴ David Axe, “Russia’s ‘Killer Satellites’ Re-Awaken,” *The Daily Beast*, May 19, 2017, available at <http://www.thedailybeast.com/articles/2017/05/19/russias-killer-satellites-reawaken>.

¹¹⁵ Mike Rogers and Jim Cooper, “Tenth Anniversary of the Chinese Anti-Satellite (ASAT) Missile Test,” *Real Clear Defense*, January 11, 2017, available at http://www.realcleardefense.com/articles/2017/01/11/tenth_anniversary_of_the_chinese_anti-satellite_asat_missiletest_110617.html: “The Russian Duma officially recommended in 2013 that Russia resume research and development of an airborne antisatellite missile to ‘be able to intercept absolutely everything that flies from space.’”; See also, Clapper, *Worldwide Threat Assessment of the US Intelligence Community*, 2016, op. cit., p. 10.

¹¹⁶ Alexander Zudin, “Russia to deploy anti-satellite weapon on MiG-31BM,” *IHS Jane’s Missiles & Rockets*, February 22, 2017, available at <http://www.janes.com/article/68102/russia-to-deploy-anti-satellite-weapon-on-mig-31bm>.

¹¹⁷ David Cenciotti, “Russia has completed ground tests of its high-energy Airborne combat Laser System,” *The Aviationist*, October 5, 2016, available at <https://theaviationist.com/2016/10/05/russia-has-completed-ground-tests-of-its-high-energy-airborne-combat-laser-system/>.

¹¹⁸ Sam Jones, “Satellite Wars,” *Financial Times*, November 20, 2015, available at <https://www.ft.com/content/637bf054-8e34-11e5-8be4-3506bf20cc2b>; Bill Gertz, “Russia Flight Tests Anti-Satellite Missile,” op. cit.

the United States to restrain its development of ASATs. Moreover, the Russians are accustomed to violating arms control agreements that it they have signed. Writes defense analyst Mark Schneider: "There is no reason to expect Russia to break a habit of ignoring its arms control and treaty obligations. By doing this, it has gained military advantages for decades."¹¹⁹

Russian space force application currently relies on ICBMs and various types of reentry vehicles. Russia continues to modernize and test its very capable land- and sea-based ballistic missile forces which travel through the space environment towards their targets. It also has a military doctrine that allows for the possibility of using nuclear weapons first in retaliation for a non-nuclear attack.¹²⁰ According to U.S. sources, Russia has about 1,200 nuclear warheads on ICBMs, most of which are capable of being launched within minutes of receiving a launch order;¹²¹ it is expected to retain the largest ICBM force outside the United States, and its modernization efforts are ongoing. In 2012, the Russians tested the SS-27 Mod 1 ICBM, a new missile designed with countermeasures to ballistic missile defense systems, and it is now deployed in silos and on launchers. Russia began deployment of the road-mobile version of the SS-27 Mod 1 in 2006 and deployed in 2010 a MIRV version of the SS-27, the SS-27 Mod-2 (RS-24). A new rail-mobile ICBM is under development.¹²²

A new heavy liquid-propellant ICBM also is under development to replace the aging SS-18 for deployment in the 2018-2020 timeframe.¹²³ Russia has tested "hypersonic combat blocks" for the lighter and more capable Sarmat ICBM, which is the 10-MIRV replacement for the SS-18 (Satan). It is currently developing advanced hypersonic glide vehicle technology, which might be capable of outmaneuvering missile defense systems. According to former chief of the main staff of the Strategic Missile Forces, Victor Yesin, the new missile would be able to strike targets not only through the North Pole but also through the South Pole. According to Deputy Defense Minister Yury Borizov, "improved energy characteristics will allow ... surmounting of American antimissile defense." Also, he stated, "the new missile will be able to counteract to the space component of the strike means [sic] and it will be possible to launch practically from any area and in all directions." Borisov called this "one of the most important achievements of the design bureau in the last few years."¹²⁴

The Fractional Orbital Bombardment System (FOBS) banned by SALT II (which was never ratified) and the START Treaty was not banned in the New Start Treaty, and Russia has experimented with this reentry technology in the past. A FOBS de-orbits its warheads before making a complete revolution around the earth. A FOBS could be used to attack the United States from space over the south pole (rather than the north pole, which a ballistic missile trajectory launched out of Russia would overfly). An orbital attack from the south would evade existing missile defense early warning and tracking radars and tracking and discrimination radars

¹¹⁹ Mark B. Schneider, "Russia Cheats," *Air Force Magazine*, July 2016, available at <http://www.nipp.org/wp-content/uploads/2016/07/Schneider-Russia-Cheats.pdf>.

¹²⁰ Vladimir Isachenkov, "Russia may answer conventional attack with nukes," *The Associated Press*, December 11, 2013, available at <https://www.yahoo.com/news/russia-may-answer-conventional-attack-nukes-155829813.html>.

¹²¹ W.J. Hennigan and Ralph Vartabedian, "As U.S. nuclear arsenal ages, other nations have modernized," *Los Angeles Times*, September 10, 2014, available at <http://www.latimes.com/nation/la-na-nukes-silos-20141110-story.html>

¹²² "Russia to Revive Nuclear Missile Trains—RVSN Commander," *Interfax*, December 16, 2014, <http://dialog.proquest.com/professional/docview/1636587290?accountid=155509>.

¹²³ National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, 2013, op. cit., p. 18.

¹²⁴ Dmitry Litovkin, "Warheads for Sarmat passed through tests," *Defense and Security (Russia)*, May 11, 2016, available at <http://dialog.proquest.com/professional/login>.

currently deployed and under development for deployment in the northern latitudes, such as the Long Range Discrimination Radar, to be deployed at Clear Air Force Station, Alaska.¹²⁵ Russia also reportedly is developing, and already testing an engine for, a bomber to launch nuclear attacks from space and then return to home base. Such a space capability would allow a strike in one to two hours from any place on earth.¹²⁶

Iran

Iran's interests in the Middle East region diverge sharply from those of the United States. Teheran's strategic goals are to ensure the survival of the regime, expand its influence in the region, and build up Iran's military and deterrence posture.¹²⁷ The Iranian regime has extremely negative views of the United States, called by the regime's leaders the Great Satan. Teheran sees the United States, a principal ally of Israel, as the primary opposing force to the establishment of an Iranian-led Islamic Republic. Iran funds international terror groups and provokes U.S. and allied forces in the Middle East.

Iran's leaders are keenly aware of the importance the wide variety of space functions has played in U.S. military operations in Afghanistan and Iraq, and desire to have a similar capability so as to deny the United States the ability to use space in a regional conflict. Indeed, Tehran views its space program as critical to its national pride and the fight against its external enemies.¹²⁸ Iran's space activities have increased over the past decade and include sending non-functioning satellites into orbit, sending a monkey into space in 2013, and creating a tracking center to monitor space objects.¹²⁹ Iran reportedly uses satellite signals to guide and extend the range of UAVs, bypassing the need for line-of-sight control.¹³⁰

Similar to programs in other countries, Iran's space program—particularly its space launch vehicle development activities—is closely related to its development of technologies for long-range ballistic missiles. Iranian leaders understand the strategic value of being able to place a satellite in orbit and, reportedly, its investments to develop space technology have not diminished.¹³¹ With the July 2015 Iran nuclear deal (Joint Comprehensive Plan of Action) and subsequent lifting of U.S. and U.N. sanctions that provide Iran with a significant source of cash for investment, Teheran will be in a position to accelerate its space programs. That said, Iran's space program and infrastructure are not as advanced as those of China, India, or Israel. It does not have the high-

¹²⁵ Russian officials have said that the Russian heavy ICBM, Sarmat (which has more throwweight than the large SS-18 ICBM), would be capable of attacking the United States from the south. Author interview with Mark Schneider from the National Institute for Public Policy in Fairfax, VA, January 13, 2016. Schneider cites retired Colonel General Viktor Yesin, former commander of the Strategic Missile Troops, announced that the Sarmat has 5,000 kg "into orbit." Schneider mentioned that this is an odd thing to say about an ICBM because ICBMs do not typically go into orbit.

¹²⁶ Sputnik News, "New Russian Bomber to Be Able to Launch Nuclear Attacks From Outer Space," *Sputnik News*, July 13, 2016, available at <https://sputniknews.com/military/201607131042888473-russia-space-bomber-engine/>.

¹²⁷ Vincent R. Stewart, "Statement for the Record: Worldwide Threat Assessment," 114th U.S. Congress, House Armed Services Committee, March 2, 2016, available at <http://www.dia.mil/News/Speeches-and-Testimonies/Article-View/Article/684250/statement-for-the-record-worldwide-threat-assessment/>.

¹²⁸ Radhakrishna Rao, "Iran's pipe dream in space," *Asia Times Online*, May 31, 2012, available at http://www.atimes.com/atimes/Middle_East/NE31Ak01.html.

¹²⁹ Amanda Hoover, "Could Iran's space program work with NASA?" *Christian Science Monitor*, October 4, 2016, available at <http://www.csmonitor.com/Science/2016/1004/Could-Iran-s-space-program-work-with-NASA>.

¹³⁰ Adam Kredon, "Iran Satellite Launch Prompts Fear of Long Range Ballistic Missile Attack," *Washington Free Beacon*, August 31, 2016, available at <http://freebeacon.com/national-security/iran-satellite-launch-prompts-fear-long-range-ballistic-missile-attack/>.

¹³¹ Craig Covault, "Iran unveils new space rocket and satellite designs," *Spaceflight Now*, February 13, 2010, available at <http://www.spaceflightnow.com/news/n1002/13iran>.

tech industrial base required to realize its dream of manned space flight on the timeline leaders have laid out. However, steadily, Iran is making progress.

The Iranian Space Agency (ISA), ostensibly a civil space agency but increasingly influenced by military tasking and currently under military control, is the highest authority responsible for space affairs. Iran has two space launch facilities, with another in development, in addition to having signed an agreement with Kazakhstan to use the Baikonur Cosmodrome. Iran has been building and expanding its ground infrastructure to support space launches and satellite operations, including satellite tracking, telemetry, control facilities and a space situational awareness center.¹³²

Teheran has relied on foreign-made satellites and foreign launchers to place payloads in orbit, yet it also has demonstrated some recent success in placing lightweight, low capability, short-lived objects into space using its modified Shahab-4 ballistic missile and Safir rocket technologies, which are stepping stones to longer-range missile capabilities. It launched its first satellite in 2009. In 2010, Iran introduced the larger Simorgh space launch vehicle, indicating that it will likely continue to pursue more capable space launch vehicles, which could give it the ability to launch somewhat heavier payloads into low earth orbit.

Iran uses its satellite program to serve a dual purpose—to gain a foothold in space and develop competency in that increasingly important environment, and help it develop its long-range ballistic missile force. Iran is continuing efforts to acquire intermediate- and intercontinental-range systems capable of striking the territories of our European allies and the United States. The intelligence community believes Iran could deploy an operational ICBM by 2020.¹³³ The only plausible payload for the Iranian ICBM is a nuclear front end. It is pursuing these capabilities in defiance of UN Security Council resolution 2231, which calls upon Iran to refrain from launching nuclear-capable missiles. Iranian supreme leader Ali Khamenei has said the United States could not “do a damn thing” about Iran’s missile program.¹³⁴

Teheran also has demonstrated an interest in acquiring counter-space capabilities. With the development of medium-range ballistic missile systems that can reach up to 1,000 km into space, Iran is reportedly interested in developing anti-satellite capabilities.¹³⁵ Iran is believed to have attempted to interfere with US broadcasting satellites from a base in Cuba, and there are reports

¹³² “Iran signs space launch agreement with Kazakhstan,” *Space Watch Middle East*, April 2016, available at <https://spacewatchme.com/2016/04/iran-signs-space-launch-agreement-kazakhstan/>.

¹³³ William E. Gortney, “Statement of William E. Gortney, United States Navy, Commander, United States Northern Command, and North American Aerospace Command, 114th U.S. Congress, Senate Armed Services Committee, March 10, 2016, p. 6, available at http://www.northcom.mil/Portals/28/Documents/Gortney_Posture%20Statement_SASC_03-10-16.pdf; National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, 2013, op. cit., p. 19; Bill Gertz, “Iran Conducts Space Launch,” *The Washington Free Beacon*, April 20, 2016, <http://freebeacon.com/national-security/iran-conducts-space-launch/>.

¹³⁴ Cited in Times of Israel Staff, “Khamenei: ‘U.S. ‘can’t do a damn thing’ about our missile program,” *The Times of Israel*, May 24, 2016, available at <http://www.timesofisrael.com/khamenei-us-cant-do-a-damn-thing-about-missile-program/>.

¹³⁵ National Air and Space Intelligence Center, *Ballistic and Cruise Missile Threat*, 2013, op. cit., p. 19; Jason Sherman, “Pentagon Dials Back Longstanding Assessment That Iran Could Test ICBM By 2015,” *Inside Defense*, July 10, 2014, available at <https://insidedefense.com/201407092476438/Inside-Defense-General/Public-Articles/pentagon-dials-back-longstanding-assessment-that-iran-could-test-icbm-by-2015/menu-id-926.html>; Iran has been flight-testing ballistic missiles in violation of a U.N. resolution, which demonstrates how little it may care for “international norms” and “codes of conduct.” Carole Landry, “Iran Missile Launch Violated UN Resolution: UN Experts,” *Yahoo News*, December 15, 2015, available at <http://news.yahoo.com/iran-missile-launch-violated-un-resolution-162410451.html>; Covault, “Iran unveils new space rocket and satellite designs,” op. cit.; Jason Koebler, “Iran’s ‘Space Program’ May Be Cover for Developing Better Ballistic Missiles,” *Motherboard*, February 18, 2015, available at <http://motherboard.vice.com/read/irans-space-program-may-be-a-cover-for-developing-better-ballistic-missiles>.

that Iran continues to jam space systems.¹³⁶ In June 2013, Teheran announced plans to build a space monitoring center, which would allow it to track satellites that overfly Iranian territory and conduct operations to disrupt or destroy enemy satellite operations. Iran has a reputation for conducting more interference attacks against U.S. military and commercial satellites involving lasers and jammers than any other country.¹³⁷

If Iran were able to develop nuclear warheads or buy them from North Korea, it would have the capability to generate an electro-magnetic pulse in space. Despite the above-mentioned JCPOA, Iran is also believed to be pursuing a program that would allow it to process uranium to a purity suitable for nuclear weapons; a nuclear ASAT would destroy satellites in the immediate vicinity of the detonation and damage more distant, unhardened satellites. The 2015 Iranian nuclear agreement negotiated by the Obama Administration does not eliminate Iran's nuclear program and it has provided Iran with a \$150 billion windfall. The deal expires in 15 years (some believe Iran may restart this program at any time), at which point Iran may very well be in a position to complete its nuclear weapons program (or before then, if it cheats).

North Korea

North Korea's military build-up is intended to maintain a large conventional force, an arsenal of ballistic missiles and nuclear warheads, as well as chemical and biological weapons. It also has a stridently confrontational posture against the United States. The government publicly declares the United States, which maintains a strong military presence in South Korea, to be the main enemy of the country.

In their effort to bolster their country's military power, North Korean leaders have striven to develop and demonstrate space launch vehicles and the launching of satellites, even at the expense of feeding their own people and despite a stagnant economy. The aggressiveness of the leaders of this pariah state is not to be underestimated. When North Korea launched its first satellite in December 2012, it made a statement, not only about its desire to be considered a space power, but also, in the same vein as the Soviet Union's Sputnik launch in 1957, its ability to reach across vast oceans with a (potentially nuclear tipped) ballistic missile. Pyongyang has spent a great deal of effort developing its ballistic missile forces, to include long-range systems such as the Taepo-Dong 2 or Unha-3 (a fixed base space launch vehicle/ICBM) and the KN-08 and KN-14 mobile ICBM.¹³⁸ The nation, which has the goal of producing an intercontinental ballistic missile capable of delivering a nuclear payload to the United States, has recently conducted a series of tests (most of which have failed) of its intermediate-range ballistic missile, or Musudan, which would

¹³⁶ Robert K. Ackerman, "Space Vulnerabilities Threaten U.S. Edge in Battle," *Signal Magazine*, June 2005, available at <http://www.afcea.org/content/?q=space-vulnerabilities-threaten-us-edge-battle>.

¹³⁷ Micah Zenko, *Dangerous Space Incidents: Contingency Planning Memorandum No. 21*, Council on Foreign Relations, April 2014, available at <http://www.cfr.org/space/dangerous-space-incidents/p32790>.

¹³⁸ James R. Clapper, "Remarks as delivered by James R. Clapper, Director of National Intelligence, Worldwide Threat Assessment," 112th U.S. Congress, Senate Select Committee on Intelligence, March 12, 2013, p. 7, available at <https://www.dni.gov/files/documents/Intelligence%20Reports/WWTA%20Remarks%20as%20delivered%2012%20Mar%202013.pdf>; See also, John Schilling, Jeffrey Lewis and David Schmerler, "A New ICBM for North Korea?" *38 North*, December 22, 2015, available at <http://38north.org/2015/12/icbm122115/>; "KN-14 (KN-08 Mod 2)," *CSIS Missile Defense Project*, August 8, 2016, <https://missilethreat.csis.org/missile/kn-14/>.

be capable of delivering a payload to Guam.¹³⁹ Chinese space firms have provided critical assistance to North Korea's development of space launch vehicles and ballistic missiles.¹⁴⁰

According to former U.S. Forces Korea Commander General Curtis Scaparrotti, North Korea is within three to four years of having a proven ICBM capability, in addition to a sea-launch capability, as well as more nuclear warheads.¹⁴¹ It has displayed what intelligence officials believe to be a new type of ICBM, the KN-14, which is a longer-range variant of the KN-08 road-mobile ICBM. Few details about the capability of the system are known.¹⁴² It is also assessed that North Korea has the capability to place nuclear weapons on its KN-08 and KN-14 ICBMs and launch them against the United States.¹⁴³ North Korea reportedly has conducted a test involving a very large rocket engine that is capable of reaching geosynchronous orbit as well as the United States.¹⁴⁴

As part of its five-year plan, North Korea reportedly is focused on launching earth observation satellites in addition to a geostationary communications satellite, which would represent a major technological step forward. The totalitarian state launched the Kwangmyongsong 4 (Brilliant Star 4) into orbit in February 2016. As of the writing of this report, North Korea had two of these satellites in orbit, KMS-3 and KMS-4. KMS-4 reportedly is functioning and sending images back to the North Korean leadership. North Korea has proceeded down this path despite the United Nation's sanctions that were put in place to put a halt to its ballistic missile and satellite launches. Signaling North Korea's commitment to leveraging space for national purposes, the Director of Scientific Research in North Korea's Department of National Aerospace Development Administration has been quoted as saying, "Our country has started to accomplish our plan and we have started to gain a lot of successes. No matter what anyone thinks, our country will launch more satellites."¹⁴⁵

According to Admiral Cecil Haney, then-Commander of U.S. Strategic Command, North Korea has successfully jammed GPS satellites, doing so for several weeks at a time in May 2012.¹⁴⁶

¹³⁹ Anna Fifield, "Did North Korea just test missiles capable of hitting the U.S.? Maybe," *The Washington Post*, October 26, 2016, available at https://www.washingtonpost.com/world/asia_pacific/did-north-korea-just-test-missiles-capable-of-hitting-the-us-maybe/2016/10/26/984e8a21-e6a7-4689-81e0-21d7d25c302f_story.html.

¹⁴⁰ Joby Warrick, "Kim Jong Un's Rockets Are Getting An Important Boost—From China," *The Washington Post*, April 13, 2017, available at https://www.washingtonpost.com/world/national-security/kim-jong-uns-rockets-are-getting-an-important-boost-from-china/2017/04/12/4893b0be-1a43-bcc2-7d1a0973e7b2_story.html?utm_term=.32e7781192bf.

¹⁴¹ "Ex-USFK commander: N. Korea could have proven ICBM capability in 3-4 years," *Yonhap*, July 30, 2016, available at <http://english.yonhapnews.co.kr/news/2016/07/30/0200000000AEN20160730000300315.html>.

¹⁴² Bill Gertz, "Pentagon Confirms New North Korean ICBM," *The Washington Free Beacon*, March 31, 2016, available at <http://freebeacon.com/national-security/pentagon-confirms-new-north-korean-icbm/>.

¹⁴³ Stephen Schwalbe cites, Admiral Bill Gortney, Commander of the North American Aerospace Defense Command, "North Korea's Ballistic Missiles and Their Threat Potential," *Inhomelandsecurity.com*, October 12, 2016, <http://inhomelandsecurity.com/north-koreas-ballistic-missiles/>.

¹⁴⁴ John E. Hyten, "Hearing on the Nomination of General John Hyten to be Commander of U.S. Strategic Command," *114th U.S. Congress*, September 20, 2016, p. 23, available at http://www.armed-services.senate.gov/imo/media/doc/16-70_9-20-16.pdf.

¹⁴⁵ Eric Talmadge, "North Korea hopes to plant flag on the moon," *Associated Press*, August 4, 2016, available at <http://bigstory.ap.org/article/88fa76909dec40b299658a34b489dc1a/ap-exclusive-north-korea-hopes-plant-flag-moon>; "N.K. vows to launch satellites, hints at possible long-range rocket test," *Yonhap News Agency*, October 20, 2016, available at <http://english.yonhapnews.co.kr/northkorea/2016/10/20/45/0401000000AEN20161020006552315F.html>.

¹⁴⁶ Christian Davenport, "A fight to protect 'the most valuable real estate in space,'" *The Washington Post*, May 9, 2016, available at https://www.washingtonpost.com/business/economy/a-fight-to-protect-the-most-valuable-real-estate-in-space/2016/05/09/df590af2-1144-11e6-8967-7ac733c56f12_story.html?utm_term=.1aacb31314de; and, Sean Gallagher, "North Korea Pumps Up the GPS Jamming in Week-Long Attack," *Ars Technica*, May 9, 2012, available at <https://arstechnica.com/information-technology/2012/05/north-korea-pumps-up-the-gps-jamming-in-week-long-attack/>.

The successful jamming of GPS signals would have the effect of disrupting timing of U.S. military operations and impairing the use of precision guided weapons that rely on the GPS signal.

North Korea may be capable of threatening distant nations with strikes on their territories or the use of an electro-magnetic pulse to disable space and ground systems.¹⁴⁷ North Korea is reportedly developing ASAT weapons.¹⁴⁸ Not only does it have the missile capabilities needed to boost a kill vehicle into low-earth orbit, it also is believed to have made progress in the development of nuclear warheads that may be used against territorial targets or detonated in space. North Korea conducted its fifth nuclear test in September 2016, said to be the largest to date (possibly 20 to 30 kilotons), which North Korean officials claim is a hydrogen bomb. By one estimate, North Korea may have as many as 79 nuclear devices by the end of 2020.¹⁴⁹ Some observers in the intelligence and defense communities believe that North Korea already has the technology to miniaturize nuclear weapons and deploy reentry vehicles atop long-range ballistic missiles.¹⁵⁰

Digital Warfare (Cyberwar and EMP)

Desert Storm showed us many things about the changed way of warfare, especially the degree to which digital technologies were increasingly being integrated into modern warfare to make the U.S. military the most powerful in the world. Today, these technologies are essential to the operation of weapons, tactics, and even higher level domains of human activity such as strategy and decision-making (which increasingly relies on the speed and near-real-time situational awareness and updating made possible by digital networks). Precision guided bombs, cruise missiles, and missile defenses all depend on satellite-generated information and relays. Today's modern, digitally-enabled armed forces are able to react quickly, project power across great distances, and conduct highly lethal conventional operations executed with precision and a high degree of situational awareness.

The United States has a growing reliance on cyberspace and the electromagnetic spectrum. The growing dependence means growing risk to the extent U.S. leaders do not take steps to protect against cyber intrusions and interference with the electromagnetic spectrum. Cyber attacks, intrusions into U.S. government and commercial computer networks, are growing with each passing year, with the potential to create large-scale damage. There are significant concerns

¹⁴⁷ William R. Graham, "North Korea Nuclear EMP Attack: An Existential Threat," *Realcleardefense.com*, June 5, 2017, available at http://www.realcleardefense.com/authors/william_r_graham/ Graham concludes that "even if North Korea only has primitive, low-yield nuclear weapons, and if other states or terrorists acquire one or a few such weapons as well as the capability to detonate them at an altitude of 30 kilometers or higher over the United States," the EMP Commission has warned in its 2004 report "the damage level could be sufficient to be catastrophic to the Nation, and our current vulnerability invites attack."

¹⁴⁸ Zenko, *Dangerous Space Incidents: Contingency Planning Memorandum No. 21*, op. cit.

¹⁴⁹ Ju-min Park and Jack Kim, "North Korea conducts fifth and largest nuclear test," *Reuters*, September 9, 2016, available at <http://www.reuters.com/video/2016/09/09/north-korea-conducts-fifth-and-largest-n?videoid=369800166>; Yonhap News Agency, "N.K. seen capable of building nearly 80 nukes by end-2020: expert," *Yonhap News Agency*, October 18, 2016, available at <http://english.yonhapnews.co.kr/northkorea/2016/10/18/67/0401000000AEN20161018005951315F.html>. The South Korean press has reported that South Korean intelligence believes that NK now has enough fissile material for 60 weapons: "N. Korea nuclear stockpile can make up to 60 nuclear warheads: report," *Kyodo news service*, February 9, 2017, <http://dialog.proquest.com/professional/docview/1865952611?accountid=155509>; Another source projects North Korea to have between 25 and 50 nuclear weapons by 2020. See David Albright, "North Korea's Nuclear Capabilities: A Fresh Look," *Institute for Science and International Security Report*, April 28, 2017.

¹⁵⁰ R. James Woolsey and Peter Vincent Pry, "How North Korea could kill 90 percent of Americans," *The Hill*, March 29, 2017, available at <http://thehill.com/blogs/pundits-blog/defense/326094-how-north-korea-could-kill-up-to-90-percent-of-americans-at-any>.

about the security of space systems against cyber attack, that is, to being hacked or used maliciously.¹⁵¹

Cyber Vulnerability

While this monograph is not the place for an in-depth analysis of cyber challenges to U.S. systems, we can frame the cyber security challenges to space systems. The United States is believed to have the most powerful cyber weapon arsenal in the world.¹⁵² Yet we also know that other nations, to include China, Russia, North Korea and Iran, are honing their cyber assault skills and even putting them into practice.¹⁵³ If you can hack your way into the logic of a satellite's control system, it would be possible to turn the satellite off or have it do things it was not intended to do, turning solar panels towards the sun to burn them or maneuvering the satellite into the path of other satellites, possibly causing a diplomatic crisis. There is also the challenge of identifying the attackers—and if you cannot identify the trouble-makers, how do you deter them or respond to them?

Space and cyber warfare are very similar in the functions they perform, that is, to provide information, or the channels and pathways for information, and to deny those information channels in a time of conflict.¹⁵⁴ Compared to investments in satellites, launch facilities, and satellite operations infrastructure, entry into the cyber domain is relatively inexpensive, which opens up the possibility of non-state actors engaging in threatening activities. Digital attacks are like bombings. They have the ability to shut down a system, close down a factory, and destroy electrical, banking, transportation infrastructure at all levels of society, including those levels that contribute to national defense. Denial of service or loss of system performance can mean denial or loss of capability, which means such attacks have the same impact as a kinetic assault on defense and economic assets that rely on digital systems. Space systems, which are part of the information network that relies entirely on digital systems and data flow and on software and radio-frequency links, are especially vulnerable to such attacks.

Cyberspace is, to put it plainly, the domain of worldwide information flows between humans and machines that is enabled by a complex system of computing, switching, storage, and relay devices and infrastructure (e.g., fiber optic cables). In this view, the space systems are inherently a component of, and not separate from, cyberspace. Satellites are nodes in a network, and their value is derived from their ability to collect and disseminate information on the network.¹⁵⁵

¹⁵¹ Andrew Griffin, "Cyber attacks on satellites could spark global catastrophe, experts warn," *The Independent*, September 22, 2016, available at <http://www.independent.co.uk/life-style/gadgets-and-tech/news/cyber-attacks-on-satellites-could-spark-global-catastrophe-experts-warn-a7321361.html>.

¹⁵² R.C. Porter, "America's Secret Arsenal: Cyber Weapons Of Mass Disruption," *Fortuna's Corner*, December 14, 2015, available at <http://fortunascorner.com/2015/12/14/americas-secret-arsenal-cyber-weapons-of-mass-disruption/>; Andy Greenberg, "Weapons of Mass Disruption," *Forbes*, April 8, 2010, available at <http://www.forbes.com/forbes/2010/0426/opinions-cyberwar-internet-security-nsa-ideas-opinions.html>.

¹⁵³ According to U.S. intelligence chiefs, more than 30 countries are developing offensive cyber attack capabilities. Steve Ranger, "US intelligence: 30 countries building cyber attack capabilities," *ZDNet*, January 5, 2017, available at <http://www.zdnet.com/article/us-intelligence-30-countries-building-cyber-attack-capabilities/>.

¹⁵⁴ See General John E. Hyten, "Hearing on the Nomination of General John Hyten to be Commander of U.S. Strategic Command," op. cit.

¹⁵⁵ National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report* (Washington, D.C.: The National Academies Press, 2016), p. 9, available at <https://www.nap.edu/catalog/23594/national-security-space-defense-and-protection-public-report>.

North Korea is estimated to have one of the best and most organized cyber attack capabilities, according to Army General Vincent Brooks, Commander of U.S. Forces in South Korea. The U.S. Federal Bureau of Investigation and the Director of National Intelligence have high confidence that North Korea's Reconnaissance General Bureau was behind the 2014 attack on Sony Corporation's information technology infrastructure.¹⁵⁶ Chinese hackers use cyber attacks to prepare for military conflicts and plan to seize information dominance in the beginning by attacking command and control centers, satellites, and communications networks.¹⁵⁷ Russia too has engaged in multiple cyber attacks over the past decade, including attacks on Estonia (2007), Georgia (2008), Ukraine (2014), Germany (2015), and the United States (2015).¹⁵⁸

Computers are integrated into and across U.S. weapons systems and, because of the ubiquitous nature of digital technologies, "the capabilities and the vulnerabilities they imbue are exponential as opposed to strictly additive."¹⁵⁹ So as the U.S. armed forces take on greater cyber capability, they become more effective on the conventional battlefield but more vulnerable to a pre-emptive attack against their digital networks and technologies. There is also another emerging reality—these same forces are less able or unable to conduct analog or non-digitized operations, which means the availability of alternative weapons and operations off-network will be restricted. Bottom line: the continued development of cyber capabilities means that potential adversaries will increasingly view counter-cyber activities as a weapon to use against the United States.¹⁶⁰

There are significant advantages, in other words, in striking at the vulnerabilities of cyber-dependent capabilities, meaning there may be clear incentives to strike at the digital underbelly of the militarily superior United States before the battle begins—an electronic first strike. It might be the only way for a militarily inferior actor to prevent defeat or even manage a victory.¹⁶¹

Electro-Magnetic Pulse

There are scenarios in which a hostile state or a terrorist organization might build or acquire a nuclear warhead that it would launch and detonate above the United States, releasing an electro-magnetic pulse. This raises concerns that an above-atmosphere detonation would paralyze national information, energy, communications, and transportation infrastructure. An EMP pulse might carry out this havoc not only on earth, but also within satellite systems. Given orbital

¹⁵⁶ Tony Capaccio, "North Korean Cyber Capability Among World's Best, Brooks Says," *Bloomberg*, April 20, 2016, available at <https://www.bloomberg.com/news/articles/2016-04-19/north-korean-cyber-capability-among-world-s-best-brooks-says>.

¹⁵⁷ Adam Segal, "How China is preparing for cyberwar," *Christian Science Monitor*, March 20, 2017, available at <https://www.csmonitor.com/World/Passcode/Passcode-Voices/2017/0326/How-China-is-preparing-for-cyberwar>.

¹⁵⁸ Robert Windrem, "Timeline: Ten Years of Russian Cyber Attacks on Other Nations," *NBC News*, December 18, 2016, available at <http://www.nbcnews.com/news/us-news/timeline-ten-years-russian-cyber-attacks-other-nations-n697111>.

¹⁵⁹ Jacquelyn Schneider, *Digitally-Enabled Warfare: The Capability-Vulnerability Paradox* (Washington, D.C.: Center for a New American Security, 2016), p. 5, available at <https://s3.amazonaws.com/files.cnas.org/documents/CNASReport-DigitalWarfare-Final.pdf>.

¹⁶⁰ See, for example, a 2013 Defense Science Board report, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Resilient Military Systems and the Advanced Cyber Threat* (Washington, D.C.: Defense Science Board, January 2013), available at <http://www.acq.osd.mil/dsb/reports/2010s/ResilientMilitarySystemsCyberThreat.pdf>.

¹⁶¹ A recent official appointment by China indicates how closely the relationship is between cyber threats and space. There is significant concern in the Defense Department about the use of Lenovo computer and other digital products within the Department, that they may be used to facilitate cyber intelligence-gathering against classified and unclassified systems by covertly communicating with remote users. Roughly 27% of Lenovo Group Ltd. is owned by the Chinese Academy of Science. In April 2016, a space expert from the Academy was appointed to a senior post in the Chinese military's Strategic Support Force, which is in charge of space, cyber, and electronic warfare. Bill Gertz, "Military Warns Chinese Computer Gear Poses Cyber Spy Threat," *The Washington Free Beacon*, October 24, 2016, available at <http://freebeacon.com/national-security/military-warns-chinese-computer-gear-poses-cyber-spy-threat/>.

mechanics, U.S. satellites have to circle the globe, so that an EMP released anywhere in the world might affect U.S. military, civil, or private space systems. A key conclusion of the EMP commission report was that, “A determined adversary can achieve an EMP attack capability without having a high level of [technical] sophistication.”¹⁶²

An electromagnetic pulse generated by a high altitude nuclear explosion, the effects of which we do not fully understand, could have a devastating impact on the entire country if the weapon had a yield in the megaton range or was an enhanced EMP design.¹⁶³ Its destructive consequences could reverberate around the world. There is strong evidence to support the belief that electromagnetic pulses produced by a nuclear weapon would interact with the atmosphere and earth’s magnetic field, propagating on a line of sight to the horizons, potentially covering hundreds of miles at the speed of light.¹⁶⁴

Experts who have looked at this question have concluded that an EMP from a nuclear detonation, which would produce enhanced radiation effects, may generate immediate and long-term damaging effects on many satellites.¹⁶⁵ By some estimates, the radiation vulnerability of satellites from a nuclear attack is a medium to low risk (much of this depends on whether the satellite is hardened against such an attack), while the vulnerability to EMP attack of general purpose forces and critical infrastructure is much higher.¹⁶⁶ Nevertheless, the potential threat to space systems is very real, and the collateral damage to satellites has been measured and studied following more than a dozen high altitude nuclear detonations that took place between 1958 and 1963. In the wake of just one of those tests, Starfish Prime, in July 1962, at least eight satellites (U.S., Canadian, and British) suffered damage.¹⁶⁷

The risk of not taking this threat seriously is simply too great to ignore, especially given what we have learned can happen to electronics in the wake of a natural EMP that results from massive solar flares.¹⁶⁸ Any state (or non-state actor) with access to missile lift technology and nuclear weapons miniaturized to sit atop the missile, would have a capability to inflict radiation damage to a host of unprotected satellites in low earth orbit, including commercial satellites that support a wide array of military communications needs. The Russians have reported that their “brain-drain”

¹⁶² “Abstract” in *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Volume 1: Executive Summary*, http://www.empcommission.org/docs/empc_exec_rpt.pdf.

¹⁶³ According to Ambassador Henry Cooper, Russian (former Soviet) Generals and EMP experts in 2004 told EMP Commissioners they had passed how to build a “Super EMP” weapon to North Korea and we could expect them to build one—13 years ago. He also noted that the Russians did better over-land HEMP testing in the early 1960s than did the United States. Author interview with Ambassador Henry Cooper, May 19, 2017. See also Testimony of Ambassador Henry F. Cooper before the Senate Energy and Natural Resources Committee, “On Protecting the Electric Power Grid,” May 4, 2017.

¹⁶⁴ “Statement by Dr. Lowell Wood,” House Armed Services Committee, July 22, 2004, <http://www.house.gov/hasc>. You have the option of selecting a detonation point or altitude that will impact satellites but not ground area if you want to use it purely as an ASAT weapons. A burst over Omaha at 100 to 200 miles altitude would have a nationwide effect.

¹⁶⁵ Edward E. Conrad, et al., *Collateral Damage to Satellites from an EMP Attack* (Fort Belvoir, VA: Defense Threat Reduction Agency, August 2010), DTRA-IR-10-22, p. 1, available at <http://www.dtic.mil/docs/citations/ADA531197>.

¹⁶⁶ Joint Defense Science Board/Threat Reduction Advisory Committee, *The Nuclear Weapons Effects National Enterprise* (Washington, D.C.: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics), June 2010, p. 14, available at www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA523661.

¹⁶⁷ Conrad, et al., *Collateral Damage to Satellites from an EMP Attack*, op. cit., pp. 11-15.

¹⁶⁸ Paul Bedard, “Massive solar flare narrowly misses Earth, EMP disaster barely avoided,” *The Washington Examiner*, July 31, 2013, available at <http://www.washingtonexaminer.com/massive-solar-flare-narrowly-misses-earth-emp-disaster-barely-avoided/article/2533727>. Such an event occurred in Canada in 1989.

helped the North Koreans develop EMP weapons, which may be launched using a Scud missile from a freighter off the U.S. coast or the new sea-launched ballistic missile.¹⁶⁹

The detonation of a single nuclear weapon over the United States, depending on the location, yield, design, and height of the burst, could literally wreck critical infrastructure, most of which is unhardened, and indirectly kill U.S. citizens. Looking at a worst case scenario, the resulting electromagnetic shock could shut down or severely disrupt regional electrical power grids and force sections of the nation to rely on 19th century technologies.¹⁷⁰ The interdependent telecommunications, transportation, food production, banking and financial infrastructures and emergency services could be significantly damaged. This situation could jeopardize the very viability and political underpinnings of the nation and leave the country exposed to follow-on or new threats and attacks.

It is standard in the space business to harden satellite payloads to survive the natural space radiation environment (radiation that is produced by cosmic rays, direct solar emanations, and particles trapped by earth's magnetic field in the Van Allen belts). Nevertheless, there is a virtual certainty that any satellite that is unhardened against EMP and exposed to an EMP detonation would be damaged or completely knocked out. While the United States may view the private commercial satellite operators who operate communications sites in LEO as offering sufficient redundancy and capacity to fend off ASAT attacks, an EMP burst over a particular region might have a mass-casualty effect by making it difficult for these same systems to operate reliably. Many military satellites are hardened to withstand the effects of an EMP attack. Unfortunately, as most businesses judge the likelihood of an EMP attack to be very low on the spectrum of risks, most commercial satellites do not have the required protections to withstand an attack. From a business standpoint in a highly competitive space market, hardening a satellite would add considerable cost to the system, reduce benefits, limit booster payloads, and seriously undermine their competitive position.¹⁷¹

The concern is that the United States still has not made adequate headway in implementing recommendations made by the Commission to Assess the Threat to the United States from Electro-magnetic Pulse attack, recommendations that included hardening of power plants, electrical transmission and distribution lines, and telecommunication and transportation systems. The result is that the United States is still vulnerable to EMP attack from space. Defense professionals are concerned that North Korea could miniaturize its nuclear weapons sooner than some expect and that North Korea could use such a weapon without first testing it.¹⁷² Nuclear-armed satellites in such an orbit would evade U.S. missile defense radars as they orbited over

¹⁶⁹ R. James Woolsey, "U.S. National Missile Defense and the Growing Threat: Is a Limited Defense Enough?," 113th U.S.

Congress, House Armed Services Committee, July 23, 2014, p. 2, available at

<http://docs.house.gov/meetings/AS/AS29/20140723/102528/HHRG-113-AS29-Wstate-WoolseyJ-20140723.pdf>. See also R. James

Woolsey and Peter Vincent Pry, "The Growing Threat From an EMP Attack," *The Wall Street Journal*, August 12, 2014, available at <https://www.wsj.com/articles/james-woolsey-and-peter-vincent-pry-the-growing-threat-from-an-emp-attack-1407885281>.

¹⁷⁰ See, for example, John Foster, Jr., et al., *Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack, Volume 1: Executive Report*, Report to Congress (Washington, D.C: EMP Commission, 2004), available at http://empreport.ida.org/EMPCExecRpt_FinalToSandS.pdf.

¹⁷¹ Conrad, et al., *Collateral Damage to Satellites from an EMP Attack*, op. cit., pp. 2, 4.

¹⁷² R. James Woolsey and Peter Vincent Pry, "The miniaturization myth," *Washington Times*, April 24, 2016, available at <http://www.washingtontimes.com/news/2016/apr/24/r-james-woolsey-peter-vincent-pry-obama-wrong-on-n/>; R. James Woolsey and Peter Vincent Pry, "Don't Underestimate North Korea's Nuclear Arsenal," *The Wall Street Journal*, February 27, 2017, available at <https://www.wsj.com/articles/dont-underestimate-north-koreas-nuclear-arsenal-1488239693>.

the United States.¹⁷³ The United States currently does not orient its missile defense radars to pick up objects approaching the country from the south.

Space Debris

This monograph is chiefly concerned about counter-space operations, that is, deliberate efforts to disrupt or destroy U.S. space systems. Orbital debris is a concern, to be sure, for all space systems, and especially manned space systems. Efforts can be made to prevent it, reduce it, or avoid it.

Given its dependency on satellites, the United States must concern itself with the proliferation of space debris in all orbits. Space debris consists of dead satellites, used booster stages and rocket motors, and various smaller parts that may have broken off from these pieces of debris. Travelling at 17,500 miles per hour, even small pieces of debris following impact can terminate a satellite's function. Two incidents alone created thousands of pieces of debris in low earth orbit, the 2007 Chinese destructive ASAT demonstration using its own defunct weather satellite, which is said to have created more than 4,500 pieces of space debris, and the accidental collision in 2009 of a Russian satellite Cosmos 2251 and a U.S. commercial Iridium satellite. Clearly a kinetic war in space could lead to the proliferation of space debris and would be a major concern to the United States.

The problem and the challenge of space debris is that it persists in orbit for a long time. Debris in LEO, roughly 99 miles to 1,200 miles altitude, will over time get pulled into the destructive atmosphere by earth's gravity and burnup upon reentry.¹⁷⁴ At higher altitudes, debris can remain for decades or centuries. Currently the majority of the world's satellites operate in LEO, including remote sensing and reconnaissance satellites operated by U.S. intelligence services and the military. It is also true that space is a big place, which may explain why, despite the fact that the United States tracks over 23,000 items over 10 centimeters wide, and that there are over 500,000 even smaller pieces of debris that are not being tracked today, we do not hear about satellite collisions with debris on a regular basis.

¹⁷³ Barbara Hollingsworth, "GAO Report: US Still Not Prepared for Possible EMP Attack," *CNS News*, May 3, 2016, available at <http://www.cnsnews.com/news/article/barbara-hollingsworth/gao-report-us-remains-vulnerable-emp-attack>; and, F. Michael Maloof, "EMP alert: 2 N. Korean satellites now orbit over U.S.," *WND*, April 24, 2016, available at <http://www.wnd.com/2016/04/emp-alert-2-n-korean-satellites-now-orbit-over-u-s/>.

¹⁷⁴ There is, of course, a very big difference between 99 and 1,200 miles in terms of how long satellites or debris will stay in orbit.

Chapter 3: Protecting and Exercising U.S. Space Power

There really is no such thing as war in space, it's just war. But war can extend into space, and it isn't a stretch to imagine how a terrestrial conflict can migrate into space.¹⁷⁵

--Chief of Staff, Air Force, General David Goldfein, February 2017

The U.S. space infrastructure, which enables a global U.S. presence and the rapid projection of power, reflects its national strategic character. The U.S. armed forces have long sought the acquisition of capabilities to overcome distance and time to be ready for action half way around the world on short notice to defend national interests. Space force enhancement capabilities help the United States overcome these limitations which, in turn, make U.S. forces reliant on space to carry out their power projection missions.

Use of complex and very expensive Cold War-era strategic space systems by the United States has grown and evolved since Desert Storm where, for the first time, the United States used networked command and control, overhead reconnaissance and precision navigation platforms to its advantage in battle. Space will grow in importance as U.S. forces continue to integrate space and digital systems into warfighting operations in order to achieve even greater efficiencies. No other country has such a reliance on space assets. Although it clearly gains advantages from exploiting space, China is in a better position to rely on terrestrial assets, if need be, to accomplish many of its strategic goals in the Asia-Pacific region. Russia also is less reliant on space systems to pursue its military and strategic goals in Europe and the Middle East; although, as discussed above, it has leveraged space to achieve greater military efficiencies in battles outside its national borders in the absence of any ASAT threat from the United States.

U.S. technological superiority makes possible the advantages it enjoys in space.¹⁷⁶ The Pentagon public space budget is roughly \$22 billion a year. "Space is not just an enabler for the other operational domains," argues General John Hyten, former Commander of Air Force Space Command and the current Commander of U.S. Strategic Command, "it directly impacts the calculus of national security."¹⁷⁷ Says General Hyten, "There is no soldier, sailor, airman, Marine, anywhere in the world that is not critically depending on what we provide in space."¹⁷⁸ For today's warfighter, there is no replacement or alternative for space systems.

U.S. Response to Space Threats

The change in the security environment has altered the calculus for the use of space, which used to be performance prioritized over protection of space systems. Since 2014, the U.S. Department

¹⁷⁵ Sandra I. Erwin, "Military Rethinking How to Wage Space Wars," *National Defense Magazine*, February 27, 2017, available at <http://www.nationaldefensemagazine.org/blog/Lists/Posts/Post.aspx?ID=2426>.

¹⁷⁶ This view of U.S. technological superiority in space must be tempered by the reality that the country lacks a heavy lift capability and is currently reliant on Russian engines for this capability.

¹⁷⁷ General John E. Hyten, "National Security Space Budget for FY17: Presentation to the Subcommittee on Strategic Forces," *115th U.S. Congress*, House Armed Services Committee, March 15, 2016, p. 2.

¹⁷⁸ Phillip Swarts, "Space Wars: The Air Force Awakens," *Air Force Times*, February 15, 2016, available at <https://www.airforcetimes.com/story/military/2016/02/15/space-wars-air-force-awakens/79804228/>.

of Defense has experienced what some have called a “counter-space awakening,” essentially a response to recent Chinese and Russian anti-satellite activities. This transformation has taken place in the public eye, rather than behind the traditional closed doors of the defense space community, in part, no doubt, to serve as a warning to other countries that may seek to interfere with U.S. space systems. It is widely stated that China’s 2013 missile shot near geosynchronous orbit was the inciting incident because of the apparent ASAT linkage. The Commander of U.S. Strategic Command had concerns about the ability of the country “to move fast enough to build those capabilities [to defeat adversaries who threaten the United States in space] that we need to respond to the specific threats.” He went on to report that “we’re moving much slower in certain areas than our adversaries. We need our industry and our acquisition process to move faster.”¹⁷⁹

With counter-space threats on the rise, in 2014, the Air Force and the Defense Department conducted a comprehensive Space Strategic Portfolio Review. In 2015, the U.S. Air Force completed a Space Situational Awareness review that focused on critical security issues and has since taken steps to prepare for a time when space will be contested by a foreign power. According to one DoD official in 2016, “[t]he rapid evolution and expansion of threats to our space capabilities in every orbit regime has highlighted ... an asymmetric disadvantage due to the inherent susceptibilities and increasing vulnerabilities of these systems.”¹⁸⁰

In April 2016, the Air Force Space Command announced the completion of the Space Enterprise Vision (SEV), jointly developed by the command and the National Reconnaissance Office. Wrote General Hyten at the time of the release: “Most U.S. military systems were not designed with threats in mind, and were built for long-term functionality and efficiency, with systems operating for decades in some cases.”¹⁸¹ The old approach did not take threat into account and assumed a benign space environment.

In an effort to reorient thinking on this subject and build resiliency into the space enterprise by 2030, the SEV speaks to the importance of an integrated approach across all U.S. space activities to develop resilient architectures that deliver “space mission effects” to the warfighter as well as the ability to defend space assets against threats: resilience and space mission assurance. According to Air Force Space Command, on-orbit challenges, adversary threats, CONOPS, and friendly force readiness will be used to assess U.S. space enterprise mission assurance.¹⁸² The concepts of operation are to be “matured through analysis and wargames, and inculcated into operating forces through training and exercises.”¹⁸³ The vision involves seeing space capabilities as an enterprise, sharing information and data, doing command and control from common ground services among all parties (including international partners). It involves keeping up with technological advances and the threat by doing things such as building smaller satellites, with

¹⁷⁹ General John E. Hyten, *Hearing on the Nomination of General John Hyten to be Commander of U.S. Strategic Command*, 114th U.S. Congress, Senate Armed Services Committee, September 20, 2016, p. 20, available at https://www.armed-services.senate.gov/imo/media/doc/16-70_9-20-16.pdf.

¹⁸⁰ Dyke Weatherington, “Testimony before the House Committee on Armed Services, Subcommittee on Strategic Forces,” 115th U.S. Congress, March 15, 2016, p. 3, available at <http://docs.house.gov/meetings/AS/AS29/20160315/104620/HHRG-114-AS29-Wstate-WeatheringtonD-20160315.pdf>.

¹⁸¹ Air Force Space Command Public Affairs, “Hyten announces Space Enterprise Vision,” *AF.mil*, April 13, 2016, available at <http://www.af.mil/News/ArticleDisplay/tabid/223/Article/719941/hyten-announces-space-enterprise-vision.aspx>.

¹⁸² Written responses provided by Air Force Space Command, March 31, 2017.

¹⁸³ Air Force Space Command, “Space Warfighting Construct,” Handout produced April 2017, available at <http://www.afspc.af.mil/Portals/3/documents/Space%20Warfighting%20Construct%20Handout%20-%203%20Apr%202017.pdf?ver=2017-04-05-191055-757>

three to five year life spans, that are launched more frequently.¹⁸⁴ The SEV is an effort to take a comprehensive approach to create an environment where the armed forces and the private sector can collaborate and share ideas on designing interoperable architectures that can be modified as threats change. One area where industry can contribute significantly is in the area of data analysis, sifting through the mountains of data delivered daily by U.S. space systems.¹⁸⁵ All of this will be achieved through partnerships within the U.S. government (Department of Defense, Intelligence Community, and civil space organizations), allies, and the commercial sector.¹⁸⁶

In June 2017, the Air Force announced it had created a senior military position to oversee space missions, putting it on an equal footing with the Air Staff. The purpose of this new three-star position is to better integrate, normalize and elevate space operations within the Air Force. It is intended to increase decision-making speed and assist the Air Force in this evolving security environment to protect against hostile counter-space operations and ensure freedom of movement in space.¹⁸⁷

Today, concerns about foreign counter-space efforts of states that already pose a threat, including China and Russia, and new actors, continue to rise. According to Air Force Major General Nina Armagno (Air Force Space Command), "Russia and China, by the year 2025, will be able to hold at risk every one of our satellites in any orbit."¹⁸⁸ Admiral Cecil Haney, former Commander of U.S. Strategic Command, noted in August 2016 that he expects an "increase in the number of nations who may wish to deny the peaceful use of space."¹⁸⁹

Over the last few years the United States has taken steps to improve the resiliency of its space systems, including disaggregation, distribution, diversification, protection, proliferation, and deception (all of which are well-understood passive defense techniques). Disaggregation efforts involve leveraging allied and commercial assets, or essentially attempting to eliminate a single point of failure. It improves survivability by removing single centers of gravity in space, increasing the number and diversity of potential targets. The more recent shifting of tactical communications to commercial SATCOM operating in LEO, such as Iridium and Globalstar, exploits the distributed nature of these systems and the cross-linking that takes place in the Iridium constellation to provide some protection against deliberate jamming attempts to shut the United States out of specific regions.

SpaceX reportedly has plans to deploy 4,425 satellites in LEO to provide global internet coverage.¹⁹⁰ The U.S. Department of Defense is deploying Mobile User Objective System (MUOS), a global cellular service to support the warfighter with cellphone-like capabilities, which gives warfighters a tactical capability to operate in disadvantaged environments, such as heavily

¹⁸⁴ Interview with Maj Gen Nina Armagno, Air Force Space Command, February 27, 2017.

¹⁸⁵ Erwin, "Military Rethinking How to Wage Space Wars," op. cit.

¹⁸⁶ Air Force Space Command, "Space Warfighting Construct," Handout produced April 2017, op. cit.

¹⁸⁷ Oriana Pawlyk, "Preparing for War in Space, Air Force Reshuffles Leadership Team," *DoDbuzz.com*, June 16, 2017, available at: <https://www.dodbuzz.com/2017/06/16/preparing-for-war-in-space-air-force-reshuffles-leadership-team/>

¹⁸⁸ Cheryl Pellerin, "Advanced Space Surveillance Telescope Has Critical Military Applications," *Defense.gov*, October 22, 2016, available at <https://www.defense.gov/News/Article/Article/983007/advanced-space-surveillance-telescope-has-critical-military-applications>.

¹⁸⁹ Mike Gruss, "Haney: JICSpOC will prove U.S. is prepared for space threats," *Space News*, August 16, 2016, available at <http://spacenews.com/haney-jicspoc-will-prove-u-s-is-prepared-for-space-threats/>.

¹⁹⁰ Arjun Kharpal, "SpaceX wants to launch 4,425 satellites into space to bring super-fast internet to the world," *CNBC.com*, November 17, 2016, available at <http://www.cnbc.com/2016/11/17/spacex-wants-to-launch-4425-satellites-into-space-to-bring-super-fast-internet-to-the-world.html>.

forested regions. There are four MUOS operational satellites and four ground stations, one each in Australia, Italy, and the states of Hawaii and Virginia. This is inherently more robust and safe when compared to concentrating communications traffic through a more distant satellite node in GEO. The U.S. Air Force is also attempting to facilitate international space collaboration to improve resilience by increasing supply diversity. Said one Air Force spokesman, “[i]f we can move between our own milsatcom capabilities, commercial capabilities and allied capabilities, it makes it difficult for our adversaries to know where we are.”¹⁹¹

Disaggregation also protects space systems against natural threats and space debris. Another benefit of disaggregation is that it allows systems to be less complex (and less costly and able to be developed in less time), since one platform would no longer have to be host to multiple strategic and tactical missions. The Air Force has identified numerous advantages for this approach.¹⁹²

Disaggregation can raise the uncertainty in the enemy’s mind that he will be successful. This is old fashioned passive defense, which is also known as deterrence by denial. It is hoped that these efforts will complicate the adversary’s mission of impeding U.S. access to space and thereby neutralize the unparalleled advantages the United States armed forces enjoy in space. So, for example, instead of relying on just one or two highly advanced intelligence satellites, the United States could leverage multiple commercial and allied imaging satellites.¹⁹³ It also could use different orbits to improve overall surveillance coverage when new satellites are launched. Despite the evolution in thinking that survivability in space would be helped by dispersing critical strategic and tactical satellite functions among many platforms, the United States still depends on large, expensive satellites to support warfighting and inform senior leaders for space-based imagery and signals intelligence, high resolution imagery for reconnaissance, the positioning, navigation and timing provided by the GPS constellation, global communications and global command and control of military forces from military and commercial satellite sources, and meteorological data.

In the future, the U.S. armed forces may choose to depend on commercial operators for remote sensing, Digital Globe, Skybox, and Planet Labs.¹⁹⁴ The United States plans to incorporate lower resolution commercial satellites into its architecture, expanding and improving its surveillance and reconnaissance network. Digital Globe sells imagery up to the U.S. legal limit of 30 centimeters, which reportedly is about the resolution of Russia’s current fleet of reconnaissance satellites.¹⁹⁵ The capability in the commercial world clearly is there. Exploitation of low-resolution commercial alternatives would free up the fleet of extremely high-resolution satellites to obtain more detailed pictures of sites of special interest on earth in addition to providing some valuable redundancy. The United States has the capability to stay in constant contact with these satellites, a capability that keeps it ahead of its technologically advancing rivals. The use of diverse satellites that

¹⁹¹ Quote is from Deanna Ryals, chief of the international military satellite communication division at the U.S. Air Force’s MilSatCom Systems Division. Peter B. de Selding, “U.S. defense officials say partnership with allied satcom systems is a priority,” *Space News*, November 10, 2016, available at <http://spacenews.com/u-s-defense-officials-say-partnership-with-allied-satcom-systems-is-a-priority/>.

¹⁹² For example, see, Air Force Space Command, *Resiliency and Disaggregated Space Architectures*, White Paper, FAS.org, 2013, available at <https://fas.org/spp/military/resiliency.pdf>.

¹⁹³ David Axe, “Vladimir Putin Plots a New Fleet of Spies in Space,” *The Daily Beast*, August 8, 2016, available at <http://www.thedailybeast.com/articles/2016/08/08/vladimir-putin-plots-a-new-fleet-of-spies-in-space.html>.

¹⁹⁴ Bob Work, “Remarks at the Space Symposium,” Colorado Springs, Colorado, *Defense.gov*, April 12, 2016, available at <https://www.defense.gov/News/Speeches/Speech-View/Article/723498/remarks-at-the-space-symposium>.

¹⁹⁵ Axe, “Vladimir Putin Plots a New Fleet of Spies in Space,” op. cit. The article quotes space analyst Brian Weeden who believes, “the U.S. still has a pretty sizable advantage at least qualitatively, if not quantitatively.”

expands to international partners would mean that, should an adversary wish to expand the fight to include allied satellites, there would be a steeper political price to pay since an attack on many could result in a stronger coalition of forces to oppose the aggressive forces.

Space Situational Awareness

In 2014, Deputy Secretary Work made space a priority, saying in a private meeting as recollected by General Hyten, that “if, God forbid, someday a conflict does extend from the Earth to space, what are you going to do about it.”¹⁹⁶ If the country is going to fight in space, its leaders are going to have to see what is happening in space. The United States is moving towards capabilities to provide persistent surveillance of the space environment, which is required and absolutely necessary to detect, track, collect, disseminate, and characterize threat activity in all orbits. The nation has terrestrial and space systems that provide what defense officials call space situational awareness, or SSA. SSA is critical to defensive and offensive counter-space operations and is essential to space deterrence strategy.

The Joint Space Operations Center currently tracks about 23,000 objects in orbit. Space Fence, an Air Force system based at Kwajalein in the Pacific Ocean and scheduled to be operational in 2018, will be part of a layered space sensor architecture (terrestrial and space) that will allow better tracking of near-earth orbit debris in space, improving the ability to catalogue space objects from 23,000 to over 200,000 tracked objects.¹⁹⁷ The Air Force Space Fence uses ground-based radars to significantly improve the detection of space objects when compared to what was available from the existing Space Surveillance Network. It is intended to produce thousands of observations a day, track surprise events in space (such as threatening satellite maneuvers), and cover almost all orbital inclinations. This new capability will give visibility to unforeseen events, to include satellite maneuvers, and enable warfighters to search space to determine what an object is. This type of SSA capability, and the ability to share data with the intelligence community, commercial entities, and allied nations, is essential to any plan to employ or protect U.S. space assets. The United States also uses a Self-Awareness Space Situational Awareness system that reportedly enables operators to identify the source of a laser attack on its satellites.¹⁹⁸

Geosynchronous orbit is home to critical communications and early warning satellites. To increase space situational awareness in this region, the U.S. Defense Department launched two Geosynchronous Space Situational Awareness Program (GSSAP) satellites to undertake a sort of “neighborhood watch.” These satellites will monitor GEO above and below this belt to capture close-up views of events, to include the deployment of space mines and other capabilities to destroy satellites.¹⁹⁹ They will have enhanced maneuverability and be capable of rendezvous

¹⁹⁶ Ibid.

¹⁹⁷ David J. Buck, “Statement of Lieutenant General David J. Buck, Commander, Joint Functional Component Command for Space,” *115th U.S. Congress*, March 15, 2016, pp. 5-6.

¹⁹⁸ Omar Lamrani, “What the U.S. Military Fears Most: A Massive Space War,” *The National Interest*, May 18, 2016, available at <http://nationalinterest.org/blog/the-buzz/what-the-us-military-fears-most-massive-space-war-16248>.

¹⁹⁹ James Dean, “Delta IV blasts off with threat-detecting military satellites,” *Florida Today*, August 19, 2016, available at <http://www.floridatoday.com/story/tech/science/space/2016/08/19/deltaiv-rocket-blasts-off-air-force-satellites-cape-canaveral-air-force-station-afspc6/88826330/>.

and proximity operations for the collection of intelligence.²⁰⁰ Two more satellites in this four satellite constellation were launched in August 2016.

The purpose of the satellites, according to General Hyten, is to tell the world that “anything you do in the geosynchronous orbit we will know about. Anything.”²⁰¹ GSSAP satellites can give the Air Force a heads up should an adversary decide to target a GEO satellite. Reportedly, an attack by a direct-ascent ASAT weapon would take four to six hours to reach that altitude, giving satellite operations critical time in which to react.²⁰² They can also inspect satellites experiencing problems and help determine whether the problems are accidental, caused by natural phenomenon, or caused by a potential adversary. GSSAP acts as a deterrent to bad behavior and can help in the effort to maintain a safe, secure, and stable space environment.

As a leader in space, the United States shares space situational awareness information with other nations and commercial firms in order to reduce the chance of collisions. Sharing with other nations also builds U.S. data bases to strengthen U.S. awareness. The United States recently expanded its Combined Space Operations concept to include New Zealand, which represents the U.S. effort to improve SSA through enduring partnerships. Long-term goals are to integrate and leverage combined capabilities to support global synchronized operations, which require interoperable battle management command and control systems. A converted space launch tracking radar has been deployed to Western Australia to watch the southern hemisphere. The U.S. Air Force recently activated one of its most sophisticated sensors, the Space Surveillance Telescope, which is a dedicated sensor in Australia and part of the Space Surveillance Network. The telescope reportedly is capable of searching an area in space larger than the continental United States and viewing more than 10,000 objects as small as a softball.²⁰³

Early warning satellites are required to detect ballistic missile launches. The United States still relies on the 1970s Defense Support Program (DSP) satellites, which work in tandem with the more recent Space Based InfraRed System (SBIRS) satellites parked in GEO and inserted into Highly Elliptical Orbit (HEO). These satellites provide Overhead Persistent Infrared surveillance to give early warning of missile launch events (ballistic missile, space launch, or missile-boosted ASAT), including in the territories of Russia, China, North Korea, and Iran. In September 2016, the Pentagon brought online a new Battlespace Awareness Center to process data from these imagery satellites, which helps to give the warfighter persistent global surveillance.²⁰⁴ SBIRS satellites, aside from the ability to detect ballistic missile launches, also have the ability to pick up heat signatures from small explosions and large fires, and they reportedly have been used successfully to provide intelligence on Islamic State positions in Iraq and Syria by detecting the heat signatures of explosions and combining this information with other electronic and signals intelligence and video.²⁰⁵

²⁰⁰ General William Shelton as quoted in, Atlantic Council, “Transcript: The US Future in Space,” *Atlantic Council*, July 23, 2014, available at <http://www.atlanticcouncil.org/news/transcripts/transcript-the-us-future-in-space>.

²⁰¹ Gruss, “Haney: JICSpOC will prove U.S. is prepared for space threats,” op. cit.

²⁰² Swarts, “Space Wars: The Air Force Awakens,” op. cit.

²⁰³ Pellerin, “Advanced Space Surveillance Telescope Has Critical Military Applications,” op. cit.

²⁰⁴ Tamir Eshel, “SBIRS Satellite Provide ‘Unblinking Eyes,’ Constantly Monitoring Hotspots Worldwide,” *Defense Update*, October 31, 2016, available at http://defense-update.com/20161031_sbirs.html.

²⁰⁵ Anthony Capaccio, “Islamic State Positions Tracked by U.S. Satellites as a Bonus,” *Bloomberg*, October 6, 2016, available at <https://www.bloomberg.com/news/articles/2016-10-06/islamic-state-positions-tracked-by-u-s-satellites-as-a-bonus-ity445lk>.

The Missile Defense Agency also has expressed the need to have a greater presence in space, to include a space-based sensor layer. According to Vice Admiral James Syring, the former Director, “given where the [ballistic missile] threat is going with hypersonics and more ICBMs and so forth, this persistent tracking and discrimination capability from space is a must.”²⁰⁶ He was referring to the possible deployment of sensors in medium earth orbit. With the upcoming deployment of 22 experimental Space-based Kill Assessment sensors on a network of commercial satellites, the United States will obtain a capability to improve knowledge of what is happening in space, thereby improving stability and increasing the efficiency of the Ballistic Missile Defense System by collecting information that will help operators understand when a ballistic missile warhead has been destroyed.

Reconstituting Space Assets

The first condition necessary for the successful exploitation of space for national security purposes is the ability to provide reliable access to space. “Assured access to space is a prime National Security Space Directive. A fundamental part of assured access to space is safely getting our satellites to orbit, which is extraordinarily challenging and technical.”²⁰⁷ Reconstitution of space assets may be required should there be a need to position satellites over uncovered geographic areas, to overcome interference with satellites that have resulted in an attrition within the architecture (especially if those satellite assets are critical to the warfighting effort), or to execute U.S. counter-space operations (requiring the deployment of assets on orbit) to deny freedom of action to an enemy. It should also be noted that the existence of on-orbit spares for space warfighting missions are also vulnerable to enemy attack in space, as are U.S. spaceports, which operate on both U.S. coasts.

To date the United States has deployed highly advanced systems intended to stay in orbit for a long time—an approach that makes sense in a benign space environment. Yet there is growing recognition within the U.S. Department of Defense that a better approach would involve delivering smaller systems (space and ground systems) in a shorter amount of time that also may have shorter mission timelines and cost significantly less money to develop and launch. Integration across the Intelligence Community and DoD and improved battle management infrastructure also are recognized as needed in the approach to improve responsiveness and architecture resiliency.

To be effective, space force reconstitution must be timely if it is to affect the battle or crisis at hand. This, of course, requires the United States to have the launch capacity and flexibility to execute as well as having the satellite payloads available. The United States is nowhere near where it needs to be to have a truly responsive space reconstitution capability, but there has been some notable progress. Over time, the United States has gradually taken NASA and the Air Force out of the space logistics business and has turned to private industry to take over such missions. Today the U.S. Air Force relies on industry to provide the launch infrastructure, and industry is accordingly investing in the development of new engines, launch vehicles, and associated infrastructure. The cost of launch should come down as a result of competition and innovation

²⁰⁶ Cited in Mike Gruss, “MDA’s Syring: Space-based sensors are a ‘must,’” *Space News*, August 17, 2016, available at <http://spacenews.com/mdas-syring-space-based-sensors-are-a-must/>.

²⁰⁷ Lt Gen Sam Greaves, USAF program executive officer for space, cited in Justin Ray, “Missile warning satellite launch slips into 2017 due to thruster concerns,” *Spaceflight Now*, September 26, 2016, available at <https://spaceflightnow.com/2016/09/26/missile-warning-satellite-launch-slips-into-2017-due-to-thruster-concerns/>.

among private launch providers which, when redundant multiple launch providers is calculated in, also carries the promise of making national launch capabilities more responsive.

To help meet the goal of rapid satellite reconstitution, the United States today has an Operationally Responsive Space Office that plans and prepares for the rapid development of capabilities to deliver satellites to space to support the warfighter.²⁰⁸ Explicit in its mission is the ability to reconstitute assets on orbit that have been lost. The U.S. Operationally Responsive Space Office leverages the miniaturization trend to develop on a faster timeline smaller less complex satellites than those in service today and launch systems that may be used to surge space platforms into orbit. Responsiveness is a key element in resiliency in an era when commercial innovation and the escalating threat suggest that we should no longer rely on an acquisition approach that only deploys expensive, large, complex satellites that take a decade to develop, and are not easily replenished.

The commercial launch market is expanding, with at least 10 rocket companies internationally vying for satellite customers. United Launch Alliance, a Lockheed Martin and Boeing joint venture, has been promoting a new RapidLaunch service that promises the launch of a payload about three months from the placement of the order.²⁰⁹ Space X, which is promoting its reusable Falcon 9 rocket, has been certified to launch U.S. Air Force payloads and, as of late 2016, had approximately 70 missions (private industry and government) on its launch manifest.²¹⁰ Other promising commercial competitors include Blue Origin and Virgin Galactic. Reliability and responsiveness, as well as cost, are likely to be the key ingredients to commercial success.

There also is a growing concern in the United States regarding the U.S. reliance on foreign rocket technology and the impact that dependence might have on the country's ability to place heavy payloads in orbit. The U.S. Atlas V launch vehicle is powered by a Russian rocket engine, which is the only engine in the world right now to do that job.²¹¹ U.S. strategy requires uninterrupted national access to space, which the reliance on the Russian engine undercuts. In a sense, the nation is relying on Russia to maintain its security interests. NASA's contract with Russia extends through June 2020. The vulnerability is clear. In 2014, in response to threatened sanctions, Russian Deputy Prime Minister Dmitry Rogozin openly threatened to withhold the Russian engines. In effect, according to Senator John McCain, "today Russia holds many of our most precious national security satellites at risk before they ever get off the ground."²¹² Similarly, the U.S. manned space program requires the use of Russian spacecraft to deliver humans to the

²⁰⁸ This office is a joint initiative of several DoD agencies that was established in 2007.

²⁰⁹ Samantha Masunaga, "SpaceX faces a more crowded rocket launch market, even when it returns to flight," *Los Angeles Times*, September 15, 2016, available at <http://www.latimes.com/business/la-fi-spacex-competitors-20160914-snap-story.html>.

²¹⁰ As of June 2017, the SpaceX Falcon 9 had accomplished nine consecutive launches with successful landings of the first stage on a drone ship or on land when the company attempted such a landing. Jeff Foust, "SpaceX launches second batch of Iridium satellites," *Space News*, June 25, 2017. Available at <http://spacenews.com/spacex-launches-second-batch-of-iridium-satellites/>

²¹¹ The United States does not have an American-made first-stage liquid rocket engine and has not had one since the decision to end development of rocket engines other than those required by the Space Shuttle. Once the shuttle program was cut back and terminated, the U.S. manufacturers and suppliers were no longer in a position to begin a new development. This unfortunate situation has been (and still is) the result of government and industry making the wrong choices over the course of 45 years. The United States still does not have a program to focus on new technological developments. See Wayne Eleazer, "The engine problem," *The Space Review*, August 3, 2015, available at <http://www.thespacereview.com/article/2799/1>.

²¹² Nenad Drca, "The Mighty Have Fallen: American Space Dependency on Russia," *Modern Diplomacy*, May 27, 2016, available at http://moderndiplomacy.eu/index.php?option=com_k2&view=item&id=1454:the-mighty-have-fallen-american-space-dependency-on-russia&Itemid=642.

space station in low-earth orbit. Building launch capacity and capability in the private sector should help solve this problem as well.

Countering Enemy Satellites—Space Control

Each of the U.S. Armed Services receives daily intelligence estimates on the status of adversarial space systems and the threats they may pose. Each Service is also responsible for developing denial and deception countermeasures and operations security for dealing with threats posed by enemy satellites. While methods for dealing with enemy satellites are classified, one can presume that warfighters will practice reconnaissance satellite avoidance operations and undertake technical camouflage measures (such as camouflage netting for land vehicles). It is also possible to take advantage of weather conditions to disguise operations on the ground, avoiding detection by many imagery satellites. These are mostly passive means for dealing with the threats posed by adversary satellites.

More active measures might include radio-frequency telemetry jamming between satellites and ground stations. Cyber warfare may be used to crack a satellite's control signal encoding and encryption. Low power laser dazzling is another method for obscuring what an adversary can see from space. There are also weapons that may be placed in space, such as co-orbital jammers and lasers for dazzling. Then, if things get heated on the battlefield, it may be possible to use lethal force to include kinetic and directed energy weapons to eliminate the threatening satellites. Space-based interceptors for missile defense, if developed and deployed, could also be used in extreme situations as a space control weapon. It may be possible to develop on-orbit disabling or capturing technologies to neutralize a particular satellite.

Today space control capabilities are very limited or at least not very public. This is particularly true with regard to kinetic capabilities. The capabilities currently in the national arsenal would not appear to pose a great risk to enemy satellites, though there is little doubt that the currently operative space control squadrons would be able to cause some disruptive effects.²¹³ There is the Counter-Satellite Communications System to disrupt satellite communications signals using a mobile jammer; reportedly there are at least seven of these systems now available for deployment. The United States would also be capable of using terrestrial radio transmitters to beam high-power radio "noise" at selected satellites to jam their receivers.²¹⁴ Ground-based lasers (especially if they are mobile) would be useful in dazzling enemy optics in space. The United States already uses fixed low-power lasers to track satellites, but these would not be useful in combat for the space denial mission since they are fixed assets that could not be moved to optimal locations to target specific satellites.

The United States has had the capability to destroy low-earth orbit satellites since the F-15 fighter demonstration in 1985, when it destroyed an old military satellite. Although it is not their mission and the use of a kinetic kill capability would cause considerable debris in orbit, currently deployed

²¹³ Eric Heginbotham, et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996-2017* (Santa Monica, CA: RAND Corporation, 2015), pp. 238-41.

²¹⁴ Heginbotham, et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996-2017*, op. cit., p. 235. The study reports that the mobile ground-based, reversible effects program Counter Surveillance Reconnaissance System, which was intended to deny the ability of enemy satellites to collect imagery on U.S. forces, was cancelled following its termination by the Air Force and funding cuts by the Congress in 2004.

missile defense interceptors with sufficient range may be used in emergency situations to take out enemy satellites.

The United States demonstrated this capability in February 2008 when it modified a Standard Missile-3 missile defense interceptor launched from an Aegis Ballistic Missile Defense ship to destroy in very low earth orbit a non-functioning, out of control, but fully fueled U.S. government payload about to reenter earth's atmosphere. The uncertainty of when and where the satellite would reenter and the near certainty that the fuel tank would survive reentry made this an urgent mission. The successful intercept of the satellite occurred, by design, at a very low altitude where its destruction would not add to orbital debris. This joint mission prevented the possible dispersal of toxic hydrazine fuel over a populated area as the satellite reentered earth's atmosphere. Officials at the time made it clear that this operation did not represent an operational anti-satellite capability; it did not represent the responsive and robust capability that would be needed to attack enemy space assets in wartime.²¹⁵

As this one-time counter-satellite mission demonstrated, it is possible to utilize current missile defense capabilities in a critical national security situation to control space. Given the 2008 mission, it is also highly probable that the existing interceptor and weapon system capabilities would have to be modified to undertake such a non-standard intercept mission, which means these current capabilities would only be used in extraordinary situations. They do not represent a responsive capability.

Moreover, given the range of current missile defense interceptor capabilities, intercept would likely have to occur in very low to low earth orbit. The Standard Missile-3 Block IA and IB and the Terminal High Altitude Area Defense, or THAAD, interceptors would have this inherent capability and could be modified for the mission to intercept in very low earth orbit. The longer-range Standard Missile-3 Block IIA currently under development with Japan for deployment on Aegis BMD ships and at Aegis Ashore sites in Romania and Poland, as well as the Ground Based Interceptors emplaced at Fort Greely, Alaska and Vandenberg, Air Force Base in California, for homeland defense could also be modified for the counter-space mission. These interceptors would have a greater range and could probably reach further into LEO where imaging, ocean surveillance, and weather satellites are deployed, among other satellites. This is, however, not their primary mission.

The country has made impressive strides in the development of hit-to-kill technologies. Nevertheless, there is a push to unleash the truly game-changing possibilities of directed energy weapons for missile defense and, one might add, counter-space missions. Directed energy weapons on airborne or space-based platforms could offer the capability and opportunity to destroy offensive missiles when they are most vulnerable, in the boost phase soon after launch, or in the lower reaches of space. A mobile platform would be capable of deploying to any area of interest worldwide and provide an immediate deterrence and defensive capability. In 2010, the Airborne Laser accomplished two historic kills of boosting missile systems at a California test range, demonstrating the feasibility of the concept. The United States has had no plans for boost

²¹⁵ For example, see MDA Director Lt Gen Henry A. Obering, "Lieutenant General Henry A. Obering III, USAF, Director, Missile Defense Agency, Prepared Statement," *110th U.S. Congress*, House Armed Services Committee, April 17, 2008, pp. 3-4, available at <http://www.dod.mil/dodgc/olc/docs/testObering080417.pdf>.

phase missile defense program since the Obama Administration terminated the Airborne Laser and Kinetic Energy Interceptor acquisition programs.

Work on directed energy weapons is being done not only by the Missile Defense Agency, but also by the Services and U.S. international partners. The Army and Marine Corps are testing a high energy fiber optic laser for use against rockets, artillery and mortars. The Navy has deployed a 100-150 kw operational solid state laser on the USS Ponce in 2016 for ship defense. This is the first time a laser weapon is being used in active service. The Air Force plans to further investigate the use of lasers on aircraft and plan to fire directed energy weapons from drones and aircraft in the next decade.²¹⁶

Finally, the United States has been developing a pilotless military space plane. In May 2017, the X-37B space plane that had been in orbit for almost two years was brought back to earth; this was the program's fourth flight.²¹⁷ The Air Force first launched the X-37B in April 2010; these planes are designed to stay in orbit for a year or even longer. The space plane missions are a secret, but it is said to be a platform for testing advanced guidance, navigation and control, thermal protection, avionics, propulsion, autonomous flight, reentry and landing technologies, among other things.²¹⁸ With a payload the size of a truck bed, the plane is a reusable vehicle, and the United States is believed to have two in the fleet. While its payloads and activities are classified, it is possible the plane could be quickly launched and used as a weapon, possibly even to deliver or snatch satellites from orbit or even repair satellites.²¹⁹ The craft, in any case, has successfully tested reusable technologies for flight, re-entry, and landing. Reportedly, DoD (DARPA) is currently moving forward on a new type of spaceplane, one that would ferry satellites into low-earth orbit on a daily basis. This project is expected to debut in 2020.²²⁰

Countering Temporary Space Denial Efforts

The security environment clearly has become more transparent with the proliferation of space imagery. Moreover, growing access to communications and navigation satellite services also will enable the armed forces of the adversary to operate more efficiently. Yet a far greater concern for the U.S. military is the threat posed by counter-space assets.²²¹

Unlike kinetic kill and an EMP burst that would have permanent destructive effects, counter-space operations may involve "reversible effects," such as radio frequency jamming or dazzling (or temporary blinding) using directed energy. High powered lasers, of course, also could be

²¹⁶ Daniel Goure, "DoD Needs To Light A Fire Under Directed Energy Programs," *Lexington Institute*, January 2, 2014, <http://lexingtoninstitute.org/dod-needs-to-light-a-fire-under-de-programs/>; and, NBC News, "Navy unveils powerful ship-mounted laser weapon," *NBC News*, April 8, 2013, available at http://usnews.nbcnews.com/_news/2013/04/08/17658147-navy-unveils-powerful-ship-mounted-laser-weapon?lite.; and, Kris Osborn, "US Air Force Fighters & Drones Will Fire Laser Weapons by the 2020s," *Scout Warrior*, January 5, 2017, available at <http://www.scout.com/military/warrior/story/1666650-best-of-2016-air-force-arms-jets-with-lasers>.

²¹⁷ Marina Koren, "What Is America's Secret Space Shuttle For?" *The Atlantic*, May 9, 2017, available at <http://www.theatlantic.com/technology/archive/2017/05/why-so-secretive/525969/>; Leonard David, "Air Force's X-37B Space Plane Mystery Mission Wings by 500 Days in Orbit," *Space.com*, October 10, 2016, available at <http://www.space.com/34343-x37b-space-plane-otv4-mission-passes-500-days.html>.

²¹⁸ Swarts, "Space Wars: The Air Force Awakens," op. cit.

²¹⁹ Samantha Masunaga, "SpaceX will launch secretive X-37B spaceplane's next mission," *The Los Angeles Times*, June 7, 2017, available at <http://www.latimes.com/business/la-fi-spacex-x37b-20170607-story.html>.

²²⁰ Irene Klotz, "Boeing, DARPA to build prototype spaceplane," *Reuters.com*, May 24, 2017, <https://www.reuters.com/article/us/us-space-boeing-spaceplane-idtUSKBM18K31R>

²²¹ Interview with Maj Gen Nina Armagno, Air Force Space Command, February 27, 2017.

destructive to the optical sensors on satellites. The United States relies on satellites that offer a range of protections against reversible interference tactics. Highly secure, jam-free, and hardened communications satellites (such as the Advanced Extremely High Frequency satellites) for nuclear command and control are essential to security. Commercial satellites provide much of the Defense Department's satellite communications, and yet these are less likely to be highly secure or jam-free compared to the MILSATCOM systems, although some private companies are taking steps to help counter jamming. Air Force Space Command and the Space and Missile Systems Center are developing capabilities that will allow the user to move from MILSATCOM to a commercial SATCOM coverage and then to coverage from a different commercial vendor. This work will add increased jam resistance and flexibility to commercial SATCOM systems.²²² Nevertheless, concerns about the range of destructive and reversible threats to the security of U.S. communications satellites and tactical networks continue to grow. The DoD's Defense Science Board recently issued a report with the following statement:

The estimated projected electronic threats against satellite communications (SATCOM) have rapidly escalated in the last few years and will continue to increase in the foreseeable future. Under severe stress situations, jamming can render all commercial SATCOM and most defense SATCOM inoperable, except for the low-and medium-rate modes of defense extremely high frequency (EHF) SATCOM. This reality should be considered a crisis to be dealt with *immediately*. In addition, network operations in stressed situations can be spotty to non-existent.²²³

The United States is taking steps to counter efforts to temporarily impede the functions of its satellites through the employment of resistant antenna designs, filters, surge arresters and fiber-optic components to counter jamming, dazzling and blinding.²²⁴ System configuration and employment of some satellites, such as U.S. SIGINT (signals intelligence) and ocean surveillance satellites, also help mitigate the risk of radio frequency jamming. Ocean surveillance satellites operate in LEO over wide ocean areas, making them less accessible to potential jammers, which are typically located on land. Also, SIGINT operation in highly elliptical orbit means that these satellites spend only a very brief time at low altitudes above earth and have very long dwell times at very high altitudes over targeted regions, which makes them very difficult to jam. “[U]nlike communications satellites, SIGINT sensors are ‘passive’ in that they quietly monitor signals without transmitting RF energy that would reveal their presence. The highly distributed nature of these sensors, combined with uncertainty about what frequencies any one of them is monitoring at any given time, would complicate efforts to locate and jam them.”²²⁵ Missile launch warning satellites, such as the U.S. SBIRS HEO and GEO satellites, also have received improved protection against lasing to blind or dazzle, to include the installation of sensors that would allow

²²² Written responses provided by Air Force Space Command, March 31, 2017. The effort referred to here is the Protected Tactical Enterprise Service (PTES), which enables the use of Protected Tactical Waveform (PTW) over currently unprotected systems.

²²³ Defense Science Board, *Task Force on Military Satellite Communication and Tactical Networking: Executive Summary*, March 2017, available at http://www.acq.osd.mil/dsb/reports/2010s/DSB-MilSatCom-FINALExecutiveSummary_UNCLASSIFIED.pdf. Not to go unnoticed in the report is the vulnerability of the current ground network architecture to jamming. Emphasis is in the original report.

²²⁴ Lamrani, “What the U.S. Military Fears Most: A Massive Space War,” *op. cit.*

²²⁵ Heginbotham, et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996-2017*, *op. cit.*, pp. 252, 53.

them to operate in multiple frequency bands. Operation in GEO and HEO, given the distance from earth, also complicates such counter-space aggression.²²⁶

GPS III next generation satellites are introducing new capabilities to meet higher military demands and reduce the chance of counter-space attacks (especially downlink jamming by Russian or Chinese systems against satellites and attacks against terrestrial GPS receivers to protect against intrusion and misdirection). These satellites will have greater signal strength and better accuracy, which will make jamming more difficult.

Countering Destructive Space Denial Efforts—Active Defense and Space Control

There are scenarios when passive defenses will not be sufficient to protect satellite functions, and the employment of active defenses, or defensive force application, may be necessary. At the high end of conflict, the stakes may be very high and worries about space debris and any domestic or international condemnation of the action will pale in comparison.

At this point in time, however, the United States does not appear to be in a position to respond with agility to destructive space threats, at least not within the space environment. Deputy Secretary of Defense Bob Work noted that “from the beginning, if someone starts going after our space constellation, we’re going to go after the capabilities that would prevent them from doing that.... Let me just say that—having the capability to shoot the torpedo would be a good thing to have in our quiver.”²²⁷ The defensive capabilities referred to by Mr. Work could be located in space or on earth. At present, space warfighters can only watch what happens in the space battlefield or possibly move some assets around, given enough warning. They are, as Work seems to have implied, unable to actively fight and defend against the threat.

There are options available today using U.S. missile defense assets. In order to defeat threatening co-orbital satellites in LEO and directed-ascent ASAT weapons, the United States could leverage the progress it has made to refine these missile defense assets for the satellite-defense mission. Interceptors could be deployed on the ground or at sea as well as in space. According to Ambassador Henry F. Cooper, former Director of the Strategic Defense Initiative Organization, we should not underestimate the capability of the Aegis BMD system and the Standard Missile (SM)-3 Block IA and Block IB interceptors to perform the counter-counter-space mission. He believes that with software changes in the Aegis weapon system, an Aegis BMD interceptor could shoot down, for example, North Korean satellites before they overfly the United States in a polar orbit by striking the launching missiles in the boost phase.²²⁸ A lighter kill vehicle on the SM-3 would increase the velocity of the interceptor, making it more agile in this role. The SM-3 Block IIA, which is a larger and more agile interceptor, would offer an even greater capability. He also believes the Ground-based Interceptors currently deployed in California or Alaska could be capable against a North Korea (nuclear-payload) satellite coming towards the United States from the south, given adequate cueing from sensors oriented to the south.²²⁹

²²⁶ Ibid., pp. 255, 256.

²²⁷ Cited in Jim Sciutto, “US military prepares for the next frontier: Space war,” *CNN*, November 29, 2016, available at <http://www.cnn.com/2016/11/28/politics/space-war-us-military-preparations/>.

²²⁸ Boost phase intercept requires that the operator be very close to the launch site and directly in the line of flight of the missile.

²²⁹ Interview with Henry F. Cooper, March 18, 2017.

Organization

To deal with the counter-space threat, the Defense Department and the intelligence community have established the Joint Space Doctrine and Tactics Forum, which is intended to ensure U.S. space policy, doctrine, strategies and planning reflect the idea that space is a contested domain, “populated with dynamic actors.”²³⁰ The intelligence community, the collectors and analysts of information critical to national security, and the Defense Department, the nation’s agents responsible for executing military power, are essential to warfighting involving the space domain. Their “seamless” collaboration can be seen in exercise and wargames and the development of joint doctrine, tactics, techniques and procedures.

They have also established the experimental Joint Interagency Combined Space Operations Center (JICSpOC), which in 2017 was renamed the National Space Defense Center (NSDC), to permit more integrated space operations and push for greater unity of effort and understanding among the Defense Department, the National Reconnaissance Office, and the intelligence community. JICSpOC/NSDC was opened at Schriever Air Force Base in Colorado Springs to respond to hostile actions in space. Experimentation and operationally realistic exercises and wargames give important insights into how to operate in the space domain and assist with the development of warfare concepts and tactics, techniques, and procedures. NSDC reportedly will handle military engagements in space (conflict that extends into the space domain) using improved battle management and command and control of space assets, while the Joint Space Operations Center, or JSpOC, will focus on the terrestrial fight, that is, the provision of space support to the warfighter.²³¹ The JSpOC, located at Vandenberg Air Force Base in California, is focused on planning and executing U.S. Strategic Command’s Joint Functional Component Command for Space mission. It is made up of the four services as well as U.S. allies, the United Kingdom, Australia, and Canada.

Today, the JSpOC can track orbital debris over 10 centimeters, and there is strong interest in increasing the capability to track even smaller pieces. The United States performs this as a notification service to other nations. The JSpOC has alerted China and Russia to possible impacts hundreds of times when satellites are on a collision course with tracked debris.²³² Since it is in the best interest of the United States to maintain a safe operating environment, it makes sense to provide notifications to other nations in order to avoid the creation of more space debris. Knowledge of debris location and predicted paths enables satellite owners to take evasive maneuvers, if necessary.

Using information provided by JSpOC, satellite maneuvers may be undertaken by the satellite owner to avoid direct ascent or co-orbital ASATs and orbiting debris that are predicted to collide with the satellite. While operators are capable of moving satellites, one wonders how quickly they may be moved. In other words, the maneuvering option may be fine for avoiding debris (the path of which may be predicted well in advance of collision) but less practical (if even possible) when an attack may take place quickly. One would presume that there is greater leeway for action for

²³⁰ Admiral C.D. Haney, “Statement of Admiral C.D. Haney, Commander, US Strategic Command,” *114th U.S. Congress*, March 10, 2016, p. 18, available at https://www.armed-services.senate.gov/imo/media/doc/Haney_03-10-16.pdf.

²³¹ Mike Gruss, “Hyten tells Senate DoD needs to focus on space control, battle management system,” *Space News*, September 20, 2016, available at <http://spacenews.com/hyten-tells-senate-dod-needs-to-focus-on-space-control-battle-management-system/>.

²³² Micah Zenko, “Waste of Space,” *Foreign Policy*, April 21, 2014, available at <http://foreignpolicy.com/2014/04/21/waste-of-space/>.

satellites in GEO (where it may take hours for a threat missile to arrive) compared to satellites in LEO.

The United States is also taking steps to involve commercial satellite operators to develop better space situational awareness. For example, officials have set up a Commercial Integration Cell to improve integrated space situational awareness and command and control by improving computer interfaces between military and commercial operators. This means that the same rigor that is applied to prevent, for example, satellite collisions in space will be put into place in order to understand and ensure improved awareness of interferences to satellite operations, which would help operators understand if there is malicious tampering taking place.²³³

In 2016 RAND Corporation completed a study on how to enhance space resilience addressing non-materiel solutions for improving space protection, i.e., doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy.²³⁴ The report highlights that the Air Force still has significant work to do even in areas that do not involve satellite hardware. Distancing itself somewhat from the past focus on disaggregation and other passive space protection measures (to include distribution, diversification, protection, proliferation, and deception), this report encouraged consideration of both passive and active measures for defense. The study's authors advocated, among other things, changing the prevalent mindset within the space operator community that "space is a sanctuary." There are a number of other steps leaders could take as well within the space organization, including development of an end-to-end, space protection concept of operations to improve resilience by enhancing the capability of space operators to respond in a timely, effective manner to adversary counter-space activity. According to the report, other critical steps that need to be taken include providing timely counter-space threat and weather effects advisories, developing tactics to counter threats, and updating training and exercises to refine responses to adversary counter-space challenges.

Cybersecurity

The Department of Defense has taken several steps to address the accelerating threat of cyberwarfare and make cyber defense a top priority, to include cyber threats to U.S. space systems. Air Force System Program Offices are building in cyber resilience into space weapon systems, the Air Force Chief Information Officer has a Cyber Squadron-Initiative where Missile Defense Teams provide persistent defense of space systems and, beginning in fiscal year 2018, Air Force Space Command is executing the Air Force Weapon System and Installation Cyber Defense concept to provide an enterprise-level Defensive Cyberspace Operation capability. Moreover, there are physical security measures in place at satellite control centers, encrypted command and control signals to the spacecraft, and communications satellites are using the latest technologies to ensure secure communications are available to U.S. warfighters and international partners.²³⁵

²³³ Amy Butler, "Space Control Finally Gets a Boost," *Aviation Week & Space Technology*, May 1, 2015, available at <http://aviationweek.com/defense/space-control-finally-gets-boost>.

²³⁴ Gary McLeod, et al., *Enhancing Space Resilience Through Non-Materiel Means* (Santa Monica, CA: RAND Corporation, 2016), available at http://www.rand.org/content/dam/rand/pubs/research_reports/RR1000/RR1067/RAND_RR1067.pdf.

²³⁵ Written responses provided by Air Force Space Command, March 31, 2017.

International Cooperation

The United States also is expanding international cooperation in the area of defense space. According to Air Force Major General Nina Armagno, international space cooperation “benefits each of our respective nations [and] anyone who uses space across the globe. The United States simply can’t do anything that we do in space without our allies, and the value of these partnerships will only continue to grow in the future.”²³⁶ There is significant opportunity for partners interested in working with the United States to contribute to space security architectures. U.S. cooperative international relationships have existed for many years with certain countries, especially Canada, the United Kingdom, Australia, and New Zealand. The “Five-Eyes” partners have a space cooperation charter, signed in 2013. Cooperative relationships improve intelligence gathering, increase space situational awareness, and help synchronize the space enterprise through improved communications and monitoring. Augmentation through international partnerships also can help ensure persistent space capabilities. This approach can complicate the decision by the adversary to aggressively act against the United States in space.

International partnerships, for example, provide a very tangible role in assuring our allies and in providing and sustaining important military capabilities. For example, the U.S. partnership with Australia helps sustain the current Space Surveillance Network. The newly acquired Space Surveillance Telescope fills a critical void in the surveillance network, providing the ability to see thousands of objects at one time. This telescope is located in Australia and operated by RAAF personnel, with both nations having access to the information.²³⁷ The early warning radars (now upgraded to do the ballistic missile defense mission) at Fylingdales in the United Kingdom and Thule in Greenland (Denmark) have long helped the United States perform the space surveillance mission. These nations also participate in wargames to exercise the space architectures. A C-band radar once based on the island of Antigua has been moved to western Australia and is now also part of the SSA network. U.S. Strategic Command also has a vibrant program to develop international agreements to share space situational awareness data with 13 allies, in addition to the more than 60 commercial satellite owners, operators, and launch companies that also participate in the program.²³⁸

The United States has a significant on-going cooperative project to upgrade the White House’s, State Department’s, and the military’s ability to communicate, providing information, maps, imagery, video, and voice calls anytime, anywhere around the globe. The Wideband Global SATCOM (WGS) began launching satellites in 2007 and will finish in 2018 with a 10-satellite constellation. This service will also be available to international partners, including Australia, Canada, Denmark, the Netherlands, Luxembourg and New Zealand. Indeed, Australia was the first international partner in this program and funded the first satellite.²³⁹

Galileo represents a cooperation tool that could provide the United States with redundant navigation capabilities. Receivers have been built that will receive both the Galileo and GPS signals, which means that should GPS be jammed or go down, the possibility would remain that

²³⁶ Pellerin, “Advanced Space Surveillance Telescope Has Critical Military Applications,” op. cit.

²³⁷ Written responses provided by Air Force Space Command, March 31, 2017.

²³⁸ Richard Tomkins, “Norway joins U.S. Air Force on space data sharing program,” *UPI*, April 6, 2017, available at http://www.spacedaily.com/reports/Norway_joins_space_data_sharing_program_999.html.

²³⁹ Justin Ray, “Upgraded satellite for communications among U.S. military forces ready to launch,” *Spaceflight Now*, December 5, 2016, available at <https://spaceflightnow.com/2016/12/05/upgraded-satellite-for-communications-among-u-s-military-forces-ready-to-launch/>; Interview with Maj Gen Nina Armagno, Air Force Space Command, February 27, 2017.

users could tap into the Galileo signal. International coalitions can strengthen the U.S. space posture by adding capabilities, robustness and resilience. The redundancy will help support deterrence by reducing the opportunity for an adversary to completely deny the United States and its allies' and partners' space utilities. The idea that an adversary could shut the United States out of space by attacking a few satellites becomes more problematic. International public opprobrium for such behavior may be more significant when multiple nations have a stake in the space architecture, but this alone would not likely stop a determined adversary.

Chapter 4: Implications for U.S. Defense Policy

U.S. reliance on space began during a time when the United States did not have to be concerned about threats to those systems. Either space assets were protected under the umbrella of global nuclear deterrence (given the linkage that once existed between strategic satellite operations and nuclear operations) or by the fact that very few other countries had access to space or counter-space weapons. This has changed, of course, with the proliferation of space actors since the Desert Storm era.

Within this changing environment, the reliance by U.S. military forces on force multiplying effects of space services continues to grow. These services are becoming ever more critical around the globe, especially in vast regions such as Asia-Pacific. While U.S. forces do train to operate in a degraded space environment, the alternative structures for communication across vast distances among forces in-theater and from theater to command centers, for example, are far from robust and reportedly vulnerable to enemy attack.²⁴⁰

Were the United States to be at war, or in a crisis, with another state (or possibly even a non-state actor with access to counter-space weapons), national space assets could be at risk. “I cannot stress enough,” General Hyten warned, “competitors have the capabilities now to disrupt or deny our troops the advantages of our space and cyberspace capabilities.”²⁴¹ Despite their distance from earth (or maybe even *because* of their distance from earth and *because* they are virtually invisible forces), the strategic importance of space assets may make them the most attractive target. After all, what better way to measure the will of U.S. policy makers or test their responses than by attacking an asset that causes no immediate bloodshed and is potentially unseen or undetected (but not unfelt for long) by the public? Indeed, states may engage in a form of piracy or blackmail, or cause sporadic disruptions of communications or Global Positioning System satellites, as a way to blackmail U.S. leaders and terrorize a population. The threat of dramatically altering a way of life would be very powerful.

The nation is not completely defenseless in space. To a large degree, naturally occurring threats (sun flares and space weather, meteors) are taken into account when a satellite is designed (though there is little one could do to protect against a meteor strike). Natural causes of interference or disruption are expected and steps are taken to operate through these natural threats. The challenge today is the rise of man-made threats to space systems and the need to plan for and build protective measures into the designs to defend against such threats that could do damage to satellites and other parts of the space system (including ground systems and communications links). Intentional threats to satellites (from cyber attacks, to jamming, to satellite destruction using kinetic or directed energy), as opposed to accidental damage from collision with space debris or meteor fragments and space weather, are the only types of threats that are conducted with strategic effects in mind. They are intentional and meant to cause damage that

²⁴⁰ Jeff Kueter and John B. Sheldon, “An Investment Strategy for National Security Space,” *Heritage Foundation*, Special Report #129, February 20, 2013, p. 7, available at http://thf_media.s3.amazonaws.com/2013/pdf/SR129.pdf.

²⁴¹ General John E. Hyten, “National Security Space Budget for FY17: Presentation to the Subcommittee on Strategic Forces,” op. cit., p. 8.

could cause long-lasting harm to U.S. national security and the national economy. They must be addressed.

Space and Implications for Warfighting

Interference with or destruction of U.S. reconnaissance satellites would draw down the opportunities to assess enemy force strength and degrade the employment of operational weapon systems. The result of the loss of critical situational awareness would leave U.S. forces vulnerable to surprise. Reconnaissance and high resolution intelligence satellites help with military planning and deliver tactical intelligence to assist targeting and the employment of precision-guided munitions. These capabilities would be impaired along with the ability to do battle damage assessment to determine whether reattacks are required. Loss of weather satellites also could reduce the ability to perform military planning for battlefield operations.

Satellites are a critical element of U.S. global missile defense capabilities. Impairment of missile launch early warning satellites (SBIRS HEO, SBIRS GEO, and DSP satellites), by blinding or dazzling the infrared sensors, could seriously degrade the ability to detect and provide initial track information on ballistic missile launches from points around the world and critically affect the operational performance of the Ballistic Missile Defense System. Degraded missile defenses could leave the U.S. homeland and its deployed forces and allies vulnerable to an increasingly dynamic and sophisticated ballistic missile threat. The United States has other terrestrial sensor assets in place to detect missile launches, especially in regional conflicts, but these capabilities are limited in their coverage and persistence.

Advanced Extremely High Frequency communications satellites provide critical command and control over U.S. nuclear forces and communications with U.S. forces.²⁴² Just four satellites are required to provide strategic and tactical worldwide assured coverage. Should one of the satellites be lost, however, it reportedly would cripple communications over a large geographic area, which might make it impossible for command authorities to communicate with forces in that region. Loss of communications satellites could affect command and control at the strategic and tactical levels. Impairment of LEO mobile communications satellites could disrupt troop movements and logistics in a region. There are also communications satellites in GEO that are critical to command and control of nuclear forces and the ability to operate a communications architecture that has global reach.

Navigation satellites are relied on to move troops and operate forces on land, sea, and in the air. Loss or impairment of Global Positioning System satellites also reportedly could degrade the employment of some precision-guided munitions. The United States has invested in the electronic protection of GPS satellites as well as anti-spoofing technologies. The country also has a constellation in excess of its actual need (24 satellites on six planes), which increases the resiliency and accuracy of the constellation. There are five to 10 satellites in view of any given point on earth when only four are required, and there are several spares on orbit.²⁴³ There are also plans to deploy a next generation satellite that will increase resilience against jamming. At this point in time, barring a wide-scale destruction campaign or cyber attack, passive defenses and the architectural design of the system seem to offer the on-orbit GPS constellation good protection from attack. It is important to understand the different implications of different types of

²⁴² Atlantic Council, "Transcript: The US Future in Space," op. cit.

²⁴³ Weatherington, "Testimony before the House Committee on Armed Services, Subcommittee on Strategic Forces," op. cit., p. 7.

threats to U.S. space systems. Temporary jamming threats to GPS satellites would not rank in significance to a kinetic attack on an early warning satellite.

Although it is beneficial to leverage the commercial sectors to add robustness to the U.S. defense space architecture, certain satellite operations are best provided by the government, to include early warning to cue Commands that control the Ballistic Missile Defense System and U.S. retaliatory nuclear ballistic missile forces, secure communications to support nuclear command and control, and signals intelligence. One could even argue that it is the job of the government to provide very high resolution imagery from space, although significant progress has been made by commercial entities in this area.

Dealing with the Space Threat

Space threats are not highly salient to the public. Not only is there little awareness of the developing anti-satellite capabilities worldwide, there is perhaps a perception by many that space war would be non-lethal and have limited impact on everyday life. Outside of images we might see, space assets are by and large invisible to us, and it is therefore difficult to get a vivid understanding of the possible menace before us. It may take time for the public to realize the full impact of a space assault. Additionally, debates about space often are politically charged, with some viewing any preparation for war as provocation for war. Yet as more satellites are placed in orbit, and as more defense and military functions move to space and dependence on space grows, the frequency and intensity of space threats will likely increase over time.

This reality poses a challenge to those who seek to develop more active responses to potentially threatening foreign space and space force application (ballistic missile) developments. While some measures may be taken in the political and diplomatic arena to protect U.S. interests in space, the U.S. capability to mount a thorough military response to protect space assets does not exist today.²⁴⁴

For decades, Administrations and Congresses have prevented the United States from putting weapons in space or developing ground-based ASAT capabilities. This policy stemmed from concerns about proliferating debris in space, as well as a view that ASATs are destabilizing and threaten the security of space. Yet there is no similar political constraint on Russia, China, North Korea, or Iran, which may result in a situation where the United States, having refrained from looking at ways to exercise force in space, would be at a severe disadvantage in a war.

The United States for decades has sought to promote responsible behavior through agreements among nations, such as codes of conduct and transparency measures, to “ensure” space remains a sanctuary.²⁴⁵ And, as noted in previous sections, the United States has simultaneously

²⁴⁴ Current U.S. ballistic missile defenses are not configured to operate with agility and reliability in the counter-space role.

²⁴⁵ See, for example, Robert M. Gates and James R. Clapper, *National Security Space Strategy 2011* (Washington, D.C.: Office of the Director of National Intelligence, 2011), available at https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2011_nationalsecurityspacestrategy.pdf; Christopher Stone, “Security through vulnerability? The false deterrence of the National Security Space Strategy,” *The Space Review*, April 13, 2015, available at <http://www.thespacereview.com/article/2731/1>; See also Micah Zenko, *Dangerous Space Incidents: Contingency Planning Memorandum No. 21* (Washington, D.C.: Council on Foreign Relations, April 2014), available at <http://www.cfr.org/space/dangerous-space-incidents/p32790>. Sam Jones, “Satellite Wars,” *Financial Times*, November 20, 2015, available at <https://www.ft.com/content/637bf054-8e34-11e5-8be4-3506bf20cc2b>. Frank Rose, US Assistant Secretary of State for Arms Control, stated “we don’t want conflict in outer space. But be assured, we will be able to operate in a degraded space environment.” While it is commendable to want to be able to operate without full access to space, retreat from space can become a self-fulfilling prophecy without the tools to reassert national influence in that arena.

developed passive defenses to complicate an adversary's aggressive actions in space. Yet these measures have not prevented the development of space weapons by others.

Because U.S. efforts to assure peace in space have not prevented China and Russia from developing ASATs, it is imperative that Washington examine future protection options, to include changing its approach from passive deterrence to one that includes offensive retaliation capabilities. The first step toward this goal is to change the mindset from one that makes deterrence of war in space a taboo. Effective deterrence of war in space will require, not only making US satellites as safe from attack as possible, but also potentially placing at risk the satellites (or terrestrial assets) of any identified nation that attacks U.S. space assets.

Addressing U.S. Vulnerabilities: Alternatives to Space

Space provides a forward deployed presence everywhere, all the time. It has been argued that, "[i]f the United States can still deliver unacceptable damage to an enemy, even if deprived of its unique space assets, what material advantage is to be gained for an adversary to invest the financial, military, and political capital to attack those systems?"²⁴⁶ That, of course, is a big "if."

It is worth restating this observation from former Commander of Air Force Space Command and the current Commander of U.S. Strategic Command, General Hyten: "Space is not just an enabler for the other operational domains, it directly impacts the calculus of national security."²⁴⁷ Space systems directly impact how we go about bolstering national security, which means, when it comes to "replacing" space systems, simply plugging in other enabling capabilities from terrestrial environments will be insufficient. There is no replacement for space systems. Space assets offer capabilities that alternative (terrestrial) capabilities cannot offer, which make space a strategically critical arena. It is, therefore, an arena that must be defended.

Diminished access to space would impair the ability of the United States to maintain its presence and conduct military operations abroad to defend strategic and regional interests. "If we cannot deliver all the advantages associated with space and cyberspace, joint warfighting capabilities become less effective and we risk going back to industrial-age warfare."²⁴⁸ Indeed, today's armed forces are accustomed to fighting in the space age, not in the industrial age. Therefore, one also would have to believe that without having trained to fight an industrial-age war and without being equipped to fight an industrial-age war (the country does not have 19th century weaponry on hand and one would suspect that some of the computerized 21st century weapons would only work in the 21st century), that they would not be able to fight such a war very well.

When considering vulnerabilities to space systems, it is more sensible to think about alternatives to space services to either act as redundant systems or (temporary) replacement systems. Unmanned Aerial Vehicles (UAVs), for example, are possible substitutes for imagery satellites, while terrestrial radio and microwave towers and fiber-optic cabling could act as partial substitutes for communications satellites. Improved inertial guidance and ground-based position, navigation, and timing capabilities, such as Enhanced LORAN,²⁴⁹ reportedly would provide a robust backup

²⁴⁶ Roger G. Harrison and Deron R. Jackson, "Space deterrence: a response," *The Space Review*, June 22, 2015, available at <http://www.thespacereview.com/article/2775/1>.

²⁴⁷ Hyten, "National Security Space Budget for FY17: Presentation to the Subcommittee on Strategic Forces," op. cit., p. 2.

²⁴⁸ Hyten, "National Security Space Budget for FY17: Presentation to the Subcommittee on Strategic Forces," op. cit., p. 7.

²⁴⁹ Enhanced LORAN is said to meet the "accuracy, availability, integrity and continuity performance requirements for maritime harbor entrance and approach maneuvers, aviation non-precision instrument approaches, land-mobile vehicle navigation and

to GPS. These ideas make sense, of course, when it comes to supplementing space services, yet they cannot come close to replacing what satellites have to offer.

Terrestrial-based alternatives would not be able to perform as fully or as efficiently as space systems. While many terrestrial services (cell towers, radio microwave communications, and fiber optic cables) may function perfectly during peace time, they may not be up to the battlefield stresses presented in crisis or war. Satellites offer predictable, persistent global 24/7 coverage and access to denied territories; they can do so with enough altitude to afford them overflight privileges as well as some protection. Because they are essentially perceived as being “off the battlefield,” and because of the reliability of the connectivity they offer, U.S. military forces rely heavily on communications satellites. At sea, the U.S. Navy really has no suitable alternative to tactical or strategic satellite communications—there are no cell towers at sea. So, one may reasonably ask, are these world-circling platforms really off the battlefield today? The fact is, “loss or degradation of the information services that space systems provide would not just be inconvenient, but could generate significant hardship and endanger lives.”²⁵⁰

UAVs nearly always operate in a permissive environment or in areas where enemy air power or ability to establish control over airspace from the ground is negligible. This is an environment where the operators rarely have to worry about the threat of direct attack on their airborne platforms. Yet airborne assets might not be able to operate freely over contested territories and could be targets of counter air attacks. Their deployment might require overflight permission from countries just to be able to fly in or into the relevant regions. According to Vice Admiral Syring, UAVs with tracking and discrimination capabilities would be challenged “in terms of orbits and the number of UAVs.”²⁵¹ Syring is on record as saying the most efficient way to do the ballistic missile tracking mission is from space. Spacecraft enjoy complete freedom of overflight, which means they would avoid the political and diplomatic challenges that would invariably arise with air overflights, and may pose other challenges to those who might want to exercise space control.

Potential adversaries of the United States understand the limitations of UAVs and appear determined to make the growing U.S. reliance on UAVs an increasingly risky strategy. With this in mind, U.S. operators are already making plans to operate these systems without satellite communications by possibly giving UAVs more autonomy. UAVs are becoming increasingly sophisticated with built-in control and guidance systems and pre-scripted navigation with movement towards on-board processing. Without the ability to network (through space), however, how useful would UAVs be in establishing an alternative to space systems? Weapons release now depends on communications satellites and this is not likely to change unless we restrict the use of UAVs to attacks on known fixed targets. UAVs rely on communications satellites and consume large amounts of bandwidth to transmit video feeds and other sensor data back to intelligence centers and forces on the ground.²⁵² UAVs require high-resolution satellite images for adequate cueing; how efficiently would they function without imagery from space? Moreover,

location-based services.” Stephen Bartlett, Gerard Offermans and Charles Schue, “Innovation: Enhanced Loran,” *GPS World*, November 23, 2015. Available at <http://gpsworld.com/innovation-enhanced-loran/>.

²⁵⁰ National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report* (Washington, D.C.: The National Academies Press, 2016), p. 19, available at <https://www.nap.edu/catalog/23594/national-security-space-defense-and-protection-public-report>.

²⁵¹ James Drew, “MDA’s Missile-Hunting UAV Buy Paced by Laser Development,” *Aviation Week*, August 17, 2016, available at <http://aviationweek.com/awindefense/mda-s-missile-hunting-uav-buy-paced-laser-development>.

²⁵² Grace V. Jean, “Remotely Piloted Aircraft Fuel Demand for Satellite Bandwidth,” *National Defense*, July 2011, available at <http://www.nationaldefensemagazine.org/archive/2011/July/Pages/RemotelyPilotedAircraftFuelsDemandforSatelliteBandwidth.aspx>.

if the terrestrial based systems, such as UAVs, are to function efficiently, they require access to space to acquire the guidance (GPS) data and communications streams to do their missions.²⁵³ A combination of enhanced inertial guidance and the provision of a terrain contour matching guidance backup (as opposed to relying on inertial navigation systems) would mitigate the effect of GPS loss.

As far as prosecuting a war using land-based, sea-based, or airborne systems, having developed the capabilities to strike targets on earth with pinpoint accuracy using GPS guided munitions, the United States could be a victim of its own success should it ever be deprived of its connections to those satellites, particularly if its adversaries were not similarly deprived. Given the reliance of many precision weapon systems on GPS satellites for guidance, the loss of these space assets would cripple many U.S. stand-off and precision strike capabilities.

According to the National Academies, “[i]n the abstract, were all of the space systems suddenly to shut down, the global information infrastructure would cease to function as the world has come to expect; were the use of space to be denied in perpetuity, current information capabilities would be nearly impossible to reconstruct.”²⁵⁴ The bottom line is that functions enabled by space systems are integral to life in the United States and they cannot be adequately performed by systems on land, at sea, or in the air. At best, some of the critical functions enabled by space (reconnaissance, communications, navigation) would certainly lack global application should they be performed by terrestrial substitutes; they would be performed irregularly and probably poorly.

The nation is in space for a reason, and that is because space provides unparalleled advantages that an adversary would happily take away. Granted, it is highly unlikely that the United States will ever be completely without space. But even being shut out of a portion of space for a period of time could have great negative strategic consequences. Without space or certain space assets, it would be reasonable to expect that a serious degradation of U.S. military capabilities and significant compromise of national security would result.

Addressing U.S. Vulnerabilities: Deterrence

“Our ability to deter major power conflict also depends on our ability to deter major conflict in all domains—particularly in space and cyber.”

—General John E. Hyten²⁵⁵

Weakness, we know, invites aggression. Should an aggressor perceive points of U.S. vulnerability that it can exploit to its advantage, the chances that it would consider attacking at those points in order to pursue its strategic aims would be greater than if it saw strength and opposition. This logic applies to space as well; exploitable vulnerabilities can invite attack—which is wholly contrary to the goal of deterrence. By merely threatening to attack U.S. space systems unprotected by a strong deterrent or defenses, the enemy might be able to deter, or significantly

²⁵³ While this capability has not yet been developed, efforts are underway to develop microelectromechanical systems to provide navigation-grade inertial measurement, which would enable the use of precision-guided munitions should GPS signals be denied. Graham Warwick, “Northrop MEMS To Guide Weapons When GPS Denied,” *Aviation Week & Space Technology*, April 11, 2016, available at <http://aviationweek.com/defense/northrop-mems-guide-weapons-when-gps-denied>.

²⁵⁴ National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report*, op. cit., p. 2.

²⁵⁵ General John E. Hyten, *Statement of John E. Hyten, Commander, U.S. Strategic Command Before The Senate Armed Services Committee*, April 4, 2017.

alter the manner of, the country's entry into a conflict, or even willingness to enter a conflict. U.S. leaders and planners understand this and have begun to take steps to make U.S. satellites "hard to find, hard to catch, hard to hit, hard to kill."²⁵⁶ Satellite ground control facilities would also have to be made hard to destroy.

The current U.S. approach to deterrence of attacks in space is to deny the adversary victory by reducing the likelihood of success which, accordingly, would induce the adversary to decide not to attack at all. To mount such an attack against a disaggregated or proliferated system would be viewed as too expensive or difficult. Keys to this "deterrence-by-denial" strategy are the use of different orbits, mobility, deception, and distributed architectures, all of which are considered to be traditional passive defense measures. It involves making GPS satellites, military satellite communications, and early warning satellites resilient to attack, to survive through attack and continue to provide space services. The United States also has pushed to grow international "buy-in" to space systems. The idea behind this is to make space systems something all countries use, so that damage to one nation's space systems would also harm the interests of other nations. In this way the support culture for space can grow.²⁵⁷ Without question, such passive defenses—enhancing the space architecture resilience and enhancing international buy-in—are important parts of making U.S. space operations more secure.

Today's space deterrence strategy rests firmly on the pillars of "deterrence-by-denial." The logic behind it is simple. Behavior of a possible aggressor is influenced by hoped-for results. If those hoped-for results are not expected to materialize, and the decision is thus made not to execute that behavior for fear of not being able to achieve the results (at the chosen time), the result is a form of deterrence. Yet passive defenses are only part of a comprehensive deterrence package. The nation also may bolster its deterrence by denial position by adding active defenses to its arsenal, i.e., military capabilities that may be used to counter enemy ASAT operations. If an aggressor state does not believe it can succeed in its attack against U.S. space systems, it may be convinced not to undertake the aggressive action altogether.

Consider now the possibility that attempted deterrence by denial in space may not actually deter attempts to disrupt satellite operations and may, in fact, *invite* a limited attack on space systems. For example, we already have examples of such interference (e.g., jamming) involving GPS satellites. When there are many dispersed satellites in operation (performing the same function, such as GPS), which is one of the ways we are told we "deter" by denial, the adversary may not believe it can knock out the entire network and achieve the hoped-for results. Yet, he may be free to conduct aggressive actions against individual satellites without fear of punishment as a way to test tactics and measure results.

Ironically, "deterrence by denial" (alone) also may lead to the proliferation of orbital debris precisely because it does not provide *the strongest incentive* to behave in space. Misbehavior in the form of aggressive action against a satellite may result not only in the incapacitation of the satellite, but possibly even its breakup. An attack on a satellite system that is highly redundant—for example, where there is such flexibility in the architecture that the loss of one or more satellites will not bring the system down (resilience)—may be more likely, in other words, because the aggressor might not anticipate a military response to the attack because the effects of the attacks on the United States may be negligible to modest. The penalty risk for the attack is low, which

²⁵⁶ Work, "Remarks at the Space Symposium," op. cit.

²⁵⁷ Interview with Maj Gen Nina Armagno, Air Force Space Command, February 27, 2017.

may make such an attack more likely, which in turn increases the risk of proliferating orbital debris. Sure there might be diplomatic repercussions, but this is not the same as fear of suffering considerably and tangibly for this action. The same reasoning applies to having a surge or rapid replenishment capability. The targeted country can reliably replace satellites on orbit. This is a good passive defense capability, but there might be little there that would actually cause an adversary to cease its efforts to disrupt a satellite's operation.²⁵⁸

Defenses and the ability to threaten credibly are at the heart of deterrence, and it is these defenses that must be exercised (because a state cannot "exercise" deterrence). "Defenses can be tested and exercised; deterrence threats cannot: their efficacy depends on the perceptions and actions of a foreign government."²⁵⁹ Deterrence is rooted in psychology, decisionmaking, and expected consequences. Although "deterrence by denial" would have some deterrence value (by potentially frustrating aggressors into not acting), the nation also needs a deterrence by punishment approach to have a truly effective deterrence strategy. The aggressor must perceive and fear that unacceptable costs will be imposed following an action, or the aggressor must believe that he will not gain anything of consequence by aggressive action and that there could be costs involved. This two-pronged deterrence approach is the most comprehensive, and may be necessary given the diversity of opponents and threats. The idea must be to convince the adversary that, through deterrence (made manifest to an aggressor through the deployment of offensive retaliatory capabilities) as well as passive and active defense, it will not succeed in the attacks. The costs, in other words, will vastly outweigh the benefits and, additionally, the likelihood of success will be low.

Deterrence can succeed when the enemy finds the threat of punishment to be possible, if not certain. "Deterrence by punishment" is only an option if the enemy perceives that the United States has the capability to pull off the type of punishment threatened. Being prepared to wage a war in defense of space assets, to go on the offensive, would go a long way to influencing the calculations of any enemy who otherwise may decide to do the United States harm. This means having actual capabilities (known to the adversary) that may be employed in space or on earth. Indeed, deterrence threatens punishment and, in some cases, it does so by not being so explicit about the response (although in other cases being explicit about the response, depending on the recipient of the deterrence threat, could also have a strong deterrent effect). Uncertainty in the adversary's mind about the U.S. response may not preclude the functioning of deterrence.

Passive defenses and denial deterrence represent only one element of deterrence and, given the variety of threats and enemies involved, having deterrence capabilities that are as comprehensive as possible is most prudent. Because the stakes are so high, we want to prevent even one major deterrence failure. Thus, we should want a more comprehensive deterrence strategy as opposed to a more narrow deterrence strategy, and the combination of denial and punitive should be comprehensive. Why pursue only one approach when we may very well need both?

Deterrence of attacks on space systems presents a special problem, but not an unsolvable problem. It begins with the idea that not all countries have the same respect for the space domain as the countries that rely heavily on space systems for their economy and security. The greater

²⁵⁸ It may also be said that if the effects of attack are minimal, the benefit to the adversary also is likely to be minimal; so the deterrent risk may not be perceived as high, but the benefit of the attack also cannot be perceived as high. That could be a helpful deterrent position to be in for the deterrence of any large-scale attack.

²⁵⁹ Bob Butterworth, "Fight For Space Assets, Don't Just Deter," *DoD Buzz*, October 24, 2008, available at <https://www.dodbuzz.com/2008/10/24/fight-for-space-assets-dont-just-deter/>.

powers in the world look increasingly to space to enhance their strengths. The lesser powers, such as North Korea and Iran, do not leverage the space domain to the same extent and hence can afford not to respect it. North Korea has repeatedly engaged in jamming GPS signals along its borders, for example.²⁶⁰ “Mutual Assured Destruction” will not work in space, simply because there are some countries that just do not care and do not accept many of the norms followed by the majority of nations. How does one nation deter another nation who has little respect for the space domain from doing harmful things?

Retaliation in kind for an attack on U.S. satellites may not work against an adversary that does not rely on space systems to the same degree as the United States, though increasingly space is being integrated into the economies and armed forces of foreign states. Such a threat (in kind) against a state that does not depend on space would not be much of a deterrent and such attacks are unlikely to significantly affect military realities on the ground. Yet the functioning of deterrence would depend on the enemy’s expectation of consequences for interfering with or destroying U.S. space systems.

Deterrence may require the involvement of the entire national security infrastructure, military, diplomatic, intelligence, and economic. It may also involve the national security infrastructures of U.S. allies, since the United States is unlikely to be involved in combat alone. In other words, effective deterrence, especially in a world where some countries do not respect the space domain, may require a multi-domain response. A credible threat of retaliation of some sort—it does not have to be “in kind” (i.e., against the adversary’s space systems)—is important if the deterrence strategy is to have teeth.

A special challenge today is in deterring non-destructive and reversible interference which, although having temporary effects, could have far-reaching and deadly consequences when done at critical moments in a military campaign. Such interference is not an attempt to gain a lasting advantage through the termination of a space system. However, who needs that advantage to be “lasting” when the strategic effects of the moment are realized and strategic goals achieved? In other words, temporary should not be equated with benign; it could have a highly significant strategic effect.

Unfortunately, there are no universal boundaries to frame the adversary’s decision-making and soothe our own expectations about what is likely to happen, all of which would facilitate the formulation of a deterrence strategy. Western expectations about the functioning of deterrence based on the assumption that the enemy will be “rational,” often, in fact, simply are based on the presumption that enemies have the same judgments, goals, tolerances, values, and priorities as Western leaders, and thus the functioning of deterrence is relatively predictable. In such cases, “rational” is conflated with that which fits within “reasonable” Western norms. This expectation of rational actors with shared “worldviews” has been a staple of Western deterrence theory for decades, but it is very likely to create unwarranted expectations about the decision making of foreign leaders, and thus lead to surprises.²⁶¹ A common understanding of what is deemed to be “rational” may have been appropriate (or something closely resembling it) during the Cold War when the United States focused so intently on the Soviet Union, but not in today’s security

²⁶⁰ Phillip Swarts, “North Korea poses unique challenges to space, experts say,” *Space News*, March 9, 2017, available at <http://spacenews.com/north-korea-poses-unique-challenges-to-space-experts-say/>.

²⁶¹ This distinction between expectations based on “rational” and “reasonable” foreign decision making in response to U.S. strategies of deterrence is discussed in, Keith B. Payne, *The Fallacies of Cold War Deterrence* (Lexington, KY: University Press of Kentucky, 2001), pp. 7-15.

environment, where potential adversaries to be deterred are diverse culturally, politically, economically, and militarily, and they have different command chains and methods for making decisions. For this reason, “an initial intelligence/analytical priority is to identify as accurately as possible the important participants in these [decision] chains and assess whether they are or can be made susceptible, directly or indirectly, to the deterrence tools available to the United States for this purpose.”²⁶² To be as effective as possible, deterrence must be tailored to specific opponents and contexts. One should not make broad, universal statements about it in so far as a proper functioning deterrence strategy precludes this approach.

Given the variability in opponents and contexts, there is no universal application of deterrence strategy that can be known in advance to have the desired effect. For example, what may deter North Korea may not deter Iran or China. The functioning of deterrence is unique to each actor and context. Consequently, it is critical to understand the opposing leaderships’ polity, values, perceptions and channels of communication. On that basis, it may be feasible to determine how deterrence strategies may be approached most effectively with regard to potential aggressive acts in space. The question is: how can the United States establish credible deterrence strategies vis-à-vis each prospective enemy to address such aggressive acts?

We cannot assume that deterrence of aggressive acts in space based on punitive threats will have the desired deterrent effect until we examine the leaders and contingencies we seek to deter. In space, deterrence by punishment is not so simple. For the United States, retaliation in kind for a destructive ASAT attack may be akin to shooting yourself in the foot. Given the fact that the United States relies very heavily on integrated space capabilities, and creating greater debris in space may damage U.S. spacecraft to the same degree as might an enemy attack, the threat of retaliatory strike on enemy space systems (at least one that results in the kinetic destruction of a satellite), may not appear credible to knowledgeable opponents. Indeed, the kinetic destruction of space systems could be part of an offensive package when the stakes at hand are greater than any concern over the proliferation of space debris; but when it comes to deterrence, such a threat may be considered highly suspect.

A U.S. deterrent threat based on striking an aggressor’s homeland also may not appear credible, especially during a crisis or in the absence of a serious provocation on the ground. So, who the aggressor is matters a great deal. The threat to destroy an enemy’s satellite may rarely be credible, given the U.S. dependence on space, but demonstrating U.S. capabilities to disable a network of satellites through incapacitation operations in space, cyber, or active measures on the ground that do not pose self-defeating consequences for the United States, may be a basis for establishing deterrent threats that appear credible to enemies.

The United States may be able to engage in what might be called “source retaliation,” or engaging in a military response against the source of the threat. For example, the United States could make it clear that it will destroy any launch center that is responsible for delivering an operational ASAT payload into orbit. The benefit of such a linkage (“I take your spaceport for your destruction of my satellite”) is that it denies the aggressor further access to space while avoiding the creation of additional space debris that could be highly disadvantageous for the United States. The fact that spaceports are not located near heavily populated areas may make them an ideal target in a deterrence strategy that desires also to limit collateral damage. Of course, the United States also

²⁶² Keith B. Payne, *The Great American Gamble: Deterrence Theory and Practice from the Cold War to the Twenty-First Century* (Fairfax, VA: National Institute Press, 2008), p. 368.

would have to, and should anyway, take the vulnerability of its own coastal spaceports into account. The same approach may be taken with locations on earth (and potentially in space, depending on the incapacitation tactic used) that are the sources of U.S. satellite jamming or dazzling.

An appropriate response to an EMP space attack (failed or successful) may very well take place in a domain other than space. Any nation with miniaturized nuclear weapons and a capability to launch has such an ability to launch an EMP strike. The U.S. nuclear command and control architecture, including its space missile warning and satellite communications infrastructure, is “very well positioned” to survive and respond to such an attack. But, according to General Hyten, “the rest of our infrastructure is not as well prepared to respond.” Regarding GPS, “there would be a slight degradation of the signal—if a single electromagnetic pulse went off, it would potentially take out certain elements of the GPS constellation.” Nevertheless, it is “fairly resilient because of numbers.”²⁶³ When it comes to an EMP assault in space, there is a much greater concern for the civilian space infrastructure.

Deterrence based on the threat of in-kind retaliation might be deemed credible if an enemy’s satellite could be taken off line through cyber attack, physical removal (snatching) from orbit, or some other type of incapacitation operation that does not pose a threat to U.S. space systems. Indeed, as space systems become further integrated into the economies and warfighting infrastructures of more nations, so much so that they become highly valued assets, it may make considerable sense for deterrence purposes to threaten in-kind retaliation. Of course, U.S. leaders would need to demonstrate the capability to target and capture enemy space systems, to disable them on-orbit or on the ground, before such a deterrence strategy could gain credibility.

To deter aggressive behavior in space, the United States must be able to see the provocation and be manifestly prepared to hold the aggressor accountable, which requires a capability to attribute those aggressive actions to a particular actor and respond on a tactically relevant timeline. It may be difficult to attribute the use of certain counter-space weapons, to include reversible countermeasures. Deterrence assumes that the United States will be able to recognize if an attack has occurred, when it occurred, by whom, and with what. Identifying the adversary and the aggressive action is the first step required for a punitive retaliatory response. Presumably the nation’s leaders would have an idea of the effect of an aggressive act against a U.S. space system. Ideally, space situational awareness will be in place to confirm any attack that has taken place. The United States should strive to have a capability to detect and assess the threat and attribute responsibility in a timely manner; inability to do so may undercut the U.S. deterrent threat, especially if that possibility is suspected by opponents.

Consequently, efforts must be made to communicate accurately what the United States intends to do in retaliation for an aggressive action in space and to pump up the perception of U.S. capabilities to detect an attack, attribute it to an actor, and affirm the intention to hold that actor accountable. Communication also should confirm perceptions about the strength of U.S. passive and active defenses, preventive measures, and damage-limitation strategies;²⁶⁴ this will

²⁶³ Hyten, “National Security Space Budget for FY17: Presentation to the Subcommittee on Strategic Forces,” op. cit. According to General Hyten, “the concern is that an electromagnetic pulse that goes off in space. That’s the concern. It is the most dangerous threat that a space officer ... is concerned about because it is the most threatening and the most damaging.”

²⁶⁴ Keith Payne discusses this in the context of nuclear deterrence, but the basic principles may be applied to space deterrence. Payne, *The Great American Gamble: Deterrence Theory and Practice from the Cold War to the Twenty-First Century*, op. cit., pp. 372, 373.

contribute to the potential for denial deterrence effects. For deterrence, the adversary should have a good understanding that its own assets would be at risk as a consequence of attacking the United States, be they in space, or on land, at sea, or in the air. The credibility of U.S. deterrence threats, however, may be difficult to establish, if based on threatened actions before a conflict has begun—the threatened response must be credible, even in this situation. Would the United States strike another state's targets using military forces before a war has broken out? There is a case to be made that, yes, depending on the severity of the prospective space attack, a potential adversary should and could be made to expect such a response.²⁶⁵

Deterrence against attacks on U.S. space systems requires other nations or non-state actors to recognize that attacks on the United States not only will lead to an unacceptable punitive U.S. response, but that their attack also will not succeed in being militarily effective. As stated earlier, this requires changing the growing perception that U.S. space assets are tempting targets and a weak link in the warfighting calculus. Adversaries must be disabused of the notion that they can, by denying U.S. military forces access to space capabilities, effectively counter a U.S. response or even defeat the United States on the battle field. A weak deterrent can lead other nations to believe they can deter U.S. entry into a conflict or, looking at it another way, can encourage other nations to believe they have a chance of besting U.S. forces on the battlefield in the pursuit of their strategic interests. If U.S. leaders cannot deter attacks on U.S. space systems, the destruction of those assets would impact the warfighting ability of the U.S. military.

Deterrence, which presents a threat of unacceptable counteraction to the potential aggressor, must be reinforced by the full range of powers available to a nation, to include the ability to act to secure its space systems when deterrence fails. The current strategy of the United States (which is essentially passive) does not provide a confident answer to the question: What happens when another nation strikes our space systems? Is there a credible deterrent in place if we do not identify the various types of retaliation (active responses) to be expected? The United States must put forth a declaratory policy that states clearly that the United States will respond to hostile acts in space (to include actions that seek to temporarily deny the country the use of space) and that it will consider the use of all available means, to include the use of force on earth and in space, to preserve its rights, protect its capabilities, and ensure its freedom of action in space.²⁶⁶

In some cases, ambiguity in this regard may be adequate for deterrence purposes, particularly *vis-à-vis* a risk adverse enemy. But, in some cases, the ambiguity of U.S. deterrent threats, and thus ambiguity regarding the consequences for an enemy's provocation, undercuts deterrence—especially in the context of a risk tolerant enemy that sees in ambiguity the opportunity to move as opposed to a threat to avoid.

To summarize: Deterrence operates in a world of shifting threats and opponents, with considerable variability in the most effective approaches to deterrence. Understanding deterrence is about understanding the behavior and decision making of the potential adversary. Personal histories, preferences, and goals all can influence decision making. Psychological,

²⁶⁵ "Any response to an attack in space will have to take into account the totality of U.S. interests, not just those directly affected by space. This approach can help to better identify and plan against those circumstances in which the country's own processes deny it the full benefit of its capabilities by posing barriers to effective implementation of deterrence messaging or actions. Categorizing and prioritizing risks in space and creating closer whole-of-government response plans are likely to have more value than drawing redlines in space." National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report*, op. cit., p. 26.

²⁶⁶ See Chapter 5, "Recommendations," for a proposed declaratory policy statement.

organizational, and cultural factors can influence decision makers as well. Deterrence threats must be credible (opponents must believe that the United States has the political resolve and the capability to carry them out). Correspondingly, the United States should tailor deterrence strategies to the particular adversary and contingency, and communicate that threat to the responsible and accountable leaders. Deterrence must exploit adversaries' strategic vulnerabilities, which may include space-based assets. Interference during peacetime will not likely be responded to in the same manner as one would to interference during crisis or war. The risk that there will be a response against the attacker must increase in time of war (in some respect, independent of space situational awareness—if the nation is at war there is a blackout of certain satellite functions, and certain inferences may be drawn that might lead to responses against the adversary). The potential attacker should be made to fear U.S. deterrence strategies and see them as credible; it must understand that the United States is able to attribute provocations to the source, and will hold that source accountable.

Addressing U.S. Vulnerabilities: Provocations in Space

According to the Space Commission led by former Secretary of Defense Donald Rumsfeld, which released its report in 2001, space warfare is a “virtual certainty,” and this, to be sure, aroused interest and, in some quarters, panic.²⁶⁷ The commission recommended that Washington look hard at the advantages of expanding the military uses of space to do two things: enhance deterrence and improve defense.²⁶⁸ “If the US is to avoid a ‘space Pearl Harbor,’ it needs to take seriously the possibility of an attack on US space systems,” said the commission, referring to the 1941 Japanese attack on US naval forces in Hawaii’s Pearl Harbor.²⁶⁹ “The US is more dependent on space than any other nation. Yet the threat to the US and its allies in and from space does not command the attention it merits,” said commission members, Republican and Democratic lawmakers and experts from the military and the private sector. “Those hostile to the US,” concluded commission members, “can acquire on the global market the means to deny, disrupt or destroy US space systems by attacking satellites in space, communication links to and from the ground or ground stations that command the satellites and process their data.” The trends identified by the commission have been confirmed by developments over the past 16 years.

An adversary, especially one that is at a conventional disadvantage with the United States, may look upon the disruption or denial of U.S. space systems during a crisis as a risk worth taking. An attacker could degrade U.S. space capabilities using electronic means (as opposed to a direct kinetic attack), which it believes could be viewed by the United States as less provocative or less “escalatory.” “Killing” space systems is not the same as drawing blood on earth, which may be a key variable when considering public support for retaliatory response options to the aggression. Moreover, while there is a taboo against using nuclear weapons (though one may legitimately question whether this taboo has sway in Russia, China, and North Korea), there is no equivalent taboo against the use of counter-space weapons. Certainly it would appear to be easier and less

²⁶⁷ Donald Rumsfeld, *Report to the Commission to Assess United States National Security Space Management and Organization* Executive Summary (Washington, D.C.: Department of Defense), January 2001, p. 10, available at <http://www.dod.gov/pubs/spaceintro.pdf>.

²⁶⁸ *Ibid.*, p. 12. In 2001, the Commission members made this observation: “We know from history that every medium—air, land and sea—has seen conflict. Reality indicates that space will be no different. Given this virtual certainty, the U.S. must develop the means both to deter and to defend against hostile acts in and from space. This will require superior space capabilities. Thus far, the broad outline of U.S. national space policy is sound, but the U.S. has not yet taken the steps necessary to develop the needed capabilities and to maintain and ensure continuing superiority.” We have not progressed in any significant way over the past 16 years.

²⁶⁹ The author drew the analogy to a “space Pearl Harbor” in 1995, “Space Control in Desert Storm and Beyond,” *Orbis*, Vol. 39, No. 3 (Summer 1995), pp. 417-433.

provocative to use temporary or reversible effects to counter space weapons (such as jammers or dazzlers) than it would be to use destructive kinetic weapons or turn off the satellite using cyber warfare. There would be less pressure for the United States to retaliate against a state that disrupted a U.S. satellite for a short time as opposed to disabling it.

When considering space systems and deterrence in crises, it is important to take into account the type of weapon used (yielding either reversible or irreversible effects), the type of target (commercial satellite versus nuclear command and control satellite), and what is happening on earth at the time. Not all satellites are created equal—disruption of commercial satellite operations may not have the same effect as the disruption of GPS or early warning satellites. As with just about every decision involving the use of military force, it is situational. Electronic jamming of communications satellites occurs all the time in the Middle East, mainly an effort by state leaders to block information flow to their state populations. Should a nation rely on commercial communications satellite for military communications, their disruption could significantly affect that same nation's defense interests.²⁷⁰ What is happening on earth is a key determining factor in a response to such a disruption.

Given that the nation's leaders may not know exactly why and how a space weapon was used, the use of counter-space weapons could lead to miscalculation. This is certainly the case in all domains involving human action. There will always be factors that are open to interpretation, and pressing timelines for making decisions may be expected to further complicate matters. This should underscore the importance of space situational awareness capabilities for general crisis stability, to include stability in space.

There is no evidence to suggest that building a common diplomatic framework for dealing with activities in space and focusing on dialogue in peacetime can give us a plausible route to the assurances we are seeking or the prevention of provocative actions. Establishing rules of the road in space will work with some, but only for those who see decisive value in obeying rules rather than violating them when necessary or convenient. Rules may cut down on the instances where accidents or misunderstandings in space might lead others to see those same actions as provocative, and this of course is a good thing. Everything in the rule-making business, however, hinges on the assumption that rules can be enforced, and that we are dealing with rational actors who have a stake in the current system and are willing to accept the commitments they have made, even when inconvenient and potentially costly. The contrary is generally the experience in international relations. International rules typically, at best, are seen as useful and, correspondingly, commitments are kept until a country feels the need to take contrary steps to support important goals, to include moving militarily in space, if needed.

Iran, for example, has a history of engaging in terrorism and military intimidation, to include the support of terrorist groups and the use of small boats to harass U.S. warships, and Iranian-backed Houthi rebels to launch missile attacks from Yemen against U.S. Navy ships in the Persian Gulf. Such attacks indicate the degree to which fear of U.S. retaliation (i.e., deterrence) has declined in the Middle East, especially if those attacks are restrained and brief.²⁷¹ Based on this track

²⁷⁰ See, for example, James P. Finch, "Bringing Space Crisis Stability Down to Earth," *Joint Forces Quarterly*, Issue 76, 1st Quarter, December 30, 2014, available at http://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-76/jfq-75_15-20_Finch.pdf.

²⁷¹ See, for example, Jonathan Spyer, "Behind the Lines: Tremor in Yemen" *Jerusalem Post*, October 22, 2016, available at <http://www.jpost.com/Middle-East/Behind-the-Lines-Tremor-in-Yemen-470572>. With its 2017 bombings of terrorist camps in Afghanistan and strikes against Syrian assets, the Trump Administration may be starting to alter the Iranian calculations of the U.S. political will to respond to aggressive actions against U.S. interests.

record, it is conceivable that Iran could use similar intimidation tactics against U.S. or allied satellites, especially in times of crisis, and especially if those tactics involved reversible effects. That is, we might assume such behavior unless the United States is able to bolster its space deterrent by announcing credible punishments in response to this type of aggression.

Those who believe that China will follow “rules of the road” when the stakes are high need only look at China’s disdainful response to international legal findings against it with regard to its island-making activities in the East China Sea, or its aggressive behavior in proximity to U.S. vessels on the high seas. In 2015, the Chinese Navy acted provocatively toward the U.S. Navy, simulating a missile attack. According to U.S. Representative Randy Forbes, “coming on the heels of anti-satellite and other demonstrations, this latest incident should be a reminder of the destabilizing course that China is on and the challenges we face in maintaining a stable military balance in the Asia-Pacific region.”²⁷² Russia also is used to engaging in provocative behavior and brinkmanship. According to NATO Secretary General Jens Stoltenberg, “Russia has also significantly increased the scale, number and range of provocative flights by nuclear-capable bombers across much of the globe. From Japan to Gibraltar. From Crete to California. And from the Baltic Sea to the Black Sea.”²⁷³

There is an approach to protecting U.S. space systems that touts the “process of dialogue with the national space security community to discuss priorities and concerns.”²⁷⁴ This approach, called “strategic restraint,” is focused on diplomacy and “signaling,” to convince others, “particularly China and Russia,” to “take a step back” and reevaluate their own goals. “Even without a reciprocal move on the part of the two near-peer competitors in space, however,” this argument goes, “the United States will benefit internally by taking the time to seriously reassess its space security house.” Essentially, strategic restraint means doing very little, if anything, to shore up deterrence with the support of military power while conversing with countries who have shown little interest in backing away from their own military space agendas (agendas that have evolved despite very little military space activity by the United States). This space diplomacy would strive to establish norms and rules that sharply delineate acceptable and unacceptable behavior and may strive to ban space arms (which may be defined in a way to impede missile defense capabilities). The effort to manage and control confidently developments in space would involve dialogue with China and Russia with the goal of providing “mutual assurance measures” that reduce the risks of misconceptions, and “breakers” (or “circuit breakers”) to turn off the escalation of activity leading to war.

Prevention of war in space is a desirable goal. Today, no nation has more to lose by such a confrontation than the United States. The question is, will the emphasis on preventing wars in space fuel the conditions for space confrontations? While some might argue that issuing private demarches and undertaking trust-building exercises with countries such as China, North Korea and Iran might help teach them about the highly adverse consequences of using a kinetic ASAT

²⁷² Bill Gertz, “Chinese Submarine Practiced Missile Attack on USS Reagan,” *The Washington Free Beacon*, December 15, 2015, available at <http://freebeacon.com/national-security/chinese-submarine-practiced-missile-attack-on-uss-reagan/>

²⁷³ Jens Stoltenberg, “Adapting to a Changed Security Environment,” Speech, Center for Strategic and International Studies, Washington, D.C., May 27, 2015, http://www.nato.int/cps/en/natohq/opinions_120166.htm.

²⁷⁴ Theresa Hitchens and Joan Johnson-Freese, *Towards a New National Security Space Strategy: Time for a Strategic Rebalancing*, Atlantic Council Strategy Paper No. 5 (Washington, D.C.: Atlantic Council, 2016), p. iv, available at http://www.atlanticcouncil.org/images/publications/AC_StrategyPapers_No5_Space_WEB1.pdf. The authors call efforts to ensure protection of space assets through offensive and defensive space control “hegemonic means,” implying that a course other than dialogue is tainted by an imperialistic, aggressive motive.

and avoiding inadvertent conflict,²⁷⁵ steps taken to educate the other side or build confidence and trust (i.e., information exchanges, notifications, crisis communications channels, warnings, demarcations, consultative mechanisms, shared space situational awareness, development of best practices in space) only work when both sides want the same thing. If they are truly interested in avoiding a situation that could escalate into a larger conflict, then improved communications and education are good steps to take.

Achievements of diplomacy, and strategic restraint, are never the last words when it comes to strategic competition. If there are no steps taken to prepare for the breakdown of deterrence or diplomacy, then there is no margin for error at all. This approach, in other words, is high risk. Indeed, Admiral Cecil Haney has concluded that “despite our efforts, a future conflict may start, or extend, into space.”²⁷⁶ In other words, it is important not to handcuff agencies within the state responsible for responding militarily to possible aggression against U.S. space interests.

Addressing U.S. Vulnerabilities: Arms Control

Other nations may use diplomacy to manipulate arms developments in other countries, as Russia and China are currently attempting to do with the United States. The danger of declaring or negotiating agreements for peacetime moratoriums on direct-ascent ASATs, for example, is that it would limit the development, testing, and potentially the operation of ballistic missile defenses, especially the more capable regional Standard Missile-3 interceptors deployed by Aegis BMD ships and Aegis Ashore sites in Europe. As noted, the United States used a modified Standard Missile-3 to reach into low earth orbit to destroy an errant and toxic U.S. government satellite in 2008. This was a unique and unanticipated use of a weapon system in an emergency situation. Moreover, there are very serious definitional and verification problems associated with an ASAT agreement. ASAT weapons can be tested without the target vehicle actually being in orbit.

Russia and China continue to push treaties to constrict the deployment of U.S. defenses to protect its space activities. Both nations have long promoted the Prevention of the Placement of Weapons in Outer Space Treaty (PPWT), which the United States continues to argue is unverifiable and does not deal with the threats posed by terrestrially-based anti-satellite weapons (electronic jammers and direct-ascent ASATs)—weapon systems currently under development by Russia and China. Russia is also promoting a “No first placement of weapons in outer space” initiative, which the United States argues will not reduce mishaps, misunderstandings, and miscalculations.²⁷⁷ The United States has consistently avoided such legally binding commitments while arguing for voluntary commitments to agreed-upon transparency and confidence-building measures, such as the 2013 United Nations Group of Government Experts on Transparency and Confidence-Building Measures in Outer Space Activities.

The PPWT has been pushed by Russia and China and opposed by the Obama and, presumably, Trump Administrations. This is the right position as the treaty in question is designed to unduly constrain U.S. actions to defend itself in space and could affect its current and future missile defense plans. The compromise agreement by the European Union, Code of Conduct, has since

²⁷⁵ Zenko, *Dangerous Space Incidents: Contingency Planning Memorandum No. 21*, op. cit.

²⁷⁶ Cited in Davenport, “A fight to protect ‘the most valuable real estate in space,’” *The Washington Post*, op. cit.

²⁷⁷ Remarks by Frank Rose, Assistant Secretary, Bureau of Arms Control, Verification and Compliance, “The Role of Diplomacy in Keeping Outer Space Safe, Secure, and Sustainable,” *State.gov*, April 14, 2016, available at <https://2009-2017.state.gov/t/avc/rls/255834.htm>.

been replaced by the International Code of Conduct (ICoC) for Outer Space Activities. As with any arms control arrangement or code of conduct, they are only as good as their participants—the United States lives up to the letter and spirit of its international agreements; but the same cannot be said of other key participants, particularly Russia. Also, to what extent will adherence to the ICoC hinder steps that the United States must take to protect its space assets and deploy defenses? It is important to ask what the real benefits of signing such an accord will reap—what does the ICoC provide that the United States does not already practice in space? Commercial satellite operations already abide by norms to avoid collisions and spectrum interference. Ultimately, however, U.S. leaders must ask themselves whether they believe the ICoC will constrain these countries of greatest concern.

In response to the relative strategic restraint demonstrated by the United States, both Russia and China continue to build up and modernize their ballistic missile and counter-space capabilities. Iran and North Korea, in defiance of international sanctions, have developed ballistic missiles and have leveraged their respective space programs to improve missile programs. North Korea, also in defiance of several UN Security Council resolutions and the international community, to date has conducted five underground nuclear tests. These activities not only demonstrate the desire by these states to modernize and improve weapon systems to exploit U.S. and allied vulnerabilities, but also highlight the limited nature, if not futility, of arms control as it has often been practiced. U.S. officials should not get locked into the illusion that the United States can cause or prevent an “arms race” in space. As we have witnessed over the past decade, the United States does not have to be involved in an arms race in space for other nations to focus their investment into the development of counter-space weapon technologies.

There are, of course, numerous documented pitfalls to arms control—verification difficulties and non-compliance are chief among them. Russia has a history of violating key arms agreements, to include the Intermediate Nuclear Forces treaty.²⁷⁸ There was the supreme failure of the 1972 Anti-Ballistic Missile Treaty, which held the United States back from developing technologies and systems to defend the country against Soviet missile threats, while doing nothing to prevent the expansion of the growing Soviet missile force—with the consequent increase in the vulnerability of U.S. deterrent forces to Russian nuclear forces. There is also overwhelming evidence of the failure of the New START treaty to lead Russia to join the United States in lowering the salience and numbers of nuclear forces. Unverifiable arms control agreements on space would likely be as subject to violation by Russia (and perhaps China) as the numerous other arms control agreements with which it is in noncompliance.

Though history is replete with examples of nations that develop weapons to counter the weapons of other nations to depict the cause of arms development as an “action-reaction” cycle instigated by the United States is often overly simplistic and factually mistaken. Strategic national aims drive weapons development for all nations. The development of a Space Based Interceptor, for example, might fulfill an urgent need to provide effective defenses against ballistic missiles and direct-ascent ASATs, so much so that it justifies the United States being the first to deploy space-based weapons. The deployment of SBI would not necessarily drive other states to deploy such a system if they were not otherwise going to do so, simply because they may not have the

²⁷⁸ Franklin C. Miller and Keith B. Payne, *No More US-Russian Arms Treaties Until Moscow Stops Violating Existing Treaties and Agreements*, National Institute for Public Policy Information Series No. 418 (Fairfax, VA: National Institute Press, March 9, 2017), available at <http://www.nipp.org/wp-content/uploads/2017/03/IS-418.pdf>; Mark Schneider, *Russian Violations of the INF and New START Treaties*, National Institute for Public Policy Information Series No. 410 (Fairfax, VA: National Institute Press, August 15, 2016), available at <http://www.nipp.org/wp-content/uploads/2016/08/IS-410-final.pdf>.

technical expertise, capabilities, or the money to do so, or may not have the same requirement to defend against ballistic missile attack or defend space systems. Indeed, it should not surprise us that other nations deploy defenses, potentially including space-based defenses; other states will deploy weapons that are tailored to their strategic aims whether or not we move in a similar manner before or after.

The United States has a significant stake in promoting a space environment that is secure and free to operate in since it deploys significant space assets to support national security, but this does not mean that by refraining from steps to defend its interests through force that space will not somehow become more armed. Other nations will follow their security interests regardless of what the United States does (China and Russia seem to understand there may be a significant strategic payoff in having capabilities to deny other nations the use of space). The United States, as a powerful actor in that environment, does not have the only voice. Idealism must be balanced by the practical. We might have a vision for space that is completely free of conflict and weapons deployments, but we should not be deceived into believing that our vision will not be overcome by the visions of others.

Obama's National Security Space Policy

U.S. national security space strategy in the Obama Administration emphasized the importance of all nations acting responsibly, peacefully, and safely in the use of space. Encouraging responsible behavior is desirable. However, the strategy failed to provide unambiguous guidance on how to respond to the hostile use of space by potential adversaries. There was, instead, a rather dismissive attitude to the whole notion of space control: "We believe it is in the interests of all space-faring nations to avoid hostilities in space. In spite of this, some actors may still believe counterspace actions could provide military advantage."²⁷⁹

A recent unclassified national security space strategy report provides no indication that the Obama Administration was preparing to actively counter the space capabilities of adversaries; rather, the Obama Administration apparently was attempting to balance its highly idealistic language with the potential realities of conflict. Yet it must be pointed out that U.S. leadership in the world today is predicated heavily on its military might. Leading by example without strength to bear against those who would transgress U.S. interests would most likely lead the nation to retreat from the defense of its interests. Moreover, such a display of weakness could lead to attacks on the United States. History does not tell us that merely leading by example through living responsibly and peacefully is the best way to defend the nation. Why would we expect this tactic to work in space? Today, counter-space operations against U.S. assets are getting attention, but there seems to be no attention given to providing the United States with capabilities to counter the hostile space activities of other nations.

There is significant discussion in official circles today about bolstering behavioral norms in space. But to whose "norms" will nations adhere? As the U.S. Deputy Assistant Secretary of Defense for Space, Doug Loverro put it, "we don't want people shooting at satellites, we don't believe that's a good thing for mankind."²⁸⁰ It has also been said that the establishment of norms "serves as a

²⁷⁹ Gates and Clapper, *National Security Space Strategy 2011*, op. cit., p. 11.

²⁸⁰ Interview with Warren Ferster and Mike Gruss, "The Price of Space Dependence," *Space News*, January 4, 2016, available at <http://www.spacenewsmag.com/feature/the-price-of-space-dependence>.

reminder that any battle for control over the use of space to support military operations begins well before forces begin to mobilize on Earth.”²⁸¹

We cannot assume, however, that the norms which other states adopt will be those norms we deem appropriate to ensure peaceful actions and safe behavior in space. The last decade is replete with examples of other countries, some of which are potential adversaries of the United States, practicing direct ascent ASAT maneuvers; one of these was destructive, demonstrating co-orbital ASAT operations, and practicing reversible interference through jamming of radio signals or dazzling infrared sensors. The norm of self-serving behavior that advances national goals is the norm that has been most obvious in international relations for centuries. And, this norm has been reflected in space over the past 10 years. Are efforts to create benign “rules of the road” likely to replace this norm? While possible in principle, it seems extremely unlikely, and would be highly imprudent to assume as a basis for defense planning.

Another norm that characterizes the current age and should inform our thinking about space is invasion of sovereign nations. In February 2014, Russia’s president Vladimir Putin invaded Ukraine, starting with the annexation of Crimea (part of Ukraine). Since the invasion, more than 10,000 Ukrainians have been killed. This has happened despite international norms, treaties, and agreements that condemn such aggressive behavior and consider it to be politically shameful; indeed, international agreements and shaming speeches have been entirely ineffectual. The Ukrainians either did not consider that such a transgression could occur, or believed that the world would rally to their side to push back the invasion. Neither belief, of course, was based in reality. All that matters today are the facts on the ground—i.e., the nature of the regimes confronting us and the strategies they are pursuing.

There are broad national security implications of not having access to space. On land, at sea, and in the air, the United States customarily strives for peaceful, safe, and responsible behavior to avoid accidents, ensure international tensions do not flare up, and essentially collaborate with other states to ensure a stable, predictable environment—but it does so armed all the same, prepared to defend interests in each of those environments. Why? Because history is replete with violations of broken conventions and international agreements, and because peace does not last.

²⁸¹ Harrison and Jackson, “Space deterrence: a response,” *op. cit.*

Chapter 5: Recommendations

U.S. defense leaders must strive to guarantee U.S. freedom of action and provide a strong deterrent to aggressive behavior in space that prevents efforts by other nations to control orbits. These are the core interests of the United States in space. However much U.S. leaders and many of the American people and U.S. allies would never want to fight a war that extends into space, the United States must be prepared to defend its operations in that domain and, if necessary, fight through the loss of access to space capabilities. Space is an obvious place for the adversary to look to upset the advantage currently carried by the United States. This is why the nation's leaders must act to defend and deter in space.

The following are the key recommendations of this study:

The Administration should undertake a comprehensive space threat study. The nation needs a comprehensive assessment of the emerging security environment and challenges to U.S. security in space in order to craft sensible space policy, goals, priorities, strategy, and capabilities. This review of U.S. vulnerabilities in space could be modelled after the 1998 Rumsfeld Commission study which was conducted to assess the long-range ballistic missile threat to the United States. A bi-partisan commission should be created to assess the foreign threat to U.S. space systems, develop a vision for U.S. conduct in the space environment, and propose recommendations, to include options for addressing current and future threats to U.S. interests in space. The results of this comprehensive study should have classified and unclassified versions. Additionally, the Congress should continue to involve itself in this process by holding classified and unclassified hearings on space threats to the United States.

The Administration should develop national policies and strategies to guide the development and execution of space protection efforts. In conjunction with the space threat study, it is essential to revisit the National Space Policy and National Security Space Strategy. The apparent escalation of the threat to U.S. space systems demands attention now. Proliferation of space and counter-space capabilities is a concern that may not be adequately addressed in existing policy and strategy documents, particularly with regard to development of a deterrence strategy and the acquisition of systems necessary to defend U.S. interests in space. The new space policy needs to provide the right terms, and the Pentagon must be prepared to defend against multiple and diverse attacks in space from different adversaries that will have different levels of impact and will demand different types of responses. A revised declaratory policy and revised policy and strategy documents should help leaders, planners, and executors whose job is to determine what constitutes a provocation and/or an attack in space, and is, therefore, a violation of U.S. sovereignty.

The Department of Defense must develop a credible comprehensive deterrence strategy. The idea of attacks in space are not as unthinkable as one might imagine—certainly not as unthinkable as nuclear war—because we have witnessed multiple demonstrations by China, Russia and other nations involving reversible and irreversible anti-satellite warfare. The threat of international economic and diplomatic isolation is hardly a credible deterrent to reversible and irreversible attacks on U.S. space systems. Successful deterrence strategy must target the leadership in each individual country with command-and-control authority—who has the ability to

authorize a space attack, and how can that individual or group of leaders be deterred? An effective warning must be based on credible capabilities. The United States needs to work to protect its advantage in space, to include the development of a robust deterrent to first strikes in space. A comprehensive study of each country of concern should be undertaken to identify the special challenges posed by each and the vulnerabilities that may be targeted to bolster deterrence.

The United States must respond when national security space systems are violated and not risk giving the wrong impression that perhaps the United States does not have either the capability or the will to follow through on its declared policies. There will be significant positive benefits to preparing to defend and retain the key “geographic” region of space which will also result in a stronger deterrent and convey the proper perspective to potential adversaries. The United States needs to clearly spell out to its own national security leadership and command authorities and inform the world what it will mean when U.S. national security space networks come under attack, networks that could very well include U.S., foreign government, or commercial systems that provide national security functions. This may not mean drawing public “red lines” since a certain ambiguity over just what the United States will consider an attack might be beneficial (and it would avoid tempting potential adversaries from probing and pushing right up to the red lines). Those policies should make it clear what immediate or long-term responses the potential adversary should expect as a result of its violations. It starts with a policy declaration that forms the basis for a deterrence strategy to shape the behavior of a particular country.

A proposed declaratory policy statement reads as follows: All states possess the sovereign right of self-defense, and the United States will respond to hostile acts in space, to include acts to temporarily deny it the use of space. The United States considers U.S. military, commercial, and allied space systems to be vital to its national security and will use all necessary and appropriate means, including the use of force in the domain of its choosing, be it a terrestrial domain or space, to preserve its rights, protect its capabilities, and defend its freedom of action in space, and to deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests, as appropriate and consistent with applicable international law.

Develop a strategic messaging plan. Officials in the White House and the Department of Defense must communicate clearly with the U.S. Congress and the American public, the members of the Armed Services, allies, and foreign audiences the critical role space plays and the reason the United States needs an active space protection and space control strategy. There is also a need for strong Executive-Legislative Branch collaboration on defense space issues. The Administration should explain to Congress the importance of funding military space activities to ensure robust space protection and space control options.

Strategic messaging is critical to a successful deterrence strategy, especially communicating what will be done should deterrence fail. The United States needs to reaffirm its right to self-defense in space and strive to be clear on what other nations should expect should they violate U.S. space systems. This will involve increasing transparency into U.S. deterrence strategy and clearly and unambiguously declaring the range of options available to the United States for purposeful interference with U.S. defense space operations. It will also require the Administration to continue the trend of shedding light on the counter-space operations of foreign nations, especially China, Russia, North Korea, and Iran. Official and unclassified government reporting released to the

public will help support U.S. efforts to respond to potential adversaries' efforts to interfere with U.S. space operations.

Statesmanship involves alerting citizens and engaging them in discussions about the realities of national security space before critical capabilities are lost. This public education is important if U.S. leaders are to develop new policies and initiate new programs to further the space protection priority. Discussion is required to fully assess the rationale and requirements for space defense, costs and benefits and, importantly, the implications of experiencing a loss of space assets. This discussion of space and cyber threats in the public arena, including discussion of costs associated with destructive activities in space, are essential to attaining the support of the American people for U.S. freedom of space initiatives.

With the Defense Department's decision in 2014 to speak more openly about the space threat, and the decision to hold Congressional hearings on the space threat in March 2015, March 2016, and March 2017, the process of shedding light on the "black world" has begun. Indeed, 2016 was the year in which the Pentagon began to "adjust the U.S. space posture to the realities of a future space environment that could be contested."²⁸² And, to some extent, it is being done in the public eye. Yet it must go further. This requires declassifying—consistent with national security—some information in the black world in order to ensure that discussion is informed. This is essential if the nation is to have the political will to see through and publicly defend major space defense initiatives and investments. Some might argue that broadening the public discussion would be "provocative," and that closed sessions featuring a reliance on indirect and diplomatic language in public is preferable. This approach is overly sensitive to the bluster proffered by Russian and Chinese officials and negotiators, as well as domestic opponents, all of whom have are adept at pushing the buttons of Americans who are concerned about provocative language and who are accustomed to labeling any discussion of defenses they do not favor as offensive and provocative (e.g., the missile defense debate). Such an approach, however, is at odds with the nature of the democratic republic, where citizen involvement to the greatest extent possible in major foreign policy or military decisions is most desirable.

The Defense Department should request that the U.S. Congress provide the necessary resources and programs to improve space system protection and defense. The fact that nations have demonstrated the technical ability to disrupt, damage, or destroy satellites makes it incumbent upon U.S. leaders to devise military and political solutions to address what is a growing and increasingly dire threat. This requires that the United States invest in and devote political capital to the development of systems or weapons which deny potential enemies the opportunity to disrupt U.S. space operations during times of crisis or war. Resources allocated to space protection and space control missions thus far have been paltry, with funding for space research and development at a 30 year low. Aside from not funding programs that would make the United States more responsive to space threats, the lack of attention and inadequate funding has allowed the space industrial base to erode.²⁸³

²⁸² Douglas Loverro, *Statement of Douglas Loverro, Deputy Assistant Secretary of Defense (Space Policy)*, 114th U.S. Congress, House Armed Services Committee, March 15, 2016, p. 2, available at <http://docs.house.gov/meetings/AS/AS29/20160315/104620/HHRG-114-AS29-Wstate-LoverroD-20160315.pdf>.

²⁸³ General William L. Shelton, USAF (Ret), *Statement before the House Armed Services Subcommittee on Strategic Forces and House Homeland Security Subcommittee on Emergency Preparedness, Response and Communications*, "Threats to Space Assets and Implications for Homeland Security," March 29, 2017, p. 6, available at <https://armedservices.house.gov/legislation/hearings/threats-space-assets-and-implications-homeland-security>.

Given that a kinetic space war is not in the best interest of the United States, the most suitable option is to deter reckless and aggressive behavior in space. Effective deterrence requires U.S. leaders to be willing and able to fight to defend U.S. space capabilities, which in turn will bolster the deterrent against aggression in space. This will require satellites that are harder to jam, impair, or destroy. The United States also must be able to defend against anti-satellite attacks and be able to replace satellites in a timely and cost-effective way to ensure U.S. forces can continue operation. This may also require the ability to temporarily and less-effectively operate on earth without the full complement of space forces. There are different threats, and U.S. leaders need options to respond to all of them, including active defenses against threats to assets in space and threats to assets on the ground that would come through space (such as ballistic missile reentry vehicles). U.S. leaders should not allow other nations to practice temporary disruptive effects against its satellites as such tactics may be put to use during a crisis to major strategic effect.

The Department of Defense should invest in additional situational awareness sensors in space and on earth. The nation's policy and defense leaders must ensure the United States has robust space situational awareness so that no nation or non-state actor is able to attack U.S. or allied space systems (military, civil, and commercial satellites) without detection. The United States needs to continue building a space-based global tracking capability to supplement current and planned ground-based and space-based sensors. "We need to be able to broadly use the global nature of space to be able to add a global tracking capability because that not only allows us to track but allows us to operate weapon systems more efficiently than just firing many at one time."²⁸⁴ The United States must be able to attribute U.S. satellite failures to a particular cause with a high degree of confidence. Better space situational awareness is the cornerstone of our ability to operate in that environment and it is the bedrock of any convincing deterrence strategy. Accurate and actionable information on what is happening in space allows U.S. warfighters to understand what an object is, where it is, and where it is going, as well as its intentions. Increased space situational awareness will also aid Service attempts to counter enemy reconnaissance satellites. Efforts should be made to make the SSA network more capable of observing and understanding activities in space. Such capabilities will provide increased discrimination capabilities and expanded coverage, to include approaches to the United States over the southern hemisphere. This should involve leveraging missile defense space sensors and command and control systems to support space defense missions.

The Defense Department should develop the capabilities to exercise positive space control. There is a need to sharpen the focus on space control programs to accompany the revised declaratory policy.²⁸⁵ Since there is a growing dependence on space by potential adversaries, U.S. leaders should consider kinetic and non-kinetic ways to deny them space-enabled information in times of conflict. Increasingly, if the nation cannot deny adversaries space-based navigation guidance used in increasingly long-range cruise missiles, then the effectiveness of their attacks against the United States would substantially increase. At a minimum, warfighters should have options available to them to respond with force. This does not mean that the United

²⁸⁴ General John E. Hyten, "Hearing on the Nomination of General John Hyten to be Commander of U.S. Strategic Command before the Senate Armed Services Committee," *114th U.S. Congress*, Senate Armed Services Committee, September 20, 2016, p. 77, available at https://www.armed-services.senate.gov/imo/media/doc/16-70_9-20-16.pdf.

²⁸⁵ Mike Gruss, "Hyten tells Senate DoD needs to focus on space control, battle management system," *Space News*, September 20, 2016, available at <http://spacenews.com/hyten-tells-senate-dod-needs-to-focus-on-space-control-battle-management-system/>. There are indications that the Department is looking for faster development of offensive weapons and combat tactics in space. Andy Pasztor, "Pentagon Ramps Up Space Warfare Effort," *The Wall Street Journal*, April 26, 2017, available at <http://www.wsj.com/articles/pentagon-ramps-up-space-warfare-effort-1493199003>.

States must use a destructive capability to execute the space denial mission in space (although in times of extreme danger to the nation, the United States may want to destroy or neutralize a selection of enemy satellites); it may accomplish this using innovative technologies (possibly developed in the private commercial sector)²⁸⁶ to disable or temporarily impair satellites, essentially cutting the enemy off the information nodes in space. This, of course, may also be accomplished at some level by incapacitating ground stations.

The Department of Defense should work to move missile defense intercept capabilities to space and consider steps to improve missile defenses against threats from southern trajectories. The entire earth and the space above it is the battleground for missile defense and satellite defense. The United States should invest in missile defense technology to improve protection against increasingly sophisticated ballistic missile and fractional orbital bombardment systems, and provide a line of defense against boosting satellite attack missiles. Space-based interceptors (SBIs) would be in the best position to offer both enhanced territorial protection of the United States and defense of critical satellite assets, especially against attacks from the ground. SBI is the one defense system that can be deployed that will provide global protection against direct-ascent ASATs and be a key element in the layered Ballistic Missile Defense System. SBI would be capable of intercepting ASATs in very low earth orbit, which would make the space debris issue negligible. This is an important capability in a world where technologies for direct ascent ASAT development are becoming more sophisticated. The threat of nuclear weapon deployment also makes development and deployment of SBI matters of urgency.

A missile defense architecture with an Aegis Ashore southern tier in the United States could also address a fractional orbital bombardment system (FOBS) attack and potentially provide layered missile defense of the U.S. homeland. A FOBS would use an orbital trajectory (and not necessarily make a complete orbit) to gain extremely high velocities before falling out of its orbital assist to strike targets in the United States. A FOBS might also be used to detonate a nuclear weapon over the United States, releasing an Electro-Magnetic Pulse. North Korea and Iran have demonstrated a capability to launch payloads into low earth orbit over the south polar regions.²⁸⁷ The United States demonstrated it could hit an object in very low earth orbit with the February 2008 satellite shoot-down, when it used an interceptor (the ship-based SM-3 Block IA) that is less capable than the SM-3 Block IIAs currently being developed. When fired vertically, the SM-3 can reach targets as high as 310 miles.²⁸⁸ The United States had excellent intelligence for that shoot-down mission (since orbiting satellites are highly predictable) and excellent intelligence would be instrumental in defeating a FOBS. A Ground Based Interceptor from Vandenberg or an SM-3 IIA with an even lighter kill vehicle would be needed to reach higher altitudes within low earth orbit.²⁸⁹ A space based interceptor, however, would be in the best position around the clock.

²⁸⁶ National Academies of Sciences, Engineering, and Medicine, *National Security Space Defense and Protection: Public Report* (Washington, D.C.: The National Academies Press, 2016), p. 3, available at <https://www.nap.edu/catalog/23594/national-security-space-defense-and-protection-public-report> “[F]renetic innovation in the commercial space sector has the potential to be the main driver of change in the space domain.”

²⁸⁷ Henry F. Cooper, “April 17, 2014—Defeat Iran’s FOBS!” *High Frontier*, April 17, 2014, available at <http://highfrontier.org/april-17-2014-defeat-irans-fobs/>.

²⁸⁸ Joe Pappalardo, “Satellite Shot Offers Navy Key Space Defense Trial: How It Works,” *Popular Mechanics*, February 14, 2008, available at <http://www.popularmechanics.com/technology/military/missile-defense/4249458>.

²⁸⁹ J.D. Williams, “Improving Aegis Ballistic Missile Defense Command and Control,” *Heritage Foundation*, May 2, 2011, available at <http://www.heritage.org/defense/report/improving-aegis-ballistic-missile-defense-command-and-control>; and Cooper, “April 17, 2014—Defeat Iran’s FOBS!,” op. cit.

The nation should continue to integrate allies and partners into space operations, share situational awareness, and exercise together. Bilateral and multilateral relationships with partners around the world can complement and supplement U.S. space capabilities. Data sharing, interoperability, and hosting tracking assets are other possible cooperative activities. While significant progress has been made in this area, U.S. leaders should continue to exercise and train with U.S. allies and international partners and engage them in more rigorous discussions about national security space; international partners add resiliency and redundancy to U.S. space architectures. Several allied nations have high-resolution imagery satellites, military communications satellites and launching infrastructures. The additional launch capacity could be used to replenish what we have on orbit.²⁹⁰ Foreign systems of allied and friendly nations appropriately integrated into the architecture would also improve redundancy and provide overlapping, surge, and backup capabilities. Over-classification (to the extent this is happening) also can harm information-sharing with allies.

Shape the international laws, regulations and codes affecting military space activity. The United States must remain focused on preserving the peaceful uses of space which, given the history of peace and war, requires the United States to have an ability to influence events and defend freedom of action in space, to include militarily significant operations. Although it is not sufficient for deterrence, the United States should continue to promote responsible behavior and engage other nations in the development of non-binding norms and confidence-building measures. U.S. leadership should not participate in any international agreements that involve an ASAT ban in space. For one, the repercussions for missile defense could be significant; secondarily, it would hamper U.S. ASAT development efforts. Indeed, such a solution seems unlikely to inspire confidence given the compliance difficulties and verification challenges involved in other treaties. National space policies must be driven by national security needs and not by arms control idealism.

The Department of Defense should revisit the 2001 Report of the Commission to Assess United States National Security Space Management and Organization. Some have argued that “the Nation has been left with a 20th century construct for managing space in a 21st century threat environment.”²⁹¹ Although this monograph did not set out to examine the advantages and disadvantages of the current management structure across the national security space community, it makes eminent sense to return to the 2001 Report of the Commission to Assess United States National Security Space Management and Organization (the Rumsfeld “Space Commission”) as a starting point to grade U.S. progress in addressing proposed reforms. The nation and its Defense Department must give adequate priority to space. Moreover, both must be properly organized, unified and synchronized to respond to the threats discussed in this monograph. In the current security environment, it is imperative that the United States be properly structured and managed so that it can respond rapidly, if necessary, to deliver capabilities to defend U.S. space systems.

²⁹⁰ Work, “Remarks at the Space Symposium,” op. cit.

²⁹¹ Mike Rogers and Jim Cooper, “10-Year Anniversary of the Chinese Anti-Satellite Test,” *House Armed Services Committee*, January 11, 2017, available at <https://armedservices.house.gov/news/defense-drumbeat/rebs-rogers-and-cooper-real-clear-defense-10-year-anniversary-chinese-anti>.