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Space and Cyber

Shared Challenges, Shared Opportunities

Edited Remarks to the USSTRATCOM Cyber and Space Symposium

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I VERY MUCH appreciate the opportunity to discuss the many challenges facing us in space and cyberspace and the strategies the DoD has developed and published over the course of the last year. These strategies set out a good framework to address the many space and cyber challenges. Although there are many physical and technical differences between the space and cyber domains, there are many similarities in the challenges confronting each domain, which have allowed some shared and similar approaches to addressing the problems.

Space and cyberspace are global capabilities and global enablers that together enable the United States, our partners, and allies to maintain a strategic advantage over potential adversaries and enhance our national security. These capabilities allow us to stay on the leading edge. They also enable economic growth, better standards of living, and rapid communications that foster the financial and social links indispensable in our everyday lives. These links also allow us to maintain close real-time relations with our partners. Our cyber and space capabilities are connected in very real ways, both for our war fighters and for our society as a whole.

Cyber and space capabilities are connected operationally. A bit of data from an analyst sitting at a computer may be directed through a local network, transmitted by satellite, and then received by troops in the field halfway around the world. Space capabilities supplement and enhance cyber capabilities, and vice versa. The timing function provided by GPS enables all of the base stations in a data network to stay synchronized.

And the measurements and observations collected by our weather satellites are transmitted and processed through cyberspace, enabling more precise weather forecasts as well as tactical and operational capabilities that otherwise could not be implemented. In many cases, space and cyber capabilities ride on the same infrastructure. That bit of data may ride on fiber for a while before being directed up through a satellite and back down to another terrestrial network. Our space and cyberspace capabilities are distributed, networked, and global; we must utilize and protect them accordingly.

Cyber and space capabilities are connected by common threats. Each of these depends on the electromagnetic spectrum and IT infrastructure that affords us great capabilities but also creates cross-domain vulnerabilities and challenges. An attack on our space capabilities may start in cyberspace, and attempts to hack our cyber capabilities get routed through space.

Low barriers to entry have allowed states and nonstate entities to contest our use of both space and cyberspace. "Low barriers to entry" may sound strange when applied to space capabilities, but counterspace capabilities, as we know, do not always require a space program. Increasingly, satellites are jammed by commercial equipment easily acquired by state and nonstate actors. The low barriers to entry in cyberspace allow a range of adversaries to have effective capabilities against networks and computer systems, unlike those anywhere else—here, cyber criminals, proxies for hire, and terrorists could leverage capabilities that previously only governments possessed. As former deputy secretary Bill Lynn wrote in his latest *Foreign Affairs* article, "The United States is now in the midst of a strategic shift in the cyber threat."

In both space and cyberspace, maintaining an edge is always a challenge. We know our adversaries seek advantage through industrial espionage and the theft of intellectual property, which places burdens on our industrial base. An increasingly more sophisticated international workforce is also challenging our own workforce, seeking to out-innovate and out-develop. We need to strengthen our industrial base through better, more advanced acquisition and export control processes, and remove the outdated restrictions that hamper our industrial base today. In space and cyber, attracting the next generation and retaining the current generation of skilled professionals will continue to be a challenge.

Space and cyberspace are connected in how we have organized ourselves. My office—the Office of the Assistant Secretary of Defense for

Global Strategic Affairs—develops policy on cyber and space issues, along with other global issues, including countering weapons of mass destruction, nuclear forces, and missile defense. Similar responsibilities are found at STRATCOM, executed by the men and women who are the leaders in strategic deterrence and the preeminent global war fighters in space and cyberspace. We are not the only ones, however, who have seen the benefit of organizationally integrating space and cyberspace. Many of my international counterparts on space issues are also my counterparts on cyber issues. This similar organizational integration, while fairly new, will over time, I hope, ensure that both domains are more effective, more resilient, and more coordinated with our international partners.

Not all of the challenges for the space domain are equally difficult for cyber, and the reverse is, of course, true. The two developed differently and at different times. Fifty years ago, space was largely the private preserve of the United States and the Soviet Union. Over time this changed, and today over 60 countries or government consortia operate satellites, and the number of commercial satellite owner/operators continues to increase. Cyberspace moved out of the realm of government control much more quickly than space, as many people both inside and outside governments appreciated the advantages provided by networked systems. Very quickly, the development of cyberspace became characterized by openness and interoperability. We have watched these technologies revolutionize our economy and transform our daily lives, but we have also watched offline challenges move online. Of course, the different physics and technical realities of space and cyberspace result in somewhat different threats. But despite the differences in our use of space and cyberspace, there are many similarities in the challenges.

In the face of these shared and similar challenges, we have developed similar approaches to protecting the strategic advantages enabled by space and cyberspace, as well as protecting the industrial base and the domains themselves. Since last year's separate cyber and space symposia, the DoD has completed the *National Security Space Strategy*—co-signed by the director of national intelligence—and the *Department of Defense Strategy for Operating in Cyberspace*. Both of these strategies start by acknowledging that we are in new territory from a threat perspective. Although we have much more experience operating in space, the threats have evolved fairly rapidly over the past few years and changed dramatically. The Chinese antisatellite test in 2007 was a turning point for space. Today in cyberspace, we have the opportunity to take actions now to ensure that we can rely on this domain into the future, taking full advantage of the competitive advantage it provides. As it happens, both of these strategies have five strategic approaches or initiatives for addressing these challenges.

Both strategies acknowledge the importance of international partnerships. These partnerships allow us to maximize our scarce resources, mitigate risks, and utilize each partner's core strengths. International cooperation is also important to increase situational awareness in both space and cyberspace so we can understand and differentiate between a man-made disruption and a natural or technical anomaly. Partnering strengthens all of us. And as Gen Bob Kehler, STRATCOM commander, said in May, "We want to work to develop means of collective self-defense in space and [in] cyberspace."

The interoperable nature of cyberspace means that an important part of our international cooperation is sharing the necessary knowledge, training, and other resources with our partners and allies to build technical and cyber security capacity. In the space domain, we seek to expand mutually beneficial agreements with key partners to utilize existing and planned capabilities that make us all stronger and more resilient. Ultimately, international cooperation is vital to maintaining and enhancing the advantages we derive from space and cyberspace. No single state or organization can maintain effective cyber defenses on its own; international collaboration is necessary to address the increasingly congested, contested, and competitive nature of space.

An important part of this international collaboration is emphasizing norms and guidelines for space and cyberspace. Both space and cyberspace strategies emphasize the need to encourage responsible behavior in their respective realms. Practices that promote the responsible, peaceful, and safe use of space will help ensure a space environment that is stable, safe, secure, and sustainable. Moreover, the development and promotion of international cyberspace norms and principles will promote openness, interoperability, security, and reliability. In both areas, government and private-sector actors have an important role to play. And in both areas, there are things that the international community generally agrees are bad, like botnets and space debris. Together, we can work to address these common threats.

Situational awareness is the foundation necessary to maintain and enhance our space and cyber capabilities. Both hostile actions and adverse, but natural or unintentional, conditions can impact our ability to use space and cyber capabilities. As the tools and techniques developed by cyber criminals continue to become more sophisticated, we must likewise continue to develop our ability to detect and respond to these threats and intrusions while increasing the cost to the attacker. Similarly, our ability to track objects in space and monitor our spacecraft is absolutely vital. We must develop and enhance our capabilities to identify indications and warnings of hostile actions in space, to rapidly warn of these activities to key decision makers, and be able to verify and attribute hostile actions to enable appropriate mitigation measures or response. Space and cyber situational awareness are essential to reducing mishaps, misperceptions, and mistrust.

Both of the DoD strategies recognize that even as we promote responsible behavior and enhance international partnerships, we must also prepare to operate in a degraded environment should deterrence fail. Resilience is a key concept in both strategies; we must ensure that the functions necessary for mission success endure in spite of hostile action or adverse conditions. Resilience can be enhanced through cross-domain solutions or alternative government, commercial, or international capabilities. Both strategies make it clear that if our capabilities in either area are attacked, we reserve the right to respond at the time and place of our choosing and not necessarily through the domain that was attacked.

Both strategies also address challenges to our industrial base and propose new ways of working with industry to meet these challenges. The strategies start with the need to encourage development of a future workforce by attracting students to the science, technology, engineering, and math (STEM) fields and then ensuring that they continue in relevant careers. These careers can be in the military, as government civilians, in defense and other industries, as well as the scientific and academic communities, as all are needed to ensure a strong future. As Secretary Panetta recently said, "Over the past two decades, our military has made particularly striking advances in precision-guided weapons, unmanned systems, cyber and space technologies—but our advantages here could erode unless we maintain a robust industrial and science and technology base. If we lose that base, it will impact on our ability to maintain a strong national defense—it's that simple." The DoD needs to maintain a strong, capable industrial base that is robust, competitive, flexible, and healthy. We can do this through improved acquisition practices that take advantage of the creativity of the private sector and harness the power of emerging concepts.

The technologies may be different, but our approaches to space and cyberspace are often similar. We cannot artificially divide the two. Although some details vary, and some difficulties for one may never challenge the other, I urge you to think about how these two domains interact and complement each other and how our efforts can do the same. Both our space and cyberspace strategies note that capabilities in the respective domains have greatly enhanced our national security. Both also note that those benefits go well beyond national security and that the United States is not alone in benefiting. The *National Security Strategy* states, "Neither government nor the private sector nor individual citizens can meet this challenge alone—we will expand the ways we work together." That was written in reference to securing cyberspace, but I believe it applies to space as well and to the intersection between the two. I challenge you to help identify those tough questions, like cross-domain deterrence, and explore how the similarities between space and cyberspace can and should inform our policies.

Madelyn R. Creedon
Assistant Secretary of Defense
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Enhancing Security by Promoting Responsible Behavior in Space

To maintain and enhance the strategic advantages the United States derives from space, we must address the challenges of a domain that is increasingly congested, contested, and competitive. Global security and prosperity are increasingly dependent on space capabilities. Information transmitted through space enables our military to project global power and underpins an increasingly globalized economy. Protecting our ability to operate effectively in space is a key component of the new defense strategic guidance signed by Defense secretary Leon Panetta in January 2012.

The *National Security Space Strategy* (*NSSS*), cosigned by the secretary of defense and the director of national intelligence, establishes multiple ways to protect our advantage in an evolving strategic environment. These include increasing the effectiveness and resiliency of our space-based capabilities and leveraging growing commercial and foreign capabilities. Foundational to the overall approach is promoting the responsible use of space through cooperative approaches that strengthen the sustainability, stability, safety, and security of the domain. Safeguarding space strengthens the security of the United States and its allies.

Collaboratively defining what it means to act responsibly in space can create a community of national and commercial space operators with a common understanding of and interest in acceptable behavior in this part of the global commons. As more operators act responsibly, interference with space systems may decline, enabling those military and intelligence missions and civil and commercial applications that rely on space capabilities. Additionally, a common space "rule set" can enable military space operators and intelligence analysts to more easily identify irresponsible actions by aggressive or rogue actors, enabling accurate attribution and possibly building consensus for coalition or international action to uphold freedom of access to the space global commons. Over time, this should discourage destabilizing, irresponsible acts such as China's 2007 test of an antisatellite weapon.

Each segment of the space community can contribute to defining responsible behavior—from top-down diplomatic approaches pursued by nations and multilateral institutions to bottom-up best practices developed and demonstrated by commercial operators, academic institutions, and other technical experts. With more than 50 years of space experience, the DoD has an important role to play in many of these initiatives—and a stake in their success.

The Challenges of an Evolving Domain

Space capabilities enable our economy and our military, allowing our troops to see with clarity, communicate with certainty, navigate with accuracy, and operate with assurance. Satellites collect weather data and images of the earth for a variety of civil, commercial, and national security applications. The ubiquitous timing signal of the US Air Force global positioning system enables financial markets, search and rescue, agriculture, global supply chains, and precise navigation anywhere on Earth. US and allied forces rely upon satellites to operate far from established terrestrial networks. Satellite communications provide the backbone for long-haul intelligence, surveillance, and reconnaissance data streams such as those provided by remotely piloted vehicles, which themselves are operated via satellite. All of these capabilities are critical to a joint force projecting power to protect US and allied interests.

But space systems face an increasing range of potential threats—both purposeful and unintentional. Space is increasingly congested, contested, and competitive. Today approximately 60 nations and government consortia own or operate satellites, and commercial space services are expanding. The DoD tracks approximately 1,100 active satellites and 21,000 pieces of debris, and the National Aeronautics and Space Administration (NASA) estimates there are likely several hundreds of thousands of additional pieces of debris too small to track with current sensors yet still capable of damaging satellites in orbit. For an adversary seeking to disrupt or deny the ability of the United States to project power, space capabilities may provide an appealing target set, especially early in a crisis or conflict. Counterspace systems, in particular low-end jammers, are proliferating and becoming an integral part of antiaccess/area denial efforts of potential adversaries.

Defining Responsible Behavior to Enhance National Security

The growing use of space presents shared challenges for current, emerging, and future space-faring nations. As stated in the 2010 US *National*

Space Policy, "All nations have the right to use and explore space, but with this right also comes responsibility." The policy further "calls on all nations to work together to adopt approaches for responsible activity in space to preserve this right for the benefit of future generations."

Establishing widely accepted guidelines for responsible behavior in space can enhance the national security of the United States and its allies while enabling the peaceful space activities of all who seek to benefit from space. Together with enhancing the resilience of US and partner space capabilities, collaborating with other responsible space operators, and maintaining the capability to respond to potential attacks, promoting responsible behavior in space is the foundation of a multilayered approach to deterring threats to US space systems.

Strengthening the responsible use of space will enhance our ability to derive benefit from national security space activities, in particular as the space domain becomes more sustainable, stable, safe, and secure. We will maintain our strategic advantage if our national security "eyes and ears" can perform their mission without the threat of purposeful or unintentional interference. This underpins the success of our military forces, intelligence collection, and the many civil and commercial space services foundational to our economic security.

Additionally, we may be able to simplify identification and attribution of hostile or other bad behavior by developing international consensus around what defines responsible, peaceful, and safe behavior. If nations commit to a standard of conduct, actions outside of the norm will be easier to recognize. We can therefore be more efficient in our use of space situational awareness (SSA) resources to identify those behaviors recognized as indicators of hostile intent. If an irresponsible act takes place, a community of operators committed to responsible behavior can more quickly come together to isolate rogue actors, and we can build on these partnerships to create coalitions of responsible space-faring nations.

The Department's Role in Promoting Responsible Behavior

The DoD has an important role to play in US government and international discussions of responsible behavior. First and foremost, the department has significant operational experience that can be brought to bear in developing "rules of the road" for space. The DoD fields satellites in almost every space mission area and has the most extensive SSA network in the world. Second, it has, over the past two years, expanded its relationships with commercial and international space operators through the US Strategic Command (USSTRATCOM) SSA-sharing program. Through SSA sharing, the DoD is establishing a reputation as a valuable resource for ensuring spaceflight safety for all space operators.

Finally, the department has much to lose from irresponsible acts that threaten the sustainability, stability, safety, and security of the domain. The DoD must take action to ensure it can continue to derive national security benefit from the space domain. We will draw on our operational expertise and expanding relationships to work with the Department of State, NASA, and other US government, commercial, and foreign space operators to define responsible behavior.

Ways to Define Responsible Behavior

The United States will continue to lead in defining the responsible, peaceful, and safe use of space with the many nations, commercial firms, and intergovernmental organizations that field, or aspire to field, space capabilities. But because space is no longer populated by government satellites alone, a variety of means must be pursued to cooperatively define responsible space operations. Everything from diplomatic initiatives, such as an international code of conduct for space, to technical standards and best practice guidelines can contribute to this goal. As stated in the *National Security Space Strategy*, "The United States will support development of data standards, best practices, transparency and confidence-building measures, and norms of behavior for responsible space operations." These different approaches to defining responsible behavior can and should be pursued by different segments of the growing community of space operators and space users.

Transparency and Confidence-Building Measures

Consistent with *National Space Policy* guidance, one top-down diplomatic initiative the United States is pursuing is bilateral and multilateral transparency and confidence-building measures (TCBM) to encourage responsible actions in, and the peaceful use of, space. TCBMs generally consist of information sharing and mutual assurances to reduce the chances of mishaps, misperception, and mistrust. The United States is currently engaged in a number of bilateral TCBMs with Russia, including visit exchanges to military space installations and sharing of information on space policies and strategies. These measures are important for increasing understanding, fostering trust, and enhancing stability. Additionally, the United States participates in bilateral space security dialogues with other major space-faring nations to exchange information and develop deeper understanding of each others' policies and programs. The department also leads its own space cooperation forums to support direct military-to-military exchanges with key allies and partners.

TCBMs, however, need not be limited to bilateral relationships. The United States has subscribed to the voluntary Hague Code of Conduct (HCOC) against Ballistic Missile Proliferation, which requires subscribing states to announce to other subscribing states planned ballistic missile and space vehicle launches. The HCOC consists of a set of general principles, modest commitments, and limited confidence-building measures and is intended to complement, not supplant, the Missile Technology Control Regime.

An upcoming UN Group of Governmental Experts will examine space TCBMs in a multilateral forum with the goal of developing a catalog of measures that define aspects of responsible behavior related to space. The United States intends to play an active role in this group and believes proposals could include measures aimed at enhancing the transparency of national security space policies, strategies, activities, and experiments; notifications regarding environmental or unintentional hazards to spaceflight safety; and the use of international consultations regarding outer space operations to prevent incidents and minimize the risks of potentially harmful interference. While there will always be limits to the national security information shared by the United States and other nations, broadly increasing dialogue between space-faring nations can help build understanding and strengthen relationships that could prove invaluable during a potential crisis.

Codes of Conduct

Space-faring nations can work cooperatively to capture key TCBMs and other elements of responsible behavior in a diplomatic code of conduct. An international code of conduct for outer space activities, such as the one proposed by the European Union (EU), could serve as a voluntary framework that describes how responsible states operate in space. The core elements of a code should include those measures that are in the interests of all space-faring nations.

A code of conduct can enhance US national security by serving as one of the most visible and political ways in which nations commit to acting responsibly in space. Nations willfully acting contrary to a code could expect to be isolated as rogue actors. A code of conduct such as the EU's draft proposal would enhance US national security by building international political consensus around precepts such as debris mitigation, collision avoidance, hazard notifications, and general practices of spaceflight safety. The precepts in the EU's proposal are largely consistent with current US practices and, because the draft focuses on behaviors, not capabilities, it would not constrain development of, for example, missile defense. Also to the benefit of US national security, the EU draft applies only in peacetime and explicitly recognizes that the inherent right of individual and collective self-defense extends to the space domain.

The development and negotiation of a code could play an important role in building international political consensus and understanding around key concepts of responsible behavior. To ensure the broadest adoption and implementation of such a code—and the benefits that would entail—it should be developed collaboratively by all responsible space-faring nations.

Best Practice Guidelines

Moving away from top-down initiatives undertaken by nations are bottom-up best practice guidelines for all phases of a space system life cycle—design, launch, operation, and end of life. Best practice guidelines develop over time and grow out of successful experience and operator requirements. In some ways, developing best practice guidelines is the most inclusive process because all operators, irrespective of whether they are governmental, commercial, academic, or otherwise, have a shared interest in spaceflight safety.

International space debris mitigation guidelines are one successful example of the collaborative development of space best practice guidelines. Based on the US government Orbital Debris Mitigation Standard Practices, the Inter-Agency Debris Coordination Committee (IADC)—an international committee of national space agencies—developed a set of technical guidelines for minimizing the creation of space debris. The Scientific and Technical

Subcommittee of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) used the IADC guidelines to develop a similar set of UN debris mitigation guidelines, which were subsequently adopted by the full committee and endorsed by the General Assembly.

The upcoming COPUOS working group on the long-term sustainability of space activities presents a similar opportunity for developing best practice guidelines in other areas of space activity. Beginning in 2012, technical experts from all COPUOS member states will be invited to participate in a working group examining, among other things, best practice guidelines for debris mitigation, debris removal, collision avoidance, rendezvous and docking, launch notification, collaborative sharing of space situational awareness, and space weather. This working group will collaboratively develop a compendium of guidelines that, in essence, define how those involved in space activities—from engineers to operators—can contribute to the long-term sustainability of space activities.

The United States intends to play an active role in the UN work on sustainability. Building upon the experience of NASA, NOAA, and DoD space operators, as well as US commercial space service providers, the United States will share its best practices in many of these areas. The department's experience in space system design, launch, operations, and end of life will serve as a solid foundation for US government inputs to this forum. The experience of USSTRATCOM in providing SSA support to other operators will prove especially valuable. Through the USSTRATCOM SSA-sharing program, commercial or international space operators can, with a negotiated agreement, receive assistance in screening maneuver plans, screening launch and disposal windows, and locating and resolving sources of interference. Operators also receive notifications of potential close approaches within predefined safety volumes.

These collaborative opportunities to work through shared operational challenges will result in common understanding of the best practices that define responsible space activities. As new technologies enable new operating concepts—such as on-orbit servicing and distributed and fractionated architectures—new best practices will, over time, naturally emerge to govern these activities in ways that benefit all future users of space. All space operators engaged in new types of space activity—government, commercial, academic, or otherwise—will play a role in establishing guidelines as they gain design, development, launch, and operational experience.

Technical Standards

Finally, truly bottom-up technical standards also have a role in defining responsible behavior. Organizations such as the International Organization for Standardization (responsible for the ISO-9000 series of standards on quality management, for example) use a rigorous and disciplined technical process to develop standards ranging from screw thread tolerances to information system formats. They have developed several standards on space safety and orbital debris mitigation. Though the process of developing standards can be long, it is one that involves a variety of stakeholders—including government, industry, and academia.

The Consultative Committee on Space Data Systems is developing standards for space data and information systems to facilitate collaboration among space agencies. USSTRATCOM is working with this committee and other standards organizations to develop space standards for space situational awareness information. These types of standards will reflect the best practices of industry and government and enable greater collaboration and information sharing in the future.

An Integrated Approach

Each of these ways to define responsible behavior should be pursued by the many nations, commercial operators, and intergovernmental and nongovernmental organizations operating or benefiting from space capabilities. Each approach has its strengths and weaknesses, and each can be best developed by a particular segment of the space community.

No matter which venue is most successful or pursued most vigorously, all can enhance the national security of the United States and its allies while protecting the strategic advantages we derive from space. Increasing responsible behavior in space can make the space domain a safer and more secure operating environment, discourage irresponsible acts but identify them if they occur, and build consensus for maintaining order in an increasingly congested, contested, and competitive domain. Reducing threats to US and allied space systems will enhance our ability to project power over global distances to deter aggression and assure our allies and regional partners.

As stated at the outset, promoting responsible use of space is just one element of our *National Security Space Strategy*. To effectively contribute to our security, it must be complemented by effective space capabilities responsive to new threats and war-fighter needs; demonstrated resiliency in key mission areas enabled by space, including through backup capabilities in other domains; and a readiness to respond in self-defense, including in other domains. A common space rule set can advance our interests but is no substitute for robust and resilient military capabilities.

Secretary Panetta's new strategic guidance calls for the United States to continue leading global efforts to assure access to and use of the global commons, both by strengthening international norms of behavior and by maintaining necessary military capabilities. The Department of Defense has an important role to play in both areas.

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Implementing the National Security Space Strategy

C. Robert Kehler, General, USAF

The US approach to implementing its national space policy will determine its future course in space. Will our nation act as a collaborative partner that leads by example? Or will we try to move forward unilaterally in space? What steps should the United States take today to ensure security in space for the future? Gen C. Robert Kehler, the commander of US Strategic Command, provides his perspective on the implementation of the National Security Space Strategy *as a means to promote international cooperation, establish norms, and provide mission assurance for space-delivered assets vital to US leadership.*

Leadership has been a defining hallmark of the US space effort since the beginning of the Space Age. From John F. Kennedy's bold challenge to put a man on the moon by the end of the 1960s, to our military's unprecedented use of space-based capabilities, to the evolution of the global positioning system (GPS) as a free global utility, the United States has aspired to—and attained—a leadership position in space, deriving significant benefits across the spectrum of scientific, military, commercial, and civil activities.

Our dependence on space has never been greater, yet our nation faces a new global security environment and strategic turning point that, if not addressed, will challenge our continued leadership and place increased stress on our ability to preserve the benefits we have come to rely on from our space capabilities. Many of the challenges are obvious: an austere fiscal environment where we will likely be expected to do more with less; a congested space environment where more than 20,000 man-made orbital objects are increasing the demand for better situational awareness; a contested security environment where freedom of operations and access will

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be far from guaranteed; and a competitive international environment where our space industrial base—still the best in the world—will have to innovate and adapt to produce the capabilities we need in the future. Still other challenges may not be as obvious; therefore, we must also become more agile, flexible, ready, and technologically advanced to prepare for the possibility of strategic and operational surprise.

The reason for our concern is clear. Space capabilities offer the United States and its allies unprecedented advantages in national decision making, military operations, homeland security, economic strength, and scientific discovery. Space systems provide unfettered global access and are vital to monitoring strategic and military developments as well as supporting treaty monitoring and arms control verification. Space systems are also essential to our nation's ability to respond to natural and man-made disasters and to monitor environmental status and trends. When combined with other capabilities, space systems allow joint forces to see the battlefield with clarity, navigate with accuracy, strike with precision, communicate with certainty, and operate with assurance.[1]

Preserving the national security advantages we derive from space is critical to modern military operations and our future success and remains a key objective of the United States. The Department of Defense (DoD) recently reaffirmed this imperative. In his new strategic guidance, Secretary of Defense Leon Panetta emphasized the need to operate effectively "in cyberspace, space, and across all domains."[2] Similarly, the new guidance stresses the United States' intent both to "work with domestic and international allies and partners and invest in advanced capabilities to defend its networks, operational capability, and resiliency in cyberspace and space" and to continue to lead global efforts to "assure access to and use of the global commons" (including space).[3]

US Strategic Command (USSTRATCOM) is one of the key organizations charged with preserving these advantages in the face of the changing strategic environment, and we are using the *National Security Space Strategy (NSSS)* as our guide. Although USSTRATCOM is not assigned a specific geographic area of responsibility (AOR), our scope of responsibility stretches from beneath the sea's surface (where our strategic ballistic missile submarines operate) to 22,000 miles above the earth's surface. USSTRATCOM's diverse responsibilities in space include:

- Planning and conducting military space operations
- Advocating for space capabilities

- Representing US military space interests internationally
- Assisting human spaceflight operations
- Providing warning and assessment of any attacks on space assets, and
- Conducting space situational awareness operations that benefit the US public and private sectors, human spaceflight, and—as appropriate—commercial and foreign space entities.

These critical responsibilities are more important than ever given the significance of space to our globally networked approach to deterrence and warfare. Future conflicts will, of necessity, be multidomain in nature and require more than one command's actions. Capabilities like space, which assure so many mission-critical capabilities, are powerful force multipliers. Space is essential to, and a great strength of, an interdependent joint force, assuring key missions and expanding the benefits derived from limited resources.

The Changing Strategic Environment and Space

The Space Age began in the context of the Cold War. Yet despite tensions that characterized their relations throughout the early days of the Space Age, the United States and the Soviet Union, in a surprisingly cooperative manner, signed the 1967 Outer Space Treaty. All parties to this treaty agreed outer space would be free for access, exploration, and use by all states; celestial bodies in space would be free from national appropriation or military bases, fortifications, exercises, and testing; that states would refrain from placing in orbit around the earth nuclear or other weapons of mass destruction.[4] These principles continue to serve as the foundation for our approach to the space domain.

Access to space and space capabilities during most of the Cold War, however, was limited to states with the technological and economic means to get there—namely, the two Cold War superpowers. The United States deliberately turned to space to meet some of the most difficult and unique security problems of the Cold War. As a result, it produced space capabilities that yielded unprecedented strategic advantages. Space provided a "global perspective" to allow the United States "access to large areas of the Earth's surface," especially those areas denied to conventional terrestrial capabilities and forces.[5] In particular, space capabilities afforded US decision makers with access to information, including force status and overall battlespace awareness, at a rate which most other states could not (and in most cases cannot yet) achieve. Along with assured command and control, these capabilities ensured senior US leaders maintained a decision-making advantage over potential adversaries. Space also provided the primary means to warn of nuclear ballistic missile attack, monitor treaties, and connect the president to the nuclear retaliatory forces.

By the start of the twenty-first century, the de facto monopoly the United States and one other superpower shared disappeared. Advances in technology and commercial growth reduced the cost for nation-states and nonstate actors to gain access to space and space capabilities. Indeed, the *National Security Space Strategy* notes, "There are approximately 60 nations and government consortia that own and operate satellites in addition to numerous commercial and academic satellite operators."[6]

However, at the same time technological advances allowed friend and foe alike to develop capabilities to derive their own benefits and advantages from space, potential adversaries became keenly aware of the advantages space provided for the United States. The world watched as military operations like Desert Shield/Desert Storm demonstrated the value of "strategic" space for operational and tactical use, and they became equally aware that America's reliance on space may also be a vulnerability to exploit. As a result, some seek to exploit a perceived overreliance by the United States on space by developing capabilities to prevent access to and use of space capabilities in order to deny or limit our overall military, economic, and technological advantage.[7]

As states continue to pursue benefits from space to enhance and secure their national interests, competition will only intensify,[8] and the United States may find it more difficult to guarantee its access to and use of space capabilities. Unless we act, this may adversely affect our ability to secure our national security interests and maintain our economic, military, and technological leadership advantage. The *National Space Policy* (*NSP*) and the *National Security Space Strategy* outline objectives that are intended to ensure the United States continues to realize the significant national security benefits of space.

The *National Space Policy* and the *National Security Space Strategy*

The *National Space Policy*, released by President Obama on 28 June 2010, establishes the goals that the United States will pursue in its national space programs. They are "energize competitive domestic industries; expand international cooperation; strengthen stability in space; increase assurance and resilience of mission-essential functions; pursue human and robotic initiatives; and improve space-based Earth and solar observation."[9] The integrating fiber woven throughout the *NSP* is that the United States should "help to assure the use of space for all responsible parties."[10]

Building on the *NSP*, in January 2011, the secretary of defense and the director of national intelligence (DNI) promulgated the *National Security Space Strategy*, which "seeks to maintain and enhance the national security benefits" resulting from US actions and capabilities in space. To achieve the tasks assigned by the *NSP*, the *NSSS* established specific objectives to "strengthen safety, stability, and security in space; maintain and enhance the strategic national security advantages afforded to the United States by space; and energize the space industrial base that supports U.S. national security."[11]

The Five Pillars of the *NSSS*

The *National Space Security Strategy* provides the roadmap for implementing US space policy and achieving our objectives in space. It consists of five core principles, or pillars, which prescribe the framework within which USSTRATCOM and others will act:

1. Promote the Responsible, Peaceful, and Safe Use of Space

The first pillar of the *NSSS* calls for the United States to "lead in the enhancement of security, stability, and responsible behavior in space" and to develop transparency and confidence-building measures that will "encourage responsible actions in, and the peaceful use of, space."[12] As outlined in the *NSP*, specific actions include domestic and international measures to promote safe and responsible operations in space; improved information collection and sharing for space object collision avoidance; protection of critical space systems and supporting infrastructures, with special attention to the critical interdependence of space and information systems; and strengthening measures to mitigate orbital debris.[13]

Central to this pillar is the opportunity to begin the necessary dialogue among international space-faring participants on the development of a foundational set of standards, norms of behavior, and best practices designed to promote the safe and responsible use of space. Defining responsible behavior could, over time, discourage destabilizing acts that threaten the overall safety, stability, security, and sustainability of the space environment. USSTRATCOM is actively engaged with the Office of the Secretary of Defense and the Joint Staff to examine and propose a variety of measures that could strengthen international stability and security as well as increase the safety and sustainability of space operations.

2. Provide Improved US Space Capabilities

The second pillar of the *NSSS* calls for the United States to improve its capabilities in space and energize our space industrial base. Indeed, a stable, responsive, and innovative national industrial base is at the core of the new DoD strategic guidance and, combined with continued investment in science and technology and human capital, is vital to assuring continued US leadership in space. A strong industrial base and supporting workforce is also one of our best insurance policies against surprise or other "shocks" in the strategic, operational, economic, and technological spheres mentioned in the new defense strategy.[14] But problems exist.

Since the Space Age began, we have rarely been so reliant on so few industrial suppliers. Many firms struggle to remain competitive as demand for highly specialized components and existing export controls reduce their customers to a niche government market.

Nevertheless, long-term, uninterrupted capability from space requires a capable industrial base dedicated to protection, resilience, augmentation, and reconstitution of assets in space, supported by timely design and development, cost-effective acquisition, and the ability to assure high-confidence space access. Any discussion of resiliency must also include consideration of new architectural approaches that leverage partnership opportunities with commercial entities and allies, and that use the full range of space and nonspace methods to deliver capabilities. Leased payloads, ride sharing, distributed capabilities, and new partnerships are among the means we need to pursue.

However, our resources are finite, and in the current fiscal environment, budgetary pressures are likely to constrain our operating and acquisition plans for some time. Accordingly, USSTRATCOM is working with our service components to ensure our requirements are realistic and achievable and that our actions fully reflect a culture of savings and efficiency that delivers essential services in support of military operations, serves as a force multiplier for global power projection, and maintains our technological edge. We are also working to help bring stability to our requirements, budgets, and programmatic approaches.

3. Partnering with Responsible Nations, International Organizations, and Commercial Firms

The third pillar calls for increased engagement and partnering with other space-faring nations, appropriate international organizations, and commercial actors. USSTRATCOM is actively committed to this pillar and is already engaging with many partners, having signed more than 29 agreements with commercial entities to share selected situational awareness information. We recently received the authority to negotiate similar agreements with non-US governmental agencies and intergovernmental organizations and stand ready to work with responsible space actors by sharing and exchanging safety of spaceflight information.

USSTRATCOM is also actively seeking additional partners, especially those with whom there has been little if any previous engagement. We already partner and engage with long-standing friends and allies like Australia, Canada, and the United Kingdom, as well as other NATO allies. And we are undertaking greater efforts to sustain those traditional partnerships while we seek new opportunities with potential partners in Europe, Asia Pacific, Latin America, South America, the Middle East, and Africa.

4. Prevent and Deter Aggression against US Space Infrastructure

USSTRATCOM's grand challenge is to protect and assure US space capabilities for joint use and other national security purposes—defined in the fourth pillar as preventing and deterring aggression against US space infrastructure. Space defense demands full understanding of the operating environment so we can recognize indications and warnings and operate effectively to protect our assets, provide resilience, and if challenged, employ alternatives as needed. This pillar includes operations to acquire and maintain an understanding of the location, activities, ownership, and intent of objects in the space operational area and to provide warning and assessment of attack in, from, and through space.

Space situational awareness (SSA) enables all of our operational activities. An important means to add capability and capacity to SSA would be to expand partnerships and increase international cooperation. To this end we are looking to transition the Joint Space Operations Center (JSpOC) in California into a Combined Space Operations Center (CSpOC).

Initially, in full collaboration with our closest partners, such a step would enable us to leverage our individual strengths and, consistent with national policies, provide a framework and environment that could help address common space security needs. Further, such a transition would be consistent with the mandate of the *NSSS* to "build coalitions of like-minded space-faring nations."[15] This partnership would allow us to act in a coordinated manner, synchronize our efforts, and, together with those partners, promote responsible behavior in space to ensure the long-term sustainability of space.

5. Prepare to Defeat Attacks and Operate in a Degraded Environment

The final pillar of the *NSSS* calls for the United States to prepare to defeat attacks in space and operate in a degraded environment. This approach is generally based on "mission assurance" concepts and includes activities to deliver mission-essential space capabilities to US and coalition forces and to assure mission success via alternate architectures and means, as appropriate, through all conditions of conflict and stress.

Mission assurance involves the need to defend and protect critical US, allied, and partner space capabilities, to include enhancing the resiliency of critical space systems, improving the use of alternative means and domains to assure the mission, and demonstrating the ability to operate through a stressed environment if and when capabilities are degraded.

Beyond awareness in space we need robust, resilient architectures—both space-based constellations and terrestrial assets—to ensure today's essential space-based services are available to accomplish the mission.

Finally, to enhance deterrence we have committed ourselves to preparing our forces to "fight through" any possible degradations or disruptions to our space capabilities. Through regular global and tabletop exercises, we are improving our operational concepts and tactics, techniques, and procedures to enhance both protection and resiliency. We also leverage commercial, civil, and partner capabilities to support our military operational needs and ensure we fully appreciate and understand the interdependencies between military operations and those capabilities. And, as stated by the *NSSS*, "The U.S. will retain the right and capabilities to respond in self-defense, should deterrence fail."[16] A US response may include actions in other domains.

Conclusion

The space domain continues to grow more congested, contested, and competitive at the same time as nations rely increasingly on space and space-based capabilities for critical civil and national security activities. Space mission assurance—including access to and use of all space capabilities—is essential to current and future US and allied civil life, economic strength, and military activities. Assuring continued US and allied access to and use of space demands a broader strategic approach that protects our critical capabilities, leverages our partners, and promotes safe and responsible use of the domain.

As it has been throughout the space age, leadership remains the key to our success. Active US leadership requires a whole-of-government approach that integrates all elements of national power, from technological prowess and industrial capacity to alliance building and diplomatic engagement. USSTRATCOM is taking concrete steps to contribute to that leadership, and we look forward to continuing this role as we assure our vital space missions. SSQ

Notes

1. *National Security Space Strategy*, unclassified summary (Washington: DoD, January 2011), i.
2. Secretary of Defense Leon Panetta, letter, 5 January 2012.
3. *Sustaining U.S. Global Leadership: Priorities for 21st-Century Defense* (Washington: The White House, January 2011), 3.
4. *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, 27 January 1967, 18 U.S.T. 2410, T.I.A.S. No. 6347, 610 U.N.T.S. 205 (entry into force, 10 October 1967).
5. Martin E. B. France and Jerry Jon Sellers, "Real Constraints on Spacepower," in *Toward a Theory of Spacepower: Selected Essays*, eds. Charles D. Lutes, Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine Bunn (Washington: National Defense University Press, 2011), 57–58.
6. *National Security Space Strategy*, 3.
7. Ibid.
8. Robert L. Pfaltzgraff Jr., "International Relations Theory and Spacepower," in *Toward a Theory of Spacepower*, 40–41.
9. *National Space Policy of the United States of America* (Washington: The White House, 28 June 2010), xx.
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11. *National Security Space Strategy*, 4.
12. *National Space Policy*, x.
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16. Ibid., 10.

Space

Disruptive Challenges, New Opportunities, and New Strategies

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February 17, 1864 was a cold night just outside Charleston Harbor. The War of the Rebellion had raged for the prior three years as a bitter struggle of will and staying power. Key to that staying power—or more precisely, to breaking it—was the strategic blockade Union forces had imposed on the South, the so-called Anaconda Plan;[1] and no single point in that blockade was more important than Charleston Harbor. As the site of the Civil War's first real battle and the largest port in the South, it bore both symbolic and strategic significance.

On that night, though, a new strategic dynamic was about to unfold. Beneath the dark, frigid waters of the Atlantic, the *H. L. Hunley* steered toward its target, the USS *Housatonic*. RADM John Dahlgren, the US

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Navy commander of the South Atlantic Blockading Squadron, had heard of the new Confederate vessel—a submersible that could engage ships while under water—and its two previous failed missions;[2] but this knowledge was not able to save his fleet from loss. As alarms rang out above, and with cannons ill adapted to target the low lying vessel, the *Hunley* rammed its 135-pound torpedo into the hull of the *Housatonic*, and in less than five minutes, the *Housatonic* was lowered to its watery grave (along with its attacker just a few hours later). Submarine warfare had begun, and the Union navy, and every subsequent navy, had to either adapt or sink into insignificance.

A century and a half later, "In the predawn darkness of 11 January 2007,"[3] a similar strategic shift was emerging. Symbolically and strategically, the US position in space had been a source of strength and prowess since the dawn of the space age. The space race of the late 1950s and early '60s was a formative surrogate for the more expansive superpower contest that raged on for the next three decades. The US "victory" in the race for the moon was a defining moment for our nation and for our adversaries. That symbolic victory underscored the strategic import yet to come.

The technological edge that led to this victory had sharpened over the ensuing 50 years. At the close of the last millennium, the United States enjoyed dominance in space power that, while waning, was still head and shoulders beyond its closest competitors. The US reliance on that dominance had not gone unnoticed. Chinese strategists recognized their ability to counter US military capability lay, in part, in the ability to target space.[4] As in the case of the *Hunley*, the US apparently knew of the upcoming Chinese kinetic antisatellite (ASAT) weapon test and its previous failures.[5] But with measures ill adapted to intervene in such a test, all the US could do was observe and take heed. Space warfare had begun anew, and the space community, along with every space-faring nation, was now on notice that they had either to adapt or plummet into insignificance.

> *In times of disruptive change your expected future is no longer valid. Leaders need to think and act differently in order to chart a new course for the enterprise.*
>
> —Doug Berger, *Innovate*, August 2005

Disruptive change is not a new phenomenon. New technologies, unexpected threats, novel tactics and techniques, and altered approaches can create changes to the strategic environment in which we operate. Those changes can alter the landscape in ways that, if not addressed, can dramatically upset the existing order. They can render effective strategies impotent, change winners into losers, and turn victory into defeat.

Disruptive change has been a decisive force throughout history. The English longbow rendered knights' armor ineffective in the Battle of Crécy and is considered by many historians as the beginning of the end of classical chivalry.* Assembly line mass production not only dramatically impacted the speed at which manufactured goods could be assembled, but also reset the productivity curve for each worker, significantly increasing their value and wages and precipitously driving down the cost of manufactured goods†—a major step in the growth of the middle class. Today, digital music and file sharing have upset 50 years of unimpeded growth in the record industry, with many predicting its end is near.[6]

Disruptive change rarely involves a single element, nor does it happen abruptly. It has taken over 30 years for the record industry. The introduction of digital music in 1982,[7] along with high-speed Internet, high-capacity digital storage drives, and a change in public focus from high-quality music to readily available music, have all led to the extended downhill slide that leaves many big music labels grasping for how to cope with the threat.

How will disruptive change impact the direction of US space power, and what strategies will be effective in dealing with it? The answer lies in our understanding of the rise of space power and how that led to the conditions of today. This article examines the forces of disruptive change in addition to the ASAT threat, presents a set of possible responses to the challenges, and investigates whether the responses group into logical categories of actions. It then delves into how those actions might be implemented in future architectural states for space systems and if the conditions of the space market are appropriate for those responses. Finally, it asks how we might change the acquisition of space capabilities to better allow these responses and what that might mean in specific mission areas.[8]

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*Once mounted, knights became vulnerable to common soldiers firing from a distance; the classic use of armored cavalry and hand-to-hand battle became of lesser significance in the outcome of battles.

†For example, wages in the Ford factory doubled while the cost of an individual automobile fell by almost 30 percent.

The Growth of Space Power

The current generation of US satellite systems emerged in an era far removed from today. From the very beginning of the space age to the last days of the Cold War, most space systems were focused on strategic conflict. They were highly classified, with services and information that had little impact on the tactical landscape. Space warfare was viewed as unlikely—just another element of the strategic détente between the Soviet Union and the United States. If a war in space were to occur, it would be as a prelude to a strategic contest between the world's two superpowers.

Depending upon one's view, either the United States or the Soviet Union was the preeminent space power during the early days of the Cold War.[9] But by the late 1970s, the US space industrial base—powered by simultaneous investments of Apollo, ICBMs, and SLBMs—was unmatched, robust, and vibrant, with multiple competitive sources of supply at every level of production. Retired general Tom Moorman said, "The 1960s and early 1970s saw the rapid growth of military space technologies, infrastructure and programs. The breadth of space capabilities developed during this time was indeed quite remarkable and in a word—breathtaking."[10]

In those days technology was king, and experimentation in the military uses of space was expansive. From manned military programs, such as Dyna-Soar and the Manned Orbiting Laboratory (MOL),[11] to unmanned nuclear detection and warning programs and early space reconnaissance programs, failures preceding success were common, if not expected. And failures could be tolerated, because dependence on specific systems for everyday war-fighting was minimal. In fact, due to their highly classified nature, most of the failures were shielded from the kind of scrutiny that other programs endured.[12]

Lastly, the cost of space, while important, was of lesser concern. As part of the superpower contest between the United States and the Soviet Union, most space programs were viewed as vital and nonnegotiable. The price tag for a program was regarded in contrast to its larger strategic purpose rather than as an element of discretionary military spending.

With these conditions as backdrop, the US space program and the systems it developed were aimed at only a few primary ends—pre-conflict intelligence, nuclear attack warning and response,[13] and continuity of nuclear command and control.* Continuous war-fighting resiliency, short of

*It is interesting to note that the GPS system was justified for part of its development, not on the basis of its impact to tactical maneuver warfare, but on the role it played in nuclear attack assessment.

nuclear survivability,[14] was sacrificed for technical capability. There was no "live-fire survivability testing" or requirement that accompanied similar war-fighting systems. Additionally, space was viewed as an extension of strategic détente; the same kind of deterrence that prevented nuclear war was relied upon to protect satellite systems.

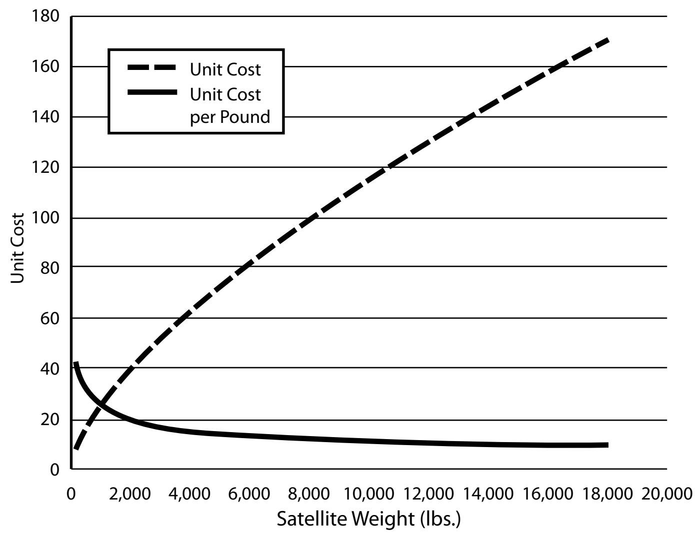

Figure 1. Satellite cost versus weight (Graph generated through the unmanned space cost model, or USCOM.)

These forces had a direct impact on the way space systems were designed. An unchanging dynamic of space systems is that their utility on a per-pound basis tends to increase as their weight increases, with a simultaneous decrease in cost per pound (see fig.1). Similarly, the cost of launch was significant, but once a launch vehicle was determined, it made economic sense to maximize the system weight within the launch vehicle constraints.

In traditional war-fighting systems, the concentration of so much capability onto a single platform might not make military sense; but the lack of a direct threat to the system reduced the consequences of that decision. Plus, given the short lives of space systems (most at that time were planned to last 3–5 years), production runs were relatively large and replacement satellites could be called up in comparatively short time frames.

As the space enterprise matured, this approach continued. The evolution of the defense meteorological satellite program (DMSP) is instructive. The original (Block 1) satellite launched in the early 1960s weighed about 175 lbs. By the late 1990s, the Block 5 satellites had swelled to over 2,500 lbs. Had it been completed, the replacement national polar orbiting environmental satellite system (NPOESS) would have weighed in at over 5,000 lbs. Even though the cost-per-pound of such a satellite would be about one-third of the initial smaller design, the total cost would have increased by a factor of 10.

Space Begins to Blossom

As the Cold War began to thaw, space was poised for change. Space capabilities during that era had been primarily focused on supporting strategic warning, intelligence, and continuity of operations in the event of nuclear war. In contrast, its role in non-nuclear force enhancement was modest at best.[15] Yet today, US space dominance has become a crucial element of how the United States fights wars. Our use of space capabilities has transformed over the past two decades.

The First Gulf War was labeled by then–Air Force chief of staff Gen Merrill McPeak as "the first space war."[16] Indeed, the impact of space power on the conduct of Desert Shield/Desert Storm was substantial;[17] substantial enough for both space advocates and non-advocates to take notice. However, the true war-fighting impact was arguable. Precision bombing was still dependent upon laser or electronic designation* rather than GPS guidance;[18] imagery products, too large for broadcast through existing satellite communication (SATCOM) networks, were delivered to theater by air transport; and while DSP-detected scud launches were useful for warning troops and civilians, the information was neither timely nor accurate enough to allow "scud hunters" to find their targets.[19] Space power was still in its infancy.

These facts were not lost on senior DoD and Air Force leadership. Their sentiment was best expressed by the commander of Desert Storm allied air forces and future commander of US Space Command, Gen Chuck Horner: "What we have to do is change our [space] emphasis from strategic war to theater war. We have to get over the Cold War and make sure

*For example, in the 1991 Gulf War, 92 percent of the bombs were unguided and 8 percent were laser guided. By contrast, nearly 60 percent of the bombs dropped on Afghanistan in 2001 and 2002 were either laser or GPS guided.

that we're equipping and training and organizing to fight the kind of war that's probably going to be thrust upon us."[20] And from his perch at US Space Command, he had the wherewithal to make it happen. Over the next 10 years, the integration of space and theater tactical forces expanded beyond expectations. While these capabilities exercised their adolescence in Kosovo, they reached true adulthood in Operations Enduring Freedom and Iraqi Freedom.

Today, the direct combat support role of space is inarguable.[21] Without exaggeration, the combat effects we have come to expect from our smaller, more mobile force structure would not be possible without space capabilities.[22] The impact of GPS alone has fundamentally shifted the way US forces locate and destroy targets, plan operations, control both material and war-fighting assets, synchronize effects, and guide both troops and remotely piloted aircraft (RPA) home. Beyond GPS, the impact of SATCOM (RPA control, direct broadcast of real-time imagery), space imagery (target location and identification), space weather (route and operations planning), and overhead persistent infrared reconnaissance (missile warning, missile defense, and battlespace awareness) have had wide-ranging impact on every element of war.

Compounding Changes—Disruptive Forces

As stated by then–Deputy Secretary of Defense Bill Lynn, "In less than a generation, space has fundamentally and irrevocability changed. . . . Without [space capabilities], many of our most important military advantages evaporate."[23] In Clausewitzian terms, space has become a US center of gravity,[24] a fact as apparent to our adversaries as to our own defense establishment. Thus, borrowing from their own military philosophy, "What is of supreme importance is to attack the enemy's strategy,"[25] Chinese planners set out upon an ambitious effort to hold US space systems at risk; an effort that culminated with the events of January 2007 described in the prologue above.

China is not the only nation capable of threatening US space capabilities. The technological capability to jam satellites is fairly simple and can be easily assembled by either individuals or nations for a fairly modest investment. Multiple reports of both state and nonstate groups jamming satellites have been seen over the last decade. GPS jammers are well known and offered openly for sale on the Internet. Satellite transit times are available from several websites and can be downloaded onto smart phones.[26] While none of these threats rise to the level of an in-space ASAT test, they demonstrate how technologies once reserved for only advanced space-faring nations are now the purview of smaller states and individuals alike. The days of space chivalry are clearly numbered.

These fundamental changes—the growth of space as a tactically vital resource and the demonstration by adversaries of their intent to make space a target in both a nuclear and conventional contest—are two of the critical disruptive forces sweeping over US space strategy today. However, there are others.

Space technological strength is no longer a monopoly for American industry; multiple nations now boast a fully developed space industrial base, from satellite technologies to launch. By 2011, over 50 countries had at least one satellite in orbit;[27] they, and multiple consortia, vie for orbit positions and expansion of capabilities and can buy those capabilities from an increasing number of companies that provide space technology to the world.

The expansion of space industrial capability beyond the shores of the United States or Russia coincided with the "peace dividend" in the early 1990s; both led to a rapid consolidation of industry within the United States. The robust industrial base of the ICBM and Apollo eras that had empowered growth and competition in the space industry during the Cold War was disappearing. US suppliers, especially those in the second and third tiers, came at risk due to inconsistent acquisition and production rates, long development cycles, consolidation of suppliers under first-tier prime contractors, and a more competitive foreign market.[28]

At the same time industrial competitiveness waned, costs began to grow, and delivery times began to stretch. Since the mid-1990s, we have seen some of the longest delivery times for major space systems since the beginning of the space age.[29] The causes are multifaceted—higher spacecraft complexity, fewer sources of space-qualified parts, increased software complexity—and it is the continuation of a trend that started a decade before.

Higher costs were already leading to fewer satellites being ordered, each one built with greater and greater capability. As older satellites began to die, cautions were raised by many, including STRATCOM commander Gen Kevin Chilton, about the fragility of satellite constellations and "gap management."[30] Launch costs had also been rising for well over a decade, and the flexibility of the launch base had decreased. Driven by the critical role satellites had come to play in both nuclear and routine defense activities and the increased investment of dollars and schedule that those satellites represented, launch was becoming a "fail-safe" activity. The space business had come a long way from the days of Corona, where the first 13 missions ended in failure, to the present. Figure 2 provides a broad picture of how some of these forces were leading to change in the space establishment.

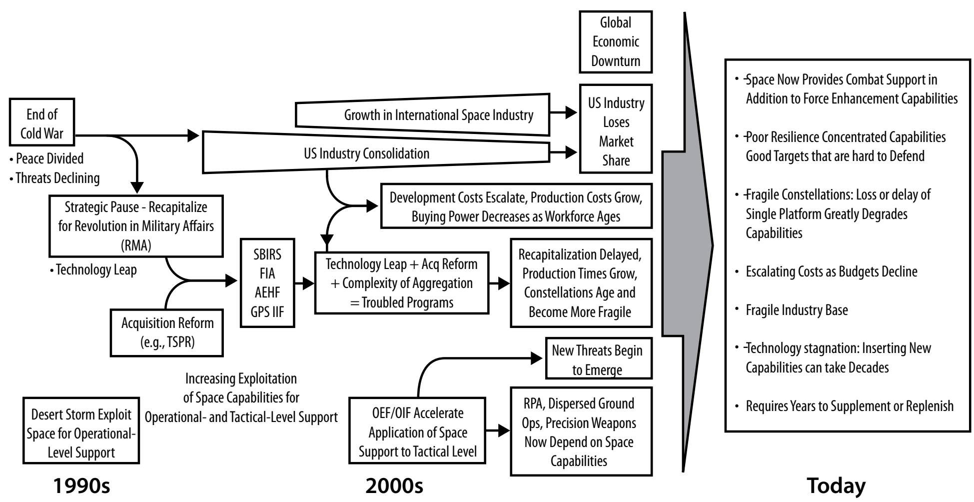

Figure 2. Evolution of today's challenges

These forces tended to build upon one another. Shrinking constellations, rising launch costs, increasing satellite costs, greater reliance, and longer build cycles have all led to the phrase, "The vicious circle of space acquisition." While there are several illustrations of this cycle, the one developed by Maj Gen Tom Taverney provides perhaps the most comprehensive view (fig. 3).

The cycle drove multiple undesirable outcomes. One of the worst was the impact on technology risk. As constellations become more fragile, and satellite costs increase and schedules are extended, the risk of inserting new technologies into a space-system build increases. As a result, spacecraft planned for construction in the next decade are still using computer processing technology from the late 1990s when they were designed. For example, some billion-dollar satellites launching in 2020 will have missed over 24 years of capability increases driven by Moore's law, or roughly 16 cycles of processing power increases.* Another by-product of this cycle is an increase in ordering period

*Moore's law states that the processing power of semiconductors doubles about every 18 months. By missing 16 cycles, the processing speeds of our future spacecraft could be more than 50,000 times less capable than they could be if technology risk did not inhibit its adoption.

between satellites. As it does, obsolescence creeps in, factories become less efficient, and any industrial learning to be garnered is lost. The result, of course, is that costs climb and the cycle spins off into a parallel spiral.

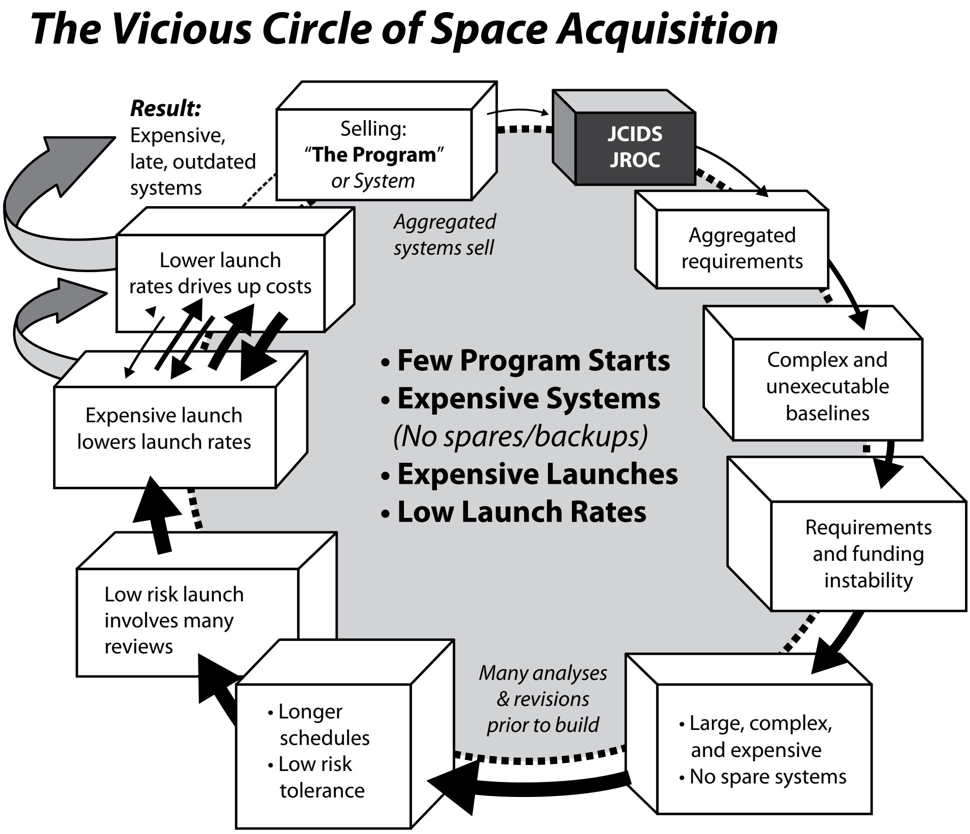

Figure 3. Space system acquisition "vicious circle" (Maj Gen Thomas Taverney, "Resilient, Disaggregated, and Mixed Constellations," Space Review, 29 August 2011.)

The Final Straw

The forces discussed in the preceding section represent significant changes in the industrial-dependency-threat equation under which space systems developed. The uses, importance, industrial base, cost dynamics, complexity, and competitiveness of space have all fundamentally changed from where we began; but the trajectory of system architectures did not change with them—rather, they continued on their original path. This disparity might be practical if money was no object, but unfortunately it is.

The days of unhindered spending for space superiority and technical advancement are over. At the annual Acquisition Symposium at the Naval Postgraduate School in 2009, Secretary Gates said:

> Given America's difficult economic circumstances and perilous fiscal condition, military spending on things large and small can and should expect closer, harsher scrutiny. . . . The gusher has been turned off, and will stay off for a good period of time. . . . The Defense Department must take a hard look at every aspect of how it is organized, staffed, and operated—indeed, every aspect of how it does business.

The combination of all these forces represents disruptive change in the way we approach space systems. As with the music industry discussed earlier, the changes have occurred over decades. Some, such as the Chinese ASAT attack, were acute; others, such as changes in the industrial base, evolved slowly. But the sum total is disruption of the forces that led to the path we have taken. Like the music industry, we ignore these changes and continue on that path at our own peril. A more prudent approach would be to examine the elements of these changes and try to understand if a better path exists.

Formulating Responses

Recognizing disruptive change is difficult enough—determining how to deal with it is even harder. The first step is to try to understand more clearly how the various forces combined with other elements of the system to create the challenges faced. We examined several elements including the impact of acquisition policy and reform, technology readiness, the rise of a commercial satellite market, and the competition for engineering talent. We found the most important elements were not the conditions surrounding what we build, but rather the architectures we choose to build. In figure 4 we trace the impact of building aggregated, highly integrated, long-lived satellites. The impact of that choice contributes directly to many of the challenges we discussed above. Dealing then with those challenges will require we deal with this underlying architectural issue.

Adapting to disruptive changes through an architectural response is not unique to the space industry. In the prologue, we discussed the first submarine attack during the Civil War. As noted there, Admiral Dahlgren was aware of the possibility of attack by this new submersible. In his orders to the fleet a month before, he noted:

> I observe the ironclads are not anchored so as to be entirely clear of each other's fire if opened suddenly in the dark. This must be corrected . . . It is also advisable not to anchor in the deepest part of the channel, for by not leaving much space between the bottom of the vessel and the bottom of the channel it will be impossible for the diving torpedo to operate except on the sides, and there will be less difficulty in raising a vessel if sunk.
>
> Order of Rear-Admiral Dahlgren, U.S. Navy, commanding South Atlantic Blockading Squadron, FLAG-STEAMER PHILADELPHIA, Off Morris Island, South Carolina, January 7, 1864.

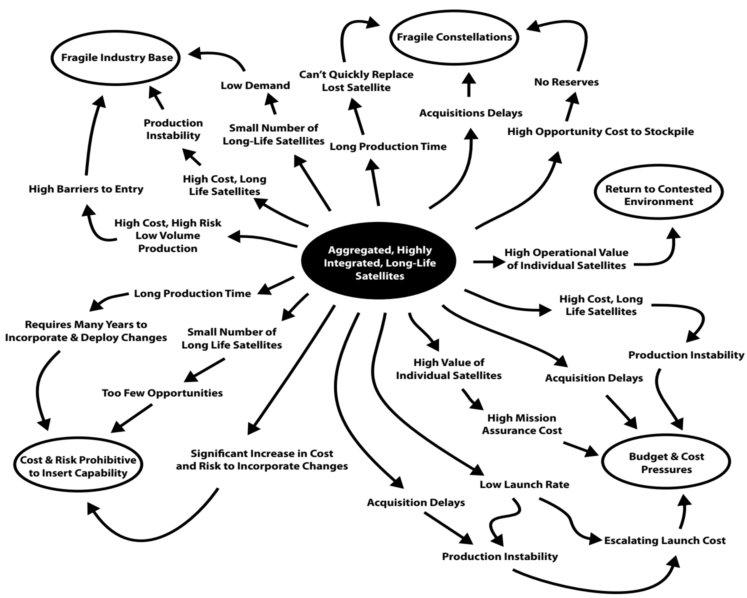

Figure 4. Effect of aggregated, highly integrated, long-life satellites

Both these tactics involved deployment or architectural responses to the new weapon he anticipated within the limits of what he could do with the equipment he had. Of course in the century following the attack, the navies of the world adapted many more responses to this submarine threat (and to an air threat still to come) by creating naval battle groups consisting of disaggregated capabilities as opposed to the unitary battleship architecture which previously had been the rule.

A similar architectural response is demonstrated by the successful music companies of the current decade. Those successful companies (Apple, Amazon, et al.) changed the architecture of the music (and book) distribution business in response to the digital challenge brought about by the CD, Internet, and storage discussed earlier. Interestingly, this shift was not just a change in the architecture of how music was delivered but also what was delivered. The record industry had abandoned the "single" decades earlier in favor of an integrated album. By delivering songs for 99 cents each, Apple changed both how music was delivered and what was delivered. These architectural responses serve as a guide for how we might address the disruptive challenges we find ourselves facing today.

Understanding the Details

The preceding discussion is a simplification of both the historical examples as well as the current challenges in space power. In fact, we did a detailed analysis of a variety of areas to understand the root causes of these challenges to determine what responses would be most successful in addressing them.[31] Using an eight-step approach, we decomposed each of the challenges into its driving causes and then looked across all challenges to identify the causes with the greatest effects.

The primary causes found to be propelling all the challenges are shown in table 1. When combined with the lessons we derived from the architectural response to the historical challenges, they provided us with guideposts to judge the adequacy of our responses.

Table 1. Primary causes of disruptive challenges

• Aggregated, concentrated architectures
• Systems vulnerable, little/no ability to deter/withstand attack
• Integrated, closed ground architectures
• High cost of launch
• Export controls limiting competition/partnering
• Space acquisition culture and processes biased toward top-down redesign and re-optimization for all new requirements

Next, using the same eight-step process, we analyzed potential responses to each of the challenges. We decomposed all the challenges through a series of fishbone charts and examined potential responses to each. We were especially interested in determining if there were common solutions that simultaneously addressed multiple challenges. For example, when we examined the challenge of fragile constellations, we found several possible solutions including investing in protection, buying more and smaller satellites, storing spare satellites in orbit, and reducing satellite complexity. Similarly, we examined the hesitancy to adopt new technologies due to the impact on the cost and schedule of a system. Possible responses here included taking more risk, buying more and smaller satellites, investing a greater share of resources in technology maturation, and changing US export controls. In both cases, we noted one common response: buying more and smaller satellites. We did this same exercise for each of the challenges enumerated in the discussions above and collected all the common potential responses, as shown in table 2.

Table 2. Common Responses to Challenges

Challenges	Common Responses
• Fragile constellations • Lack of resilience • Technology stagnation • Fragile industrial base • Inability to quickly supplement or replenish • Rising, uncontrollable cost	• More, smaller, less-complex satellites • Mixed constellations • Increase constellation size • Distribute capability • Encourage low-cost medium launch • Change export controls

Finally we examined whether the common responses were able to deal with the fundamental causes enumerated in table 1. It was clear that by using more, smaller, and less-complex satellites, we directly addressed the issue of aggregation. Disaggregation lowered the cost of individual vehicles and the operational impact of losing a vehicle. This approach allows more tailored mission assurance and smaller launch vehicles, which reduces the cost of launch. Encouraging the development of low-cost, medium-launch vehicles can lower associated costs even further. By reducing the operational impact of losing an individual vehicle, increasing constellation size, and distributing capability, we also change the effect of an attack and make it harder for an adversary to attain his intended results. Thus, distributing capabilities becomes a foundation for changing the conditions for deterrence. Using smaller satellites, coupled with increased constellation size, requires a more continuous production rate. A production line enables lower-cost options for on-orbit sparing, ground reserves for reconstitution, and a responsive capability if a surge is needed. Finally, smaller, more distributed capability leads to a more open ground architecture, which is now required to integrate the contributions of these individual and potentially mixed families of capabilities.

While it is clear in theory the responses discussed above could address the challenges that have grown into the space enterprise, it is less than clear if they can be executed in practice. The responses will surely lead to increased resilience and help unwind the vicious circle discussed earlier. And it is clear these responses are *capable* of controlling cost escalation of individual satellites and launches; however, we need to establish disaggregation and production modes which are also affordable at the architectural level. Disaggregated architectures certainly provide greater resilience, more opportunity for technology integration, an enhanced industrial base with more-frequent production buys, and the means for a quick response to changes in the strategic dynamic. But are they more affordable? To understand this question, we looked at the conditions existing in the commercial space market.

Commercial Space Market

The maturity of technology and markets outside of DoD acquisition has changed substantially since the current generation of systems was developed. Historically, the national security segment dominated the global market. In terms of number of vehicles launched, the commercial and military markets reached rough parity around 2000. In 2010, the commercial market launched 50 percent more than the military segment, with growth projected to double the military market by the middle of this decade.[32] This growth and maturity have created new realities in the marketplace that provide significant new opportunities for the DoD.

First, the commercial satellite bus market is the most competitive segment of the space enterprise. This competition has driven companies to find efficiencies in parts and processes to minimize costs and time to market. The result has been to maximize the use of common bus components and modular structures, providing a core capability that enables them to configure, rather than redesign, a satellite to meet its specific mission requirements. This approach minimizes the amount of redesign required for different missions, reducing cost and production time. The result has been a consistent ability to produce satellites in 24 to 36 months, and at much lower price points than the DoD has been able to realize.[33] If our architectures can be adjusted to take advantage of this highly competitive market, we have the potential to gain substantial savings.

Second, many of the commercial and international satellites being launched today have sufficient margins to allow for a secondary, or "hosted," payload. With the large number of vehicles going to orbits compatible with DoD missions, hosted payloads provide an opportunity to deploy capabilities at a fraction of the cost of our current systems. There are limitations we must be aware of in using this approach, such as restrictions on the ability to reposition the asset in response to contingencies. But given the global nature of our space missions, hosted payloads could provide a base level of coverage with DoD-owned satellites providing the flexible response needed.

The third opportunity in this commercial environment is the emergence of new entrants, such as SpaceX and Orbital Systems, to the medium-launch market. Both have contracts for 10–12 launches to supply the International Space Station. SpaceX is also under contract with a variety of commercial satellite vendors to support their payloads.[34] This volume is sufficient to establish the reliability and price point these vendors will require to offer medium-launch services and reintroduce competition into this segment of the launch market. While the jury is still out on these specific carriers, the handwriting on the wall is clear—the launch market is going to be more, not less, competitive in the years to come.

If we are to take advantage of these opportunities, the technology enablers must be in place to package our space systems to use commercial buses, hosted payloads, and smaller launch vehicles. With the exception of nuclear hardening, those enablers are already in place today. We demonstrated these enablers recently with the hosting of a wide-field-of-view (WFOV) infrared sensor package aboard a commercial communications satellite launched by SES Americom. The so-called commercially hosted infrared payload (CHIRP) was launched from an international launch base late last year and is now undergoing checkout on orbit.

The CHIRP demonstration showed that standard commercial bus specifications were sufficient to support the power, pointing, and stability necessary for overhead persistent infrared (OPIR) mission area sensors. We likewise have demonstrated off-the-shelf commercial bus capabilities can meet the core requirements needed to support DoD missions and payloads in the communications mission area. The wideband global SATCOM system (WGS) was developed based on commercial capabilities and is produced on a commercial production line at Boeing. Power, pointing, and stability requirements are met using commercial components.[35]

It is interesting to note that the WGS was originally the wideband *gap-filler* system. It was intended as a placeholder until a more ambitious (advanced wideband) satellite could be developed; later advanced wideband was supplanted by the drive toward an even more ambitious system, the transformation satellite system (TSAT). Both these programs would have represented one more run around the vicious circle with costs constraining us to a four-ball constellation. By staying with the less-complex, more easily produced WGS system, the DoD has been able to save substantial cost, and the size of the WGS constellation has grown from the originally envisioned four satellites to an inventory of 10. Given this experience, it is clear we have the ability to use a commercial bus at a lower cost to significantly reduce the time to produce and deploy capabilities for the war fighter, and to provide those capabilities in a more resilient mode than we have done historically.

The technology to package militarily useful capabilities small enough to be hosted, or to make use of smaller launch vehicles, was demonstrated by CHIRP. Similar small sensors from other vendors have been through ground testing. In the communications mission area, robust commercial encryption standards and components are being leveraged to define releasable, protected communications waveforms, payloads, and terminals that are smaller and less complex than our current systems. Commercial capabilities for unprotected wideband communications supporting RPAs and AISR are already in use and can be packaged as either a hosted payload or on a dedicated platform. These technologies enable options for both hosted payloads and smaller, less-complex satellites. In turn, the smaller satellites enable expanded use of medium-launch vehicles.

Taken together, these opportunities indicate there are approaches available to implement the common responses of smaller, less-complex satellites and distributed capabilities. This opportunity encourages the lower-cost medium-launch market and allows disaggregation of mission capabilities, which supports mixed constellations of small distributed capabilities complemented by the more robust, nuclear-hardened systems.

The successes of the commercial space marketplace suggest these responses can serve to reduce overall system cost.

Changing How We Buy—A Payload-Based Approach

To take advantage of opportunities and effectively and efficiently implement a distributed architectural strategy, some of our acquisition strategies will have to change. Our historic approach to designing and procuring satellites has been to optimize performance from the top down, which almost invariably results in a highly customized bus for each mission, requiring uniquely designed and manufactured components. This approach served us well when the space industry was still in the early stages of discovering what is possible for the war fighter from space. Now the industry and market have matured from building almost exclusively unique and cutting-edge technology systems to a more flexible model of commoditized capabilities and economies of scale; a payload-based approach allows us to follow them.

Continuing our top-down performance optimization approach, which drives unique requirements for things like the satellite bus, will prevent the DoD from taking advantage of the most competitive part of the space industry. It also hamstrings our ability to take advantage of hosted payload opportunities. Today's "top-down" payloads require unique support from the bus; using them as a hosted payload would require support to be added to the commercial bus, or re-engineered in the payload itself. At best, this requirement just adds cost. In most cases it prevents using the payload as a hosted capability at all because the changes in the technical baseline and schedule are unacceptable to the host, even if we are willing to pay the additional cost.

For this new strategy, we need to consider a focus shift of DoD space system development efforts more toward mission payloads. If we design a payload to provide the capability needed by the war fighter and be supported by a commercial bus, the ability to leverage both the commercial bus market and hosted payload opportunities opens up. By acquiring the mission payloads as the core element of a mission-area architecture, we can create a product with the inherent capability to fly on either a dedicated bus or as a hosted payload with minimal or no changes to the production baseline. This shift in focus would allow us to compete for procurement of a block of buses to support the next several payloads coming off the production line, mirroring current commercial practices.

Hosting payloads need no longer be a "one off" exercise requiring heroic efforts to win approval, modify products, and meet commercial timelines. It becomes an inherent part of our strategy to deploy capabilities on orbit. We can rapidly adjust to take advantage of the host opportunity by matching the timing of a payload coming off the production line to the host schedule. Overall, the time to produce and deploy a new payload can fall from the standard 7–8 years toward the commercial standard of 2–3 years. This change in time line alone will drive a significant reduction in cost.

A second aspect to consider is the amount of capability we choose to package into a single payload. While physics and technology will determine the smallest viable increment, shifting the procurement toward a greater number of smaller payloads creates additional opportunities. If there are a sufficient number of common payloads in the architecture, we can establish production lines to realize the benefits of a learning curve, reducing unit costs and risk and allowing more tailoring for the mission assurance process. This greater number of payloads also creates regular, planned technology/capability insertion points, reducing the time to deploy enhanced capabilities.

A risk to consider is whether or not we will have to compromise mission performance if we use this new strategy. Based on the technological opportunities discussed above, the risk is low for most of the DoD space-mission capabilities.[*] Nuclear-hardened capabilities, such as strategic missile warning and nuclear command and control, are the primary areas where we will need to proceed cautiously. These complex, nuclear-hardened systems can especially benefit from disaggregation of unrelated capabilities, such as battlespace awareness and tactical-protected MILSATCOM. Disaggregation will allow us to realize more affordable and resilient capabilities for the theater war fighter while at the same time allowing smaller, nuclear-hardened cores to be retained.

*This is not necessarily the case for intelligence community space missions. The peculiar demands of intelligence are less amenable to the disaggregated, smaller approach that appears to bear benefit for the national defense side of space. This article is not intended to discuss those issues.

Finally, when we combine a payload-focused acquisition strategy with the distributed architecture strategy we can see a path to unwinding the vicious circle facing today's space acquisitions. Such an approach:

- reduces complexity, allowing for more predictable and executable program baselines;
- stabilizes requirements by providing a predictable process for capability insertion;
- reduces operational and economic consequences of losing a vehicle, allowing for a more tailored and less-costly risk management, vice risk avoidance, mission assurance approach;
- establishes a consistent replenishment cycle, stabilizing satellite and launch vehicle production lines and creating the opportunity for affordable on-orbit and ground spares;
- creates more numerous launch and deployment (hosting) opportunities, reducing the cost of getting to space; and
- complicates any adversary's calculus of its surety of ability to deny the advantages of space for an extended period of conflict.

It is interesting to note at least one satellite system has followed this architectural and procurement approach from its beginning. GPS is a distributed, disaggregated assemblage of individual payloads, none of which can do its job individually. But taken together, they form a robust, affordable, and resilient architecture, which has an established production line with routine insertions of new technology.[36] The GPS III system has also adopted a payload approach, as indicated above, that uses a nearly off-the-shelf commercial bus paired to a purpose-built navigation payload.[37]

Transition—Taking the Next Steps

These new strategies cannot be implemented instantaneously, nor do they need to be. Our current space systems, highly capable and the most technologically sophisticated in the world, are serving us well. However, we must begin to move in a new direction if we are to address the disruptive changes discussed above. To begin this shift we need to choose to go against the status quo and undertake the following:

- Define alternative architectures to provide passive resilience and enable protection in depth. Allow mixed architectures that leverage government, commercial, and international opportunities.
- Demonstrate a path through early prototyping and on-orbit demonstration.
- Begin the shift to smaller, distributed, diverse constellations.
- Curtail current productions once a new capability is demonstrated and secure.

This plan establishes a path to enable migration to a mixed architecture over the next 10–15 years. We have taken the first steps along this new path. We have examined the options and opportunities for increasing resilience and affordability in several of our mission-area architectures using the tenets established above. The most mature evaluations are in the OPIR and MILSATCOM mission areas.

OPIR

Figure 5 shows some of the future architectural options considered for the OPIR mission area and the assessment of how well those architectural options would meet our goals of delivering the required war-fighting capability while increasing the resiliency and affordability of the capability. The criterion used to assess the architectural option against those goals is shown in each respective box. The assessment concluded all the options could meet the capability requirements, but continuing with the status quo architecture (aggregated clones) or evolving the current platform could not meet the resilience or affordability criteria. Therefore, a disaggregated approach to the OPIR mission area splitting strategic and tactical missions into separate payloads which can be flown on a variety of platforms, such as the legacy platform (but now dedicated to strategic warning), a dedicated, small, commercial bus, or a commercial, international, or other US government host is required.[38]

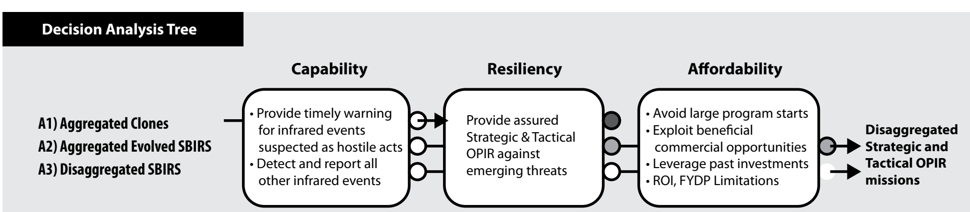

Figure 5. OPIR architecture decision analysis tree

Development of a low-cost WFOV staring-sensor payload for tactical missions offers opportunities for significantly lower cost and risk as well as increasing overall resilience by proliferating capabilities across multiple platforms.[39] Strategic warning remains healthy and is less costly due to a smaller strategic-warning payload and significantly reduced complexity and weight.[40] This approach also enables incremental deployment of tactical capabilities to augment current capabilities and gain operational confidence in how to best employ the capability. By conducting an operational demonstration of this capability based on leveraging the technology and experience gained through the CHIRP experiment, we will have the information needed to understand the costs and risks associated with a mixed architecture before needing to make a disaggregation decision on the next production increment of the SBIRS program (vehicles 7 and 8).

MILSATCOM

Figure 6 shows the future architectural options considered for the MILSATCOM mission area for both the contested/nuclear and benign operational environments. In the case of protected MILSATCOM, there is currently a significant shortfall in capability. The current protected communication capability must grow by a factor of 10 or more to support the full tactical protected requirement. Also, due to the high-grade cryptography employed, the current capability cannot be used to support lower-echelon units or RPAs where there is a likelihood of equipment capture and exploitation. As with OPIR, we assessed how well the alternative architectural options would meet our goals of delivering the required war-fighting capability while increasing the resiliency and affordability of the capability.

The assessment concluded the status quo would not be capable of meeting the required future capability. Evolving the current capability could meet the future capability requirement but with only a limited increase in resiliency and at very high cost. Disaggregating strategic and tactical protected communications enables smaller, lighter, less-expensive payloads for both services. This disaggregation creates the option for a simpler tactical protected capability using releasable cryptography supporting lower-echelon units, RPAs, and allies; it can be provided with much lower cost and risk. It also enables incrementally deploying the tactical protected capability more frequently and in smaller increments, decreasing the impact of delays or unexpected loss of a satellite, and offering a wider variety of deployment options such as hosting the tactical protected payloads or packaging them on a small commercial bus and more responsive, lower-cost launch vehicle.

Capabilities for the benign communications environment were also assessed. As in the contested environment, there is a growing shortfall in basic capacity and in the specialized support needed for long track airborne ISR platforms. Current programs were not sized to address this requirement, so some modification is necessary. Today's capabilities are largely based on commercial capabilities, the primary difference being the use of communication frequencies reserved for the military; however, they are still concentrated in a small number of platforms. In this area we have already achieved some level of distributed capability between dedicated wideband MILSATCOM platforms and widespread use of leased commercial SATCOM services. To provide the needed capabilities and increase resilience with an affordable solution, we concluded diversifying the wideband SATCOM capability is the best approach. We should continue investments to reduce the cost of our military wideband backbone, augment that capability with hosted payloads and international partnerships, and pursue innovative business strategies with commercial providers, which will enable wider and more-flexible access to commercial SATCOM capabilities.

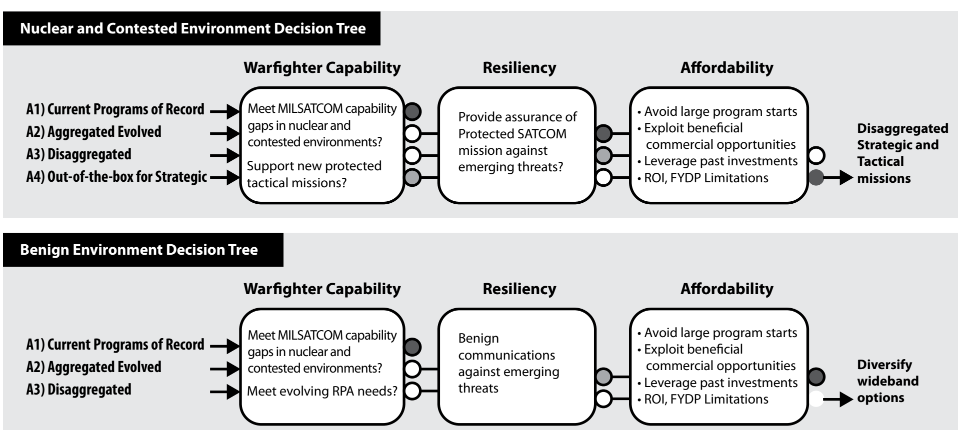

Figure 6. MILSATCOM alternative architectures decision analysis tree

Conclusions

Having looked at the disruptive changes and challenges facing the United States today in space, we formulated responses to those changes, explored the new opportunities enabling implementation of those responses, and developed a new strategy to allow the DoD to mitigate the challenges (see table 3). From this study we conclude the best means available to affordably provide resilient space capabilities the war fighter can depend upon and adapt as mission needs evolve is to use a distributed architecture strategy coupled with a payload-focused acquisition strategy that will:

- focus government development on mission payloads designed to be supported by commercial bus capabilities,
- create stable payload production rates,
- leverage the highly competitive commercial satellite bus market, and
- leverage hosted payloads on commercial, international, and allied platforms.

Table 3. Resolution to Challenges

Challenges	New Strategy
• Poor Resilience—concentrated capabilities are good targets that are hard to defend	• Distributed architecture disperses capability across multiple hosts and smaller platforms, complicating adversary targeting and making it harder to sustain effects
• Fragile Constellations—loss or delay of single platform greatly degrades capabilities	• Distributed architecture is less dependent on individual platforms; more frequent deployment of smaller increments of capability reduces impacts of delay
• Escalating costs as budgets decline	• Costs controlled or reduced through reduced complexity, leveraging highly competitive commercial bus market and hosted payloads, stable production, and more frequent launch to drive down costs through learning curve and other efficiencies
• Fragile industry base	• Stabilize lower-tier suppliers through stable production and launch; focuses development resources on maintaining intellectual capital needed for unique military capabilities

Challenges	New Strategy
• Technology Stagnation—inserting new capabilities can take decades	• Consistent and frequent technology insertion opportunities due to lower procurement risk; mirror commercial time to market of three years or less
• Requires years to supplement or replenish	• Affordably establish on-orbit reserves through smaller, less-complex satellites and hosted payloads; also enables affordable ground reserves and ability to surge production through a stable production line. More frequent launch and expanded number of launch providers enhances the capability to surge launch if needed

This approach greatly enhances the resiliency of our space capabilities. By increasing the number of platforms and dispersing our capabilities, we reduce the impact on the war fighter if a satellite is lost to mishap or hostile action. By reducing the cost of each platform, we can affordably create on-orbit reserves for rapid recovery and ground reserves for timely reconstitution. We also have determined this strategy will enhance the affordability of our space capabilities. The distributed architecture strategy looks at the entire architecture cost to determine the best trade between capabilities on individual satellites and overall architecture cost. The cost of higher quantities are offset by savings from hosting, continuous production lines, commercial bus procurements, smaller and less-complex satellites, more-frequent and lower-cost launch, and a more tailored approach to mission assurance. To achieve this goal, it is essential we implement the architectural, business, and budgeting practices to enable the DoD to create sufficient volume so we can access and realize the economies of scale we are seeing in other segments of the space marketplace.

We should also note the new strategy can form the basis of a different framework for deterrence. By using greater numbers of smaller platforms, orbital diversity, rapid recovery, reconstitution options, and international partnering, we increase the complexity of a potential adversary's attack calculus. Such a strategy imposes higher force-structure requirements, more-complex targeting and demanding situational awareness, greater risk of collateral damage, difficulty in sustaining desired effects, and the risk of entangling other parties in the conflict.

With these elements we will have taken the first substantive steps to addressing the disruptive changes that could otherwise lead to a diminution of the critical advantages space forces confer on our war-fighting capabilities today. The early airpower strategist Giulio Douhet said, "Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur."[41] The US Navy enjoyed victory in naval conflict by recognizing submarine warfare had created a disruptive change in the character of war. Major record labels, failing to recognize the disruptive influence of file sharing and digital media and adapt their systems before those changes occurred, began a long, slow decline in stature while digital-ready adversaries such as Apple and Amazon were poised to take their place.

A system's evolutionary path stays relevant only if the environment that spawned it remains static; but disruptive forces require those paths to be reevaluated. The disruptive forces that drive the need for change to our space architectural strategy are already evident. The means are available, and we have defined a way to adopt them. Space is too important to the national security of our nation for us not to adapt until after change is upon us. SSQ

Notes

1. Bern Anderson, *By Sea and By River: The Naval History of the Civil War* (1962; reprint, New York: Da Capo Press, 1989), 34.

2. *Official Records of the Union and Confederate Navies in the War of the Rebellion*, series 1, vol. 15 (Washington: Government Printing Office, 1921), 226–27.

3. Ashley Tellis, "China's Military Space Strategy," *Survival* 49, no. 3 (September 2007): 41.

4. Ibid., 45.

5. "Space to Manoeuvre—Satellite Attack Upsets US Space Supremacy," *Jane's Intelligence Review*, 7 February 2007.

6. Scott Karp, "Music Recording Industry Will Be First Traditional Media Industry to Be Utterly Destroyed by Digital Technology," *Publishing 2.0*, 28 December 2007.

7. "And 25 Years Ago Philips Introduced the CD," *GeekZone*, 1 November 2008.

8. The work reported here is an outgrowth of a think-tank study commissioned in 2010. Contributors to that study include retired general officers Lt Gen Mike Hamel, Maj Gen Tom Taverney, Maj Gen Ken Israel, Brig Gen Jim Armor, Brig Gen Tip Osterthaler, and Brig Gen Len Kwiatkowski; then–Brig Gens Jay Santee and John Hyten, then–RADM Liz Young, Dr. Pete Rustan, Gil Klinger, Joe Rouge, CEO of Orbital Space Systems Dave Thompson, President of Microcosm Dr. Jim Wertz, and author Doug Loverro. Also, a great debt is owed to Tom Cristler and Toni Arnold who led most of the analysis and did all of the writing for the white paper.

9. See Alexei Arbatov, "Russian Perspectives on Spacepower," in *Toward a Theory of Spacepower* (Washington: NDU press, 2007), chap. 23. As stated there, "In 1957, the Union of Soviet Socialist Republics (USSR) was the first nation in the history of the world to put a satellite in space, and in 1961 it followed with the first manned space flight. During the Cold War, Soviet space power was second to none—in some respects behind and in others ahead of that of the United States."

10. Gen Thomas S. Moorman Jr. (ret.), speech at American Institute of Aeronautics and Astronomy (AIAA) Space 2007 Conference and Exposition, 21 September 2007, Long Beach, CA.

11. Curtis Peebles, *High Frontier: The United States Air Force and the Military Space Program* (Washington: Air Force History and Museums Program, 1997), 15–26.

12. Ibid., 13.

13. Dana J. Johnson et al., *Space: Emerging Options for National Power* (Santa Monica, CA: RAND, 1998), 38.

14. In the strange calculus of space technology, designing a satellite to survive a non-direct nuclear attack was more straightforward than designing a system that could hold up against nonnuclear mechanisms, since many aspects of a nuclear attack were already accounted for by designing the satellite for extended stay in its natural radiation environment. For example, under natural background radiation conditions in LEO, peak flux for electrons with energy greater than 1 MeV ranges from 10^4 for the outer radiation belt to 10^6 for the inner. Enhanced solar flux is said to have resulted in >1 MeV electron flux to reach 10^8 particles/sq cm sec. Coincidentally, this is the same magnitude computed by the model due to a high-altitude nuclear explosion one day after the burst over Korea. Source: Defense Threat Reduction Agency, *High Altitude Nuclear Detonations against Low Earth Orbit Satellites ("HALEOS")*, DTRA Advanced Systems and Concepts Office, April 2001, 12.

15. *Space-force enhancement* is defined as "force-multiplying capabilities delivered from space systems to improve the effectiveness of military forces as well as support other intelligence, civil, and commercial users." JP 1-02, *DoD Dictionary of Military and Associated Terms*, 8 November 2010 (as amended through 15 October 2011), 312, http://www.dtic.mil.

16. Craig Covault, "Desert Storm Reinforces Military Space Directions," *Aviation Week and Space Technology*, 8 April 1991, 42.

17. Steven J. Bruger, *Not Ready for the "First Space War" What About the Second?* Naval War College student papers, 17 May 1993.

18. *Ensuring America's Space Security*, Report of the Federation of American Scientists Panel on Weapons in Space, September 2004, 12.

19. *Gulf War Air Power Survey*, Vol. 2, pt. 1 (Washington: GPO, 1993), 189.

20. Bruger, *Not Ready for the "First Space War,"* 21.

21. *Combat support* is defined as "operational assistance provided to combat elements." JP 1-02, 60.

22. Gen William Shelton, "The Foundational Role Space and Cyber Play in our Nation's Defense," Global Warfare Symposium, 17 November 2011, Los Angeles, CA, 8–9.

23. William J. Lynn, "A Military Strategy for the New Space Environment," *Washington Quarterly* 34, no. 3 (Summer 2011): 8.

24. The concept of a military "center of gravity" was first proposed by Carl von Clausewitz in *On War*. It is defined in JP 1-02 as, "the source of power that provides moral or physical strength, freedom of action, or will to act."

25. Sun Tzu, *The Art of War*, trans. by Samuel Griffith (London: Oxford University Press, 1971), 77.

26. "Satellite transit" describes the passage of a satellite, normally in low-Earth orbit, overhead. Knowledge of transit times allows individuals to hide their activities from unwanted surveillance.

27. Mike Orcutt, "Space Over Time," *Technology Review*, 23 July 2011.

28. *National Security Space Strategy: Unclassified Summary* (Washington: DoD, January 2011), 3.

29. For example, both the space-based infrared satellite and the GPS IIF satellite took over 14 years from contract award to delivery. Other systems (NPOESS, JWST, AEHF) saw similar delays or were even cancelled.

30. Gen Kevin Chilton, "Commander's Perspective," speech to the 2009 Strategic Space Symposium, 3 November 2009.

31. Douglas Loverro, "*Reinventing Space 2011: The Changing Dynamics of Space Power*," May 2011, presentation at the Reinventing Space conference, May 2011, Los Angeles, CA, 23.

32. "Toc-satellites-to-be-built-launched-by-2019.29," *Euroconsult*, http://*www.euroconsult-ec.com.*

33. Futron Corporation, *Satellite Manufacturing: Production Cycles and Time to Market*, May 2004, 2, http://www.futron.com/upload/wysiwyg/Resources/Whitepapers/Satellite_Manufacturing_Production_Cycles_0504.pdf.

34. SpaceX has a launch manifest of over 40 launches, including the station resupply and the Iridium constellation, plus multiple other customers. Orbital Space Systems is still in the process of securing its own launch market.

35. The WGS satellite is based on the Boeing 702HP bus. See http://www.boeing.com/defense-space/space/bss/factsheets/702/wgs/wgs_factsheet.html). This is a common platform configured to support multiple commercial communications satellites including PanAmSat, INMARSAT-5, MEXSAT and others. See http://www.boeing.com/defense-space/space/bss/factsheets/702/702fleet.html.

36. GPS modernization was made possible because we found ourselves in the late 1990s with a robust on-orbit constellation and a large number of spare satellites on the ground. We were able to spiral in new technology with the IIR-M satellites (M-code and a second civil signal), provide more in GPS IIF (aviation signal, L5), plus the change to flexible power for both systems. GPS III is being laid out in a similar fashion with routine insertion of technology into an ongoing production line and each satellite simple and inexpensive enough that the risk of insertion remains low.

37. The Lockheed A2100 bus is the basis for the GPS III system, but with hardening appropriate for the medium earth orbit (MEO) in which it flies.

38. Lt Gen Ellen Pawlikowski, "AF Space Portfolio Future Architectures," briefing to secretary of the Air Force, 24 October 2011.

39. John "Pete" Peterson and Jim Bui, "Overhead Persistent Infra-Red (OPIR) Architecture Study," DoD Executive Agent for Space, 17 June 2011.

40. "Space Modernization Initiative Alternatives Analysis," SMC/IS, 1 November 2011. The analysis used the current CAPE ICE SBIRS GEO 3/4 cost estimate as the basis for disaggregation with the following assumptions: (a) costs up to launch, no launch costs considered; (b) GEO 3 NRE and GEO 4 production article; (c) future costs indexed to inflation; and (d) for a disaggregated GEO, assume single scanner sensor and no staring sensor. Based on these assumptions, initial cost estimates show a 20-percent savings for a single scanner satellite needed to support strategic warning mission.

41. Giulio Douhet, *The Command of the Air,* trans. Dino Ferrari (1942; reprint, Washington: Office of the Air Force History, 1983).

China's Military Role in Space

Dean Cheng

As the United States tries to square its commitments in Asia with declining budgetary resources, it is essential American decision makers tread carefully with regard to its space capabilities. These global assets are the backbone that allows the US military to fight in the manner to which it is accustomed. Consequently, in the event of a conflict involving the People's Republic of China (PRC), they are likely to be a primary target.

Over the past two decades, the PRC has paid careful attention to how other nations, but especially the United States, fight their wars. Space has consistently been part of the People's Liberation Army's (PLA) thinking about future conflict. At the same time, the PRC has grown from a developing country to the second largest economy in the world, with sufficient resources to create its own substantial space presence. Unlike previous conflicts in the Middle East, the Balkans, and Central Asia, if the United States engages in a conflict in the western Pacific, it will be confronted by a nation with a comprehensive set of space capabilities to counter America's own.

This article reviews the evolution of China's military thinking and the changed role of space within that context. It briefly examines China's space capabilities and development before discussing its concepts for military space operations and concludes with future Chinese space operations.

Evolution of Chinese Thinking about Military Space

While China's space program dates from the 1956 founding of the Fifth Academy of the Ministry of Defense, little public information is available on PLA thinking about space in the early years. This is likely due, in part, to the limited space capabilities available to the PLA, since China only orbited its first satellite in 1970.

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During this initial period, Chinese security thinking was dominated by leader Mao Zedong's focus on "early war, major war, nuclear war." According to Mao, the international security situation was marked by "war and revolution." The world, as envisioned by Mao, was on the brink of major global war. To prepare for it, Chinese military efforts were focused on the likelihood of protracted warfare against either Soviet or American invaders. This was further colored by Mao's belief in the continuing importance of "people's war," relying on extensive militia forces capable of waging guerrilla warfare rather than fielding conventional forces equipped with advanced weapons. Thus, perhaps two-thirds of Chinese defense industry facilities in the 1966–1975 time frame were built deep in the hinterland—scattered in valleys or buried in mountain redoubts—intended to support an extended guerilla war against the Soviet Union or the United States.[1] Even after China orbited its first satellite, the Dongfanghong-1, the military's focus was likely more on terrestrial conflict at a low level of sophistication rather than on military space operations.

When Deng Xiaoping succeeded Mao in 1978, military space considerations became even less of a priority. Far more pragmatic than Mao, Deng fundamentally altered the basis of Chinese security thinking from "war and revolution" to "peace and development." In essence, the expectation was that the world (and especially China) was no longer confronted by the prospect of imminent, major conflict. China therefore could shift its investment and planning horizon to the longer term. This allowed Deng to reallocate national resources away from military industries to rebuild the moribund civilian economy, with the top priorities being agriculture and light industry to produce consumer goods. Deng enforced a starvation diet on the Chinese military industrial complex. China's defense industries were expected to convert to civilian and commercial production to supplement their now-meager governmental contracts. In this context, space systems had to be justified based on their contribution to national economic development. According to Deng, the Chinese space program needed to focus less on gaining prestige and headlines and instead "concentrate on urgently needed and practical applied satellites."[2] During the early years of Deng's reign, only a few communications satellites and retrievable satellites (Fanhui Shi Weixing, whose payloads returned to Earth) were placed in orbit.

Having altered the assessment of the international situation, Deng, in 1985, set forth a new appraisal of the threat environment. He informed the Central Military Commission (CMC), which is responsible for managing and overseeing the PLA, that "future conflicts were likely to be localized yet intensive."[3] Rather than "comprehensive war" or "all-out war (*quanmian zhanzheng*; 全面战争)"—major global war—the PLA would now prepare for "local war (*jubu zhanzheng*; 局部战争)," or wars that would occur within a defined area (most likely on China's periphery) using particular types of weapons (i.e., nonnuclear) with limited goals.[4]

Meanwhile, in the seventh five-year plan (1986–1990), it was reported that some 1,800 aerospace efforts were either converted or otherwise shifted toward commercial production. Indeed, Chinese computer and information technology advances during this period, including automated control systems and industrial robots, are all at least partially attributed to this shift by the aerospace industry toward civilian applications.[5]

Support for China's overall space program did not improve until 1986 when Deng, at the urging of a number of top Chinese scientists, authorized Plan 863, formally termed the National High-Technology Research and Development Plan (*guojia gao jishu yanjiu fazhan jihua*; 国家高技术研究发展计划).[6] Plan 863, which remains an ongoing effort, was seen as providing the scientific and technological research foundations essential for a modernizing economy. Aerospace, along with automation, advanced materials, and bio-engineering, were seen as key areas of high technology, justifying substantial, sustained resource investment. Even then, however, it is less clear how much it was incorporated into military planning, as the PLA was undergoing fundamental shifts in its outlook and doctrine.

At the same time, there was also recognition of the impact of modern technology. Chinese observations of the "Fourth Middle East War" (i.e., the 1973 Yom Kippur War), American military operations in Vietnam, and the 1982 Falklands conflict demonstrated that modern weapons offered increasing reach and lethality. Future conflicts would therefore be "local wars under modern conditions," an incremental improvement over World War II at the operational level, incorporating modern weapons, including precision-guided munitions.

Space and Local Wars under Modern, High-Tech Conditions

The coalition performance against Iraq in Operation Desert Shield/Desert Storm served as a wake-up call for the PLA. It demonstrated that modern high technology was not a marginal change but had fundamentally altered the operational art. As the then–deputy director of the PLA's "think-tank," the Academy of Military Science (AMS), observed, "The Gulf War marked a big step forward in both military theory and practice."[7]

The PLA engaged in extensive analysis of coalition operations and sought to incorporate the resulting lessons into its own approach to war. The result was a thorough revision of almost every aspect of PLA thinking about future conflict. In 1993, the PLA produced a new set of "Military Strategic Guidelines for the New Period," introducing the concept of "local wars under modern, high-tech conditions." These guidelines constitute "the highest level of national guidance and direction" to the Chinese armed forces.[8]

In a December 1995 speech to the CMC, party general secretary Jiang Zemin, who succeeded Deng Xiaoping, emphasized the importance of these new guidelines when he charged the PLA with undertaking the "two transformations (*liangge zhuanbian*; 两个转变)." These entailed a shift from a military focused on quantity to one focused on quality, and from a military preparing for "local wars under modern conditions" to one that was preparing for "local wars under modern, high-tech conditions."[9]

According to PLA assessments, local wars under modern, high-tech conditions were marked by several key characteristics:

- The quality as well as the quantity of the weapons mattered. The side with more-technologically sophisticated weapons would be able to determine the parameters of the conflict and effectively control its scale and extent.
- The battlefields associated with such conflicts would be three-dimensional and extend farther and deeper into the strategic rear areas of the conflicting sides.
- The conflict would be marked by high operational tempos conducted around the clock under all weather conditions.
- The fundamental approach to warfare would be different. Such wars would place much greater emphasis on joint operations, while also incorporating more aerial combat, long-distance strike, and mobile operations.
- The role of command, control, communications, and intelligence was paramount. C3I functions were seen as essential to successful

> implementation of such wars; consequently, the ability to interfere with an opponent's C3I functions also became much more important.[10]

These latter two aspects—the role of joint operations and the importance of C3I—in turn both influenced the assessment of what role space should play in the PLA's concepts of operations.

The PLA's assessment of the first Gulf War highlighted the role of joint operations—operations involving two or more services at the operational level, according to a single plan, under a single command structure.[11] An instructor at China's National Defense University (NDU) noted that the Gulf War's "characteristics of a joint operation of all branches of the military displayed in that war gave us a glimpse of things to come in the early 21st Century."[12] PLA analyses concluded that the ability to coordinate the operations of different services would produce synergies that no single service could hope to match. Joint operations were seen as the "fundamental expression" of "local wars under modern, high-tech conditions."[13]

In this light, space capabilities were recognized as playing an essential role in any effort to wage a local war under modern, high-tech conditions. The 70 satellites that were ultimately brought to bear against Iraq provided the United States, according to PLA estimates, with 90 percent of its strategic intelligence and carried 70 percent of all transmitted data for coalition forces.[14] Indeed, these assets were the first to be employed, since they were essential for the success of subsequent campaign activities. As one Chinese analysis observed, "Before the troops and horses move, the satellites are already moving."[15]

Nonetheless, there were still some doubts apparently about the importance of the role of space. In the 1997 *PLA Military Encyclopedia*, the discussion for "space warfare (*tianzhan*; 天战)" explicitly states that space is not a decisive battlefield; the key to wartime victory would remain in the traditional land, sea, and air realms. "It is impossible for it [space warfare] to be of decisive effect. The key determinant of victory and defeat in war remains the nature of the conflict and the human factor."[16] Space was seen as a supporting, not a leading, player.

This growing emphasis on joint operations ultimately led to the revision of the PLA's combat regulations (*zuozhan tiaoling*; 作战条令), the operational guidance governing PLA operations at the campaign and tactical levels. In June of 1999, the "First Generation Operations Regulations," issued in the mid 1980s, were replaced with the "New Generation Operations Regulations." The product of several years of debate and study, these new combat regulations made joint operations the capstone.[17] In essence, the PLA was stating that individual service campaigns are subordinate to joint campaigns, and it would train and equip itself to that effect.[18]

As envisioned by the PLA, joint operations would involve multiple services operating together across significant distances. The Gulf War, for example, sprawled across some 140 million square kilometers and included forces ranging from armored units to aircraft carriers and long-range bombers.[19] The successful conduct of joint operations on this physical scale, involving forces operating across a variety of domains, would therefore require close coordination, including not only extensive communications but also precise navigation and positioning information, both for units and for the growing plethora of precision munitions. Nor are joint operations solely a matter of combat forces; the demands of *local wars under modern, high-tech conditions* also require coordination of both combat and attendant logistical forces. Joint operations were therefore seen as requiring the ability to command and control operations across five domains: the traditional ones of land, sea, and air but increasingly also outer space and electromagnetic (cyber) space.

Conversely, as one PLA volume observed, future conflicts would also likely entail significant efforts at disrupting the enemy's ability to coordinate its forces, thereby paralyzing the entire array of enemy combat systems.[20] That, in turn, would entail operations in space and cyberspace to degrade enemy abilities while safeguarding one's own.

By 2002, however, this view had evolved further. In that year's supplement to the *PLA Encyclopedia*, a very different assessment is made of the importance of space. In a discussion on "space battlefield (*taikong zhanchang*; 太空战场)," the entry concludes with the observation that the impact of the space battlefield on land, sea, and air battlefields will become ever greater, and the space battlefield "will be a major component of future conflict."[21] It is clear that space, in the interval, was perceived as a substantially more important arena for military operations.

This progression may have been partly due to the intervening NATO conflict in the Balkans. The ability to defeat Belgrade through airpower clearly caught Beijing's attention. In their analyses of that conflict, the role of space power gained further prominence. NATO forces are assessed to have employed some 86 satellites.[22] These provided a dense, continuous flow of real-time data, allowing the NATO forces to establish precise locations for Serbia's main military targets for sustained, coordinated strikes.[23]

Space and Local Wars under Informationized Conditions

This shift may also have been a reflection of the ongoing development of Chinese concepts of future warfare. In 2004, Hu Jintao assumed chairmanship of the CMC, two years after becoming general secretary of the Chinese Communist Party (CCP). In December of that year, he gave a speech in which he outlined the "historic missions of the PLA in the new phase of the new century (*xinshiji xinjieduan wojun lishi shiming*; 新世纪新阶段我军历史使命)." These new historic missions include

- guaranteeing the continuing rule of the CCP;
- safeguarding national economic development through defense of sovereignty, territorial integrity, and domestic security;
- safeguarding China's expanding national interests, specifically including access to space (*taikong*; 太空) and the electromagnetic sphere; and
- helping ensure world peace.[24]

Incorporating space into the specific responsibilities of the PLA in terms of its *new historic missions* would seem to indicate a growing view of space as essential to Chinese security. It also clearly charges the PLA with undertaking military space missions.

Also during this period, the concept of future wars was further refined. From *local wars under modern, high-tech conditions*, the PLA now expected to engage in *local wars under informationized conditions*. This new phrase began in 2002 and was incorporated into the 2004 Chinese defense white paper.

Informationized conditions, in this context, did not simply refer to computers and cyber warfare. Rather, the informationized battlefield (*xinxihua zhanchang*; 信息化战场) is one in which all the relevant military activities—including tactics and operations as well as decision making—are digitized, and military materials and equipment are managed through advanced information technology.[25] The shift in terminology reflected the PLA's conclusion that, among the various high technologies, the most important with the most far-reaching impacts are those relating to information management.

This conclusion was also reflected in an apparent modification of the "campaign basic guiding concept (*zhanyi jiben zhidao sixiang*; 战役基本指导思想)." The campaign basic guiding concept is a distillation of military laws and theories and is intended to serve as a guide for PLA officers in planning, organizing, and prosecuting campaign-level operations. In some ways, it somewhat parallels the "principles of war," while taking into account contemporary conditions.

In the 2001 edition of *The Science of Campaigns*, a PLA textbook, the "campaign basic guiding concept" for "local wars under modern, high-tech conditions" was established as "integrated operations, key point strikes (*zhengti zuozhan zhongdian daji*; 整体作战， 重点打击)." *Integrated operations* meant integrating all forces, integrating operations across all domains, and integrating all methods of warfare. *Key point strikes* meant concentrating forces on the key strategic direction at the critical junctures and moments against essential enemy targets so as to cripple and paralyze enemy forces.[26]

By the 2006 edition, the campaign basic guiding concept had changed. It was now "integrated operations, precision strikes to control/constrain the enemy (*zhengti zuozhan, jingda zhidi*; 整体作战, 精打制敌)." *Precision strikes* involve the use of precision munitions to attack vital targets. The goal is not only to destroy the enemy's key points but also to precisely control the course and intensity of a conflict.[27] It also entails disrupting the enemy's system, not just his weapons or forces.[28]

Central to the conduct of such strikes is the ability to establish superiority, or dominance, over the information realm. Seizing information superiority or dominance (*zhi xinxi quan*; 制信息权), is seen as vital.[29] An essential means of attaining information dominance, in turn, would be through military space operations. "Establishing space dominance, establishing information dominance, and establishing air dominance in a conflict will have influential effects."[30]

What did not change was the central role of joint operations. These are still seen as a key part of *local wars under informationized conditions* and remain the means for the PLA "to bring the operational strengths of different services and arms into full play."[31] Similarly, space operations remain an important part of joint operations, whether under high-tech or informationized conditions. In the 2001 edition of *The Science of Campaigns*, space is described as an essential part of fighting future wars, and the ability to undertake the kinds of operations needed to win such wars is substantially rooted in the ability to exploit space.[32] The 2006 edition specifically states that "the space domain daily is becoming a vital battlespace. . . . Space has already become the new strategic high ground."[33]

Chinese Space Capabilities

Concomitant with the growing interest in the military role of space in the wake of the first Gulf War, China's overall space capabilities expanded significantly during the past two decades. Indeed, its growth during this period is in sharp contrast to its first 20 years in space.

From 1956 to 1976, China enjoyed only very limited advances in its space capabilities due to a lack of financial, technological, and trained human resources as well as repeated political upheavals that disrupted research efforts. Even after orbiting its first satellites in 1970, space development remained limited, with only a handful of satellites orbited before Mao died in 1976. As noted earlier, Deng Xiaoping initially did little to promote space development for either the military or civilian sectors. Rather than commit further resources toward space during his first several years in power, Deng diverted them toward the civilian economy, forcing the space industrial sector to fend for itself through conversion to products with civilian demand.

In the 1990s, however, China's space program benefited from renewed investment and high-level support. Under Jiang Zemin (1992–2002), China deployed both low-Earth orbit and geosynchronous weather satellites (the Fengyun series) as well as improved geosynchronous communications satellites (the Dongfanghong-3 series) and recoverable satellites with varying payloads (the Fanhui Shi Weixing-2 series).

Chinese earth observation capabilities also improved during this period. In cooperation with Brazil, China in 1999 deployed the China Brazil Earth Resources Satellite (CBERS), its first electro-optical imaging satellite capable of beaming pictures directly down to Earth. China subsequently launched several similar satellites without Brazilian involvement; these are known as the Ziyuan series to distinguish them from the CBERS satellites.

In 2000, China became only the third country to deploy a navigational satellite system, launching two Beidou regional navigation satellites into geosynchronous orbit. This system also has a communications function, which was employed during the 2008 Sichuan earthquake.[34]

Since succeeding Jiang Zemin in 2002, Hu Jintao, the current party general secretary, chairman of the Central Military Commission, and PRC president, has maintained support for China's space program. During his two terms, China has deployed a variety of additional satellites, including new remote sensing satellites (the Yaogan series), microsatellites such as the Shijian series, and improved versions of the Fengyun and Ziyuan series.

Under Hu, China has also orbited several manned spacecraft (the Shenzhou program), as well as initiated a lunar exploration program, launching the Chang'e 1 and 2 lunar probes.

These investments were not solely for military purposes; indeed, Deng's admonition to focus on national economic development still seems to resonate in many aspects of China's space program. Its development of earth observation satellites, position and navigation systems, and weather satellites all support Chinese economic development objectives. But they also provide the PLA with key pieces of information deemed essential for *local wars under high-tech conditions*, as well as *local wars under informationized conditions*. And since the PLA's General Armaments Department (GAD) runs its space facilities, the military's role in China's space program should not be underestimated.[35]

Indeed, under Hu Jintao, China also demonstrated its space *combat* capabilities. The PLA tested its direct-ascent, kinetic-kill antisatellite (ASAT) system in January 2007. Launched from Xichang Satellite Launch Center, the ASAT missile destroyed a defunct Fengyun-1C weather satellite in low orbit. In the process, it also generated a massive amount of space debris.[36] Almost precisely three years later, in January 2010, China engaged in what was termed an antimissile test involving "two geographically separated missile launch events with an exo-atmospheric collision also being observed by space-based sensors," according to the US Department of Defense.[37] This test, however, likely also helped Chinese scientists improve their ASAT system. And in August 2010, two Chinese microsatellites were deliberately maneuvered into close proximity and apparently "bumped" each other.[38]

Today, China's space program is supported by a space industrial complex believed to involve over 200,000 people. Two major aerospace conglomerates, the China Aerospace Science and Technology Corporation (CASTC) and the China Aerospace Science and Industry Corporation (CASIC), manufacture the full range of space systems, including launch vehicles, satellites, ground equipment, and the associated subsystems and support items.

Chinese Space Development Priorities

The 2011 Chinese space white paper outlines a range of new capabilities the PRC expects to field in the course of the ongoing 12th five-year plan (2011–2015).[39] Besides the commitment to studying a human mission to the moon (the first time such a project has been officially included in a formal state document), the new space white paper indicates that the PRC will be pursuing new launch vehicles, a new launch site, and a variety of new satellites. There appears to be a comprehensive modernization and improvement effort underway within China's space program. Many of these new systems will support both military and civilian users.

Launch vehicles include the Long March 5 heavy-lift vehicle, the Long March 6 light- to medium-lift vehicle, and the Long March 7 medium-lift vehicle. Interestingly, reports suggest there will be a high degree of commonality among the three designs, including possibly a modular approach to facilitate production.[40] The Long March 5, which may be comparable to the American Delta IV and the European Space Agency's Ariane 5, will likely be launched from the new facility under construction on Hainan Island, which should be completed in the course of this five-year plan. Chinese tracking, telemetry, and control (TT&C) facilities will also be upgraded, including provision of better tracking of systems beyond geosynchronous orbit.

The white paper lists a number of new satellite programs that might be orbited with these new systems. Prominent among them is a new high-resolution earth observation system, providing Chinese decision makers with "a stable all-weather, 24-hour, multi-spectral, various-resolution" capability. In essence, China, having previously deferred the acquisition of high-resolution reconnaissance satellites, will now begin developing one. This is likely to be supplemented by satellites mounting synthetic aperture radars, ostensibly for "environment and disaster monitoring."[41] In addition, China expects to continue augmenting its Beidou navigation constellation, enabling it to provide global rather than regional service.

Other programs mentioned in the space white paper include further developments in satellite applications as well as systems for tracking space debris, for simulating space debris collisions, and "a system to protect spacecraft from space debris." [42]

While some of these programs may have military applications, the space white paper itself makes no mention of military programs and only briefly mentions the term "national security" at all.

Chinese Concepts of Military Space Operations

Despite clear PLA interest in space and a substantial space infrastructure, as well as demonstrated space weaponry, as of 2011 there is no publicly available evidence that it has promulgated a specific doctrine governing military space operations. This should not be surprising. A decade after the "Year of Regulations," those combat regulations governing such operations remain classified.

Certain themes recur in Chinese writings on military space operations, however, and these are likely to be incorporated into any formal PLA space doctrine. For example, there seems to be a consensus on what "space dominance (*zhitian quan*, 制天权); also translated as "command of space," or "space superiority")" or "space control (*taikong kongzhi*; 太空控制)" means: the use of space capabilities to exert control or to maintain the initiative (*kongzhi quan huo zhudao quan*; 控制权或主导权), during a certain time, over a certain area of outer space (*zai yiding de shijian nei dui mou yi kongjian lingyu*; 在一定的时间内对某一空间领域).[43] It incorporates both military space operations and what American theory would term offensive and defensive space control as it involves efforts aimed at limiting, reducing, or disrupting the enemy's aerospace systems and combat effectiveness as well as ensuring that one's own aerospace systems can operate normally and at full effectiveness.

One seeks space dominance as a means toward obtaining information dominance, or information superiority (*zhi xinxi quan*; 制信息权). Thus military space operations are often discussed in the context of the need to obtain information or to deny it to an opponent.[44] Similarly, the establishment of space dominance is often described in holistic terms involving disparate forces, both space based and non–space based, and involving not only operations in space but also on the ground, in the air, and at sea as forces act against not only space platforms but also terrestrial support facilities and the data links that tie the two together.[45]

Insofar as "strategic concepts are translated to doctrine through the development of campaign guidelines, and these guidelines [then] drive capabilities development," Chinese writings which discuss campaign guidelines and relate them to space operations would likely reflect potential aspects of any nascent Chinese military space doctrine.[46]

In this regard, Maj Gen Chang Xianqi's writings may provide significant insight. Chang was formerly commander of the GAD's Academy of Equipment Command and Technology (*zhuangbei zhihui jishu xueyuan*; 装备指挥技术学院) which, according to PLA writings, is the main institution responsible for training the personnel that staff China's space-related facilities, including launch sites and mission control centers.[47] In

2002, Chang wrote the PLA textbook *Military Astronautics*, which was reissued in 2005 in a second edition.

In his book, Chang proposes a "guiding concept for space operations (*kongjian zuozhan de zhidao sixiang*; 空间作战的指导思想)." Interestingly, it would seem to be modeled on the earlier campaign basic guiding concept: "Unified operations, key point is space dominance."[48]

Unified Operations

According to Chang, the establishment of space dominance will entail unified operations (*yiti zuozhan*; 一体作战), which will in turn involve unified forces, techniques, and operational activities.[49]

Unified forces involve two aspects. One is the integration of civilian and military space systems, both in prewar planning and wartime application. This provides a more robust capability at a lower cost. The other is unifying space forces with land, sea, air, and electromagnetic forces in joint operations. Terrestrial forces benefit from space support and can both degrade opponents' space forces (e.g., through attacks against ground stations) and preserve one's own space capabilities (by defending against comparable attacks).[50]

Unified techniques refer to combining soft-kill and hard-kill methods. It should be noted that both soft- and hard-kill techniques serve the same ends, which is to reduce an opponent's advantage in space while preserving one's own to secure space dominance. Soft-kill techniques are less likely to incur international repercussions but may allow an opponent to recover.[51] They include not only measures aimed at space hardware, such as "dazzling," but also cyber attacks aimed at either satellite systems or their terrestrial control elements. Hard-kill techniques may also be aimed at destroying not only satellites (such as in the 2007 ASAT test), but also include attacks against TT&C facilities and launch sites. Such measures will permanently remove a facility or a system but can create significant political problems and may be seen as escalatory.[52] PLA authors such as Chang would seem to support an approach that balances disruption (soft-kill) and destruction (hard-kill) of an opponent's space systems.

Unified operational activities involve coordinating offensive and defensive operations. Offensive activities, which may include both soft-kill and hard-kill methods, are likely to be undertaken at the earliest possible moment to seize the initiative and force the enemy into a reactive mode.[53] Defensive activities, meanwhile, will also be implemented from the onset of operations to limit the effectiveness of enemy efforts to interfere with, seize, destroy, or disrupt one's own space systems.[54] These will include active and passive measures. Active defenses include the provision of air defenses and security forces. Passive measures include efforts at camouflage and concealment of space-related facilities, including launch and TT&C facilities, deception measures, redundancy, and mobility. Mobile TT&C facilities, for example, should be developed and deployed to concealed locations, ready to replace fixed sites should the latter be attacked.[55]

Key Point Is Space Dominance

The purpose of the unified operations outlined above is to establish space dominance, or space superiority (*zhitian quan*; 制天权)—the ability to exploit space for one's purposes, at the times and places of one's choosing, while denying an opponent that same freedom of action. To obtain space dominance, one needs to sustain the uninterrupted operation of space information collection and transmission systems. Key space platforms include

- reconnaissance satellites to conduct comprehensive, timely, and accurate intelligence gathering on enemy forces;
- communications satellites to provide global, all-weather, unbroken, secure, reliable communications and data relay;
- navigation and positioning satellites to allow one's own forces to engage in rapid, precise, mobile operations and engage in precision warfare against an opponent;
- weather satellites to collect global weather information; and
- survey and earth-observation satellites to precisely map various terrestrial terrain features, including potential enemy targets.[56]

Satellites alone, however, are not sufficient. Orbiting systems must be backed by a complete supporting infrastructure, including space launch facilities, TT&C systems, and the attendant data links that bind the components together. Successful efforts at establishing space dominance therefore must also take into account the sustainment of this entire structure of terrestrial and space systems and associated data and communications links, while striving to degrade or destroy an opponent's.[57]

To this latter end, one needs to conduct unified operations against an opponent's most important space targets. These are the key information and space assets which will most affect the enemy's capabilities in the main strategic direction. They should be attacked by one's best forces at the crucial moments of the campaign with the aim of degrading the enemy's ability to field unified space power.

Future Space Operations

Within the guiding operational concept that "unified operations, key point is space dominance," the PLA would likely pursue one or more specific types of space operations, including providing space information support, space offensive operations, space defensive operations, and space deterrence. It is important to recognize that such operations will most likely not be undertaken alone but in the context of a larger, joint campaign such as a joint landing campaign or a joint blockade campaign. The purpose of such operations is to effect information dominance by securing space dominance.

Space Information Support Operations

The foremost task for PLA space forces is to provide information from space-based sensors and platforms. Key tasks within this mission area of space information support (kongjian xinxi zhiyuan; 空间信息支援) to the ground, air, and naval forces include

- space reconnaissance and surveillance,
- communications and data relay,
- navigation and positioning,
- early warning of missile launches, and
- earth observation, including geodesy, hydrographics, and meteorology.[58]

Space information support is considered essential for *local wars under informationized conditions*. It allows global, real-time probing and early warning, permits intercontinental communications, and is the basis for implementing long-range precision operations. Moreover, it is not subject to limitations of national borders, weather, or geography.[59]

Space Offensive Operations

In addition to traditional space information support operations, several Chinese analysts seem to believe that future military space activities will include space offensive operations. Given the view that space capabilities include not only orbiting platforms but also terrestrial facilities and the associated data links that tie the entire network together, it should not be surprising that the general tenor of PLA writings suggests that space offensive operations involve attacking space-related targets both in orbit and on the ground.

Essential targets for securing space dominance include satellites and other objects in orbit as well as the ground components of space systems, including space launch vehicles and their launch sites and the attendant data and communications systems. Attacking an opponent's terrestrial space support functions is an essential means, in this view, of securing an advantage comparable to traditional attacks against enemy command nodes or military bases.[60] Such attacks carry the additional advantage of retarding an opponent's ability to reinforce or replace damaged or destroyed orbiting systems. As one analysis notes, striking at both space and terrestrial targets is necessary to establish local space superiority.[61]

Chinese authors, however, also recognize that attacks against terrestrial targets, especially those based in the enemy's home territory, are likely to have significant strategic implications and potential repercussions. Therefore, attacks against strategic space targets require the direction of the highest-level political authorities.[62]

Space Defensive Operations

While conducting space information operations and offensive operations, the PLA also expects to undertake space defensive operations. These seek to defend one's own space systems from attacks by enemy space or terrestrial weapons and also to protect national strategic targets from attacks from space systems or ballistic missiles.[63]

Defensively oriented operations need not mean solely passive or reactive measures. As one PLA article notes, one can, and should, also employ offensive means and seek the initiative in the course of space defensive operations. Both offensive and defensive means, moreover, should be undertaken by space forces in concert with land, sea, and air forces.[64] In the PLA's view, a combination of electronic and physical measures—including firepower strikes—may disrupt and suppress enemy space systems, especially terrestrial support components such as the TT&C facilities, thereby allowing one's own side to achieve space dominance.

Passive measures will supplement counterattacks and active defenses. Chinese writings suggest that space systems should, as much as possible, incorporate camouflage and stealth measures to hide the nature and functions of spacecraft from opposing observation and probes.[65] They should also be hardened or otherwise shielded from enemy efforts at dazzling and interference. Another option is the deployment of small and microsatellites in networks and constellations rather than single large systems. Larger satellites should be capable of altering their orbits to evade enemy attacks and should be capable of functioning autonomously, so that even if their ground links are severed, they would nonetheless be able to continue operations.[66] Other measures include deploying satellites into orbits designed to avoid enemy detection; employing political, diplomatic, and other channels to mislead opponents on real operational intentions or otherwise confuse enemy decision making; and deploying false targets and decoys to overload opponents' tracking capacities.

It should be noted that the Chinese concept of "space defensive operations" does not necessarily parallel "defensive space control," as laid out in US Joint Publication 3-14, *Space Operations*. Indeed, some aspects would seem to overlap with those of "offensive space control" in the American sense.[67]

Space Deterrence Operations

Chinese writings also indicate that a key task for China's space forces, besides the provision of information, offensive operations, and defensive operations, is effecting space deterrence. For example, in the PLA textbook *Science of Strategy*, published by its Academy of Military Science, there is an extensive discussion about the requirements for strategic deterrence which may be based not only upon nuclear, conventional, and information strength but also upon space-based strength.[68]

In each case, the intent is the same: to dissuade an opponent from pursuing certain policies while persuading that opponent to pursue other policies. As the volume notes, both persuasion and dissuasion "demand the opponent to submit to the deterrer's volition."[69] The idea that deterrence essentially allows one to achieve one's own strategic goals while frustrating an opponent without having to resort to the actual use of force is echoed in other PLA writings.[70]

Space capabilities have several characteristics that make space deterrence especially powerful. In the first place, they enhance both conventional and nuclear forces, making them much more powerful through the provision of navigational, reconnaissance, and communications information.

Moreover, space systems per se may intimidate an opponent. They are very expensive and hard to replace. By holding an opponent's space systems at risk, one essentially compels it to undergo a cost-benefit analysis. Is the focus of deterrence worth the likely cost of repairing or replacing a badly damaged or even destroyed space infrastructure? Moreover, because space systems affect not only military but also economic, political, and diplomatic spheres, damage to space systems will have wide-ranging repercussions.[71]

Implications for the United States

The clear Chinese interest in the military role of space should serve as a caution for US policy makers, whether their focus is on China, US military efforts in the western Pacific, or space policy. Of particular concern is China's capacity to undertake what the US calls "antiaccess/area denial (A2/AD)" activities. China's growing space capabilities make it qualitatively different from any other post–Cold War or potential adversary. Since the fall of the Soviet Union, the United States has not had to deal with any opponent who has the capacity to either field its own space-based capabilities or to threaten US space assets and systems. Whereas Washington could, through sheer expenditure of funds, prevent Baghdad or Belgrade from accessing space information, Beijing's possession of the full array of space information systems means this policy would not be viable in the event of a conflict in the western Pacific.

China's demonstrated capabilities in space weapons exacerbate this concern. They underscore the likelihood that Chinese A2/AD capabilities apply in both the terrestrial and space context. Indeed, the DoD has recognized this reality in the new *Joint Operational Access Concept*, noting that "a logical opening operation to any antiaccess campaign is to neutralize US space assets."[72]

Unfortunately, there is little reason to believe that the United States and the PRC will reach a mutual accommodation on space security. For the PRC, the ability to successfully engage the United States, which it still views as a technologically superior foe, is essential in effecting deterrence and fulfilling the PLA's "new historic missions." This is *not* to suggest that the Chinese government or military want confrontation. Rather, it is to note that it would be irresponsible for Chinese military officers, given their tasks and missions, not to seek ways to fulfill their orders. Both sides recognize that "space has become the primary location for global and regional reconnaissance assets used for . . . intelligence gathering, and support of combat operations on the earth's surface."[73] It is therefore logical for both sides to try to exploit space for their own ends while denying it to opponents. This situation is further complicated by the significantly different strategic situations confronting the two states and has led to asymmetric dependencies on space, given the different requirements for space capabilities.

For the PRC, although its military has slowly shifted from a contingency-based planning approach toward a capabilities-oriented one, the focus is regionally oriented. China's main security concerns are on its periphery: the foremost being Taiwan, but also the South China Sea and the Sino-Indian border. All of these potential flashpoints can be monitored without requiring space assets.

For the United States, on the other hand, its various commitments, whether to Taiwan, Japan, or the Philippines, all require an expeditionary posture. "The tyranny of distance" in the Asia-Pacific complicates American planning and operations much more than the PLA's. To provide the necessary intelligence, communications, and navigational information, the United States will therefore have to rely much more heavily on space than its Chinese counterparts. Consequently, any diminution of space capabilities will disproportionately affect American operations. Insofar as the United States is intent on effecting a "pivot" to the western Pacific, preserving access to space is an absolute prerequisite.

This dependence on space means that the United States must be able to operate in a degraded space environment, even in the face of concerted adversary action. This is likely to remain the case for the foreseeable future, even as it develops and fields alternatives to space-based systems for key mission areas. Maintaining such an ability would, in fact, serve as an effective deterrent to hostile actions in space—if such actions cannot deny US military forces vital information, then an opponent is likely to pursue alternative, nonspace means (which are likely less expensive and less challenging). Conversely, vulnerabilities, especially in such core areas as space, invite exploitation.

For US policy makers, then, the securing of American interests in space can only come from maintaining a robust space capacity, including modern systems (both in orbit and on the ground), good space situational awareness, and a healthy space industrial base to support these efforts. It must also include military space forces that are realistically trained and not hamstrung by rules of engagement, which require minutes to adjudicate when seconds count.

Within this framework is a place for space diplomacy and especially for ongoing dialogue with all space-faring powers, but only so long as participants are willing to discuss such things as space policy making and space decision making, steps toward genuine transparency, and a means of establishing crisis stability. Pursuit of space agreements, whether arms control treaties or codes of conduct, without first establishing this foundational set of interactions and mutual understanding, is an invitation to miscalculation and misconception at best and jeopardizes military training, readiness, and crisis response capabilities at worst. SSQ

Notes

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3. David Shambaugh, *Modernizing China's Military: Progress, Problems, and Prospects* (Berkeley: University of California Press, 2002), 64.

4. *Chinese Military Encyclopedia* Committee, *Chinese Military Encyclopedia*, Vol. 2, (Beijing: Academy of Military Science [AMS] Publishing House, July 1997), 317.

5. "China's Aerospace Industry and Civil-Military Industrial Integration," *China Aerospace* (March 2001): 18.

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13. Gao Yubiao, *Joint Campaign Course Materials*, 12.

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15. Gao Qingjun, "Characteristics and Deficiencies of Space Reconnaissance in High-Tech Local Wars," *Journal of the Academy of Equipment Command and Technology* 1, no. 16 (February 2005).

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17. David Finkelstein, "Thinking About the PLA's 'Revolution in Doctrinal Affairs'," in *China's Revolution in Doctrinal Affairs*, ed. James Mulvenon and Finkelstein (Alexandria, VA: CNA Corporation, 2005), 1.

18. Gao Yubiao, *Joint Campaign Course Materials*, 12–25.

19. Wang Houqing and Zhang Xingye, eds., *The Science of Campaigns* (Beijing: National Defense University [NDU] Publishing House, May 2000), 400.

20. Ibid.

21. *Chinese Military Encyclopedia*, supplemental vol., 455.

22. Zhang Yuwu et al., "Informationalized Warfare Will Make Seizing the Aerospace Technology 'High Ground' a Vital Factor," *People's Liberation Army Daily*, 30 March 2005.

23. Liu Kejian and Wang Xiubo *The First Conflict Won Through Airpower: The Kosovo War* (Beijing: AMS, 2008), 44.

24. Hu Jintao, "See Clearly Our Military's Historic Missions in the New Period of the New Century," speech to the CMC, Beijing, 24 December 2004. For further discussion of the "new historic missions," see Daniel Hartnett, *Towards a Globally Focused Chinese Military: The Historic Missions of the Chinese Armed Forces* (Alexandria, VA: CNA, 2008).

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26. For further discussion of "campaign basic guiding concepts," see David M. Finkelstein, *Evolving Operational Concepts of the Chinese People's Liberation Army and Navy: A Preliminary Exploration* (Alexandria, VA: CNA, 2002).

27. Wang and Zhang, *Science of Campaigns*, 81.

28. Wang Weiyu and Zhang Qiancheng, *Discussing Military Theory Innovation with Chinese Characteristics* (Beijing: NDU, 2009), 202–3.

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30. Ibid., 83.

31. State Council Information Office, "National Defence Policy," in *China's National Defence in 2006* (Beijing: State Council Information Office, 2006).

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33. Ibid., 87.

34. Lui Jin, "Satellite Communications—The Information Bridge during Earthquake Relief Operations," speech before the Chinese Communications Studies Association, 26 September 2008, http://www.ezcom.cn/Article/8591.

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42. Ibid.

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44. See Wang and Zhang, *Science of Campaigns*, 299, 334, 340.

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46. Cortez Cooper, "Joint Anti-Access Operations: China's 'System-of-Systems' Approach," testimony to the US-China Economic and Security Review Commission, 27 January 2010, 4, http://www.rand.org/content/dam/rand/pubs/testimonies/2011/RAND_CT356.pdf.

47. "Academy of Command Equipment and Technology," in *An Overview of Chinese Military Academies and Schools*, eds. Jin Peng and Dong Ming, (Beijing: AMS, 2002), 163.

48. Chang Xianqi, *Military Astronautics*, 2nd ed. (Beijing: Defense Industries Press, 2005), 273–79.

49. Note that *yiti* may be translated as either "integrated" or "unified." While the former translation is common, in the context here the latter would seem to be more appropriate. For that reason, as well as to avoid confusion with the term *zhengti*, which is also translated as "integrated," we will use the translation "unified" in the body of the paper.

50. Chang, *Military Astronautics*, 2nd ed., 275, 276.

51. Ibid., 290.

52. Ibid., 275.

53. Li Daguang, "The Characteristics and Rules of Law of Space Strategy," *China Military Science*, no. 1 (2002).

54. Fan Xuejun, "Militarily Strong Nations Are Steadily Developing 'Space Information Warfare'," *People's Liberation Army Daily*, 13 April 2005.

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56. Chang, *Military Astronautics*, 2nd ed., 276–77.

57. Ibid., 278–79.

58. Li, Zhao, and Huang, "Research on Concepts of Space Operations."

59. Yuan Wenxian, *The Science of Military Information* (Beijing: NDU, 2008), 320–21.

60. Hong and Liang, "Basics of Space Strategic Theory."

61. Li, Zhao, and Huang, "Research on Concepts of Space Operations."

62. The precise nature of such strategic targets, however, is not defined. Chang, *Military Astronautics*, 2nd ed., 314.

63. Zhang Qinghai and Li Xiaohai, "Space Warfare: From Vision to Reality," *China Military Science*, no. 1 (2005).

64. Hong and Liang, "Basics of Space Strategic Theory."

65. Chang, *Military Astronautics*, 2nd ed., 316.

66. Ibid., 320.

67. Joint Publication 3-14, *Space Operations*, 6 January 2009, II-6.

68. Zhou Peng and Wen Enbing, "Developing the Theory of Strategic Deterrence with Chinese Characteristics," *China Military Science*, no. 3 (2004).

69. Peng Guangqin and Yao Youzhi, ed., *The Science of Military Strategy* (Beijing: AMS, 2005), 215.

70. Zhou and Wen, "Developing the Theory of Strategic Deterrence with Chinese Characteristics."

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New Frontiers, Old Realities

Everett Carl Dolman

The coming war with China will be fought for control of outer space. Although its effects will be widely felt, the conflict itself will not be visible to those looking up into the night sky. It will not be televised. Most will not even be aware it is occurring. It may already have begun.

And yet, this new kind of war will not be so different that it will be unrecognizable. The principles of war and the logic of competition remain as they have always been. Only the context has changed. When we have this mind-set and apply the tenets of traditional realist and geopolitical theories that have survived millennia in their basic forms, the unavoidable conclusion is that the United States and the People's Republic of China (PRC) are on a collision course for war.

The following offers an interpretation of the neoclassical geopolitical context that shapes the potential for conflict between the United States and China, places that discussion within a broader theory of strategy, tactics, and war, and assesses the potential for a twenty-first-century Great Wall in low-Earth orbit.

Neoclassical Geopolitics

Almost 2,500 years ago, Thucydides foresaw the inevitability of a disastrous Peloponnesian war due to "the rising power of Athens and the fear it caused in Sparta."[1] Indeed, whenever an extant international order is challenged by a rising power, the reigning hegemonic authority is obligated to respond. Such conditions are relatively rare in history, but when they occur, the resulting war is not for minor spoils or border modifications,

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but for leadership of a new world order. It is a great war, a hegemonic war.[2] This is the context in which the world now exists. The relatively stable global hegemony of the United States since 1945, punctuated by limited wars and shifting balances of opposition, is directly challenged by the rising power of the PRC—and the fear it is generating in the United States is palpable. Such determinist theory is quickly countered by those who find its implications abhorrent. Inevitability is a crass and unsubtle divination. Because a thing has always happened does not mean that it always will. Nor does the reverse necessarily hold. Because something has never happened does not mean that it cannot be so. The realist paradigm of power politics does not have to hold sway. The cruelly consistent narrative of history need not be eternally retold. Nothing is inevitable, counter the idealists. The world can be made different; the world today *is* different.

The power of possibility is tantalizing, but the brusque strength of probability, for a decision maker, usually holds sway. The past foreshadows the future—and the calculation of probability over time, combined with risk, is more persuasive than platitudes. If an event is likely, its influence is plain and its outcome perceptible, then preparations must be made to mitigate its effects. If an event is unlikely, even if its impact is serious, actions to mitigate it are often deferred to the future—even though this form of political gambling tends to magnify the deleterious effects of the event when it eventually comes to pass. If the state's sovereignty is at risk, however—no matter how unlikely the event—it must be dealt with directly. The well understood—if not everywhere accepted—logic of raison d'état calculations is fully in accord with classical geopolitical dictums dating back at least as far in their theoretical lineages.

The resurrection of geopolitics as a valid body of military theory is in full swing. By applying the tenets and dicta of geopolitics to the current age with a focus on space activities, I hope to contribute to its revival. That classic geopolitical thought should require resurrection means that it has gone through a period of disfavor and decline, a history that will require further examination. For now it is enough to assert that geopolitics collapsed of its own weight, from the misuse and abuse that followers subjected it to by taking its less-defensible precepts to their extreme ends. Just as neoliberalism, neorealism, and neo-Marxism seek to return to founding theories for their inspiration and avoid the perversions and misapplications of often well-meaning but logically off-track followers, so too does neo-geopolitics seek a reaffirmation of basic principles and an explanation for the misuse of them in history.

Geopolitics looks to geographic or Earth-centered physical and spatial characteristics for its explanatory power.[3] The unit of analysis is the state. Its location, size, resources, and population are placed in the context of political ideology, sociocultural values, and technology to assess the dominant forms of war in a given time. The manipulation of this knowledge is called *geostrategy*—a state-dominant assessment of the geospatial bases of power in plans or strategies for continuing military, economic, diplomatic, and sociocultural advantage.

Geopolitics as a unified body of theory was not apparent until the latter nineteenth century, but its inherited lineage is clear in retrospect. To the extent that the strong do what they will and the weak suffer what they must, as Thucydides had the imperial Athenians tell the neutral Melians in his celebrated dialogue on state power and pride, realpolitik has always focused on manipulating the extant balance of power for its persuasiveness.[4] Although it is conceptually separate from geopolitics, in both meaningful theory and practice, the two schools of thought are logically inseparable.

Geopolitics describes the sources—the what—of state power; *geostrategy* explains the how. Neither provides the underlying rationale, the why. That requires a broader theoretical perspective. The one that dominated the architects of geopolitical thought clusters under the rubric of realism.

If state power, expressed in terms of capacity for violence, is the ultima ratio of international relations,[5] then geopolitical theory is extremely useful. Thucydides and Machiavelli perceived the self-interest of states coincident with that of humanity: a hierarchy of fear, interest, and honor.[6] The state that does not protect itself will be overcome; that which does not grow will wither and die. Cardinal Richelieu summed it up in the phrase "raison d'état."

In an environment of relative scarcity, the interests of states overlap, and conflict can be expected. Prudent leaders will recognize the geographically advantageous positions and capacities that enhance state power and will attempt to control those positions—or at a minimum deny control of those positions to an opponent—to ensure the continued health and growth of the state. A study of such capacities, incorporated into a plan for continuing advantage, is called *geostrategy*.

For example, Alfred Thayer Mahan argued that in the modern era, great power required the possession of a navy capable of projecting influence globally.[7] It was time, he asserted near the end of the nineteenth century, for the United States to develop a maritime force equal to its economic clout, throw off its cloak of isolationism, and take its rightful place at the forefront of nation-states. Mahan was an American nationalist, to be sure, but his theories applied to any state in a similar position. Great power leads to great responsibility, he reasoned, and America was abrogating its obligations by failing to lead.

The first truly global geostrategist, Halford Mackinder, described a cyclical clash of land and sea powers through history, a view that coincides with other prominent theories of recurring rivalries, such as the interplay of offensive or defensive technologies or capacities for maneuver or mass that tend to dominate the battlespace in a given era. Sea power, Mackinder argued, in ascendance with the development of reliable oceangoing shipping after 1500, was by the beginning of the twentieth century ceding maneuver dominance to mass-force land power as the technology of the railroad created relatively fast and inexpensive internal lines of supply and communication.[8]

As technology developed, the details of geostrategic theory morphed toward actionable decisions, but the essential logic persisted. Similar arguments were made for air and missile power and are currently in vogue for space power. As we work through the ramifications of an *astropolitik* approach, several conclusions are readily apparent:[9]

- Classical geopolitics provides the most enduring realist explanations for change in the international system.
- Many classical geopolitical theories prove readily adaptable to the realm of outer space.
- These theories, tailored for sea, rail, air, and missile power, can be viewed as segments of an evolutionary process. Space power is their logical and apparent heir.
- The special terrain of outer space dictates tactics and strategies for efficient exploitation of space resources.
- Space is a national power base today—an optimum deployment of space assets is essential on the current terrestrial and future space-based battlefield.

US *and* PRC or US *versus* PRC?

At first glance, geopolitical forces may seem to be in dynamic balance. The United States is the overwhelming sea and air power, offensively oriented and favoring maneuver and precision strike for advantage in war. The PRC is potentially the greatest land power the world has ever known, defensively established and reliant on masses of infantry as its core strength. Neither has a globally significant advantage vis-à-vis the other. There is no plausible near-term scenario in which the United States could invade and sustain an occupation of the Chinese mainland. Likewise, the United States is currently impervious to any invasion and occupation by Chinese forces. Neither state's sovereignty appears in doubt because of actions by the other. At the level of grand strategy, neither maneuver nor mass, offense nor defense, has a transformational advantage. From this perspective, war, inevitable though it might be, is not imminent.

Less-venerable theories of conflict and cooperation are more favorable toward long-term peace.[10] Economically, the United States and the PRC are tightly bound. Chinese markets are opening, and the productivity of PRC manufacturing has allowed the United States to move into a post-industrial economy. Trade is increasing substantially, and China holds much of America's foreign debt, to the point that neither state benefits fiscally by engaging in a conflict that will sever (or even just weaken) these ties. Culturally and historically, the Chinese and American people are inclined toward mutual admiration and respect. Despite the political differences between Chinese communism and Western liberal democratic capitalism, both sides value human connections and government rapprochement. An appreciation of American technological innovation and Chinese work and spiritual ethics imbues the still-developing relationship. Both sides seem willing to engage diplomatically and sustain a world system in which each nation-state has its place and its independence.

In every sphere but one, it seems, the two great powers are building toward peace. In every sphere of competition, with one exception, there is room for negotiation and mutually beneficial outcomes. That one incompatible, uncompromising realm is outer space.

Western Action versus Eastern Timing

The essential strategic view that confounds cooperation in space is paradox. The Western mind sees transparency and openness as the surest way to peace. When one state can effectively monitor another, fears of surprise attack are mitigated, and the tendency to overestimate a potential opponent's capacities and intentions is minimized. With transparency, the security dilemma is obviated and cooperation is possible.[11]

But transparency as a confidence-building measure is a purely Western mode of thought. To an Eastern strategist, letting an opponent know precisely one's strengths and weaknesses merely invites attack. The key to stability in this view is uncertainty—not knowing how strong or how weak an opponent is and never, under any circumstances, revealing one's own strengths or weaknesses. The more sure the knowledge, the more crafty the countervailing plan, and the more likely its success.

The essential disconnect between West and East in the conduct of war is in the difference between action and timing.[12] The Western strategist too often seeks to force change through positive steps. Analyses focus on the likely response to specific activities and assessments of whether more or less force is necessary to accomplish change. The future is constructed wholly through the effort and interplay of action.

To the Eastern strategist, proper war-making is a matter of timing. Balance of force is not a single calculation but a continuing one. Power is a function of capabilities, position, and morale—just as it is in the West—but it is also a result of numerous immutable and sometimes unknowable forces. Structure dominates agency. Rather than force a change through positive actions, the Eastern strategist bides time until the moment to strike is ripe. Indeed, the gardening analogy is a strong one in Chinese military writings. No matter how much effort one puts into growing a crop—learning how to garden, preparing the soil, tending the plants—there is no benefit in harvesting too early or too late.

My interaction with Chinese strategists and generals anecdotally confirms such biases. When someone suggests long-term planning is advantageous, these officials are liable to chuckle and say, "I do not know what will happen tomorrow, how can I know what will happen in years or decades?" The Eastern strategist studies, prepares, and waits. Through careful study and reflection, the strategist learns about the opponent's forces and his or her own, as well as the terrain, technologies, and sociopolitical contexts that shift in time. Through preparation and training, military forces required by the strategist are available when needed. Awaiting the proper moment for action guarantees success.

Western hubris and Eastern inscrutability thus dominate security relations between those regions. When Douglas MacArthur famously stated that there is no substitute for victory, he was affirming an agent-centered dictum.[13] His meaning was clear. Those who prevail in war need make no excuses for the manner in which the battles were fought. History is written by the victor. Alternatively, when Sun Tsu claimed that the apex of skill is to win without fighting, he did not refer to a passive or inactive strategy.[14] He averred that following the study-prepare-and-wait model leads to a position where the outcome is obvious to all parties, and a capable opponent will choose to negotiate the best terms rather than fight to a foregone and disastrous conclusion.

Geopolitical analysis has the capacity to accept the logic of both East and West. Rather than choose one over the other, the geostrategist perceives them holistically and seeks a third way that links the two without diminishing the power of either.

Strategy and the Space Domain

Within military strategy are operational categories of violence or force that are separated by domain.[15] This is more than an economizing or efficiency categorization of force. It is recognition that strategies for each realm are unique and have individual requirements for tactical proficiency. It is also the operational concept that links the logic of strategy with the grammar of tactics.

A military strategist understands the requirements of organizing, training, and equipping for war. This is the unique purpose of military power. As such, the top military strategist prepares overall force structures and establishes a plan for their continuing health and proficiency. Dividing the domains of war into land, sea, and air is useful for assigning service authority (for the United States, to the Army, Navy, and Air Force, respectively). Today space is widely recognized as a separate domain, and some state militaries have separate services for it—Russian Rocket Forces, for example. To the extent that these domains are merely convenient delineations, strategy applies equally across all, even though tactical expertise may be quite diverse in different realms. As such, how forces are divided is merely a preference, subordinate to an overall theory of war. To have a separate strategy for each domain, the unique purposes of each must be discerned. To have a strategy for space—that is, a theory of space war—the strategist must distinguish the unique roles and missions of the space domain. If nothing is unique, then a distinction does not add value.

Moreover, the distinct realms or domains of land, sea, air, and space (and perhaps cyberspace) need to be more than physically and conceptually separable. They must be of complementary value—otherwise they should be subordinate to another domain—and nested within the proper role of military power. Typically, domains are separable by physical characteristics or platform operations. In the former case, ground territory is the domain of land power, oceans and waterways define sea power, and the aerodynamic properties of the skies or orbital characteristics of the heavens define air and space power. In the latter, if it walks or moves on the earth, it is land power and properly under the control of the Army; if it floats or operates in the water, it is the Navy's responsibility; and if it flies through the air or space it is—for the United States—properly controlled by the Air Force. This causes problematic overlap when assigning domain responsibility, however. Can the Navy use aircraft to patrol the oceans? Who should own and operate a submarine-launched ballistic missile which begins in the ocean but travels through the air and space and targets a city on the earth? Does the source or origination define the authority in the submarine case (sea power), or should the target be the discriminator (land power)? Taken to an extreme, all sea, air, and space operations begin on the land; should navies and air-space forces exclusively engage in support activities for the army? This, too, creates more problems than it solves. If I discriminate by target, am I conducting economic warfare when I destroy a factory, regardless of the means? If I bomb a school with an airplane, am I conducting educational warfare?[16] That is absurd. Fortunately, the model for power discrimination has already been defined; as with military force as a means of state power, domain authority is best understood as a function of purpose. When defined this way, the conundrums above disappear.

The military purpose of land power is to take and hold territory. This is understood as control and is the mission properly assigned to armies. The military purpose of sea power is to control the sea. Navies do this. The military purpose of air power is to control the air. Fittingly, the military purpose of space power is to control space. Following the primary dictum of classical geopolitics, if one cannot achieve or sustain control, then it is vital that one's potential adversary cannot achieve or sustain control. This is called *contestation*. Land forces should thus be organized, trained, and equipped to control and contest the ground, naval forces the seas, and air forces the sky; critically, if space is a separate war-fighting domain, then space forces must be prepared and capable of controlling and contesting space.

Control provides the capacity to use the domain to create effects. In other words, what one does with land, sea, air, or space power is entirely dependent on the capacity to operate from or through the land, sea, air, or space. In the airpower case, the capacity to bomb, move supplies, or do observation with aircraft requires that one can get into the air and then to the target. As with land power, however, gaining control so that the domain can be used does not necessarily mean constant or pervasive application of military force throughout the domain. In an uncontested environment, access is based entirely on the capacity to get and use the resources necessary to move from one point to another and the extent to which legal rules are followed to deconflict operating in congested areas (e.g., airport flight control regimes). However, the continuing presence of an uncontested domain has historically been due to the existence of a military or police capacity held in reserve to ensure rules are obeyed and that unauthorized inhibiting of movement through the domain is punished. This is the current case for the global sea and air commons. The US Navy is the primary agent to ensure that the current 12-mile extension of national sovereignty into the oceans is not exceeded (as with its actions against Libya in the Gulf of Sidra), that vital narrows in sea lanes of commerce are not blocked (e.g., the Strait of Hormuz), and that nonstate criminal activity is prevented or punished (such as the ongoing efforts against Somali pirates in the Indian Ocean). However, without the ability to apply force on and in the seas, to board and inspect suspicious or rules-defying vessels, to escort and defend innocent passage, and more, the US Navy cannot defend or deter on the seas without violating other states' sovereignty or relying on non-naval assets for deterrence and punishment.

In space, no state has yet attempted to gain general control of a discernible location, and nations capable of operating in space have for the most part done so in accordance with legal or treaty obligations. This is the model that air followed in its initial development (and probably sea access, at some time in prehistory). Until World War I, the air was not contested. Unfettered access was a function of desire, technology, aerodynamics, weather, law, and money. Such is the case with space today. No state has yet acted militarily to contest any other state's use of space (that we know of). The geostationary belt is regulated by international agreement, and various rules limit the placement of weapons of mass destruction in space. Registration and liability rules have been crafted and widely accepted, and the effects available from spacecraft and the use of space are generally available to all—and yet the exploitation of space is still suboptimal.[17] No US Navy equivalent is lurking ready to ensure that rogue states cannot extend their sovereign territory beyond generally accepted limits of air-powered flight or to stop illegal activities if and when they occur. Military activities create debris and other navigational hazards, yet there is no equivalent of a minesweeper to clear out unwanted military detritus. And if some state or organization should desire to contest or control space, denying the fruits thereof to another state, there is simply no defense against such an action—there is only deterrence through the threat of asymmetric, Earth-centered retaliation.

Contestation is the ability to block or deny access to a domain. Critically, contestation does not give the capacity to use a domain; it only inhibits. This is why, to a military strategist, control is a vital concept. Control may be general or limited to specific times and places, but without the ability to get into the domain and operate there, the strategist cannot use the domain to create effects. Thus for every military domain, control is possible only from within the domain. This is obvious when the domain is contested, but control also must be exercised in an uncontested domain when illegal or harmful activities are occurring there.

A military must control a domain to be able to use it. To maintain control, a military planner must be able to contest the littoral areas of those domains that are adjacent to it. For example, a military requires an army or land force to gain control and then use contested territory. This is the much-vaunted concept of "boots on the ground": to the extent a military needs territorial control, it requires boots on the ground (or wheels, tracks, etc.). To the extent a military desires air control over enemy territory in order to bomb targets there, boots on enemy ground may be immaterial. Let us call this the "wings in the air" dictum and make another one for "oars in the water." To use the domain, I must be able to operate in the domain.

The land force that is occupying or controlling territory will not be able to maximize use of the domain if the air space above it is not controlled by friendly forces. The land force must therefore try to block access to opposing air forces or accept the free flight of enemy aircraft over its positions. The latter may be a necessity if the means to contest the air are not available, but it is an undesirable operational condition. For this reason, land forces generally have antiaircraft artillery and missiles. Land forces also properly construct coastal defenses to prevent seaborne attacks and invasion. Since the purpose of these actions is to contest the littorals of the land domain, they are properly assigned to and integrated into army operations and doctrine. For their part, navies maintain land forces—marines and shore police—to contest beaches and protect ports. Navies also have significant antiaircraft capabilities on their ships and maintain fleets of aircraft to contest the antishipping efforts of opponents. Air forces must secure bases as well and contest the antiair efforts of armies and navies. Space forces likewise should have the capacity to deny ground-, sea-, and air-based antisatellite weapons from space.

In some instances, a state may not need or desire domain control or contestation. A land-locked state will see no need to develop a naval force for sea control and likely will not acquire specialized sea-contestation capability. Most states will attempt to acquire air-contestation capabilities, such as advanced surface-to-air missiles, but many will not be able to afford air control assets. Their military strategies will develop with an understanding that effects delivered from or through the air, such as close air support or aerial resupply, are not likely to be available in a time of conflict or crisis.

If space is a military domain, then it should follow the same logic. A state that relies on military support from space—the effects it achieves from having assets in space—must plan to gain at least limited or temporary control of space in times of conflict. And, as is obvious from the description of analogous domains above, control is possible only from within the domain. If the state is unwilling to put weapons into space, then it cannot hope to ensure effects from space when another state attempts to contest its position. Its logical recourse is to wean itself quickly from space support, enhancement, and enablement, and move to a pre-space military force structure. It must then stop wasting procurement money, production, and personnel on military space. If the military might be forced to fight without assured space support, then it should train to do so. The most efficient military in a space-denied environment will be the one that does not require the use of space at all. Of course, if a military force is proficient in fighting without space, why should it spend scarce resources to organize, train, and equip itself to fight any other way? It is the height of folly for a commander to rely on a capacity that may or may not be available when needed. With the military force preparing to fight without space, government funding for military space support will be scaled back and ultimately cut. Without a military presence to protect fragile space assets and ensure treaty compliance in space, along with drastic reductions in the space industry as military contracts end, commercial space development will be severely curtailed. Developing ground-, sea-, and air-based antispace weapons would be prudent for such a military so that an opponent cannot use space freely against it, but to waste capital and effort on a nice-to-have capacity in space that is not needed to conduct operations on the earth would be ludicrous. Following this logic, denying oneself the capacity to put military force in space is tantamount to giving up on the military (and probably civil) value of space.

To be sure, the cost to weaponize space effectively will be immense. It is a cost that America, or any other state, needs to undertake if it wants a military force structure that relies on space support and enablement to operate as it does now and will increasingly do so in the future. Weaponizing space will have benefits for the military that may not be readily apparent.

Where will we get the money for this space weapons capacity? It will not come from school budgets or foreign aid programs. It will not come at the expense of health care reform or corporate bailouts. It will come at the expense of conventional military capabilities on the land and sea and in the air. There will be fewer aircraft carriers and high-dollar fighter aircraft and bombers. If the United States deploys space weapons capable of targeting the earth, relatively slow-moving ships and aircraft will become conceptually obsolete, instantly vulnerable to space weapons. As we scrounge money for space lasers and exotic kinetic-kill satellites, the systems these space weapons make defenseless will be scrapped. More funding will come from current ballistic and antiballistic missile development and deployment, as global ballistic missile defense from space is more cost-effective and practically effective than comprehensive ground- or sea-based systems. And most importantly, it will come from personnel reductions—from ground troops currently occupying foreign territory. In this way, the United States will retain its ability to use force to influence states around the world, but it will atrophy the capacity to occupy their territory and threaten their sovereignty directly. The era of US hegemony will be extended, but the possibility of US global empire will be reduced.

Maybe. The future is not determined or even determinable. I have argued elsewhere the practicality of controlling space. I will not add to that argument here. I have also pointed out that the theory animating these conclusions is precise and well-developed, but the real world is too complex to mirror theory. The political will necessary to weaponize space and follow up with a regime capable of ensuring commercial and cooperative development of space is not yet evident, and such a pure, realist *astropolitik* vision is thus not currently viable. But support for the common or collective good that could come from a properly weaponized space force may change that. Space weapons have some potential missions that could help generate the will to pay for and use them. These missions do not detract from the primary purpose of the weapons but complement the goal of space control. For example, nuclear-powered space-based lasers could, in theory, clean up debris from high-traffic orbits—good target practice for their operators. Assured access to space provided by a robust space control force could pave the way for clean, permanent nuclear and toxic waste disposal, as such items currently stored on Earth could be sent into the sun. Space-based solar power generation could provide the world with cheap, abundant energy that would deemphasize the value and authority of current oil-producing states and fundamentally change the geopolitical landscape of the Earth. These scenarios are far more likely with the monitoring and protection provided by a space-based military or police power.

These scenarios are an even more difficult dilemma for those who oppose weapons in general and space weapons in particular. Ramifications for the most critical current function of the Army, Navy, and Marines—pacification, occupation, and control of foreign territory—are profound. With the downsizing of traditional weapons programs to accommodate heightened space expenditures, the ability to do all three would wane significantly. At a time when many are calling for *increased* capability to pacify and police foreign lands, in light of the no-end-in-sight deployments of US peacekeeping forces around the world, space weapons proponents must advocate *reduction* of these capabilities in favor of a system that will have no direct potential to pacify and police.

Hence, the argument that the unilateral deployment of space weapons will precipitate a disastrous arms race is further eroded. To be sure, space weapons are offensive by their very nature. They deter violence by the omnipresent threat of precise, measured, and unstoppable retaliation. But they offer no advantage in the mission of territorial occupation. As such, they are far less intimidating to the international environment than any combination of conventional weapons employed in their stead. Which would be more threatening to a state that opposes American hegemony:

a dozen lasers in space with pinpoint accuracy or (perhaps for about the same price) a dozen infantry divisions massed on its border? A state employing offensive deterrence through space weapons can punish a transgressor state, but it is in a poor position to challenge that state's sovereignty. A transgressor state is less likely to succumb to the security dilemma if it perceives that its national survival is not at risk. Moreover, the tremendous expense of space weapons would inhibit their indiscriminate use. Over time, the world of sovereign states may recognize that the United States could not and would not use space weapons to threaten another country's internal self-determination. The United States still would challenge any attempts to intervene militarily in the politics of others, and it would have severely restricted its own capacity to do the latter. Judicious and nonarbitrary use of a weaponized space eventually could be seen as a net positive—an effective global police force that punishes criminal acts but does not threaten to engage in an imperial manner.

A Twenty-First-Century Great Wall in Space

Slightly over three years ago, China successfully engaged one of its own satellites in space.[18] This was extraordinarily provocative. The United States simply has no defense against such a weapon system, and China's antisatellite test was intended to remind the world of this weakness. Moreover, its use of a standard medium-range ballistic missile (which the PRC produces in mass) to propel the kill vehicle indicates a potential antisatellite weapons capability sufficient to target the entire US low-Earth-orbit inventory. Current efforts to place ground-based missile interceptors in strategic locations would be useless, regardless of deployment, as these are designed to engage incoming ballistic missiles in the mid or terminal phase of flight. The Chinese missile achieves orbital altitude just minutes after launch, so the only possible defense against it—which would have the added advantage of ensuring any destructive debris from a successful engagement would land on Chinese soil—would be from a network of antiballistic missile satellites operating in Earth orbit.

Just such a space-based antimissile capability, envisioned for years and technically feasible since the late 1980s, has long been the optimum solution for military planners. Yet, such a system has been annually tabled due to high cost estimates and fears of encouraging other states to develop antispace weapons. The latter concern is now overcome by events. But the cost issue remains.

With the global war on terrorism and major terrestrial deployments drawing the lion's share of attention and budget, shifting funds from immediate operational requirements to long-term security is a tall order. The *timing* of the Chinese antisatellite test coincides perfectly with their perception that the United States is ill positioned to respond with force, and they are probably right.

China's ultimate goal appears to be to assert its regional supremacy and achieve coequal (if not dominant) status as a global power. Control of space is a critical step in that direction. Without its eyes and ears in space to provide warning and real-time intelligence, the United States would be in a painfully awkward situation should the PRC put direct military pressure on Taiwan. To those who argue that China is as eager to avoid a damaging war in space as any other space-faring state, especially given its increasing integration into the world economy and dependence on foreign trade for its continuing prosperity; do not discount the capacities of its authoritarian leadership. This is the same regime that embraces the deprivations of government-induced cyclical poverty to spare its populace the moral decadence of capitalist luxury.

As with the famous Great Wall running across northern China, built for the dual purpose of inhibiting nomadic incursions and creating a magnificent public work to legitimize the government and inspire its domestic population, a significant military presence in low-Earth orbit has a parallel value for the PRC today. Its increasing capacity in space is extremely popular domestically (in addition, providing an enhanced reputation for China's capacity to develop high-technology products and services) and helps to diminish internal dissent by legitimizing the communist government. The massive government-led effort to build a dominating space presence is tantamount to the expenditures of states to create huge public works that were so important to past regimes (and modern ones as well; for example, the interstate highway system of the Eisenhower administration). Ultimately, however, the primary purpose of a controlling or at least lockdown contestation of space access would have the same general effect as the original Great Wall in keeping foreign influences out of the Middle Kingdom. For China, the past has always been prologue.

To be sure, China's increasing space emphasis and its cultural antipathy to military transparency suggest a serious attempt at seizing control of space is in the works. A lingering fear is the sudden introduction of an unknown capability (call it Technology *X*) that would allow a hostile state to place multiple weapons into orbit quickly and cheaply. The advantages gained from controlling the high ground of space would accrue to it as surely as to any other state, while the concomitant loss of military power from the denial of space to America's already space-dependent military forces could usher in a significant reordering of the international system. The longer the United States dithers on its military responsibilities, the more likely a potential opponent could seize low-Earth orbit before it is able to respond.

And in such circumstances, the United States certainly would respond. Conversely, if the United States were to weaponize space, it is not at all sure that any other state or group of states would find it rational to counter in kind. The entry cost to provide the necessary infrastructure is still too high—hundreds of billions of dollars, at minimum. The years of investment needed to achieve a comparable counterforce capability—essentially from scratch—would provide more than ample time for the United States to entrench itself in space and readily counter preliminary efforts to displace it. The tremendous effort in time and resources would be worse than wasted. Most states, if not all, would opt not to counter US deployments *directly*. They might oppose American interests with asymmetric balancing, depending on how aggressively it uses its new power, but the likelihood of a hemorrhaging arms race in space should the United States deploy weapons first—at least for the next few years—is remote.

This reasoning does not dispute the fact that US deployment of weapons in outer space would represent the addition of a potent new military capacity, one that would assist in extending the current period of American hegemony well into the future. Clearly this would be threatening, and America must expect severe condemnation and increased competition in peripheral areas. But such an outcome is less threatening than another, particularly illiberal authoritarian state doing so. Although there is obvious opposition to the current international balance of power, the majority of states seem to regard it as at least tolerable. A continuation of the status quo is thus minimally acceptable, even to states working toward its demise. As long as the United States does not employ its power arbitrarily, the situation would be accommodated initially and grudgingly accepted over time.

Mirror-imaging does not apply here. An attempt by China to dominate space would be part of an effort to break the sea-air dominance of the

United States in preparation for a new international order with the weaponizing state at the top. Such an action would challenge the status quo rather than seek to perpetuate it. This would be disconcerting to nations that accept the current international order—including the venerable institutions of trade, finance, and law that operate within it. Simultaneously, it would be intolerable to the United States. As leader of the current system, the United States could do no less than engage in a perhaps ruinous space arms race, save graciously deciding to step aside and accept a diminished world status.[19]

Seizing the initiative and securing low-Earth orbit now, while the United States is dominant in space infrastructure, would do much to stabilize the international system and prevent an arms race in space. The enhanced ability to deny any attempt by another nation to place military assets in space and to readily engage and destroy terrestrial antisatellite capacity would make the possibility of large-scale space war or military space races *less* likely, not more. So long as the controlling state demonstrates a capacity and a will to use force to defend its position, in effect expending a small amount of violence as needed to prevent a greater conflagration in the future, the likelihood of a future war *in* space is remote.

Moreover, if the United States were willing to deploy and use a military space force that maintained effective control of space and did so in a way that was perceived as tough, nonarbitrary, and efficient, such an action would serve to discourage competing states from fielding opposing systems. It could also set the stage for a new space regime, one that encourages space commerce and development. Should the United States use its advantage to police the heavens and allow unhindered peaceful use of space by any and all nations for economic and scientific development, over time its control of low-Earth orbit could be viewed as a global asset and a public good. In much the same way the British maintained control of the high seas in the nineteenth century, enforcing international norms against slavery while protecting innocent passage and property rights, the United States could prepare outer space for a long-overdue burst of economic expansion.

There is reasonable historic support for the notion that the most peaceful and prosperous periods in modern history coincide with the appearance of a strong, liberal hegemon.[20] America has been essentially unchallenged in its naval dominance over the last 60 years and in global air supremacy for the last 15 or more. Today, there is more international commerce on the oceans and in the air than ever. Ships and aircraft of all nations worry more about running into bad weather than about being commandeered by a military vessel or set upon by pirates. Search and rescue is a far more common task for the Navy than forced embargo, and the transfer of humanitarian aid is a regular mission. The legacy of American military domination of the sea and air has been positive, and the same should be expected for space.

Conclusion

Geopolitics is in ascendance because it provides practical blueprints for action to those who perceive the world in realist terms. Halford Mackinder confirmed the primary tenet of geostrategy. To dominate the battlespace, it is necessary to control the most vital positions. If the most vital positions cannot be controlled, then they must be contested. The opponent cannot have uninhibited access. This simple dictum, known by every strategist and tactician but articulated so clearly by Mackinder, is the essence of the geostrategist's logic. Control is desirable, contestation is imperative. This dictum applies to every medium and theater of war.

To be sure, America *will* maintain the capacity to influence decisions and events beyond its borders, with military force if necessary. Whether that capacity comes from space as well as the other military domains is undetermined. But the operational deployment of space weapons would increase that capacity by providing for nearly instantaneous force projection worldwide. This force would be precise, unstoppable, and deadly. The United States will maintain its position of hegemony as well as its security, and the world will not be threatened by the specter of a future American empire. SSQ

Notes

1. Robert Strassler, ed., *The Landmark Thucydides: A Comprehensive Guide to the Peloponnesian War*, trans. by Richard Crawley (New York: Free Press, 1996), 16.
2. See Robert Gilpin, *War and Change in World Politics* (Cambridge: Cambridge University Press, 1981) for a full treatment.
3. I draw on definitions by Geoffrey Parker, *Western Geopolitical Thought in the Twentieth Century* (New York: St. Martin's, 1986) for this analysis.
4. Strassler, *Landmark Thucydides*, 352.
5. The position of neorealist founding father Kenneth Waltz, *Theory of International Relations* (New York: McGraw-Hill, 1979).

6. Jack Donnelly, *Realism and International Relations* (Cambridge: Cambridge University Press, 2000), 43–44.

7. Alfred Thayer Mahan, *The Influence of Seapower upon History: 1660–1783* (Boston: Little-Brown, 1890).

8. Halford Mackinder, *Democratic Ideals and Reality: A Study in the Politics of Reconstruction* (New York: Henry Holt, 1919).

9. These hypotheses are extracted from Everett Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London: Frank Cass, 2002).

10. Less so, at least in terms of longevity. These include cooperation-producing economic theories of interdependence, functionalism, and neofunctionalism, and variants of the so-called democratic peace theory to include the Kantian peace and capitalist peace theory.

11. On the original security dilemma, see Robert Jervis, "Cooperation under the Security Dilemma," *World Politics* 30, no. 2 (January 1978): 167–74.

12. This argument is heavily indebted to Francois Jullien, *A Treatise on Efficacy: Between Western and Chinese Thinking* (Honolulu: University of Hawaii Press, 2004).

13. MacArthur was defending his conduct in Korea. For a counter opinion and critique, see Everett Dolman, *Pure Strategy: Power and Principle in the Space and Information Age* (London: Frank Cass, 2004), 6–7. For a positive account, see Theodore and Donna Kinni, *No Substitute for Victory: Lessons in Leadership from Douglas MacArthur* (Upper Saddle River, NJ: FT Press, 2005).

14. Sun Tzu, *The Art of War*, trans. by Ralph Sawyer (Boulder, CO: Westview Press, 1994), 177.

15. This section is distilled from a much fuller discussion of the roles of strategy, operations, and tactics in Dolman, *Pure Strategy*.

16. An argument adapted from an economic assertion made by David Baldwin, *Economic Statecraft* (Princeton, NJ: Princeton University Press, 1985), 6–15.

17. John Hickman and Everett Dolman, "Resurrecting the Space Age: A State–Centered Commentary on the Outer Space Regime," *Comparative Strategy* 21, no. 1 (2002): 1–19.

18. For an apologist stance, see Li Jiuquan, "Legality and Legitimacy: China's ASAT Test," *China Security* 5, no. 1 (Winter 2009): 43–52.

19. Following the logic of hegemonic stability theory (HST) as generally outlined by Duncan Snidal, "The Limits of Hegemonic Stability Theory," *International Organization* 39, no. 4 (Autumn 1985): 579–613.

20. Immanuel Wallerstein, "The Rise and Future Demise of the World Capitalist System: Concepts for Comparative Analysis," *Comparative Studies in Society and History* 16 (1974): 387–415.

Solar Power in Space?

Peter Garretson, Lieutenant Colonel, USAF

> *Whoever takes the lead in the development and utilization of clean and renewable energy and the space and aviation industry will be the world leader.*
>
> —Prof. Wang Xiji, Chinese space program pioneer

Space-based solar power (SBSP) is a concept for a revolutionary energy system. It involves placing into orbit stupendously large orbital power plants—kilometers across—which collect the sun's raw energy and beam it down to where it is needed on the earth. In theory, SBSP could scale to meet all of humanity's energy needs, providing virtually unlimited green, renewable power to an energy-hungry world.

Most renewable energy schemes suffer from intermittency and low energy density, requiring vast amounts of land and extensive storage as well as fossil fuel backup systems. Not so with SBSP systems. When placed in orbit where the sun shines constantly, they can deliver stable, uninterrupted, 24-hour, large-scale power to the urban centers where the majority of humanity lives. A network of thousands of solar-power satellites (SPS) could provide all the power required for an Earth-based population as large as 10 billion people, even for a fully developed "first world" lifestyle but without the environmental downsides of nuclear or coal.

Should space-based solar power have a role in the US grand strategy for space? Should Airmen advocate for a US program in SBSP? Depending on your viewpoint, SBSP is either the most important space project of our generation—critical to securing American long-term interests and requiring the advocacy of Airmen—or a fool's errand, an impossible dream threatening to divert valuable resources from where they are most needed today.

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Some consider SBSP an embarrassment deserving contempt and active suppression, a proposal from which Airmen should steer well clear. Airmen must seriously consider advocating for SBSP, because today there are several space-faring states with stated national objectives and active interest in developing this technology. Two very capable space-faring states already have funded programs. The implications are vast. The advocacy should consider the scope and feasibility of SBSP and the desirable space strategy for the concept. Additionally, any argument must recognize both the concerns of the detractors and international activity surrounding SBSP while presenting the opportunities and recommendations for the future of the idea.

Scope and Feasibility

> *As of 2010, the fundamental research to achieve technical feasibility for the SPS [solar-power satellites] was already accomplished. Whether it requires 5–10 years or 20–30 years to mature the technologies for economically viable SPS now depends more on the development of appropriate platform systems concepts and the availability of adequate budgets.*
>
> —International Academy of Astronautics (IAA), 2011

The world needs a constant supply of uninterrupted electrical power to enable and sustain economic growth; power its cities, factories, and vehicles; and provide energy for heating, cooling, lighting, cooking, and desalination. Long term, it is desirable to transition from an energy system based on fossil fuels—an exhaustible resource which alters the composition of our atmosphere with unknown long-term effects on our climate—to a system based upon renewable sources. Many see solar power as the answer, because the resource is so vast and available.

However, traditional solar power has limitations that make it less than a perfect match for our society. It is highly intermittent (only a 20-percent duty cycle) due to weather effects (clouds, rain, dust), and its low density requires vast tracks of land. Worst of all, it is not available at night, requiring vast storage or nonrenewable backup systems. Space-based solar is an innovation designed to retain the advantages of traditional solar power while sidestepping the disadvantages.

The basics of the idea are quite simple. Rather than cope with the unpredictability and intermittency of solar power on the ground, go where the sun always shines.

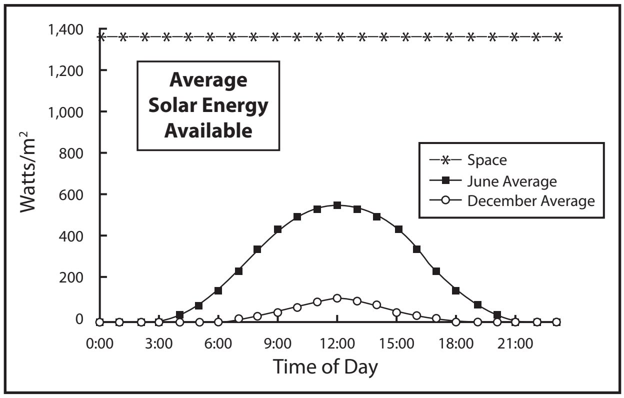

Figure 1. Solar energy available and captured (National Security Space Office, Space-Based Solar Power, 2007, 32.)

In geostationary orbit (GEO), the sun shines constantly and is 36 percent stronger, allowing a solar array to collect almost 10 times the amount of energy as the same array installed at mid latitude on the ground (see fig.1). Power can then be transferred (beamed) directly to where it is needed. The technologies to do this are not magic or unfamiliar—they are the same elements used every day to emplace, power, and communicate with every existing satellite. Building the SBSP system would rely on the same familiar solar cells, radio transceivers, and rockets to propel them to GEO, only assembled on a grand different scale. In a mature system-of-systems, multiple solar-power satellites would reside in geostationary orbit, each collecting vast amounts of power and transmitting it through active electronic beam steering, like routers in a vast orbiting power internet.

While appearing to hover above a particular location, each SPS could service multiple markets, providing power on demand to urban centers or remote locations. For example, a single satellite south of Baja California could service markets across most of North and South America; a satellite over the Indian Ocean could service markets as far apart as Africa and Indonesia, and from Diego Garcia to as far north as Russia.[1]

Power in this system-of-systems would be transmitted using a technique called retrodirective phased array, where an encrypted pilot signal from the ground handshakes with the satellite's active electronic beam-steering system to link transmitter and receiver. The beam itself would be in the ISM band (typically 2.45 or 5.8 GHz), so that it passes nearly full strength through the atmosphere, clouds, and rain. Because of low atmospheric losses (<2 percent), extremely efficient reconversion (>80 percent), and most of all, constant illumination, the beam can be safely kept at an amazingly low intensity (only one-sixth the intensity of sunlight) and yet be significantly more energy productive than a comparably sized terrestrial solar plant. The location and diameter of the beam are predictable and well confined.

Unlike communications satellites—which, because of their small-aperture antennas, cast continent-sized footprints and must be separated by degrees (and thousands of miles) on orbit to deconflict signals—SPSs have very large apertures and therefore can send very narrow beams, allowing them to be spaced much closer together. The beam itself terminates on a receiver called a rectenna, with peak intensity in its center and tapering to nearly nothing at the periphery. The rectenna, about the size of a municipal airport, is a mesh of dipole antennas that capture all the incident energy from the beam. It is nevertheless 80 percent transparent to sunlight, allowing the land beneath to remain available for agricultural uses.

Although composed of simple elements, satellites comprising this system-of-systems would constitute an amazing engineering feat of unprecedented scale and power. Individual SPSs, such as those described as feasible in the November 2011 *International Academy of Astronautics (IAA) Report*,[2] would transmit as much as 1–10 gigawatts (GW) of constant energy as compared to a typical nuclear power station output of 0.5–1.0 GW. A gigawatt could light 750,000 homes. The architecture currently favored would consist of a large, gravity-gradient-stabilized truss structure supporting large sun-facing, ultra-low-mass membrane mirrors that rotate to focus sunlight on a collector/transmitter, itself assembled from thousands of identical "sandwich" modules made of high-efficiency photovoltaic cells on top and Earth-facing phased arrays on the bottom.

The transmitting aperture alone—a phased array—would likely be a kilometer across. The entire multi-gigawatt system might be as wide as seven kilometers across and weigh on the order of 800–1,200 metric tons (mt). Depending on the designed payload size of the launcher, it might require perhaps 480–800 launches of a reusable space plane to erect the system.

The scale of this ambitious project should give the reader pause. On the one hand, in 2011 the United States launched only 18 times to space,[3] and the largest object in space today, the International Space Station (ISS) took years to assemble, has a mass of only 450 mt, and produces only .25 MW of power. On the other hand, the scale is quite modest when compared to that of logistical movement in aviation and shipping. For instance, a major US airport like Atlanta's Hartsfield-Jackson sees nearly 1,350 takeoffs daily and moves 60,000 mt annually.[4] If successful in the market, ultimately thousands of systems could be launched to geosynchronous orbit to supply part or all of the estimated 55-terawatt (TW) power requirement for all earthly energy needs by the year 2100.[5]

Humanity has never contemplated either a space or energy project on such a vast scale or one which would so alter our relationship to the cosmos. It is a space project, an energy project, a transportation project, and an infrastructure project. On a scale of ambition, it is unparalleled. It is the Apollo Project, the Manhattan Project, the transcontinental railroad, the Eisenhower interstate highways, the TVA, and the rural electrification projects all in one.

As ambitious as this vision seems, there is reason to believe it is feasible. According to the *IAA Report*, "There are no fundamental technical barriers that would prevent the realization of large-scale SPS platforms during the coming decades . . . no fundamental breakthroughs appear necessary, and the degree of difficulty in projected R&D appears tractable . . . [and] no fundamental 'show-stoppers' among the required supporting systems [Launch and on-orbit tugs]." The report provides an international roadmap noting that "systems studies are not enough. Technology flight experiments to test critical technology elements and technology flight demonstrations that validate SPS systems concepts to a high level of maturity appear to be essential."

Even if problems of energy and climate were not urgent, or if energy-satisfying substitutes existed, Airmen would still have an interest in highlighting the potential of this technology for two reasons: first, its potentially beneficial effect on US capabilities in space, and second, the fact that other nations are currently pursuing SBSP.

Desirable Space Strategy

Our current *National Space Policy* articulates the top three space-related goals as:

- Energize competitive domestic industries to participate in global markets and advance the development of satellite manufacturing, satellite-based services, space launch, terrestrial applications, and increased entrepreneurship;

- Expand international cooperation; and
- Strengthen stability in space.

It continues by articulating several foundational activities important to the nation:

- Strengthen US leadership in space-related science, technology, and industrial bases. Encourage an innovative and entrepreneurial commercial space sector.
- Enhance capabilities for assured access to space. Develop launch systems and technologies necessary to assure and sustain future reliable and efficient access to space, in cooperation with US industry.
- Develop and retain space professionals. Promote and expand public-private partnerships to foster educational achievement in science, technology, engineering, and mathematics (STEM) programs; embrace innovation to cultivate and sustain an entrepreneurial US research and development environment.
- Strengthen interagency partnerships.
- International cooperation. Strengthen US space leadership. Facilitate new market opportunities for US commercial space capabilities and services, including commercially viable terrestrial applications that rely on government-provided space systems.[6]

SBSP can be seen as a desirable strategy to achieve these national-level goals, consistent with the foundational activities, and with desirable effects for the USAF and the DoD.

Fundamentally, a successful SBSP program would transform our industrial base and competitiveness and be at least as significant for American STEM programs as were the post-Sputnik and Apollo expansions in aerospace engineering. It would greatly expand the role of commercial space, and the effect on assured access and launch would be profound. Its natural confluence of challenges in space, energy, and security offers exciting options to further interagency partnerships between NASA, DOE, DoD, FAA, FCC, EPA, DOC, and DOS. It presents excellent opportunities for the United States to lead in international cooperation.

A prophet is honored everywhere but in his own country and in his own home.

—Luke 4:24

The strategic case for SBSP was most recently articulated in 2007 when the National Security Space Office (NSSO, the executive agent for space), published a report titled *Space-Based Solar Power: An Opportunity for Strategic Security*. The report summarized the findings of a study group of world-class experts who concluded that space-based solar power was technically feasible and recommended the United States initiate a new national program. It further stated that if the United States began a coordinated national program to develop SBSP, it should expect to find that "broad interest in SBSP exists outside of the US government, ranging from aerospace and energy industries, to foreign governments such as Japan, the EU, Canada, India, China, Russia, and others." It also warned, "While the best chances for development are likely to occur with US government support, it is entirely possible that SBSP development may be independently pursued elsewhere without US leadership."[7]

China has acquired sufficient technology and had enough money to carry out the most ambitious space project in history. Once completed, the solar station, with a capacity of 100 MW [megawatts], would span at least one square kilometre, dwarfing the International Space Station and becoming the biggest man-made object in space.

—Prof. Wang Xiji, 2011

Most Airmen would like to see the United States lead in space and maintain its preeminence in technology. Adapting Billy Mitchell's dictum about airpower,[8] "space power is anything a nation can do in space," it is inescapable that if a nation can build a solar-power satellite, it can do a lot more in space than the United States is doing today. SBSP presents our nation a desirable strategy to develop underlying technologies that will determine future preeminence in space.

Were the United States to succeed in such a technological endeavor, it would offer reduced dependency on unstable foreign sources of energy and an opportunity to become a net supplier for a vast and expanding market (both in energy and launch). It may well become an industry of comparable size and value to the aviation or automotive industries, vastly expanding the nation's capabilities and market share in space while offering unique opportunities for international partnerships.

Strategically, a national SBSP program would be of enormous benefit to American security interests. A strategic source of energy that transcends our fossil fuel regime would expand US foreign policy freedom of action, making it less dependent on unstable foreign energy sources. It would curtail financing of ideologies that do not share our values of democracy and human rights while offering an inspiring solution to global climate change.

Pursuing an exportable energy system that could actually solve the problems of global energy security, scarcity, climate change, and sustainable development offers the possibility of proactively reducing the number of potential contingencies where the US military might be called upon to respond. Additionally, being seen as a good-faith supplier of such global public good and inspiring vision for humanity contributes to US legitimacy and lowers the cost and difficulty of maintaining US leadership globally.

A national program in SBSP would also help the DoD and State Department in their missions to secure global partner and US interests, promoting stability and security across the global commons in general. It would promote international collaboration and engagement with nontraditional partners in the space domain.

Tactically, America's national security space enterprise strongly leverages dual-use capabilities and would benefit in several ways from a national program in SBSP. First, the USAF and the DoD would benefit from an increased population of aerospace engineers working on an ambitious, advanced project. A national program in SBSP would necessarily create new high-tech jobs in the United States, inspire America's youth to STEM career fields, and help combat a rapidly shrinking technical and industrial base.

Benefits to the DoD include reenergizing a range of space industries, which would directly contribute to national competencies in space access, maneuver, and on-orbit capabilities (including power) that expand freedom-of-action, any of which might offer the potential to lower costs to the DoD for essential products and services that support its missions and users.

> *Only the small secrets need to be protected. The large ones are kept secret by public incredulity.*
>
> —Marshall McLuhan

With such obvious benefits for the nation and so many potential stakeholders, one would think it easy to move forward, but it is not. SBSP advocates have failed to place the idea on the national agenda. Despite addressing multiple audiences, they have failed to convince the most influential decision makers. While scattered programs which contribute to the essential competencies exist across NASA, the DOE, and the DoD, the sum total of America's commitment to SBSP is one very small grant by the NASA Institute for Advanced Concepts (NIAC) to a single US researcher for a mere $200K.[9]

The Detractors

> *There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order, this lukewarmness arising partly from fear of their adversaries . . . and partly from the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it.*
>
> —Niccolo Machiavelli, 1532

Consider that in the same month the prestigious International Academy of Astronautics released its study concluding that "solar-power satellites appear to be technically feasible as soon as the coming 10–20 years using technologies existing now in the laboratory . . . [and] economically viable solar-power satellites (SPS) appear achievable during the next 1–3 decades," a senior review panel—which included at least two former USAF chief scientists—removed any mention of space-based solar power from the draft "Air Force Energy Horizons" report, a document intended to be visionary and covering the same period of time. (See author's correction at end of article.)

The difference between the evaluations of the IAA and the USAF Energy Horizons does not portray how divided the community is or how vehement is the opposition to even due-diligence exploration of the concept.[10] How controversial is it? No other project has continually animated a small group of disempowered advocates who find the vision inspiring nor drawn the outright ire of seasoned technical professionals, as this quote from one Air Force Research Laboratory scientist demonstrates: "AFRL decided for good reason not to further support SSP. . . . A former AF Chief Scientist . . . chastised

AFRL saying it was one of the dumbest ideas he's ever seen . . . A [senior HQ NASA official] prohibited all NASA centers from any further involvement with SSP . . . there are so many other crucial areas requiring attention. . . . This is a concept the Air Force can do without, especially considering the lean years ahead."[11] And another, "If the government, especially the USAF spends one thin dime on this, I'll be a GAO whistleblower. . . . They need to avoid this like the plague, or I will surface their incompetence to management . . . or high enough that I'd find some sane person that understands. It always looks good to the clueless and uninformed."[12]

The individuals who oppose SBSP are of unimpeachable technical ability and serve the nation with distinction. They are protectors of Air Force credibility. Their arguments are sophisticated and based on a lifetime of experience and ought to rightly command attention and respect. They take the position that extraordinary claims require extraordinary proof. Often times they actively support the specific contributing component technologies but oppose organizing them under a vision they find embarrassingly incredible. Their attitude regarding the interest of competing nations is nonalarmist and might be summed up as, "Good, it will go nowhere and is cost-imposing on them; we should not repeat their mistake."

On the surface, arguments of the opposition are quite strong. They point to the failure of Earth-based solar power to achieve economic viability and ask how the added cost of lifting such systems to orbit could do anything but add cost. To them the idea that such a system could ever have a viable business case violates common sense. They point to decades of failed initiatives to achieve low-cost launch and to a scale of effort in launch and on-orbit service that, given what we find difficult today, seems utterly ridiculous. They rightly point to the extraordinary upfront costs, which at some point in a program would command a substantial share of national resources. They rightly note that the cost of an initial demonstration system is horrifically disproportionate to its actual benefit. Most convincing of all is their argument regarding opportunity costs—that perhaps such a system is in fact technically feasible, but it would be so costly that scarce resources are better spent elsewhere on projects that are less risky and have a more secure, near-term payoff.

The detractors include a host of highly credible people.[13] But it is also possible they are wrong. We should be very cautious in accepting such technological pessimism because there is a long history of prominent men of expertise getting it wrong when they are betting against the aspirations of mankind, especially when harnessed in competition:

"Heavier-than-air flying machines are impossible."

—Lord Kelvin, President of the Royal Society

"Airplanes are interesting toys of no military value."

—Marshal Ferdinand Foch, Ecole Superieure de Guerre, France

"There is no likelihood man can ever tap the power of the atom."

—Robert Millikan, Nobel Prize in physics, 1923

"The biggest fool thing we have ever done. The [atom] bomb will never go off, and I speak as an expert in explosives."

—ADM William D. Leahy to President Truman

"There is no hope for the fanciful idea of reaching the moon because of the insurmountable barriers of escaping Earth's gravity."

—Dr. Forest R. Moulton, astronomer

"Man will never reach the moon regardless of all future scientific advances."

—Dr. Lee DeForest, "Father of Radio and Grandfather of Television"

And this from Vanevar Bush, our own head of defense research and one of America's most visionary men, testifying to Congress just after World War II (1945):

> There has been a great deal said about a 3,000-mile-high angle rocket. In my opinion such a thing is impossible for many years. The people who have been writing these things that annoy me have been talking about a 3,000-mile-high angle rocket shot from one continent to another, carrying an atomic bomb and so directed as to be a precise weapon which would land exactly on a certain target, such as a city. I say, technically, I don't think anyone in the world knows how to do such a thing, and I feel confident that it will not be done for a very long period of time to come. . . . I think we can leave that out of our thinking. I wish the American public would leave that out of their thinking.

Despite this opinion, the United States began work in 1946, and its first ICBM, the Atlas D, became operational in January 1959. Even those closest to the technology can get it spectacularly wrong. Said Wilbur Wright, "I confess that in 1901, I said to my brother Orville that man would not fly for 50 years. Two years later we ourselves made flights. This demonstration of my impotence as a prophet gave me such a shock that ever since I have distrusted myself and avoided all predictions." Orville fared no better, declaring "No flying machine will ever fly from New York to Paris . . . [because] no known motor can run at the requisite speed for four days without stopping."

The problem with experts is they know, only too well, too much about what cannot be done and the difficulties involved. They misperceive as costs and liabilities what are actually investments that could pay back for generations.

We as Airmen should recognize how often the vision and tools we rely upon today have been systematically opposed by technological pessimism of even our own best and brightest and consider carefully the counsel of two men of vision: Arthur C. Clark stated what he called "Clarke's First Law: When a distinguished but elderly scientist states that something is possible, he is almost certainly right. But when he states that something is impossible, he is very probably wrong." Gen Bernard Schriever observed, "The world has an ample supply of people who can always come up with a dozen good reasons why a new idea will not work and should not be tried, but the people who produce progress are a breed apart. They have the imagination, the courage, and the persistence to find solutions."

It is difficult to say what is impossible or ridiculous or to accurately predict the time lines of technological and societal advances. The retort to the technological pessimist's argument that "extraordinary claims require extraordinary proof" is that the extraordinary benefits deserve extraordinary diligence and effort. Nearly every assessment has concluded SBSP is technically achievable.[14] Few argue that SBSP is technically impossible, only that it is economically difficult. But a system, which could actually scale to solve serious problems on the global agenda—sustainable development, climate change, energy security—and simultaneously advance mankind's ability to access and make use of the resources of space deserves serious consideration.

Indeed, one of SBSP's current detractors, Brig Gen Simon P. Worden, articulated the extraordinary benefit as the key to space development: "Power beaming technology is slowly maturing and appears today to involve coherent microwaves or lasers as the mechanisms for carrying the energy. When this technology matures, it should open an era in which the global power grid resides in space and can receive its energy inputs from space-based sources such as large solar-power satellites. Thus, the development of a global energy utility, probably decades into the future, is the key to space development."[15]

But a due-diligence effort would require resources, and Airmen are right to ask whether beyond the abstract argument against "impossible" there is reason to anticipate possible success. What do technological optimists see that makes them evaluate things differently than technological pessimists?

First, SBSP advocates see a system that can deliver constant power at predictable levels as fundamentally different than terrestrial solar power. They believe a first-generation system need not compete directly against coal or nuclear power in price but could service niche markets. Niche markets do exist, including DoD forward locations paying exorbitant prices for electricity, up to tens of dollars per kilowatt-hour (kWh). As early as 2008, the Greater Houston Partnership, an NGO which represents the international oil companies, approached the DoD executive agent for space with a formal letter requesting cooperation in examining the use of SBSP to power remote locations to extract shale gas or even manufacture liquid natural gas (LNG) directly. Proof of the concept in niche markets establishes the public viability and acceptability of the concept, increasing private capital available for financing at a greater scale and catalyzing development of further intellectual capital to lower costs.

Even then, an SBSP system need not be as cheap as nuclear or coal. There are numerous markets around the world that pay nearly an order of magnitude more for power than the lowest US utility rates. Power is also bought at premium prices at peak loads when individual generators must be brought online to cope with additional demand. Because of its unique ability to reach multiple distant markets, a single SPS could sell peak power to multiple urban centers at different times of the day.

The *IAA Report* evaluates a range of potential systems concepts and their inherent technological risks, asserting that new concepts in satellite design involving highly modular systems appear to be the lowest risk. The story of their economic viability as told by the IAA study involves an argument of scale, favoring massively modular systems and reusable launch systems that leverage known industrial learning curves.

Unlike other forms of power generation, SBSP requires no fuel to produce power and comparatively little fuel to maintain its station in GEO. While it would suffer degradation and damage due to particle radiation and micrometeoroid impacts—as would any satellite—it is a massively redundant system of mostly solid-state devices with few moving parts operating in the relatively pristine environment of space. As such it is not expected to require the sort of maintenance a ground-based power plant (subject to weather damage) would require. A nation with the capability to launch 500 times to construct an SPS certainly would have the access and capability to service it.

Therefore, the life cycle cost of a solar-power satellite is dominated by the capital cost of acquisition, measured in dollars per installed watt. This cost is principally driven by two factors: cost of the space hardware (measured in dollars per installed watt) and cost of installation, which is a product of the launched satellite mass (kilograms per watt) and cost of launch (measured in dollars per kilogram).

Space hardware for an SPS is no more complex than consumer electronics. It is expensive today because of extremely low-volume production and high overhead costs. Once a market is established, there is every reason to believe that standard industrial learning curves will apply, as suggested by figure 2.

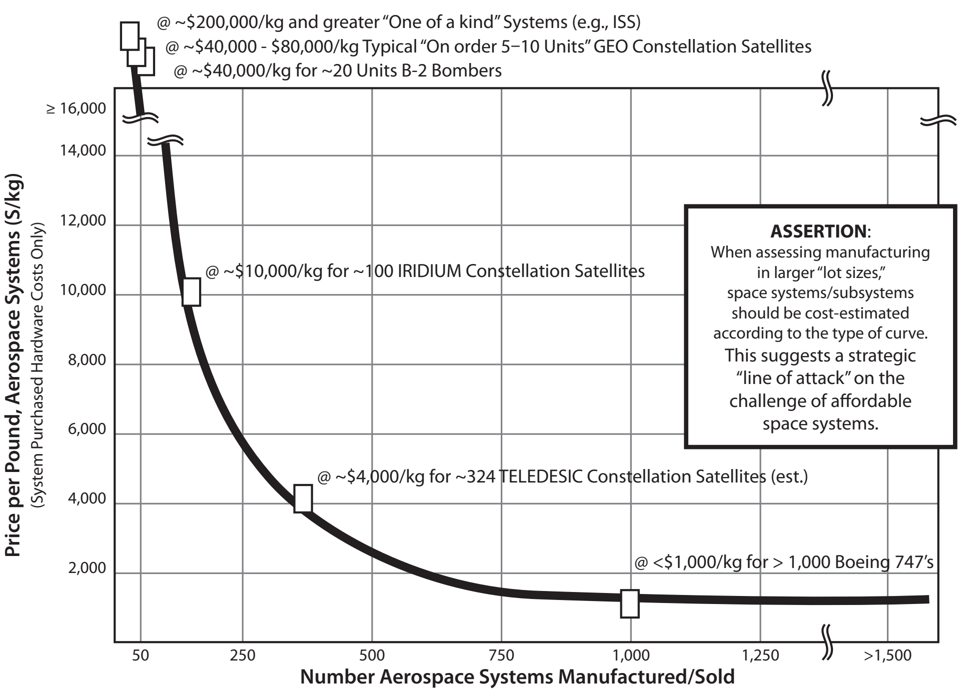

Figure 2. Industrial learning curve applied to aerospace systems (Adapted from John Mankins, "Space Solar Power—Status & Progress," November 2011 presentation to Joint Space Team.)

The same applies to launch. The high cost of space launch is not fuel or even structure, but, again, primarily a result of low-volume production and high overhead costs. The secondary reason for the high cost of launch is reliance on expendable rather than reusable structures and low flight rate. Fully reusable launch vehicles (RLV) have been technically possible for decades, but the upfront cost to develop them was not justified by the market.

SBSP, which would require on the order of 480 to 800 launches per satellite, is a sufficiently large market to justify the upfront investment in an RLV with the expectation of industrial learning curves to apply, bringing the cost of launch into the range where SPSs could be cost-competitive, at least in higher markets. Advocates also note the extraordinary upfront costs that worry the pessimists need not be applied all at once or even using mostly public funding.

The key question before any nation is the commitment to a subscale prototype. The International Space Station cost approximately $100 billion. The IAA estimates that a meaningful demonstration (a subscale system capable of delivering multiple megawatts from GEO) of approximately the mass of the ISS could be accomplished at significantly less cost—the NSSO study estimated $10 billion—and this cost could be spread internationally.

Advocates note that while the benefit of power delivered from this prototype might be small, it would establish the viability of the concept and the believability of terrestrial markets, allowing private capital to be raised. They also believe the program provides other near-term payoffs, simultaneously advancing goals we would pay for anyway: proximity operations, on-orbit servicing, on-orbit construction, in-space maneuver, improved launch, heat rejection, higher specific-power solar cells, and others.

Scale and pace are notoriously easy to underestimate, especially when low initial penetration allows a rapid exponential expansion. Following the Lewis and Clark expedition, Thomas Jefferson, a man of science and vision, declared that it would take at least 100 generations to settle the vast expanse of the West. Instead, Americans hungry for the prosperity it promised populated it within five generations.

The curve for expansion in energy has been even more dramatic. Between 1810 and 1910, oil production increased 100-fold, coal production 300-fold, and gas production 800-fold.[16] Figure 3 provides one scenario for SBSP growth.

When Edwin L. Drake tried to enlist workers to drill for oil in 1859, he was met with, "Drill for oil? You mean drill into the ground to try and find oil? You're crazy." Today it is as difficult to enlist seasoned technical US space engineers to think about "drilling up" as it was for people in 1859 to contemplate how a system of drilling for oil to feed internal combustion engines could economically replace horses with cars, pave an entire continent with concrete and gas stations, and reshape global politics.

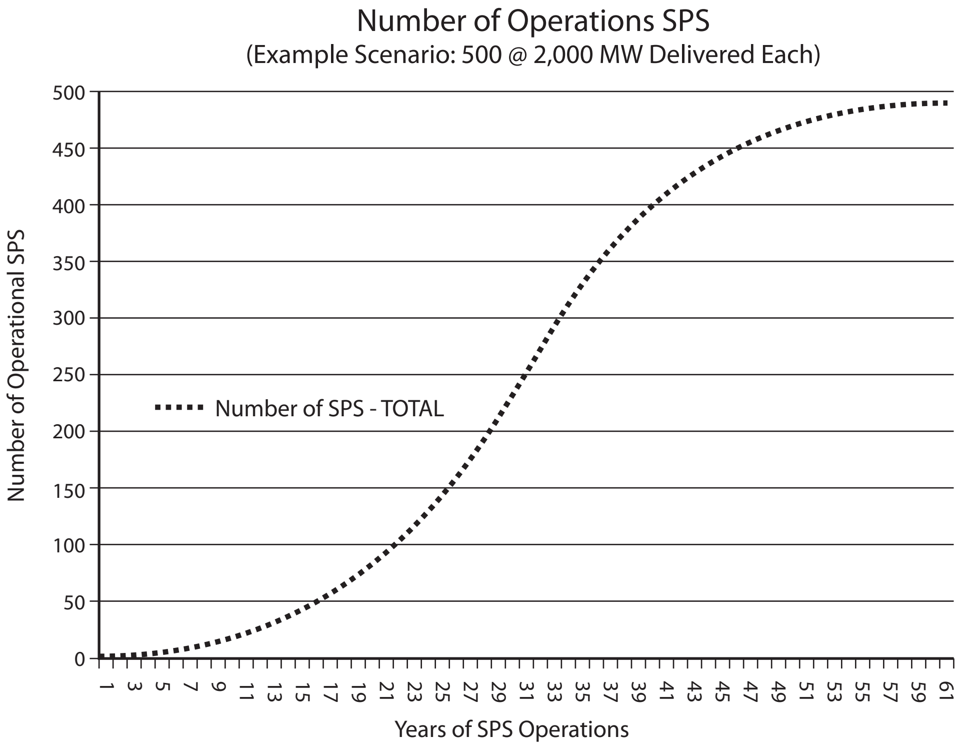

Figure 3. Potential growth scenario to first terawatt (*IAA Report*, fig. 5-2)

International Activity

Those who say it can't be done are usually interrupted by others doing it.

—Joel A. Barker, USAF strategic planning consultant

It may not be prudent to commit large amounts of resources to an unproven idea, but we should also be cautious to self-exempt from strategic competition. It is therefore important to be cognizant of what is happening abroad. While the above-mentioned 2007 NSSO report was for the most part ignored at home, it was understandably read with great interest abroad and appears to have been a catalyst for activity in Europe, Japan, India, Russia, and now China.

By June 2009, Japan announced SBSP as one of nine major national space goals and one of three strategic R&D goals in its *Basic Plan for Space Policy*.[17] It states, "Space solar power may solve the worldwide environmental and energy issues confronting humankind," and articulates that "research and development of the technology necessary to realize the solar power generation system in space for clean and stable energy utilization without any geopolitical influences." In other words, let's make our own energy instead of depending on regions of dubious stability. A nation that has spent a decade, trillions of dollars, and thousands of lives of its Soldiers, Sailors, Airmen, and Marines in conflicts abroad to protect its existing fossil-fuel-based energy ought to realize the sensibility of that.

Japan's space basic plan assigned R&D work to various agencies concerned with space technology, science, and industry as well as universities;[18] stated it would promote commercial use; and stated its intention to use its Kibo module on the ISS as an experimental platform. In November 2009, the Japanese government publically announced a major public-private partnership between METI, MEXT, JAXA, and major industrial giants including IHI, Mitsubishi, NEC, Fujitsu, and Sharp. Press coverage stated there were some 130 engineers studying the concept under JAXA's oversight and examining at least two major designs—one laser, one microwave—and plans for a 10-MW demonstration project by 2020 and a 250-MW prototype.[19] One story even stated that the consortium of 16 companies planned to spend two trillion yen ($21 billion) for a first stage in 2015 and ultimately to have a working 1-GW prototype capable of supplying power to 750,000 homes by 2030.[20]

In December 2009, Russia also expressed interest, with scientists from the Lavochkin Scientific and Production Association Federal State Unitary Enterprise claiming a new design principle and stating that "in order to address the issues of a future energy crisis and to keep up with the developed countries, Russia must begin the research today."[21]

In January 2010, Europe's EADS Astrium announced plans for a demo project, stating it planned to orbit a subscale SPS capable of beaming 10–20 kW of power and would be ready for launch in five years.[22] Matthew Perren, head of innovation at Astrium's headquarters in Paris, stated, "Looking to the future we envisage large power stations in space that are capable of transmitting energy to any point on the planet on demand."[23]

In late 2010, the China Academy of Space Technology (CAST) quietly articulated its interest and program in the *Online Journal of Space Communications*, stating that "the acquisition of space solar power will require development of fundamental new aerospace technologies, such as revolutionary launch approaches, ultra-thin solar arrays, on-orbit manufacture/assembly/integration (MAI), precise attitude control, in-situ resource utilization (ISRU) for deep space exploration and space colonial expansion." It is clear the CAST proponents see SBSP in strategic terms:

> Since SPS development will be a huge project, it will be considered the equivalent of an Apollo program for energy. In the last century, America's leading position in science and technology worldwide was inextricably linked with technological advances associated with implementation of the Apollo program. Likewise, as China's current achievements in aerospace technology are built upon with its successive generations of satellite projects in space, China will use its capabilities in space science to assure sustainable development of energy from space . . . it is necessary for China to launch an SPS-type Apollo project to increase research and development investment in all corollary fields. This will relate to the country's goal of attaining the leading position in both energy and space technology" and that therefore, "the [Chinese] state has decided that power coming from outside of the earth, such as solar power and development of . . . space energy resources . . . is to be China's future direction.[24]

CAST laid out a detailed five-step plan for achieving the first commercial SPS: "In 2010, CAST will finish the concept design; in 2020, we will finish the industrial level testing of in-orbit construction and wireless transmissions. In 2025, we will complete the first 100 kW SPS demonstration at LEO; and in 2035, the 100 mW SPS will have electric generating capacity. Finally in 2050, the first commercial level SPS system will be in operation at GEO."[25]

The concept design was finished in 2010, and in September 2011 came the first highly public announcement where Prof. Wang Xiji, a key drafter of the proposal, stated, "China has acquired sufficient technology and had enough money to carry out the most ambitious space project in history. Once completed, the solar station, with a capacity of 100 MW, would span at least one square kilometre, dwarfing the International Space Station and becoming the biggest man-made object in space."[26]

Professor Xiji articulated, "The area of space and aviation is an emerging strategic industry, and the development of a space solar-energy station requires high-end technology. . . . Such a station will trigger a technical revolution in the fields of new energy, new material, solar power and electricity, and [ultimately] lead to the emergence of several industries . . . and possibly even an industrial revolution." He emphasized that "Whoever takes the lead in the development and utilization of clean and renewable energy and the space and aviation industry will be the world leader." Professor Xiji, one of the acknowledged fathers of the Chinese space program, warned that if it "did not act quickly, China would let other countries, in particular the US and Japan, take the lead and occupy strategically important locations in space."[27]

Clearly our competitors do not seem to share the same technological pessimism that bedevils attempts to begin a US program. As chronicled by author Thomas Friedman, such ambition and technological optimism used to be a part of the ethos and identity of America.[28] One might hope that given China's demonstrated ability to construct mega projects—the massive Three Gorges Dam, high-speed rail, and entire cities, seemingly overnight—that Chinese interest in SBSP might be a wake-up call to what is truly the space race of our generation.

But so far at least, the reaction seems more consistent with the worry expressed by Friedman that the United States, as compared to China, had lost its "can-do" spirit in the early twenty-first century.[29] Airmen, as stewards of America's aerospace power, should not be so complacent. Understanding the critical link between dual-use infrastructure that contributes to access and on-orbit capabilities, an Air Force strategist might then take a much less complacent view of international competition.

> *There are no battles in this strategy; each side is merely trying to outdo in performance the equipment of the other. . . . Its tactics are industrial, technical, and financial. . . . A silent and apparently peaceful war is therefore in progress, but it could well be a war which of itself could be decisive.*
>
> —General d'Armee Andre Beaufre

For years the Air Force has kept the United States out of a major war and kept the world from another global conflict by maintaining technological preeminence and overmatch, practicing what a Cold War textbook called a "Strategy of Technology":

> The Technological War is the decisive struggle in the Protracted Conflict. Victory in the Technological War gives supremacy in all other phases of the conflict. . . . The Technological War creates the resources to be employed in all other parts of the Protracted Conflict. It governs the range of strategies that can be adapted in

> actual or hot war. . . . Military superiority or even supremacy is not permanent, and never ends the conflict unless it is used. The United States considers the Technological War as an infinite game: one which is not played out to a decisive victory. We are committed to a grand strategy of defense, and will never employ a decisive advantage to end the conflict by destroying our enemies. Consequently, we must maintain not only military superiority but [also] technological supremacy. The race is an alternative to destructive war, not the cause of military conflict. . . . The United States is dedicated to a strategy of stability. We are a stabilizing rather than a disturbing power, and our goal is preserving the status quo and the balance of power rather than seeking conquest and the final solution to the problems of international conflict through occupation or extermination of all opponents. In a word, the U.S. sees the Technological War as an infinite game, one played for the sake of continuing to play, rather than for the sake of "victory" in the narrow sense.[30]

That is not to imply that Airmen should recommend a zero-sum orientation toward SBSP competition, only that America should get its head in this game.

Because it is the policy of the United States to pursue international cooperation in space and take the lead in multilateral efforts which enhance stability and transparency in space, Airmen must consider not only the threat of losing an important technical competition but also the opportunity international cooperation could provide to advance US interests through partnerships in the domains under their stewardship.

Aerospace competition is not only technical; it also has an aspirational moral dimension, as nations are measured, admired, and respected not only by their accomplishments but also by their ambitions. Former USAF strategist Col John Boyd made clear the strategic value of vision: "What is needed is a vision rooted in human nature so noble, so attractive that it not only attracts the uncommitted and magnifies the spirit and strength of its adherents, but also undermines the dedication and determination of any competitors and adversaries."[31]

SBSP opens the doors to engagement with nontraditional partners and could promote exactly the kind of international collaboration called for in our *National Space Policy*. At least one nontraditional partner has already opened the door. In 2007 at Boston University, then-president of India, Dr. A. P. J. Kalam, laid out a 50-year vision for space with SBSP at the core.[32] Dr. Kalam has continued to articulate his vision since, even lending his name to a (so far ignored) proposal for Indo-US cooperation with the largest citizen space advocacy group, the National Space Society (NSS).[33]

In joint statement after joint statement, both countries reiterate their desire to cooperate in space, in clean energy, in climate change mitigation and sustainability, in strategic and high technologies. Both sides hand wring that after the "123" civil-nuclear deal, there is no "big idea" animating the strategic partnership. SBSP seems an obvious choice that would and has been floated by several important think tanks in both India and the United States.[34] The recent CFR-Aspen report, *The United States and India: A Shared Strategic Future*, stated, "On climate change and energy technology, the collaboration should: Conduct a joint feasibility study on a cooperative program to develop space-based solar power with a goal of fielding a commercially viable capability within two decades."[35]

The Opportunity and Recommendations

> *[It was the] consensus of the IAA that significant progress could be accomplished during the next 10–15 years—leading to a large but sub-scale SPS pilot plant.*
>
> —*IAA Report*, 2011

The *IAA Report* insists that within 15 years, the first meaningful prototype, approximately the mass of the International Space Station, could be in orbit, producing megawatts of power and delivering it in the range of $1–5 per kWh.

While the production scenario for four or more operational satellites favors a new reusable launch vehicle, the IAA study suggests (see fig. 4) that a moderate-sized demo could be emplaced least expensively with existing launch vehicles at less than the cost of the ISS. For those looking for aerospace jobs, those desiring a Manhattan Project of energy, and those seeing energy as the space race and Apollo project of our generation, that is quite a "shovel-ready" project.

Unlike other potential civil space program goals—such as human travel to the moon, Mars, or an asteroid, which only obliquely contribute to national security space—a national SBSP program would more directly benefit the DoD. The construction of a large demo necessarily advances on-orbit competencies in proximity operations, construction, servicing, and maintenance and includes the development of a space tug, which enhances on-orbit maneuver, and a large block buy of expendable commercial launch vehicles that would lower the cost for national security payloads. If successful, a proven delivered cost of $1–5 per kWh for power in the megawatts for a first-generation system is significantly less than the cost of electricity US forces are paying today after fuel is convoyed or helicoptered to forward locations and would establish the market for RLVs, further lowering the cost for DoD payloads in the longer term and opening the potential for more regular access to space.

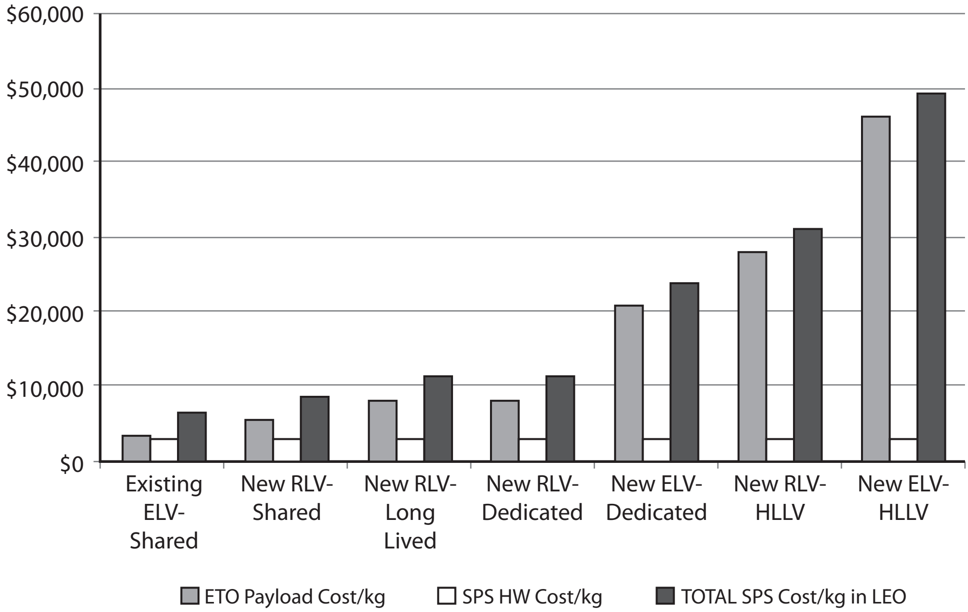

Figure 4. Launch options for a moderate-scale SPS pilot plant @400 mt (*IAA Report,* fig. 7-7)

The United States already participates in an international project of comparable duration, cost, and technological risk, the International Thermonuclear [Fusion] Experimental Reactor (ITER)[36] being constructed in the south of France,[37] but even if successful in achieving break-even energy, it will not provide the above benefits to the nation.

The longer-term benefits for our industrial base are even more profound. Total revenues in the space sector today are only $275 billion—mostly from satellite TV[38]—but revenues in the energy world exceed $7 trillion annually. The market for green power is enormous. The IAA estimates the demand for energy from renewable sources will need to grow from roughly 12,000 billion kWh per year in 2010, to more than 110,000 billion kWh per year in 2030–2040, and to more than 430,000 billion kWh per year by 2100—a 36-fold expansion. Over the next 20 years, the world is going to invest over $12.4 trillion in new infrastructure within the power sector (China, $3.1 trillion; the United States, $2.1 trillion;[39] India, $2.3 trillion;[40] Russia, $1.9 trillion;[41] and Europe and the UK, $3 trillion[42])!

That market translates directly into jobs both at home and abroad. Consider that a $1 billion investment in utility-scale photovoltaic (ground) solar would result in nearly 10,000 direct and 19,000 total jobs (well-paying jobs) in the United States and nearly 5,000 direct and 19,000 total new jobs in China, purely for 400 MW of additional capacity, according to a 2010 industry-paid study by Garten-Rothkopf. That 400-MW total is small compared to what is contemplated in SBSP, where both China and Japan talk of 1-GW individual plants.

If a mere $1 billion for terrestrial photovoltaic would result in 19,000 new jobs at home, consider that the $10 billion demo proposed in the NSSO report might be expected to generate 190,000 total jobs. There is the potential for significantly more if, as Professor Xiji notes, it would create whole new industries and spark an industrial revolution. The demo is just the beginning.

Based on the data in figure 5, the IAA estimates that should SBSP achieve financial viability and full output, "annual employment on the order of 5,000,000 individuals might be realized eventually."

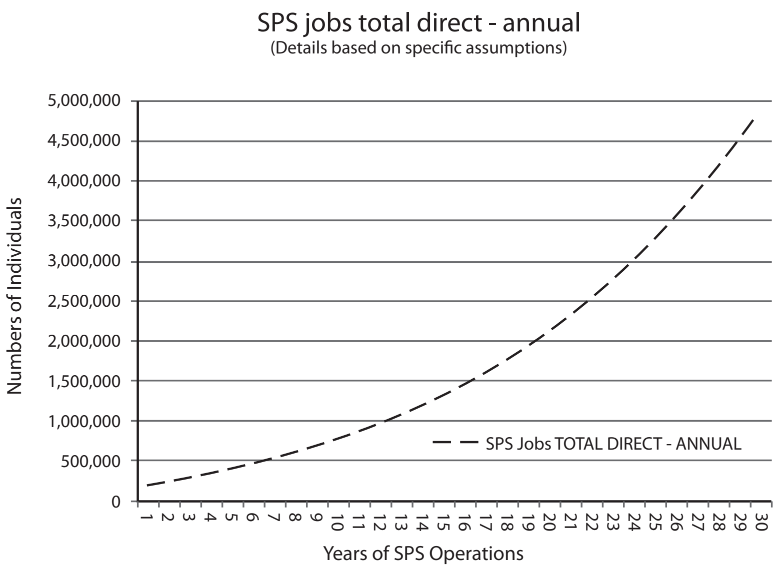

Figure 5. IAA job growth scenario to 1,000 GW of power[43] (*IAA Report* fig. 5-6, assuming logistics curve growth to 500 x 2,000-MW [2-GW] satellites)

Some argue that these austere times are not the right time to begin such a program. But it has always been in times of economic depression or challenge that the United States has begun major energy and infrastructure projects. It was in the context of conflict, hot and cold, that the United States began the Manhattan and Apollo projects. It was during the Great Depression when the United States launched such initiatives as the Tennessee Valley Authority rural electrification program. SBSP combines space, energy, infrastructure, innovation, and frontier spirit and plays to American strengths. Vision attracts talent and capital. It is when America is down that it reinvents itself with a still larger, frontier-expanding vision. If not now, when will we step out into the next great Manhattan-like project, and how will we continue to be the world leader in technology and innovation?

Right now there is no organization with a mandate to do SBSP. NASA's internal constituencies are for manned and robotic exploration. It sees a massive industrial energy project as the reason we have a Department of Energy (DOE). The DOE says it supports the vision of infinite green energy, but that the essential technology problems involve space technology, and that is why we have a national space agency. The DoD has interests in all supporting technologies—space access, in-space maneuver, on-orbit construction, beamed energy—but it is neither America's department of energy nor its civil space agency and already is underfunded to meet the core requirements of its chief customer, the war fighter.

If America is going to compete in this vital, exciting endeavor, it will have to organize for success, giving some official entity the mandate and providing the necessary resources. That will not happen without advocacy from the stewards of US technical preeminence in aerospace—Airmen.

We, as Airmen, who have the historical identity as the "technology force," who understand the critical importance of our national technology base in securing national and international security through technological preeminence, and who are the stewards of the domain of space, must rise to the occasion—lending our voices to the urgency of the hour and supplying the vision for the advancement of human activity and commerce in this new domain—and advocate for a national program to realize the promise of a new age of "space power." SSQ

Notes

1. Advance presentation of the *IAA Report* to the Joint Space Team, Pentagon, November 2011.

2 . International Association of Astronautics (IAA), *Space Solar Power, the First International Assessment of Space Solar Power: Opportunities, Issues and Potential Pathways Forward* (Paris: IAA, 2011). [Elsewhere: the *IAA Report*]

3. "Launch History," *Satellite on the Net*, http://www.satelliteonthenet.co.uk/index.php/launch-history.

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5. James M. Snead, 2009 International Space Development Conference presentation. According to Snead, geosynchronous orbit could, in theory, hold as many as 66,200 5-GW SPSs at 100-percent slot use, supplying as much as 330 TW of power against a 2100 projected requirement of only 55 TW to supply all of humanity's energy needs.

6. *National Space Policy of the United States of America* (Washington: The White House, June 2010), http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf.

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8. For an excellent discussion, see Brent Ziarnick, "To Command the Stars: The Rise of Foundational Space Power Theory," http://www.schriever.af.mil/shared/media/document/AFD-070906-081.pdf.

9. NASA, Office of the Chief Technologist, "2011 NAIC Phase I Selections," http://www.nasa.gov/offices/oct/early_stage_innovation/niac/2011_phase1_selections.html.

10. In fact, from 2007 to 2008 the AFRL had a small exploratory project—just enough to hold two small workshops. During the changeover of administrations, it was directed to cancel further activity as there was worry that "someone in the new administration [with its green energy agenda] would like it, and the AF would be stuck with a bill."

11. Personal e-mail to the author, 8 November 2011.

12. Personal e-mail to the author, 5 October 2011.

13. Skeptics and critics of the viability of the concept have included at least one past chief scientist of the AF, researchers in AFRL's power and propulsion directorate (AFRL/RZ) and its office of scientific research (AFOSR), a NASA center director, a former national security space architect, and past members of the executive office of the President's Office of Science and Technology Policy (OSTP).

14. DOE and NASA studies (1977–81); National Research Council, "Laying the Foundation for Space Solar Power" (2001); NSSO, "Space-Based Solar Power as an Opportunity for Strategic Security"; and IAA, *The First International Assessment of Space Solar Power: Opportunities, Issues and Potential Pathways Forward* (2011). All of these sources can be found at http://www.nss.org/settlement/ssp/library/index.htm.

15. Simon B. Worden and John E. Shaw, *Wither Space Power? Forging a Strategy for the New Century* (Maxwell AFB, AL: Air University Press, 2002), 81, http://www.au.af.mil/au/awc/awcgate/au/wordenshaw.pdf .

16. Vaclav Smil, *Energy in World History* (Boulder, CO: Westview Press, 1994), 185.

17. Strategic Headquarters for Space Policy, *Basic Plan for Space Policy*, 2 June 2009, available in English at www.kantei.go.jp/jp/singi/utyuu/basic_plan.pdf.

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23. "Lasers to Beam Solar Energy from Space to Earth."

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27. Ibid.

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32. Dr. A. P. J. Abdul Kalam, "The Future of Space Exploration," video of speech, http://www.bu.edu/pardee/space-abdul-kalam/.

33. See various articles and videos by Dr. Kalam at http://www.nss.org/news/releases/pc20101104.html.

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43. *IAA Report*, fig. 5-6, assuming logistics curve growth to 500 x 2,000 MW (2 GW) satellites.

Author's Correction

The Air Force Energy Horizons report was in draft form when this article was written. The final document does mention space-based solar power. The reader can find the entire report using the link below, and the space-based solar power excerpt is shown here. The author regrets this omission.

AF Energy Horizons United States Air Force Energy S&T Vision 2011–2026, AF/ST TR 11-01 31 January 2012 refer p. 27….
http://www.af.mil/shared/media/document/AFD-120209-060.pdf

> On orbit, the utilization of energy is generally relegated to the asset that generates the power. This greatly reduces the potential capability of these systems. However, new technologies may allow for increased capability for these systems through the wireless transfer of power. While there are many challenges in space-to-earth power beaming, space-to-space power beaming could be transformational and is an area which could open up entirely new ways to power sets of–fractionated, distributed satellite systems. Like air refueling, space power could be transformational, and could transfer or beam energy to other space assets, enabling them to be smaller, more survivable, and more capable than current systems. It is foreseeable that wireless energy transfer may dominate the amount of energy utilized on-board satellites, due to the technology constraints of on-orbit energy production and storage. This technology could allow for more capable systems to be launched as more payload would be available for operational systems.

Designer Satellite Collisions from Covert Cyber War

Jan Kallberg

Outer space has enjoyed two decades of fairly peaceful development since the Cold War, but once again it is becoming more competitive and contested, with increased militarization. Therefore, it is important the United States maintain its space superiority to ensure it has the capabilities required by modern warfare for successful operations. Today is different from earlier periods of space development,[1] because there is not a blatantly overt arms race in space,[2] but instead a covert challenge to US interests in maintaining superiority, resilience, and capability. A finite number of states consider themselves geopolitical actors; however, as long as the United States maintains space superiority, they must play according to a set of rules written without their consent and forced upon them. US space assets monitor the actions of authoritarian regimes and their pursuit of regional influence—a practice these regimes find quite disturbing. Therefore, any degradation or limitation of US space-borne capabilities would be seen as a successful outcome for such regimes. Cyber warfare offers these adversarial actors the opportunity to directly or indirectly destroy US space assets with minimal risk due to limited attribution and traceability. This article addresses how they might accomplish this objective. We must begin by examining US reliance on space before focusing on space clutter and the means an adversary might use to exploit it. While satellite protection is a challenge, there are several solutions the United States should consider in the years ahead.

US Reliance on Space

Network-centric warfare is dependent on the global information grid for joint war-fighting capabilities.[3] The pivotal layer creating global war-fighting

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capability is the space backbone of the information grid where space assets are the decisive element. The United States depends on space-borne capabilities for success, and US national security relies today on a limited number of heavily used satellites. These satellites are crucial for strategic deterrence, surveillance, intelligence gathering, and military communications. If strategic deterrence fails, the satellites become an integral part of offensive and defensive ballistic missile defense. Satellites are pivotal not only for American space superiority but also for information superiority—the engine in the multichannel joint war-fighting machinery that has proven to be successful in recent conflicts. American forces can fight globally because of access to satellite-supported C4ISR. Potential adversaries of all sizes and intentions understand that American military might is closely linked to the capabilities of US space assets. James Finch and Shawn Steene of the Office of the Undersecretary of Defense for Policy express this unique link between space assets and national security well:

> Although other states increasingly utilize space for economic and military purposes, the United States is by far the most reliant on space systems due to its global responsibilities and high-technology approach to warfare that heavily leverages space systems for communication, navigation, and intelligence, surveillance, and reconnaissance. This asymmetry creates an imbalance; the more a nation relies on space systems, the more tempted a potential adversary is to target those systems.[4]

Since the fall of the Soviet Union, US space superiority has not been extensively challenged, and we have seen two decades of US space supremacy. Attacks against US satellites have been a concern since the 1970s,[5] with a focus on signal jamming, laser beams from the earth,[6] and direct kinetic antisatellite (ASAT) missile attacks. William J. Lynn III, former US deputy secretary of defense, stated in the summer of 2011, "The willingness of states to interfere with satellites in orbit has serious implications for our national security. Space systems enable our modern way of war. They allow our warfighters to strike with precision, to navigate with accuracy, to communicate with certainty, and to see the battlefield with clarity. Without them, many of our most important military advantages evaporate."[7]

Lynn's comments are to a high degree drawn from the *National Security Space Strategy* of January 2011. That strategy states that space is becoming congested, contested, and competitive. It clearly outlines the importance of protecting US space-borne capabilities:

> The *National Security Space Strategy* draws upon all elements of national power and requires active US leadership in space. The United States will pursue a set of

> interrelated strategic approaches to meet our national security space objectives: Promote responsible, peaceful, and safe use of space; provide improved US space capabilities; partner with responsible nations, international organizations, and commercial firms; prevent and deter aggression against space infrastructure that supports US national security; and prepare to defeat attacks and to operate in a degraded environment.[8]

Lynn also noted the impact of the growing amount of space debris:

> The specter of jamming is not the only new concern. The February 2009 collision of an Iridium communications satellite with a defunct Soviet satellite, and the earlier, deliberate destruction of a satellite by China, produced thousands of debris fragments, each of which poses a potentially catastrophic threat to operational spacecraft. In an instant, these events—one accidental, the other purposeful—doubled the amount of space debris, making space operations more complicated and dangerous.[9]

The deliberate kinetic attack and destruction of an outdated satellite by the Chinese themselves using an ASAT missile drew attention not only to the fact that the Chinese tested the missile and its policy impact[10] but also to the debris cloud the explosion created.

A Very Cluttered Space

The question of space debris is complicated by a myriad of issues involving not only the physical hurdles encountered in removing it but also legal and international issues.[11] As a result, space is becoming more congested, with around 1,100 active and 2,000 inactive satellites in orbit.[12] The amount of space debris has steadily increased over time,[13] with the total amount of debris currently tracked at 22,000 objects. The first steps to create a debris mitigation strategy were taken in the late 1970s.[14] Since then, thousands of satellites have been launched into space, and the majority of these are now either inactive or of an older technology generation and at the end of their life spans. The United States has led the debris reduction effort to mitigate risks by actively designing space vehicles that can be disposed of safely or removed by orbital decay.[15] The overriding concern regarding space debris is the mutual interest in limiting its effects and in creating a joint effort to decrease the amount of debris so that, eventually, orbital decay and gravity would prevail.

To understand the destructive power of space debris, one must consider velocity. A standard military-issue 5.56-mm round is traveling at 940 meters per second (m/sec.) when it leaves the barrel and can easily penetrate a human being. The US Army's 120-mm tank round has a muzzle velocity of 1,740 m/sec. and can pass through a medium-sized battle tank.[16] Space debris and space junk traveling at circular orbital speed will hit a satellite at speeds of from 3,000 m/sec. up to 7,600 m/sec., depending on altitude. Debris traveling up to eight times faster than a high-velocity rifle round—whether a long-lost monkey wrench from the 1970s stamped "CCCP," small fragments, or an intentionally dispersed steel ball—creates an unprecedented impact. Deliberately creating space debris in specific orbits can radically change the probabilities of impact, even if the majority of that debris were dispersed in various directions or removed by physical effects. A targeted collision or a large debris cloud in identical orbit would nullify the option to move the target out of the targeted area. Satellites are fragile masterpieces of electronics, cables, connectors, solar panels, integrated circuits, and high-frequency antennas. Every inch has a dedicated function. Any object traveling at 7,600 m/sec. is a real threat to a satellite.

The Kessler Syndrome

Former NASA expert on space debris, Donald J. Kessler, predicted the probability for collisions in space and the risk of a high amount of space debris being generated by the impact of a high-velocity collision.[17] A chain reaction, called the Kessler Syndrome, could result. The Kessler Syndrome occurs when debris or another satellite hits a satellite or space junk with hypervelocity, creating a burst of more debris by the hypervelocity impact. If the satellite (or space junk) density is high enough, it can have a cascading effect through space. Kessler identified this problem but also clearly stated in the 1970s that the amount of space junk and satellites was too low to trigger such cascading effects and later reconfirmed that position. His contribution was to identify the potential problem and explain it. Since Kessler wrote about this phenomenon in 1978, he has returned to the topic to clarify, extend the question, or present his calculations.[18] Kessler's work is focused on unintended, random, and uncontrolled collisions. Similarly, the debate about space debris is focused on the unintentional creation of space debris by littering from space stations, exploding space boosters, and colliding objects.[19] In real terms—due to the limited probability for a random collision—the highest risk occurs with intended and premeditated creation of debris clouds that are concentrated around US mission-critical satellite orbits. If the collisions are intended, planned, and controlled, the risks are multiplied, presenting an adversary the opportunity to destroy pivotal US satellite hardware. To reach a cascading threshold, an adversary can add space debris through controlled and intentional actions. The fastest way to add space debris to an orbit is to collide the existing mass of satellites and space junk that orbits Earth. If the mass already in space can be hijacked through cyber attacks, the attacker minimizes its exposure to traceability and attribution.

Types and Means of Attack

Satellites are a major concern for any state or nonstate actor who intends to conduct operations in secrecy. Satellites gather intelligence, provide surveillance, and perform reconnaissance. This can be extremely annoying to states that seek to avoid transparency between their international commitments, their public posture, and their actions behind the scenes. Several options are available to those actors who seek to diminish this satellite threat.

Kinetic Attacks. Essentially, an adversary can choose between two types of noncyber antisatellite attacks: direct kinetic and indirect kinetic. While a direct kinetic antisatellite missile attack on a US satellite is possible, it would provide direct attribution to the attacker, thus leading to repercussions. The thruster and the heat from the missile would be identified and attributed to the country or vessel that launched the attack. A direct kinetic attack might be inviting, but the political price is high. Even though it would be inviting to attack satellites, an adversary would not be able to attack without leaving a trace of tangible evidence. Using an ASAT missile is a grave act of war and can only reasonably be used if the perpetrator anticipates and accepts a wartime response.

For a potential adversary, it can be far more advantageous to increase the amount of debris that clutters specific orbits, thus epitomizing the indirect attack. Increasing debris can be accomplished through actively adding debris to specific well-targeted orbits, systematic designer accidents, or collisions in space.

During the eighteenth century and until the Second World War, artillery units had a special round to be used if enemy infantry came uncomfortably close to the battery position—the case shot. The battery aimed toward the closing infantry and fired the case shots, which dispersed thousands of steel balls that created massive losses in the infantry ranks. Whether those steel balls hit an arm, a leg, the torso, or a hand did not matter; the infantry assault against the battery position lost momentum and ended. By applying the case shot idea to space, we can see an unsophisticated way to radically increase debris by using space boosters to reach lower Earth orbit (LEO) and then using kinetic energy to disperse hundreds of thousands of steel balls into a segment of space. Any obsolete or crude missile—exemplified by the Iranian Shahab or the North Korean Taepodong—could act as a space booster to take the payload to space. A salvo of 20 such crude space boosters delivering a significant amount of prefragmented shrapnel or steel balls could radically increase the amount of hypervelocity debris.

The probability for collision in space between a functional satellite and debris is a numbers game. Reduced to a simplified example, if the presence of 5,000 debris pieces at a specific altitude generates a risk of one satellite hit every 10 years—not taking into account additional debris generated from the impact—an additional 100,000 debris pieces would increase that risk drastically. To illustrate the principle, 20 space boosters can lift 30 metric tons of payload to LEO—roughly 400,000 steel balls—that would be spread at hypervelocity into the satellite orbits. The attack is kinetic but indirect, as the target satellites are not individually targeted but are instead approached by a swarm of hypervelocity debris that impacts the target satellites either by penetration or by destroying antennas, solar panels, or other equipment. This impact would initially generate more debris, although orbital decay would counterbalance some of it by moving it to a lower altitude; eventually it would disappear from space.

Either a direct or indirect kinetic attack would be an act of war and provide the necessary attribution to give the United States casus belli approved by at least a part of the international community. First, both the direct and indirect kinetic attack would be attributable to the nation that launched the attack, and observations from space-borne monitoring satellites would be accurate enough to give the United States a solid case. Second, creating unprecedented amounts of space debris would not only be hazardous to US satellites but also to those of other major powers. If rogue nation X launches an indirect kinetic attack, it would affect Russia's, Europe's, China's, India's, Pakistan's, and other nations' satellites. Depending on the dispersement of these debris objects, damage could be limited to small areas of space, but it would still be a space territory not used solely by the United States. Rogue nation X traditionally has avoided United Nations–supported repercussions from the international community when US interests have been damaged. Russia and/or China, in particular, are likely to veto any punitive actions proposed by the United States in the UN Security Council.[20] In this scenario, rogue nation X cannot afford to lose that support by damaging Russian or Chinese space assets as collateral damage from its attack on US satellites. Chinese space assets are quite limited compared to Russian or US inventories; therefore, an indirect kinetic attack against US assets could result in severe damage to Chinese interests, as the Chinese lack space resilience. Neither direct nor indirect kinetic attacks are suitable or viable options for a rogue nation that intends to harm US satellites.

Cyber Attacks in Space. The life span of a satellite is between five and 30 years, and even afterward it can still be orbiting with enough propellant to move through space and with functional communications which could be reactivated. Space contains thousands of satellites, both active and inactive, launched by numerous organizations and countries, hosting 5,000 space-borne transponders communicating with Earth. Every transmission is a potential inlet for a cyber attack. Older satellites share technological similarities, providing opportunities to cyber-exploit industrial systems for control and processing. Supervisory control and data acquisition (SCADA) systems within our municipalities, facilities, infrastructure, and factories are designed and built on older technology and hardware, sometimes designed decades ago, and the software is seldom updated. These SCADA systems are considered a strategic vulnerability and have drawn growing attention from the US cyber-defense community in recent years. Satellites may be based on hardware and technology from the 1980s for one very simple reason—they are unlikely to be upgraded after they have been launched into space.

Terrestrial cyber attacks are a single exploit on thousands, if not millions, of identical systems, and the exploit will be eliminated afterward by updates or upgrades. The difference between satellites and terrestrial cyber exploits is that a satellite is in many cases custom made, whereas the computing design is proprietary. Cyber attacks in space exploit a single system, or limited group of systems, within a larger group of satellites. These space-borne assets have a variety of operating systems, embedded software, and designs from disparate technological legacies. As more nations engage in launching satellites with a variety of technical sophistication, the risk for hijacking and manipulation through covert activity increases. A satellite's onboard computer (OBC) can allow reconfiguration and software updates, which increase its vulnerability to cyber attacks. A vulnerable satellite that will be orbiting for the next 10 years can be preset by a cyber perpetrator for unauthorized usage when needed.

Even with the most-advanced digital forensics tools, tracing a cyber attack is complicated on terrestrial computer systems, which are physically accessible. Space-borne systems do not allow physical access, thus, lack of access to the computer system nullifies several options for forensic evidence gathering. The only trace from the perpetrator is the actual transmissions and wireless attempts to penetrate the system. If these transmissions are not captured, the trace is lost.

If the adversary is skilled, it is more likely the attribution investigation will end with a set of spoofed innocent actors whose digital identities have been exploited in the attack rather than attribution to the real perpetrator. A strong suspicion would impact interstate relations, but full attribution and traceability are needed to create a case for reprisal and retaliation. Attribution can be graduated, and the level varies as to what would be accepted as an "attributed" attack. The national leadership can accept a lower level of tangible attribution, based on earlier intelligence reports and adversarial modus operandi, than the international community might demand, but it is restrained in taking action. China has had a growing interest in building cyber warfare capabilities[21] and is one of several nations that would have a sincere interest in degrading US space assets. Currently, nation-states are restrained by the political and economic repercussions of an attributed attack, but covert cyber war targeting US space assets removes the restraint of attribution.

A cyber attack resulting in a space collision would lack attribution and thus would be attractive to our covert adversaries. A collision between a suddenly moving foreign satellite and a mission-critical US satellite is neither a coincidence nor an accident. But without attribution, it does not matter that this is so obvious. Other forms of direct and indirect attack would be traceable to an attacker, which could result in military, economic, and political repercussions. In criminology we know that the major consideration of a perpetrator for premeditated acts is the risk of getting caught. The size of any repercussions if caught is secondary. If a cyber attack can destroy or disable US satellites with no attribution or traceability, it is likely to be considered by those who are openly adversaries and certainly by those who are covert. From a cyber warfare perspective, this creates an opportunity for a third party to hack and hijack a satellite with the express purpose of colliding with a mission-critical US satellite.

The attack could be either a direct collision or an indirect attack using the debris cloud from another collision. The ramming satellite can come from any country or international organization. The easiest way to perpetuate this attack would be to hijack satellites from countries less technically advanced or from less-protected or outdated systems.

The Hypervelocity Eight Ball. The term *hypervelocity eight ball* refers to the hitting of targeted satellites, directly or indirectly, with the intent to destroy the target by collision with hypervelocity objects. As previously discussed, the adversary can create a direct attack by ramming targeted US satellites with space vehicles through unauthorized cyber commands. The target for the initial step in an indirect attack may well be another satellite, part of a delivery vehicle, or space junk that will create significant debris upon impact. The collision creates hundreds or thousands of debris pieces that continue in space at high velocity. The debris cloud will affect other satellites in the collision orbit and may even initiate the Kessler Syndrome, causing proliferating damages if the threshold is reached.

Resolving the Space Challenge

While the problems and vulnerabilities in space and the means to attack space assets are significant, the United States does have options to mitigate these risks. The hypervelocity eight ball is more likely to occur if there are obsolete and inactive satellites abandoned in space that can be exploited for targeting and collision. Post-mission disposal (PMD),[22] the UN-initiated international effort to remove satellites after their productive life spans, would require satellites to be removed from space within 25 years[23] after their mission ends.[24] Naturally, it could happen earlier than 25 years, but it can also be a drawn-out process, as there are currently no tangible sanctions for noncompliance. If a satellite has a life span of 10–20 years, the additional 25-year allowance would increase the total number of years when the satellite can be remotely commanded to 35–45 years. Satellites launched in 1977, 1987, and 1997 are already technically outdated and several technology generations behind. The time between launch and end of operation for a satellite is the foundation for its cyber vulnerability. It is a sound financial decision to use a satellite to the full extent of its life span. But the question becomes Is it worth the risks? We must keep in mind technical leaps made since early space launches and what vulnerabilities could be embedded when space is populated by 25- to 45-year-old assets that can still navigate. Since technology today develops so quickly, PMD in reality increases the risk of cyber attack by hijacked satellites because it prolongs the time a satellite can be remotely commanded by radio signals exploiting obsolete and outdated communication equipment. The United States should propose shortening the PMD removal period and insist on communications updates to create secure control for all space assets.

If the peaceful and safe use of space is threatened, the United States will seek to deter and defeat aggression against space infrastructure. Preparedness to defeat attacks and operate in a degraded environment requires resilience—the ability to absorb loss of capacity while remaining operational. A single satellite can be used for intelligence gathering, all levels of military communications, and as a platform for different sensors. A specific type or design of satellite can be of critical importance and, therefore, a high-value target for adversaries to destroy. If a budget shortfall forces the United States to overutilize its satellites, it also increases the reliance on each individual satellite for war fighting and intelligence.[25] The obvious risk in an era of austerity is that budget cuts will prevail over resilience in pivotal space systems.

The 2010 *National Space Policy* requires us to "increase assurance and resilience of mission-essential functions enabled by commercial, civil, scientific, and national security spacecraft and supporting infrastructure against disruption, degradation, and destruction, whether from environmental, mechanical, electronic, or hostile causes."[26] Even in an era of federal austerity, it will be necessary to replace an aging fleet of US space assets because these assets are crucial for both commercial and national security functions. That would mean an increased number of satellites, even if the investment would create significant redundancy. This redundancy is a safeguard against the ability to operate in a degraded environment and provides vital resiliency.

Finally, the United States must adopt an active defense and probe the boundaries of cyber war in space. A limiting factor for success in defending space assets against cyber attack is regulatory constraints on information operations conducted by the DoD and related agencies. It is a policy decision that requires policy makers to understand the unique tenets of cyberspace. The unique character of cyber war will require easing restrictions on preemptive cyber warfare. If the United States can determine which satellites—active or inactive—can be used for designer collisions as a result of communication or navigational weaknesses, it can secure the disposal or safe removal of these vulnerabilities. By using active defenses, the United States increases its likelihood of detecting foreign countries trying to command satellite attacks.

The best way we can determine if the threat is real and if foreign space assets can be hijacked is to go out and try it ourselves—if only to determine possibilities. Assurance is not created by waiting for adversaries to execute their options and relying only on reactive incident response; instead, assurance requires mitigating the risks and determining the vulnerabilities. The only way to establish knowledge about foreign assets' vulnerabilities is to digitally probe their defenses. Taking an active defensive stand increases the opportunity to attribute and trace cyber attacks, which builds uncertainty among potential adversaries.

Conclusion

Attacking US satellites may well be a top priority for any potential or covert adversary, and the geopolitical benefit for successful covert attacks on US space assets is high. At the same time, the cost of entry into cyber warfare is low, which enables nation-states and nonstate actors that are unable to challenge US regional presence by conventional means to adapt and pursue unattributed cyber attacks against space assets to degrade US war-fighting ability.

Space assets are critical to the way the United States fights today, and it is likely the United States will be even more reliant on the use of space assets to maintain and defend information superiority in the foreseeable future. The fact that adversaries have not attacked, tampered with, or destroyed US satellites does not affirm their intent not to.

Cyber attacks are traditionally one shot, because they exploit a vulnerability that can be eliminated afterward or corrected by newer technology. In reality, with 3,000 satellites—active and inactive—on-orbit, it is likely some are already staged to be hijacked if needed. Any adversary might exploit the opportunity provided by a vulnerable satellite that will be orbiting for the next 10 years. Cyber attack also offers the option for an adversary not already at war with the United States to damage US satellites covertly.

The best solution is active defense: gather information and probe the vulnerabilities of US and foreign satellites, build new satellites to replace aging US space assets, maintain the full military radio spectrum to ensure secure communications, and increase the number of satellites to ensure resilience in a degraded environment. Renewal and expansion of US space assets is critical for national security over the coming decades. SSQ

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The Space Code of Conduct Debate

A View from Delhi

Rajeswari Pillai Rajagopalan

With outer space becoming increasingly crowded, congested, and contested, laying out some basic rules in the conduct of space activities by states is becoming particularly important. Establishing a code of conduct on space issues has assumed a certain gravity in recent years, leading to two documents—the *Code of Conduct for Outer Space Activities* prepared by the European Union (hereafter: EU Code) and a model "Code of Conduct" prepared by the Stimson Center. While the Stimson model is less controversial, the EU Code has gained greater attention around the world. The EU initially set a deadline of 2012 to adopt and universalize the code; however, this deadline has been set aside for the time being, given that a majority of non-EU countries have raised serious reservations. This offers other space-faring nations the time and opportunity to discuss the utility of a code in general while debating the EU Code in particular.

At the outset, it must be said that the EU has done a commendable job in laying out the rules of the road for space activities. However, the effort would have been more worthwhile had the EU worked in conjunction with other space-faring nations in creating these rules rather than attempting this unilaterally. Other countries are also interested in framing rules for proper conduct in outer space while keeping it safe and secure; the absence of an inclusive approach is threatening to this common interest. This article details some of the concerns raised in this regard and offers an Indian viewpoint on the emerging debate on a space code while bringing out the reservations that have developed in New Delhi and other capitals. It critiques the EU proposal, focusing on potential problem areas and India's objections; outlines India's views on a code of conduct for space; and concludes with some thoughts on harmonizing these differences.

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Critical Elements in Writing a Code

A rule-making effort undergoes several different stages. These include politico-diplomatic, technical, and legal steps that must be debated and a consensus reached, both within and between countries, before the rules can take shape as a legitimate and accepted code. Many of the countries in the West that have focused on the technological and safety aspects of outer space, such as space debris, have entirely underplayed the importance of politico-diplomatic endorsement from other major space-faring nations, especially the new space powers.

The EU in this regard clearly missed an opportunity to work with countries such as India, one of the earliest space powers, on an arrangement that would curtail activities that create harmful effects on civilian space assets and also developments that could contribute to a spiraling arms race in space. India has an obvious interest in writing rules of the road for space, given the fact it has at stake civilian assets and is equally concerned about the increasing trend toward weaponization of space.

For India, the debate begins with understanding the kind of space future it wants to see in Asia and thereafter shapes the norms that would guide conducive behavior and avoid activities that may be counterproductive to achieving that future. The political-diplomatic aspects of writing a code are driven by national security. As Michael Listner stated in a recent article, it has to do with the quantity of space debris created essentially during the Cold War years by the United States, Russia, Europe, and China.[1] However, given that the majority of space junk and debris was created by satellites which were used for military and security missions, countries to whom these assets belong will find it difficult, if not impossible, to allow foreign governments or other international bodies to examine or destroy such objects for fear of compromising national security or sometimes even national pride.

One could foresee political difficulties emerging over the kind of technology and hardware that would be used to destroy space junk and debris. Destruction of dysfunctional satellites will also lead to problems, with states not able to reach consensus on the procedures to be used. It is not difficult to foresee a scenario where the absence of a consultative process between the EU and other countries results in a sizeable number of countries believing that the EU Code is a Western ploy to limit the activities of other space-faring countries. This position is gaining momentum, particularly among the bureaucracies of several countries in Asia.

The second important aspect in instituting a code relates to technology, which would deal with space debris and arms control in space as well as overcrowding and congestion. If there is a political consensus among major space-faring nations on the utility of formulating a code, the technical and technological aspects of the problem will be much simpler. Several countries, including India, have been contemplating ways to remove space debris, among other issues. For example, the scientific establishment in India wants to explore the potential for using laser technology in space debris management. This illustrates the sense of commitment India has in addressing some of these issues. In fact, orbital debris remediation could potentially be an area for cooperation between India and the United States and other like-minded countries in ensuring that space becomes less hazardous to civilian uses.

The third and last component is the legal aspects that should feed into an effective code. This is important, since a set of norms which are voluntary in nature do not ensure good behavior. If there are violations of established norms and regulations, they have to be met with penalty-rooted steps through an effective legal framework. Western analysts have been critical of the Indian insistence on a legal framework along with enforcement and verification mechanisms. While insistent on a legal framework, New Delhi understands that such a framework may emerge only much later and that, many times, legal frameworks are a result of previous normative exercises.

Major Aspects of the EU Code

In 2008, the EU released its code of conduct on space, which was revised in October 2010. While the EU Code appears noncontroversial on the surface, there have already been several objections and reservations that have come about from non-EU capitals. Some of the major elements of the code are as follows:

- It seeks to codify new best practices while emphasizing transparency and confidence-building measures (TCBM) and "is complementary to the existing framework regulating outer space."
- The code would be a voluntary mechanism open to all states.
- The "inherent rights of States for collective self-defence in accordance with the United Nations Charter" will be observed.

- States that become party to the code would be bound by the existing legal arrangements. Their national programs are meant to be guided by the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies (1967); the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968); and the Constitution and Convention of the International Telecommunications Union and its Radio Regulations (2002).
- States that become signatories to the code are expected to formulate and implement national "policies and procedures to minimize the possibility of accidents in space, collisions between space objects or any form of harmful interference with other States' right to the peaceful exploration and use of outer space."
- State parties to the code are meant to pass on "information on national space policies and strategies, including basic objectives for security and defence related activities."
- States shall engage in consultations to "seek solutions based on an equitable balance of interests."[2]

Potential Problem Areas in the EU Code

The EU Code may be considered a good starting point. It lists certain desirable steps to be taken by states to avoid congestion and, thereafter, the potential for collision that would affect civilian assets in outer space. However, some of the provisions remain highly idealistic and are difficult to implement. For instance, Article 8.1 of the code says that states shall provide information on national space policies and strategies, "including basic objectives for security and defence related activities in outer space."[3] It is naïve to assume states such as the United States and China will release information about their strategies. This is not a realistic goal in the code, because states seek to use all means available for security, including space. The increasing geopolitical rivalry suggests that steps taken by China to strengthen its security vis-à-vis the United States cannot be disclosed. Similarly, with security dilemmas a constant feature in Asia, this objective remains highly idealistic. Even if some states do decide to outline their space strategies, these are likely to be more for public consumption rather than for reflecting the genuine national objectives and approaches.

Further, states that endorse the code would need to shape and thereafter prepare their national "policies and procedures to minimize the possibility of accidents in space, collisions between space objects or any form of harmful interference with other States' right to the peaceful exploration and use of outer space."[4] While this clause might sound quite innocuous, countries and multilateral organizations can read it very differently and create abundant scope for misinterpretation. Looking into history, the role of the great powers to make judgments about violations is not credible. For example, many times important nuclear nonproliferation goals were sacrificed for the sake of achieving quick geopolitical gains, as was witnessed during the Cold War years and even thereafter.

The consensual decision-making process in a large grouping may also prove problematic. The consensual principle worked during the Cold War years because the threat was limited in the scale of weapons as well as the number of countries seen as challenges. Today, the challenge has grown and become more widespread. More importantly, great-power politics have essentially hampered the process of consensual decision making (even in identifying challenges) in many international fora, despite the fact that the threat is understood and recognized by all the major powers. This will emerge as a bigger challenge in the years to come. Crisis decision making has become a feature of almost all nonproliferation issues. Under such circumstances, countries need to become innovative in identifying new ways to tackle these challenges.

Will bilateral or regional TCBMs work in the absence of global consensus? This is precisely the issue Listner tried to analyze. Meanwhile, other valuable questions merit attention. What does the code seek to achieve that is not achievable through bilateral or regional means? In fact, Listner has argued along these lines to suggest that bilateral agreements may be the best means to secure guarantees and security rather than global mechanisms.[5] History has shown that global arms control measures and arrangements have been openly flouted by state parties, as seen in the nuclear nonproliferation regime, reflecting the ineffectiveness of these arrangements. Therefore, attaching undue importance to these global norms and practices may not produce desired outcomes.

Asian Concerns

While the EU is making a last-minute effort to enlist support for universal adoption of the code, it has met with stiff resistance around the world, more specifically from Asian countries.[6] Having Asia on board is particularly important since it is there that one is likely to see future challenges to a secure space—many of the new space powers are in Asia. Europe must take into account Asian concerns if the code is to move forward. In the absence of such an effort, it is likely to have the same fate as the Hague Code of Conduct (HCOC) against Ballistic Missile Proliferation. It is also quite possible the geopolitics of Asia will dictate new terms and conditions on the space security discourse, which may not be palatable in Europe. But the geopolitical gravity of Asia is not something Europe should neglect.

China, one of the major space giants, has resisted several provisions in the EU Code. Most notably, it stated clearly that it will be "impossible" to share any information on its national space or defense policies to any outside body. In fact, an EU official—speaking recently at a conference in Paris—termed the discussions held with China in July 2011 "very difficult." However, absence of the Chinese endorsement would put several countries in the region at risk in the civilian security domain. With an unchecked China that would continue its military space activities, it would be naïve for the West to expect India to coalesce, sign on to the code, and take measures that would restrict its military options in space. Meanwhile, China has also been categorical that it cannot agree to an instrument that would affect its activities in the military space domain. This is a dichotomy in the Chinese approach, particularly since China has been active at the COPUOS (UN Committee on the Peaceful Uses of Outer Space) on the issue of space debris, whereas its military space program has continued unabated with little international scrutiny.

Similarly, there has been intense debate as to which is of greater importance, space debris or a potential arms race in space. Once again, Beijing has resisted any move to put space debris issues on the agenda, which suggests that China is likely to continue with its antisatellite (ASAT) tests.[7] China's tendency to underplay the space debris problem also suggests it plans a host of other activities that could contribute to space debris. India's options under such circumstances will be complicated. As long as China remains outside such an arrangement, India will be forced to walk a tight rope on the code. In the meantime, China has also suggested that while a code may be necessary, it should be debated by all the space-faring powers within a multilateral setting. To that extent, they see the EU effort as futile and lacking a truly multilateral dimension. This view is gaining popularity among non-EU countries and is likely to gather further steam in the near future. Such a development would compel the EU and the West in general to take notice of the Asian voice.

It will be interesting to see how Australia responds to the EU code. While Canberra has yet to take a formal position, the broad sense is it does, in principle, agree with the sentiments of the code. This is the same sentiment as other space-faring powers, including India. While there is broad agreement about the need for the code, non-EU third-world states are worried as to how the provisions will be interpreted and applied. In the case of Australia, it is also generally in agreement with the West on transparency and confidence-building measures. Meanwhile, Japan has extended full backing to the code. Hirofumi Katase, deputy secretary general in Japan's secretariat for space policy, has called upon all space-faring nations to become party to the code while endorsing it almost in its entirety.

Debate on the code is likely to undergo a major shift, depending on the kind of stance the United States adopts. There has been no formal US position on the code yet, although the State Department appears to be quite satisfied with the document. It may be willing to accept and adopt the code, obviously with several amendments. The Pentagon appears more reserved, since the code has the potential to significantly restrain US military space options. Similarly, Republicans in the US Congress have been more wary of the code, saying that the United States will be giving away too much. While there is no unified US position on the document, the prevalent view is that the United States should take charge of the EU Code, modify it significantly, and get other countries to become parties.

India's Reservations on the EU Code

While India has interests in drafting rules of the road on space issues, the EU has lost an ideal opportunity to co-opt India as a major space-faring power to shape the debate. India's interests in writing the rules are driven by the fact that it has been one of the earliest space powers and therefore should have been part of the debate. In addition, it has interests in formulating rules that would affect and curtail certain space activities. India's interests also have to do with its economic growth story that is increasingly dependent on space.

Overcrowding in space with the attendant potential for conflict is a problem not unique to the EU or to the West. This is a universal problem and should have been debated by all space-faring countries accordingly. India's concerns are growing in this regard due to the significant amount of civilian investment India has in space. For instance, India has assets worth around $37 billion, including ground-based infrastructure and value-added services, and clearly has a big stake in the safety of these assets.[8] While the economics of this investment is one aspect, the other equally important aspect for consideration is the utility of these assets in the daily lives of the people of India. India's growth story is heavily reliant on these assets, and their importance is going to grow manifold in the coming years.

As a voluntary measure the EU Code lacks the teeth to enforce it, and this potentially would make it an ineffective mechanism. For instance, while the Hague Code of Conduct is a good instrument, it is unfortunate that countries seen as "critical" with regard to missile proliferation remain outside this arrangement. Whereas there are nearly 130 state parties to this measure, a good number of countries that represent challenges—Pakistan, Iran, North Korea, and China—are not. This speaks volumes of the effectiveness of the HCOC. While the EU Code is a voluntary measure, it asks states to "establish and implement national policies and procedures" to manage the problems of space collisions. Such a requirement is perceived as intruding into a state's legitimate rights and interest, however indirect it may be.

The lack of a legal framework in addressing space security is also seen as a lacuna in the EU Code. One can be reasonably certain the United States will never become party to such a legal instrument, although the utility of institutionalizing an arrangement with legal means has to be acknowledged. The potential fear among US leaders may be that they will be sacrificing their nation's lead in the area as well as freedom of action. On the other hand, China and Russia may become parties to a legal instrument but potentially cheat on the arrangement as they continue advancing their programs. These concerns are valid, and they are not unique to the United States. States such as India will find themselves in a similar position, and concerns regarding China's military space activities are on the rise.

China has been notorious for signing on to treaties but flouting the provisions. Therefore, there is a fear that countries like India and the United States may sign on to a document and follow through its various provisions, which will even affect their defensive/offensive capabilities, whereas China may continue with its military space activities. This aspect merits attention, because even when China and Russia have co-sponsored a draft treaty on outer space activities (Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects—PPWT), which highlights weaponization of outer space, the Chinese PLA has continued unabated in its military space activities. Also, the fact that ground-based weapons that have outer space utility are not highlighted in the proposed PPWT indicates again China's intention to advance its military space program.

Lastly, issues of verification further complicate an already vexed issue. There is no good way to verify space technologies, given that they are inherently dual-use in nature. Rocket engines can be used either to boost civilian satellites into orbit and also as ASAT weapons or to launch ASAT weapons. This creates a verification nightmare for arms controllers.

India's Position on a Space Code

India has actively participated in various nonproliferation negotiations, including the Nuclear Non-proliferation Treaty (NPT), indicative of India's interest in tackling nonproliferation challenges under a multilateral umbrella. However, New Delhi has had mixed response if one were to audit its effectiveness in influencing various nonproliferation instruments. It appears yet again faced with the challenge of making effective interventions in the space security discourse. While India has enormous interest in formulating new norms and conditions, it has developed certain reservations about signing on to the EU-formulated code of conduct for space. The "not invented here" syndrome characterizes India's position on the EU Code. However, if India were to create a code, it might not look significantly different from the EU Code, although it is important that the debate would include India at the outset, giving it ownership in the instrument. Today, there is resistance to the code among both the Indian civil and military bureaucracies because they have not been part of the "creative process." The EU and the West in general need to understand that India has been a responsible space power that should have been part of the debate—shaping that debate, rather than being shaped by it. These differences—while they may seem innocuous—have significant political as well as geopolitical value, which Europe seems to be overlooking more often than not.

Similarly, India's stated position is for a legally binding mechanism, articulated in the relevant international forum. India, as a member of the Group of 21 (nonaligned nations in the Conference on Disarmament), has articulated the need for a legally binding mechanism while supporting TCBMs as good supplementary steps. TCBMs, however, provide too many loopholes allowing countries to flout rules which are voluntary in nature. Therefore, while they are good supplementary measures, they cannot compensate for the importance of legal measures, particularly from the viewpoint of implementation.

India has an interest in taking the lead in formulating the code, and such a lead is seen as beneficial in many ways, both direct and indirect. First, India's taking the lead would ensure that it prepares an instrument that is holistic in its approach and content. Such an instrument would ensure a legal framework along with execution and verification clauses, although India is realistic enough to understand that legal measures may not be the starting point and that it may have to work backward, beginning with a broad set of rules and regulations. India's insistence for a legal framework will not, however, preclude it from having its security options. This would essentially mean that India will formulate an instrument with built-in clauses to keep open its military options in space if there were to be a drastic deterioration in the security environment. India also has an incentive in this initiative because taking the lead would boost its image as a responsible space power willing to shoulder greater responsibilities in carrying out its role in administration of the global commons. In geopolitical terms, such a lead on India's part would enhance its leadership credentials and also send a message to friends and foes alike on its potential role in any security discourse. In short, while certainly interested, India's presence and participation in any dialogue should not be taken for granted, and the EU must understand these sensitivities.

A related issue likely to figure in future debates on space is the allocation of space or space property rights. There has already been disproportionate allocation of space rights to Western powers; indeed, it may not be inaccurate to say that the West has forcefully occupied space. Now that outer space is becoming more crowded with marginal (in relative terms) increases in the share from Asian and other developing countries, the developed countries appear to want to curtail development and growth of space assets by the developing countries. Because of the disproportionate occupation of space by the West, from an Indian standpoint it is now vitally important to articulate the need for an equitable space order, or rather an equitable utilization of space.

What is the Way Out?

It must be borne in mind that tackling issues and problems and not countries should become a guiding principle if there is to be a solution. This principle should ideally incorporate all space-faring countries, thereby providing an inclusive forum. An inclusive approach co-opting other countries into the debate in shaping new norms and regulations will have far-reaching impact. Creating a large political base will go a long way in ensuring the longevity of the space code instrument even though it may become an all-pervasive document including issues from space debris, to arms races in space, to equitable space order.

An American lead in the space code debate may reduce the gap between EU and non-EU capitals. While certain sections of the US government may argue for endorsement of the EU Code, differences exist among US bureaucracies. The United States could potentially take the lead in bringing other countries to the table and debate the concerns and issues. If India and the United States decide to work together, more can be achieved than by the EU making any last-minute effort to gather support.

Can states around the world agree to an "Intergovernmental Panel on Climate Change" model of experts to address space issues? Given that space debris or an arms race in space are universal problems confronting every nation-state, the idea of constituting a panel of experts under the aegis of the United Nations may be a good starting point. This may be the kind of inclusive mechanism India should aim for while making an effort to enlist the support of other key space-faring countries.

Obviously space traffic management is at the core of the entire issue. Countries could mull over new initiatives along the lines of the International Civil Aviation Organization (ICAO). Letting technical experts handle issues is one way to reduce political salience and competition.

Also, is the Conference on Disarmament (CD) still a relevant forum to discuss and debate space security? More than a decade has passed since the CD debated and moved forward on important security issues. Given such a track record, it is time to consider alternate venues to tackle these challenges. The ICAO model may be appropriate, since overcrowding, industrialization, and weaponization of space and management of space traffic have become critical issues.

One has to think of new platforms outside the CD, given the problems with the consensual decision-making process in the CD. Can there be a major grouping of space-faring powers similar to the P-5 who are the nuclear weapon countries recognized by the NPT? Such a grouping might be keener on making decisions and moving forward than any other conceivable forum.

Finally, the EU has to recognize that geopolitics has significant value in determining and shaping norms and establishing practices. In this regard the geopolitical weight of Asia may be in a position to dictate new terms and conditions in formulating these norms and practices. Getting as many Asian countries as possible on board would be a major plus if the EU is keen on pushing an agenda. This is also important considering the increasing trend toward securitization of geopolitics in Asia. Therefore, the EU must listen and understand the Asian realities and concerns. SSQ

Notes

1. Michael Listner, "The Legal and Political Issues of Space Debris Removal," *OnOrbitWatch*, n.d., http://www.onorbitwatch.com/feature/legal-and-political-issues-space-debris-removal.

2. *Draft Code of Conduct for Outer Space Activities* (Brussels: Council of the European Union, 3 December 2008), 5–7, http://www.eu2008.fr/webdav/site/PFUE/shared/import/1209_CAGRE_resultats/Code%20of%20Conduct%20for%20outer%20space%20activities_EN.pdf.

3. Ibid., 10.

4. Ibid., 8.

5. Michael Listner, "A Bilateral Approach from Maritime Law to Prevent Incidents in Space," *Space Review*, 16 February 2009, http://www.thespacereview.com/article/1309/1.

6. Even newer space-faring powers, such as South Africa, have resisted the EU Code because they have not been party to its creation process. It should be remembered that South Africa started its space program in a concerted manner only in 2007.

7. For details, see Rajeswari Pillai Rajagopalan, *Debate on Space Code of Conduct: An Indian Perspective*, Occasional Paper no. 26 (New Delhi: Observer Research Foundation, October 2011), http://www.orfonline.org/cms/sites/orfonline/modules/occasionalpaper/attachments/ocp26_1319777951241.pdf.

8. Subrahmanyan Chandrasekhar, "The Emerging World Space Order and Its Implications for India's Security," in *South Asia at a Crossroads: Conflict or Cooperation in the Age of Nuclear Weapons, Missile Defense, and Space Rivalries*, eds. Subrata Ghoshroy and Goetz Neuneck (Baden-Baden, GE: Nomos Verlagsgesellschaft, 2010), 219–20.

Book Reviews

National Security Space Strategy Considerations by Rick Larned, Cathy Swan, and Peter Swan. Lulu, 2010, 108 pp., $9.95.

Just in time to accompany the February 2011 release of the *National Security Space Strategy* (NSSS) by the Department of Defense, three former Air Force officers produced a thoughtful compendium exploring the intersection of national security space issues and strategy implementations. This monograph does not take a narrow view of NSSS considerations. Rather, it examines a broad swath, providing a solid overview of the strategic context in which the DoD employs national security space systems. The perspectives on US national security space capabilities presented in this book clearly reflect the extensive military backgrounds of the three authors. Larned retired from the Air Force as a brigadier general, Cathy Swan retired as a colonel, and Peter Swan is a retired lieutenant colonel. General Larned's official biography lists a diverse array of leadership positions within multiple corners of the national security space arena. Both Peter and Cathy Swan have PhDs. Clearly, this book springs from a deep reservoir of knowledge and experience within the field.

Up front, it is important to mention that the recently released *National Security Space Strategy* has not precluded the need for a book of this nature, nor does it detract from the quality of this specific work. But the reader must take care to read this for what it is, not for what he or she may want it to be. Whereas the official strategy focuses on reconciling ends, ways, means, and the associated risks with the strategic environment, this book looks beyond those elements to the myriad tangential concerns that shape (and are shaped by) the *National Security Space Strategy*. The monograph does this through recognition that any national-level strategy is a fluid and responsive living document. Understandably, this strategic discussion is a delicate ballet due to security classification issues inherent in many facets of national security space programs and projects. Therefore, some of the concepts receive light treatment, with broad assertions that the uninitiated reader must take on faith and that seasoned NSS practitioners should already understand.

The central thesis is the need for a broad, robust, and updated NSSS. The authors offer a sequential model, starting at the current environment for strategy formulation and proceeding to the operational-level implementation of such a strategy. This model then bases the NSSS in the context of emerging threats, current military space doctrine, and existing space policy (though the book was presumably written and released prior to release of the *2010 National Space Policy*: no mention is made of that document). From this foundation, the monograph moves briskly through the strategy model. The title undersells the range of the book; it actually covers at least one echelon in each direction beyond what is appropriate for an NSSS. The model and discussion segment the prospective NSSS into three components—acquisition, operations, and sustainment strategies—and provides recommended measures of effectiveness (MoE) related to performance in each of these areas. These MoEs are perhaps the single most valuable aspect of the monograph to the well-versed NSSS advocate. The book includes a synopsis of relevant studies performed in national security space acquisition, operations and sustainment culled from the last two decades, though the research presented is not exhaustive and no discriminating factors are provided for the particular selections. The piece closes with nine "red herrings," myths the authors wish to dispel about national security space strategy.

One major flaw of this work is that it tries to cover too much ground in too few pages. For example, it initially expands the conventional definition of "national security space" to include civil, commercial, and launch infrastructure in addition to that of the DoD and intelligence community. However, after this initial expansion, little time is devoted to the implications of including the larger national space community under the national security space umbrella, and the effects this inclusion may have on the acquisition, operations, and sustainment of national security space systems are not explored in any meaningful detail. In this way the authors have established the broadest domestic space definition possible, but they do not investigate the higher-order effects caused by competing ends and dispersed resources, nor the risks inherent in such a strategy. This exposes a shortcoming based in the authors' extensive, but exclusively military, backgrounds—not exploring the proposed strategy's impacts on civil or commercial space enterprises. Additionally, the conclusions reached for each strategic component (acquisition, operations, and sustainment) are largely consistent with the concepts put forth by senior DoD leaders on the topic of national security space. While the authors succeed in validating these needs, they stop short of providing novel suggestions for meeting them. It is unclear how a new strategy couched in the same elements will provide significant solutions to the problems facing national security space systems.

"National security space strategy considerations" are an ambitious undertaking, worthy of a longer and deeper treatment than this book provides. Two welcome improvements to this think piece would be to expand discussion throughout on the included topics and to outline a more intricate model of the strategic approach. By evolving this model into a more appropriate, higher-order one that perhaps recognizes the recursive relationship between many of the concepts outlined, the authors could better present the true complexity of their endeavor. Further, these improvements would bear out the sometimes tangential nature of the monograph. This slender volume in the national security space discussion is best suited for those new to any of the national security space establishments and organizations or as a survey-level introductory piece for middle- to senior-level leaders of all services, branches, and backgrounds who should be familiar with the military space program. Inclusion in joint professional military education curricula would be immensely beneficial to the students, though many of the traditional elements of national strategies (ends, ways, means, and risks) are not covered in great detail here.

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Asia's Space Race by James Clay Moltz. Columbia University Press, 2012, 288 pp., $35.00.

In his latest book, James Clay Moltz of the Naval Postgraduate School offers a comprehensive historical and contemporary analysis of the rise of Asia's 14 leading space power nations. His research is founded on discussions with regional experts at several international conferences as well as more-focused interviews through travel to China, Japan, and South Korea. This book stands out as a unique and informative study due to its regional focus while not ignoring prospective effects on the global scene.

Asia's Space Race is particularly timely in light of the 2011 US *National Security Space Strategy*'s recognition that "Space, a domain that no nation owns but on which all rely, is becoming increasingly congested, contested, and competitive." By most recent accounts, more than 40 nations own an orbiting satellite outright or through a partnership. Moltz focuses on 14 nations in a single region, of which all but one—North Korea—are space-faring nations today. He highlights the element of competition as a major catalyst for Asian growth in the space domain, whether for economics, security, or prestige. With China's release of its latest white paper, *China's Space Activities in 2011*, on 29 December, his timing could not be better.

In determining what constitutes a space program, Moltz settles on "a continuum starting on one end with possession of some space-related capability" (read North Korea in terms of its long-range missile capability) to the other end of the scale, where a nation possesses "a full spectrum of civil, commercial, and military space assets" (read China). With these criteria in mind, the author focuses on the four leading Asian space programs of Japan, China, India, and rising South Korea. Moltz highlights three historical motivations for countries to aspire to space power status: progress in science and technology, national security, and pride or prestige on an international level. All three were evident in the space race between the United States and the Soviet Union during the Cold War; likewise, these same motivations are apparent in the 14 Asian nations of this study.

Moltz extends his analysis to 10 additional emerging national space programs in the region, extrapolating historical and contemporary factors unique to each. In no particular order, save alphabetical, he examines Australia, Indonesia, Malaysia, North Korea, Pakistan, the Philippines, Singapore, Taiwan, Thailand, and Vietnam. He takes a methodical approach to compare and contrast each against the others as well as to the lead four and provides a historical perspective with regard to space, in some cases reaching back to humble beginnings during the Cold War–era space race between the United States and the Soviet Union. He analyzes current space politics with a focus on civil and commercial space dynamics, military space activities where evident, and finally in the area of regional prestige and cooperation.

How each nation achieved its current space power is as varied as each country's history, culture, politics, and education system. Some achieved space prowess as net recipients of technology from other countries, others on the backs of established space powers, while still others have their origins in technological or military (national security) needs. Likewise, each country has had differing relationships with the United States, the Soviet Union (and now Russia), and European nations in terms of space cooperation. More than once, Moltz points out the effects US sanctions and tightening of International Traffic in Arms Regulations have had on budding space nations and US commercial opportunities.

Moltz posits that Asia's lack of cooperation stems from its culture. This is not to say Asians are uncooperative by nature, but more precisely, Asian culture holds prestige at a premium, both collectively and individually. "Asia's space powers are largely isolated from one another, do not share information, and display a tremendous *divergence* of perspectives regarding their space goals and a tendency to focus on *national* solutions to space challenges and policies of self-reliance rather than on regionwide policies or multilateral approaches" (emphasis in original). This is in stark contrast to the cooperation exhibited by the 18 countries that comprise the European Space Agency.

The underlying theme of this study is whether Asia will have a space race of its own—albeit for different motives and under different circumstances than that of the Cold War superpowers—and what the potential positive and negative security outcomes would be if such a race were to develop. To avoid potential negative implications, Moltz offers possible bridging approaches to enhance cooperation in the areas of civil, commercial, and security (military) space among Asian space powers and the global community.

This articulate, comprehensive book provides illuminating insight into a region on the space-power fast track that is well worth reading for anyone with an eye toward security implications for the global domain of space. Policy analysts, international relations specialists, and academicians alike will benefit from this captivating study on Asian past, present, and potential future activities in the space realm and what these could mean for global security.

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