WHAT IS SPACEPOWER AND DOES IT CONSTITUTE A REVOLUTION IN MILITARY AFFAIRS?

A confluence of trends and recent developments has elevated national security space issues close to the top of the American defense policy agenda. During 2000, national security space issues were carefully examined in three of the most important congressionally mandated studies ever convened on this subject: The National Reconnaissance Office (NRO) Commission, the National Imagery and Mapping Agency (NIMA) Commission, and the Commission to Assess National Security Space Management and Organization (Space Commission).[1] These studies—along with the arrival of the George W. Bush Administration; the installation of Donald H. Rumsfeld as Secretary of Defense; and ongoing sweeping changes in senior military leadership positions including General Richard B. Myers as the new Chairman of the Joint Chiefs of Staff, General John P. Jumper as the new Chief of Staff of the Air Force, and General Lance W. Lord in the new four-star billet as commander of Air Force Space Command—create an outstanding opportunity to examine current national security space issues and to place them into a broader context. Accordingly, this paper attempts to outline answers to two fundamental questions concerning the relationship between space and national security: 1) what is spacepower? and 2) does spacepower constitute a revolution in military affairs?

WHAT IS SPACEPOWER?

"Spacepower" is literally a cosmic concept that is complex, indeterminate, and intangible. It is pregnant with a range of possibilities but it means so many different things to different people and groups that the concept is fraught with ambiguity. Confusion swirls on the semantic level because there is no commonly accepted definition or accepted wording for this concept.[2] There is not even agreement on basic issues such as where the atmosphere ends and space begins.[3] Yet, despite these weaknesses in the conceptual foundation for spacepower, a strong and widespread recognition of the growing importance of space to national security has developed. Indeed, this is a central theme in much of the recent literature such as the Space Commission Report, Barry D. Watts' *The Military Use of Space*, Steven Lambakis' *On the Edge of Earth*, Everett C. Dolman's *Astropolitik* and Robert Preston's *Space Weapons: Earth Wars*.[4] In addition, spacepower has figured very prominently in several of the most recent Title X wargames conducted by the U.S. Army and Air Force.[5]

This paper highlights the emerging consensus on space's growing importance but takes a wide-ranging perspective on the attributes that comprise spacepower, sees the elements of spacepower as interrelated and multidimensional, and emphasizes that the determinants of space's strategic utility go beyond just international military competition. It first looks at ways to categorize spacepower such as space activity sectors, military space mission areas, and David Lupton's four military space doctrines. Then, it examines a broad range of factors that shape our perceptions of space. Throughout, it argues that economic factors now shape spacepower in fundamental ways, primarily due to rapid growth in commercial space activities and the inherently dual-use nature of many space systems.

Ways to Categorize Spacepower

Space Activity Sectors. The attributes of spacepower are often described using four sectors of space activity: civil, commercial, military, and intelligence.[6] The Space Commission Report provides an outstanding, current, and comprehensive overview of the types of activities that are contained in each sector and how they contribute to national security:

> *Civil Space Sector*. The civil space sector is approaching a long-standing goal of a permanent manned presence in space with the deployment of astronauts to the International Space Station. The U.S. has shouldered the largest share of development and funding for this effort. Because it is an international program, however, its benefits for scientific research, experimentation and commercial processes will be widely shared. The number of countries able to participate in manned space flight has grown substantially. In addition to the U.S. and the USSR (now the Russian Federation), 21 other countries have sent astronauts into orbit in U.S. and Russian spacecraft. The People's Republic of China has announced its intention to become the third nation to place human beings in orbit and return them safely to earth. Other research and experiments in the civil sector have many applications to human activity. For example, civil space missions to understand the effects of the sun on the earth, other planets and the space between them, such as those conducted by the Solar Terrestrial Probe missions, will help in the development of more advanced means to predict weather on earth.
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> *Commercial Space Sector*. Unlike the earlier space era, in which governments drove activity in space, in this new era certain space applications, such as communications, are being driven by the

commercial sector. An international space industry has developed, with revenues exceeding $80 billion in 2000. Industry forecasts project revenues will more than triple in the next decade. Whereas satellite system manufacturing once defined the market, the growth of the space industry today, and its hallmark in the future, will be space-based services. The space industry is marked by stiff competition among commercial firms to secure orbital locations for satellites and to secure the use of radio frequencies to exploit a global market for goods and services provided by those satellites. International consortia are pursuing many space enterprises, so ascertaining the national identity of a firm is increasingly complex. The calculations of financial investors in the industry and consumer buying habits are dominated by time to market, cost and price, quantity and quality. It is a volatile market.

Nevertheless, as a result of the competition in goods and services, new applications for space-based systems continue to be developed, the use of those products is increasing and their market value is growing. Space-based technology is revolutionizing major aspects of commercial and social activity and will continue to do so as the capacity and capabilities of satellites increase through emerging technologies. Space enters homes, businesses, schools, hospitals and government offices through its applications for transportation, health, the environment, telecommunications, education, commerce, agriculture and energy.

Space-based technologies and services permit people to communicate, companies to do business, civic groups to serve the public and scientists to conduct research. Much like highways and airways, water lines and electric grids, services supplied from space are already an important part of the U.S. and global infrastructures. The most telling feature of the new space age is that the commercial revolution in space has eliminated the exclusive control of space once enjoyed by national defense, intelligence and government agencies. For only a few thousand dollars, a customer today can purchase a photograph of an area on earth equal in quality to those formerly available only to the superpowers during the Cold War. Commercial providers can complement the photographic images with data that identify the location and type of foliage in an area and provide evidence of recent activity there. They can produce radar-generated maps with terrain elevations, transmit this information around the globe and combine all of it into formats most useful to the customer. This service is of increasing value to farmers and ranchers, fisherman and miners, city planners and scientists.

Defense Space Sector. Space-related capabilities help national leaders to implement American foreign policy and, when necessary, to use military power in ways never before possible. Today, information gathered from and transmitted through space is an integral component of American military strategy and operations. Space-based capabilities enable military forces to be warned of missile attacks, to communicate instantaneously, to obtain near real-time information that can be transmitted rapidly from satellite to attack platform, to navigate to a conflict area while avoiding hostile defenses along the way, and to identify and strike targets from air, land or sea with precise and devastating effect. This permits U.S. leaders to manage even distant crises with fewer forces because those forces can respond quickly and operate effectively over longer ranges. Because of space capabilities, the U.S. is better able to sustain and extend deterrence to its allies and friends in our highly complex international environment. Space is not simply a place from which information is acquired and transmitted or through which objects pass. It is a medium much the same as air, land or sea. In the coming period, the U.S. will conduct operations to, from, in and through space in support of its national interests both on earth and in space. As with national capabilities in the air, on land and at sea, the U.S. must have the capabilities to defend its space assets against hostile acts and to negate the hostile use of space against U.S. interests.

Intelligence Space Sector. Intelligence collected from space remains essential to the mission of the Intelligence Community, as it has been since the early 1960s. Then the need to gain access to a hostile, denied area, the USSR, drove the development of space-based intelligence collection. The need for access to denied areas persists. In addition, the U.S. Intelligence Community is required to collect information on a wide variety of subjects in support of U.S. global security policy. The Intelligence Community and the Department of Defense deploy satellites to provide global communications capabilities; verify treaties through "national technical means"; conduct photoreconnaissance; collect mapping, charting, geodetic, scientific and environmental data; and gather information on natural or man-made disasters. The U.S. also collects signals intelligence and measurement and signature intelligence from space. This intelligence is essential to the formulation of foreign and defense policies, the capacity of the President to manage crises and conflicts, the conduct of military operations and the development of military capabilities to assure the attainment of U.S. objectives.[7]

Military Space Mission Areas. Another important typology for describing spacepower was first adopted by the U.S. military in the 1980s and still provides a foundational and consistent framework to categorize the military missions that contribute to spacepower.[8] Under this typology, **space support** is a very broad category that contains all activities that enable military space mission accomplishment. Space support includes the development and acquisition of all military space hardware and software; all the infrastructure required to launch, track, and command military space systems; and all the personnel and the education and training systems required to sustain military space activities. **Force enhancement** is the primary emphasis of today's military space forces. This mission refers to all military space activities that help to increase the warfighting effectiveness of terrestrial forces and is sometimes referred to as "space support to the warfighter." Force enhancement is further divided into the following areas: geodesy, weather, communications, navigation, early warning and attack

Table 1: Force Enhancement Mission Areas, Primary Orbits, and Associated Space Systems[9]

Geodesy	Meteorology	Communications	Navigation	Early Warning and Attack Assessment	Surveillance and Reconnaissance
Low-Earth Orbit (LEO)	Polar LEO	Geostationary Orbit (GSO)	Semi-synchronous Orbit	GSO and LEO	Polar LEO and GSO
Landsat	Defense Meteorological Support Program (DMSP), National Polar-Orbiting Operational Environmental Satellite System (NPOESS)	Defense Satellite Communications System (DSCS) II, DSCS III, Ultra-High Frequency Follow-on (UFO), Milstar, Global Broadcast System (GBS), Advanced Extremely High Frequency (AEHF), Wideband Gapfiller Satellite (WGS)	Global Positioning System (GPS)	Defense Support Program (DSP), GPS, Space-Based Infra-Red System (SBIRS) High and Low	Keyhole (KH) Series, Signals Intelligence (SIGINT) Satellites, Future Imagery Architecture (FIA), Integrated Overhead SIGINT Architecture (IOSA)

assessment, and surveillance and reconnaissance. Table 1 lists current and near-term space systems most closely associated with each of these six mission areas. There is widespread consensus on the elements that constitute these two military space mission areas and general agreement that the United States should perform these types of missions from space.

By contrast, there is much less consensus on the types of functions that would be required for space control and force application or on the need for the U.S. military to perform such missions. **Space control**, refers to "the ability to assure access to space, freedom of operations within the space medium, and an ability to deny others the use of space, if required."[10] The use of anti-satellite (ASAT) weapons is one commonly discussed space control mission, but a wide range of missions—including conventional or unconventional attacks on terrestrial telemetry, tracking, and controlling (TT&C) facilities—would also fall into the space control area. The final category, **Force application** is usually defined as the use of military force to, from, or within space where the primary objective is to affect the course of terrestrial conflict directly. Space-based ballistic missile defense (BMD) is often discussed as the most important near-term force application mission. Most military space activities fit into one of these four categories and, of course, most of today's military space activities are in the first two categories: space support and force enhancement.

Lupton's Four Military Space Doctrines. The four military space doctrines developed by David Lupton in *On Space Warfare* provide an important and comprehensive way to analyze the strategic rationale behind military space activities (they are summarized in Table 2 below).[11] The **sanctuary** doctrine builds on President Dwight Eisenhower's concepts of "open skies" and "space for peaceful purposes" by emphasizing that space systems are ideal for monitoring military activity, providing early warning to reduce the likelihood of surprise attack, and serving as National Technical Means of Verification (NTMV) to enable and enforce strategic arms control. The basic tenet of the sanctuary doctrine is that space surveillance systems make nuclear wars less likely. Sanctuary doctrine is closely linked to deterrence theory and the assumption that no meaningful defense against nuclear attack by ballistic missiles is possible. Sanctuary doctrine advocates believe that overflight and remote sensing enhance stability and that space must be kept a weapons-free zone to protect the critical contributions of space surveillance systems to global security. **Survivability**, Lupton's second space doctrine, emphasizes broad utility for military space systems, not only at the strategic level emphasized in the sanctuary doctrine, but also at the tactical level of space support to the warfighter that has emerged as the most important force enhancement mission since the end of the Cold War.

Table 2: Attributes of Military Space Doctrines

<table>
<tr><th></th><th>Primary Value and Functions of Military Space Forces</th><th>Space System Characteristics and Employment Strategies</th><th>Conflict Missions of Space Forces</th><th>Appropriate Military Organization for Operations and Advocacy</th></tr>
<tr><td>Sanctuary</td><td>• Enhance Strategic Stability
• Facilitate Arms Control</td><td>• Limited Numbers
• Fragile Systems
• Vulnerable Orbits
• Optimized for NTMV mission</td><td>• Limited</td><td>NRO</td></tr>
<tr><td>Survivability</td><td>Above functions plus:
• Force Enhancement</td><td rowspan="3">• Redundancy
• Hardening
• On-Orbit Spares
• Crosslinks
• Maneuver
• Less Vulnerable Orbits
• Stealth
• Reconstitution Capability
• Defense
• Convoy</td><td>• Force Enhancement
• Degrade Gracefully</td><td>Major Command or Unified Command</td></tr>
<tr><td>Control</td><td>• Control Space
• Significant Force Enhancement</td><td>• Control Space
• Significant Force Enhancement
• Surveillance, Offensive, and Defensive Counterspace</td><td>Unified Command or Space Force</td></tr>
<tr><td>High Ground</td><td>Above functions plus:
• Decisive Impact on Terrestrial Conflict
• BMD</td><td>Above functions plus:
• Decisive Space-to-Space and Space-to-Earth Force Application
• BMD</td><td>Space Force</td></tr>
</table>

The survivability doctrine also differs from the sanctuary doctrine because it highlights space system vulnerabilities and questions whether space can be maintained as a sanctuary due to ongoing technological improvements in systems such as ASAT weapons. Lupton's **control** doctrine is analogous to military thinking about sea or air control and asserts the need for control of space in order to apply spacepower most effectively. Thus, the control doctrine sees space as similar to other military environments and argues that both commercial activities and military requirements dictate the need for space surveillance, as well as offensive and defensive counterspace capabilities. Lupton's final doctrine, **high ground**, argues that space is the dominant theater of military operations and is capable of affecting terrestrial conflict in decisive ways. As a primary example of such capability, the high-ground doctrine points to the potential of space-based BMD to overturn the dominance of offensive strategic nuclear forces.

Factors that Shape Our Perceptions of Spacepower

A number of less tangible factors, including some that are not directly related to national security, may also help to shape our perceptions of spacepower in more subtle yet important ways. Due to the rapid growth of the commercial space sector during the last decade, economic considerations such as whether space has become an economic center of gravity and its role as a global utility are now key factors in shaping our perceptions about spacepower. As discussed below, other major factors that shape our perception of spacepower include seapower and airpower analogies, the frontier analogy, and the overview effect.

Space as an Economic Center of Gravity and a Global Utility. The most important set of factors that shape our perceptions of spacepower relate to the growing commercial importance of space, claims that it constitutes an economic center of gravity (COG), and its emergence as a global utility. Perceptions on the importance of these factors vary considerably but they nonetheless became a central theme in United States Space Command's (USSPACECOM) public discourse during the latter half of the 1990s. This emphasis was most pronounced during the tenure of General Howell M. Estes as Commander-in-Chief of USSPACECOM (CINCSPACE); continued during the tour of General Richard B. Myers; but, interestingly, has not been repeated thus far by General Ralph E. Eberhart, the current CINCSPACE. The increased use of the term COG to describe the commercial space sector coincided with rapid actual growth in commercial space activities in this period but it was predicated even more directly on projections of exponential growth. Forecasts during 1997 and 1998 called for growth at a "blistering rate of 20 percent a year" to support a "gold rush in space."[12]

> 550 satellites today are in Earth orbit, performing numerous critical defense and civil functions. Nearly half of them belong to the US, and half of those are commercial. US space investment now exceeds $100 billion, and the stakes are about to go higher.

> Expectations are that the US and the world's other spacefaring nations, over the next five years, will pump another $500 billion into space. They will launch at least 1,000, and possibly 1,500, new satellites. Most will be commercial systems. Many will have military significance.
>
> "We'll see commercial use of space go out of sight," said USAF's Chief of Staff, Gen. Michael E. Ryan.[13]

General Estes developed and articulated one of the most powerful visions for space of any CINCSPACE to date. Early in his tenure (August 1996-August 1998) he began emphasizing the emergence of space as an economic COG at virtually every opportunity. In one of his earliest and most sweeping speeches, delivered at the United States Space Foundation's annual symposium in April 1997, he introduced several major themes he would reiterate in speeches and in reports during the remainder of his term:

> Today, more than ever, it is important that all Americans understand that our investment in space is rapidly growing and soon will be of such magnitude that it will be considered a vital interest—on par with how we value oil today. . . .
>
> Now while it might seem appropriate that I should be more concerned with military space, I must tell you that it is not the future of military space that is critical to the United States—it is the continued commercial development of space that will provide continued strength critical for our great country in the decades ahead. Military space, while important, will follow.
>
> Commercial space, as I said earlier, will become an economic center of gravity, in my opinion, in the future and as such will be a great source of strength for the United States and other nations in the world. As such, this strength will also become a weakness, a vulnerability. And it's here that the U.S. military will play an important role, for we will be expected to protect this new source of economic strength.[14]

Space as an economic COG was also an important theme in the *Long Range Plan*, the most important report USSPACECOM released during General Estes' tenure:

> Space capabilities are becoming absolutely essential for military operations, national commerce, and everyday life. In fact, space is emerging as a military and economic center of gravity for our information-dependent forces, businesses, and society. Life on earth is becoming inextricably linked to space. . . .
>
> Although the notion of space as a sanctuary appears seductive to many, our increasing reliance on space systems, and information derived from space, creates a center of gravity potential adversaries clearly understand. Protection takes on a new dimension as non-DoD systems (commercial and third-party) become even more integrated into plans for using joint forces.[15]

General Estes linked his vision of a growing commercial space sector as a burgeoning economic COG directly to the assumption that this growth would prompt calls for an increased military role in protecting "this new source of economic strength." The logic of this "flag follows trade" argument is clear and has historical precedents but to date it has not yet prompted any significant calls for better protection.[16] If anything, the general attitude of the commercial space industry has thus far minimized threats to their systems and denied the need for better military protection.[17] It is currently unclear that military means are the best way to protect commercial satellites or that the military will be called upon to build a more robust space infrastructure based on perceived threats to commercial systems.

Despite the industry's tepid response, the Air Force continued to emphasize the flag follows trade route to a greater military space presence. General Estes was an influential member of the Air Force's General Officer "Board of Directors" that agreed following a CORONA meeting in November 1996 to issue *Global Engagement*—a sweeping new vision statement for the Air Force. This statement corresponded closely with his perception of the importance of space to the nation and asserted that the Air Force is "now transitioning from an *air* force into an *air and space* force on an evolutionary path to a *space and air* force."[18] In a related bureaucratic move, General Estes also attempted to have space designated as an "area of responsibility" (AOR) similar to the AORs assigned to regional commands by the Unified Command Plan (UCP). As a result, CINCSPACE was designated as the single focal point for all military space operations, but the 1998 UCP stopped short of his recommendation to make space a dedicated AOR.[19] After retiring, General Estes became even more outspoken in his assessments, "declaring that anyone who does not believe that space is emerging as 'an economic center of gravity for our country . . . [is] not paying attention' to what is going on. 'It is a fact—lots and lots of money [is] going to space worldwide and lots of investment in this country.'"[20]

General Richard B. Myers, General Estes' successor as CINCSPACE, was confirmed as Chairman of the Joint Chiefs of Staff in 2001. He served as CINCSPACE from July 1998 until February 2000 when he became Vice Chairman of the Joint Chiefs of Staff. General Myers generally reiterated General Estes' emphasis on space as an economic COG but added three important changes: first, that space was already a COG; second, that space was a *military* and economic COG; and third, that United States reliance on commercial space had created vulnerabilities easily exploited by potential adversaries. One of his first pronouncements along these lines came in Los Angeles at the Air Force Association Space Symposium in November 1998: "space has become a military and economic center of gravity. So much of the world's standard of living, so much of its commercial wealth depends on space."[21] Later in his tenure, General Myers put more emphasis on how U.S. reliance on commercial space was creating new vulnerabilities: "Clearly, our reliance on commercial space has created a new center of gravity that can easily be exploited by our adversaries."[22] Just before leaving his CINCSPACE tour, General Myers summarized his position and emphasized the importance of space control in an editorial for *Aviation Week & Space Technology*:

> Space is a military and economic center of gravity. We can't afford to take it for granted. Only through a robust space control and modernization vision can we thwart military or terrorist attacks, and manage the space "gold rush," while continuing to reap tremendous benefit, both in economic and national security terms.[23]

The current CINCSPACE, General Ralph E. Eberhart, assumed his position in February 2000. In his speeches and reports thus far he has usually avoided using the term COG to describe the economic and military importance of space and, in general, he has not placed as much emphasis on the growth and importance of the commercial space sector as did his predecessors. General Eberhart's approach reflects the recent slowdown in commercial space, gave some support to the Air Force's emphasis on the aerospace concept and aerospace integration in its June 2000 vision statement, *Global Vigilance, Reach & Power*, and is in line with the major recommendations in the Space Commission report.[24] The Air Force's 2000 vision statement attempted to move the Service "Back to the Future" by returning to "aerospace" (a concept originally articulated by Chief of Staff Thomas D. White in the 1950s) and abandoning the separate "air and space" construct that was introduced in June 1992 and emphasized in the November 1996 *Global Engagement* vision.[25] Instead, General Eberhart has stressed personnel issues such as retention problems; the command's efforts to come to grips with its newest missions, computer network defense (CND) and computer network attack (CNA); and, especially, the need for space control.[26] He also recommended the formation of a Space Tactical School to "develop space warfare concepts" and has created the "Space Aggressor Squadron, whose job it is to play against the Air Force and other services in wargames such as Red Flag and to heighten both military and civilian awareness of the threat[.]"[27] One of the best illustrations of these subtle changes in emphasis came in General Eberhart's November 2000 interview in *Aviation Week & Space Technology*:

> Integration has been exactly the right thing to concentrate on these last 5-10 years, as we tried to harness the national systems post-[Operation] Desert Storm. . . . The fact that we heard so much about [the need for integration] after Desert Storm, and didn't after Kosovo, tells me that we're on the right track. Now, we need to make sure we can protect the capabilities that resulted from that integration. . . . I don't think we would be good stewards of space if we only thought about 'integration.' We also need to be spending resources and intellectual capital on space control and space superiority. . . . The importance of space control and space superiority will continue to grow as our economy become more reliant on space. . . . If we only look at space in terms of 'integration,' in my view, we'll fall into the same trap we fell into with the airplane. . . . We [initially] thought of it in terms of intelligence, surveillance, reconnaissance, communication and weather [support]. If we only think of space in these ways, [it's just] a 'higher hill' as opposed to a center-of-gravity. We [also] have to be able to surveil, protect and negate under this space control mission.[28]

But is commercial space truly an economic COG for the United States? More than most, commercial space is a volatile industry that been through several boom and bust cycles and has often delivered less than promised. It is also highly complex because it is closely tied not only to economic cycles but also to many other factors such as technological developments, international politics, and domestic regulation. USSPACECOM's assertions during 1997-99 that space is an economic COG were made based on projections drawn from the commercial space sector's strongest ever growth cycle. The "gold rush" mentality of firms seeking competitive niches in the communications spectrum or in specific markets reinforced perceptions that commercial space would remain in a cycle of continuing upward acceleration. The resulting projections too often relied on best-case scenarios rather than more somber economic analysis and they also suffered from the lack of an objective and timely overall market survey. Analysts currently have far better insight into these issues due to the slower actual development of the markets over of time and the Futron Corporation's new annual *Satellite Industry Guide* helps to address the later problem.[29] Futron's guide, based on their proprietary database and published in partnership with the Satellite Industry Association and George Washington University's Space Policy Institute, uses a "consistent and reliable set of industry metrics based on primary research data" to provide a comprehensive survey of where the industry has been and where it is heading.[30]

Space activities clearly enhance and enable many economic activities; space should undoubtedly be considered a strategic sector of the global information infrastructure and the world economy. Using the Futron data to analyze the current status and trends of the commercial space sector, however, one overarching conclusion immediately jumps out: as of the end of 2000, commercial space activity simply did not develop in the directions and magnitude projected as recently as two years ago. Despite the significant growth of the commercial space sector in the second half of the 1990s, the trajectory of actual developments fell significantly short of the projected vector ($500 billion investment and 1000-1500 launches by 2003) that had been touted in forecasts as late as the end of 1998.

Where does the commercial space sector fall within the big picture context of the overall U.S. economy? Aerospace corporations form an important part of the economy but in pure dollar terms they—like any other single industry—are simply not a dominant sector or an economic COG in terms of overall value, revenues, or market capitalization. The main reason for this is the huge size of the U.S. gross domestic product (GNP). The Commerce Department estimated the 2000 U.S. GDP at $9.873 trillion, a value that dwarfs the value of any individual sector.[31] Anyone watching the financial markets during the past several years knows that revenues and market valuations are highly volatile; but, while growing, space-only revenues and valuations have never yet been that big a part of the U.S. economy at any time or under any classification scheme. Consider revenues: the 2001 *Fortune Magazine* list of the top 500 U.S. corporations by revenue does show a scattering of aerospace companies among the top 100 firms—Boeing at number 15, Motorola at 34, United Technologies at 64, Lockheed Martin at 69, Honeywell at 71, and the AMR Corporation at 98.[32] But this listing reflects *all* revenues for these firms rather than their space-only revenues. When the space-only revenues are examined the picture becomes quite different. According to the Space Commission Report, *global* commercial space activities generated a total of $80 billion in revenues in 2000, and while this is clearly a lot of money in absolute terms, it represents only 8.9 percent of the revenues of just the top five U.S. corporations (Exxon Mobil, Wal-Mart, General Motors, Ford Motor, and General Electric) from the *Fortune* 500 list for 2001.[33]

Should we consider commercial space "on par with how we value oil today"? Space is not there yet in dollar terms: the total revenues of energy corporations from the *Fortune* 500 list for 2001 was more than three times the value of the revenues from aerospace corporations.[34] But how about the market valuation of space corporations? At the end of 1999 the combined market valuation for *all* major U.S. aerospace firms (Boeing, Honeywell, United Technologies, General Dynamics, Textron, Lockheed Martin, Raytheon, TRW, Northrop Grumman, and Litton Industries) amounted to approximately $150 billion but was still less than the market valuation of Home Depot Corporation.[35] The intent of all these comparisons is not to depreciate the importance of commercial space activities; rather, they are designed to show that commercial space activities do not yet constitute a COG for the economies of the United States or the world. The comparisons also help to illuminate the true strategic utility of commercial space activities and highlight that these activities should be thought about and valued in a variety of ways other than just in terms of economics.

Despite the relatively small size of commercial space in comparison with the whole U.S. economy, it is nonetheless a vibrant sector that had grown very rapidly prior to the current recession and is still creating novel commercial activities. A few statistics and trends illustrate the overall state of the commercial space sector. During the period from 1996 through 2000, for example, global commercial space revenues rose 85 percent, going from $44.8 billion to $83 billion; and total employment rose 46 percent, from 173,400 to 253,600.[36] Likewise, from 1996 to 1998 the total number of satellites launched each year (both commercial and non-commercial) rocketed up 80 percent from 86 to 155.[37] In retrospect, however, 1998 represents a spike in launch numbers that was clearly caused by a major push to populate big non-geostationary orbit (big NGSO) constellations such as Iridium and Globalstar with relatively small networked comsats. It is unclear whether this pattern will be repeated due to the cloudy prospects for future big NGSO systems and the larger number of satellites that may be carried per launch on future systems. Total launches declined 42 percent to 90 total in 1999 and declined roughly another 15 percent in 2000.[38] Another overall trend may be more significant and enduring: the late 1990s marked the first time commercial space activities and investment approached or actually exceeded government activity in areas such as number of launches, satellite manufacturing revenue, and launch revenue.[39] With government space expenditures projected to remain relatively constant, even modest growth in commercial space activities will widen the gap and continue the transformation of the commercial space sector from the smallest sector into the largest.

Futron defines **satellite services** as the use of satellites to deliver telephony, television, radio, data communication, remote sensing data, and government services. These services are the largest single component of commercial space, saw revenue growth of 134 percent between 1996 and 2000, and accounted for $37 billion or 44.5 percent of total commercial space revenues in 2000.[40] In the past, telephony was the dominant satellite service but now the "major driver of satellite services revenue is services that are provided directly to end-user customers (for example, [direct-to-home] DTH television services)."[41] The growth in direct to end-user services such as DTH television is extremely important to commercial space but this growth should not be allowed to mask two important considerations: 1) satellite telephony now accounts for only 3-5 percent of the $1 trillion global telephony market; and 2) the growth in other end-user services served to offset the concurrent precipitous decline in satellite telephony caused by the growing dominance of fiber optics for most telecommunications services. Simply put, satellites' once dominant position in global transoceanic telephony has already been lost to fiber; fiber's share of this market grew from only two percent in 1988 to over 80 percent in 2000.[42] Moreover, because new fiber technologies such as optical switching and dense wavelength division multiplexing (DWDM) are slated to be in widespread use by 2002 and are designed to double (at least) the capacity of each fiber strand, even next generation wireless broadband such as Hughes' Spaceway system may continue to have a very hard time competing with fiber for any fixed, point-to-point telecommunication service.[43] The satcom versus fiber tradeoff is just one of the many complex issues that will shape the future of wireless broadband and the role of space systems within these markets. At present, however, it is not clear that large-scale "Internet-in-the-sky" systems such as Teledesic can be developed cheaply, quickly, and flexibly enough to compete effectively with terrestrial alternatives for most applications.

Satellite manufacturing is the second largest component of the commercial space sector. This area grew by 47.5 percent between 1996 and 2000 and accounted for $18.3 billion or 22 percent of total commercial space revenue in 2000.[44] As within the rest of the aerospace industry, there has been a great deal of consolidation and restructuring within the satellite manufacturing business. Five firms now dominate the global satellite manufacturing market: Boeing Satellite Systems (formed in October 2000 when Boeing acquired the Hughes Electronic satellite manufacturing businesses), Space Systems/Loral, Lockheed Martin, Astrium (formed by the 1999 merger of Matra Marconi Space and DaimlerChrysler Aerospace), and Alcatel. Increasing competition both within the industry and between satcom and fiber has required firms to adapt rapidly to changing market forces. Improved manufacturing processes and standardization techniques for GEO comsats have reduced the amount of time from contract award to launch from 58 months in 1991 to 29 months in 1998.[45] In an even more radical departure for the industry, most NGSO satellites are now put together using assembly line techniques within a matter of a few days. The market for both GEO and NGSO satellites is also quite cyclical; for example, 40 GSO comsats were ordered in 2000 versus only 15 ordered in 1999.[46] But is unclear that satellite builders can sustain their recent rates of growth even with the restructuring in the industry and new manufacturing techniques.

United States satellite builders face a particularly difficult challenge because they must overcome significant hurdles to obtain export licenses and now face newly consolidated but experienced and subsidized European competition that is made more attractive by a weak Euro. Indeed, satellite manufacturing representatives and many independent analysts now argue that the United States Government (USG) overreacted to the inappropriate space technology transfers detailed in the Cox Report.[47] They believe that when the government returned export license approval authority to the State Department from the Commerce Department in March 1999 it did not make common-sense distinctions between exports to allies and to others. Further, they charge that these changes created large administrative burdens and regulatory time delays that have undermined sales in this strategic sector but that do not necessarily enhance national security or keep critical technologies out of the wrong hands.[48]

Launch and **ground equipment manufacturing** form the last two segments of the commercial space sector; in 2000 they comprised $9.6

billion (11.5 percent) and $17.7 billion (21.3 percent), respectively, of the world's total commercial space revenues.[49] Between 1996 and 2000, launch revenues grew by 39 percent and ground equipment manufacturing revenues grew by over 82 percent.[50] Launch is undoubtedly the most competitive component of commercial space due to a wide variety of launch vehicle suppliers, many of which are state sponsored or otherwise subsidized by the five states that offer commercial launch services (United States, Europe, China, Ukraine, and Russia). The August 1994 U.S. Space Transportation Policy formally divided effort on new launch vehicles between the NASA and DOD, with the former responsible for developing new reusable launch vehicles (RLVs) and the latter responsible for new expendable launch vehicles (ELVs).[51] The X-33, X-34 and the evolved expendable launch vehicle (EELV) are the programs that flowed directly out of this policy.[52] Under the Space Lift Initiative (SLI) announced by the Bush Administration in March 2001, funding for the X-33 and X-34 programs was ended before any flight tests were conducted and, despite some discussions, DOD has not stepped in the save the X-33 program.[53] In the United States there are also currently no less than seven commercial RLV companies in the conceptual development phase but it is very unlikely that there will be enough demand to keep all of these efforts alive.[54] Other significant factors shaping the near-term prospects of the commercial launch industry include: the continuing string of failures in launch or in achieving the correct orbit, the expiration of launch quotas for Ukrainian and Russian launch vehicles, investments by launch providers in NGSO systems, launch range standardization and modernization plans, and the successful emergence of Sea Launch—the first commercial sea-mobile launch platform. The ground equipment manufacturing component of commercial space activities is characterized by rapid growth (especially in direct to end-user services), significant consolidations within larger companies, and the entry of a large number of smaller companies. The most important merger was between AlliedSignal and Honeywell in December 1999 and this was followed-up in October 2000 when General Electric agreed to acquire Honeywell in a tax-free merger valued at $43 billion.[55] The U.S. Department of Justice gave conditional approval for this acquisition in May 2001 but in July the European Union rejected the deal on anti-trust grounds, making it the first proposed merger of U.S. corporations blocked solely by European regulators.[56]

A final set of issues related to these commercial space considerations is the role of spacepower in providing global utilities. Like their terrestrial counterparts, space-based global utilities provide basic services or public data. Examples of space-based global utilities include weather data and Global Positioning System (GPS) positioning and timing signals. Current

U.S. policy calls for these services to be provided as a public good without direct user fees.[57] The importance of these space-based global utilities is growing and they often constitute an imbedded or enabling technology within other systems. GPS timing signals, for example, can be used to synchronize the compressed digitized packages of data within communications networks that use protocols such as Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA). Overall, these space-based global utilities form an important part of the global infrastructure for public services and commercial intercourse. However, there are a number of questions concerning the types of threats these systems face and how these might best be mitigated. Some analysts, primarily in the U.S. military, believe that threats to these systems call for increased space control efforts in order to provide protection.[58] Other analysts note that commercial satellite operators are not clamoring for military protection, wonder if similar threats warrant the development of military space control capabilities, and question whether the development of such capabilities would, in fact, protect space-based global utilities.

Seapower and Airpower Analogies. Another direct and obvious set of factors shaping our perceptions of spacepower are the oft-invoked analogies between spacepower and seapower or airpower. There is, of course, a rich literature on seapower and airpower theory. Seminal theorists who developed important perspectives on military operations in these two mediums include: Alfred Thayer Mahan, Julian Corbett, Giulio Douhet, William "Billy" Mitchell, and John Warden.[59] Some of the key concepts that these theorists developed or applied to the air and sea mediums are command of the sea, command of the air, sea lines of communication, common routes, choke points, harbor access, concentration and dispersal, and parallel attack. Several of these concepts have been appropriated directly into various strands of embryonic space theory; others have been modified slightly then applied. For example, Mahan and Corbett's ideas about lines of communications, common routes, and choke points have been applied quite directly onto the space medium. Seapower and airpower concepts that have been modified to help provide starting points for thinking about spacepower include harbor access and access to space, and command of the sea or air and space control.[60] But, of course, to date no comprehensive spacepower theory has yet emerged that is worthy of claiming a place alongside the seminal seapower and airpower theories listed above.[61]

There are also many fundamental questions concerning the basic attributes of the space medium and how appropriate it is to analogize directly from seapower or airpower theory when attempting to build spacepower theory. Few concepts from seapower theory translate directly into airpower theory—why should we expect either seapower or airpower theory to apply directly for the distinct medium of space? Questions concerning the attributes of space and the proper way to build space doctrine are also at the heart of the disagreements between the Air Force and rest of the Department of Defense (DOD) over whether air and space should be treated as a seamless operational medium (defined as aerospace by the Air Force) or regarded as distinct air and space mediums (as seen by the rest of DOD).[62]

> many of the problems with the aerospace concept and the development of space-power theory and doctrine have already been thoughtfully addressed in this [*Aerospace Power*] journal over the years. Dennis Drew, Charles Friedenstein, and Kenneth Myers and John Tockston published three of the best analyses during the 1980s.[63] These interrelated articles build on Drew's doctrine-tree model—the idea that doctrine should grow out of the soil of history, develop a sturdy trunk of fundamental doctrine, branch out into doctrine for specific environments, and only then attempt to sprout the organizational doctrine analogous to "leaves." This approach provides a comprehensive way to examine the aerospace concept and the Air Force's first official space doctrine, Air Force Manual (AFM) 1-6, *Military Space Doctrine,* released in 1982.[64] Friedenstein finds that "there is no doctrinal foundation for the term *aerospace*" (emphasis in original) and critiques the Air Force for attempting to produce "leaves on a nonexistent branch" because it had not developed environmental doctrine before issuing the organizational doctrine in AFM 1-6.[65] Myers and Tockston strongly critiqued the Air Force's tendency to "force-fit" space doctrine into the mold of air doctrine and argued that the three major characteristics of space forces are in fact emplacement, pervasiveness, and timeliness.[66]

Thus, despite several efforts to appropriate or adapt key concepts from seapower and airpower theory, we are currently still adrift without a comprehensive spacepower theory to guide us and would be wise to cast our nets more widely and beyond traditional national security considerations.

Spacepower and the Frontier Analogy. The image of a frontier to be tamed evokes powerful images, particularly for Americans, and it is therefore not surprising that it has become one of the most popular ways to describe space. Frederick Jackson Turner first advanced his frontier thesis in 1893 as a way to describe and explain what he perceived to be distinctive characteristics of American history and American political thought.[67] For Turner, numerous American cultural traits could all be attributed to the influence of the frontier—"that coarseness and strength combined with acuteness and acquisitiveness; that practical inventive turn of mind, quick to find expedients; that masterful grasp of material things... that restless, nervous energy; that dominant individualism."[68] In short, he argued that the frontier represented "the line of most rapid Americanization."[69] A very short list of important specific references to space as a frontier would include the beginning of Captain James Tiberius Kirk's opening monologue on the original *Star Trek* series; the title of Space Studies Institute founder Gerard K. O'Neill's 1977 book, *The High Frontier,* the report of the 1986 National Commission of Space, *Pioneering the Space Frontier*; and Senator Bob Smith's (R-NH) numerous references to space as the "permanent frontier."[70] As with most other concepts associated with spacepower, there is much more agreement on describing space as a frontier than on the national security implications of this association. The U.S. military obviously played a very important role in opening the frontier. It took on exploration missions such as Lewis and Clark's Expedition, surveys for railroad routes by the Topographical Engineers, construction of navigable waterways by the Corps of Engineers, and protection for pioneers. Clearly, the military helped to explore, survey, and pacify the American frontier—are these activities analogous to what will be conducted in space and is the military the proper organization to carry them out?

Spaceflight, the Overview Effect, and Religious Implications for Spacepower. A final set of perspectives on spacepower may shape our views in the most subtle and pervasive ways. At their core, these perspectives link space to humankind's purpose and destiny. Humankind has pondered its relationship with the cosmos for millennia and perceptions about space form foundational components of many religious beliefs. In the modern era, the visions of spaceflight produced by Jules Verne and H. G. Wells helped to lay the foundation for the new genre of science fiction and were echoed in the quasi-religious zeal of spaceflight pioneers such as Konstantin Tsiolkovsky and Wernher von Braun as they laid the conceptual framework for spaceflight and began to create some of the tools needed to "leave the cradle." Later science fiction authors such as Arthur C. Clarke, Robert Heinlein, and Isaac Asimov combined with the increasing popularity of this genre for television and films has pervaded the human psyche with the boundless possibilities of space and rendered our actual achievements in space mundane by comparison. Yet, as humans entered space, many people and groups believed that the rationale and importance of spaceflight took on increased significance. Mainstream views on spaceflight cover a broad range. Individuals such as Gerard K. O'Neill build on Turner's frontier thesis and emphasize exploration as a cathartic and defining human characteristic. Carl Sagan is a primary spokesman for those who view spaceflight in scientific and ecological terms and see it as essential to the survival of the human species. Visions about spaceflight undoubtedly culminate in what Frank White labels "the overview effect"—nothing less than space opening the door to the next phase of human evolution.[71]

Likewise, the links between space and religious beliefs are still very important in the modern era. The first Soviet cosmonauts, for example, went to great pains to emphasize that they had not seen God during their travel through in the heavens and this prompted Western retorts questioning whether they were pure of heart. The reading of the first ten verses from *Genesis* by the crew of Apollo 8 as they became the first humans to view an Earthrise from Lunar orbit on Christmas Eve 1968 evoked strong religious feelings. As McDougall tells us, humankind has never "been able to separate our thinking about technology from teleology or eschatology."[72] The very framework of his book warns that technocracy in general and spaceflight in particular cannot serve as humankind's Guarantor of Destiny; instead, his instinct tells us

> that our science and technology, feeble as they are in controlling Nature, are so acute in studying it that they will soon reveal their limits. It is then that man must confess the mortality of his works, without turning on them or himself with contumely. It is then that the orthodox message is a sure guide: God made us, is disappointed in us, but loves us anyway, by which we are redeemed. Technology is our subcreation. We made it, we will be disappointed in it, but we must love it anyway, or it cannot be redeemed.[73]

The message for analysts attempting to understand spacepower is simple: the medium is the message. To a greater degree than any other physical domain, space is shaped in fundamental ways by our very broad-ranging perceptions about it. Any comprehensive analysis of the strategic utility of spacepower must attempt to take these factors into consideration.

DOES SPACEPOWER CONSTITUTE A REVOLUTION IN MILITARY AFFAIRS?

As with virtually everything else associated with spacepower, there is a wide range of opinion on this question. In order to address this question, we must first engage the issue of revolutions in military affairs (RMAs) more generally. During the 1990s, discussion of RMAs became a cottage industry within strategic studies and defense policy analysis. Unfortunately, to this analyst at least, it is unclear whether this whole endeavor has generated more light than heat. Nonetheless, in order to continue we need some working definition of RMA and some sense of what constituted past RMA.

This paper adopts the definition of RMA advanced by Dr. Andrew Krepinevich and his Center for Strategic and Budgetary Assessments (CSBA). They define an RMA as a major discontinuity in military affairs.

> They are brought about by changes in militarily relevant technologies, concepts of operation, methods of organization, and/or resources available, and are often associated with broader political, social, economic, and scientific revolutions. These periods of discontinuous change have historically advantaged the strategic/operational offense, and have provided a powerful impetus for change in the international system. They occur relatively abruptly—most typically over two-to-three decades. They render obsolete or subordinate existing means for conducting war.[74]

CSBA makes the case that there have been "at least a dozen cases of revolutionary change in the conduct of war: Chariot, Iron Age Infantry, Macedonian, Stirrup, Artillery/Gunpowder, Napoleonic, Railroad, Rifle, Telegraph, Dreadnought/Submarine, Air Superiority/Armored Warfare, Naval Air Power, and Nuclear Weapons."[75] Brief descriptions of the six most recent RMAs help to further clarify the concept:

> *The Napoleonic Revolution.* During the last decade of the eighteenth century, a social and political revolution in France transformed war. The advent of universal conscription—the *levée en masse*—dramatically expanded the size of armies and increased their reconstitutability. Equally important, the new conscript armies—composed of literate citizen soldiers—had a fundamentally different relationship to the societies from which they were drawn. All-weather roads and a new

form of military organization—the corps—transformed logistics, and mass column assaults and mobile artillery transformed tactics.

The Railroad, Rifle, and Telegraph Revolution. The commercial development of the railroad and telegraph and the military development of the breech-loading rifle between 1840 and 1870 revolutionized war on land. The railroad revolutionized logistics, the rifle transformed tactics, and the telegraph fundamentally changed strategic command and control. With the advent of the railroad and telegraph, time, i.e., speed of mobilization, became a critical measure of military effectiveness. The large-scale movements of armies made possible by the new industrial infrastructure also gave birth to a new level of war—the operational level. By often giving statesmen a better sense of the overall military situation than that possessed by senior commanders in the field, the telegraph also transformed civil-military relations.

The Dreadnought/Submarine Revolution. The advent of steam propulsion and metal construction in naval shipbuilding ushered in a period of near constant technological change during the last decades of the nineteenth century. The completion in 1906 of the H.M.S. Dreadnought—the world's first all-big gun, turbine-driven battleship—provided existential evidence of another revolution in military affairs. With its uniform main armament—ten 12-inch guns—Dreadnought could outshoot any older warship. A principal impetus of the Dreadnought Revolution—the submarine—proved to be equally revolutionary. As a result of the increasing threat that these new weapons posed to battlefleets, the long-standing naval strategy of close blockades of enemy ports had to be abandoned. Even more important, the "hierarchy of power" in naval warfare, which had been established with the advent of the capital ship more than three centuries earlier, had been severely undermined.

Armored Warfare/Air Superiority. The stunning victory of German forces over the French, British, Dutch, and Belgian armies in May-June 1940, marked another departure in land warfare. From then on, the unit of account in measuring any army's strength would no longer be the number of soldiers it had under arms. While the development of armored warfare depended upon the maturation of the dominant technology—the tank—technology itself was not sufficient to effect the revolution. Several other developments—in supporting technologies (e.g., tank radios), organization (combined arms formations and supporting air arms), operational concepts (deep penetrations on narrow fronts and air superiority), and climate of command (mission-oriented tactics, or *auftragstaktik*)—were essential components of the transformation launched by the blitzkrieg.

Naval Air Power. World War II also saw a transformation of war at sea. With the advent of naval air power, fleets that formerly could not engage their enemy unless they were in visual range could now hurl blows at one another from distances of hundreds of miles. Moreover, whereas naval battle had previously been characterized by gunnery duels, destructive force could now be delivered in great pulses of power. As with armored warfare, the breakthroughs in carrier warfare depended upon a number of developments: modifying airplanes so that they were rugged enough to withstand the problems associated with landing and taking off at sea, developing techniques to manage space on a crowded deck, employing carriers in combined strike forces to attack land and sea targets, etc. By the autumn of 1943, when American building programs began to amass the sheer numbers of platforms required for sustained large-scale carrier operations, the transformation of war wrought by the ascendance of naval air power had become complete.

The Nuclear Revolution. The detonation of atomic bombs over Hiroshima and Nagasaki provided evidence of another military revolution. Far exceeding the prophesies of even the most zealous pre-war strategic bombing theorists, subsequent developments in intercontinental ballistic missiles and nuclear fusion brought the prospect of nearly instantaneous destruction of whole societies into the strategic calculus. As with previous revolutions, the advent of nuclear weapons saw the emergence of new warfighting doctrines and military organizations. In the minds of most strategists, however, the sole purpose of the new weapons had shifted from warfighting to deterrence.[76]

The question, however, remains whether the military and strategic contributions of spacepower to date constitute an RMA. Some analysts make the case that spacepower's contributions in the Gulf War (the first space war) already mark it out as an RMA. Others make the case that, regardless of its specific performance in any individual war, spacepower *is* the RMA.[77] It is probably more useful, however, to view the current relationship between spacepower and RMAs in two primary ways: first, in terms of spacepower's preeminent *contributions* that enable the global reconnaissance, precision strike RMA that first emerged in the Gulf War; and, second, in terms of spacepower's *autonomous* but nascent potential for a space weaponization RMA.

Many systems combine into the system of systems that create the global reconnaissance, precision strike RMA that has more clearly emerged and become increasingly powerful over the course of the past decade. Some of the more important systems for this RMA include: modern communications, command, control, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems, stealth platforms, and precision weapons. Spacepower makes the single most comprehensive and important contribution to this RMA. Among other things, spacepower fuels this RMA with 24/7 global ISR, it binds it together with communications connectivity, and it enables precision strike via GPS. In many cases, space provides the best or even the only medium from which to make these enabling contributions. In sum, it is clear that spacepower has now moved beyond merely enhancing terrestrial forces and has become the single most important contribution that enables the global reconnaissance, precision strike RMA.

Space weapons hold the potential to revolutionize warfare in even more powerful and fundamental ways. They could operate from the lowest tactical level up through the grand strategic level, could provide nearly instantaneous and simultaneous global strikes, and might even minimize the power of offensive nuclear forces. Such systems would create an RMA at least as profound as the six cases of modern RMAs discussed above. The path to space weaponization, however, still contains many extremely difficult political, fiscal, and technical challenges. Moreover, before starting down the path to space weaponization, we must anticipate that such powerful weapons will almost inevitably provoke countermeasures in the unending dialectic between offensive and defensive weapons and we must avoid the fallacy of the last move. Cumulatively, the breadth and depth of the challenges for space weapons to overcome means that this RMA may not emerge for some time to come—despite all its potential. Given these two separate relationships between spacepower and RMAs, this paper returns to an analysis of the military implications of commercial space activity since these factors are more likely to shape spacepower's continuing contributions to the global reconnaissance, precision strike RMA in major ways in the near-term.

Military Implications of the Growth in Commercial Space Activity

This section relies primarily on the Air Force's *Commercial Space Opportunities Study* (CSOS) to assess military opportunities and risks within a number of commercial space areas including: launch services, launch ranges, remote sensing, and navigation.[78] The CSOS report finds a number of areas where the military can leverage commercial activities to create new or improved military capabilities. Overall, however, it has a much harder time identifying many areas for large potential cost savings and it cannot find the "pot of gold" that many had hoped the growth in commercial space activities would create.[79] It is also hard to argue with the judgement in the Space Commission Report: "The U.S. Government, as a consumer, a regulator or an investor, is currently not a good partner to the national security space industry."[80]

Launch Services. According to the CSOS, commercial launch services hold the potential to create the largest cost savings in both percentage and absolute terms of any commercial space area. The military is projected to spend $1.5 billion on launch services in the future years defense program (FYDP) and stands to save some $62-125 million (or 25-50 percent) in annual launch costs once the EELV comes on line beginning in 2002.[81] If the EELV program is successful in significantly reducing costs-per-pound-to-orbit, it will represent a major breakthrough since, despite years of repeated promises from other new launchers such as the Shuttle, launch costs have remained constant or actually risen since the opening of the space age.[82] The EELV program is a novel partnering arrangement between the Air Force and two prime contractors (Boeing and Lockheed-Martin) to build the *Delta IV* and *Atlas 5* as two separate families of medium-to-heavy lift vehicles. Instead of following the normal process of selecting a single prime contractor, in October 1998 the Air Force awarded $500 million each to Boeing and Lockheed-Martin and each of these companies is contributing more than $1 billion of their own funds to develop these systems.[83] The EELV and other commercial launch systems lower costs through a combination of factors including reduced launch staffs, less time-on-pad, standardization of launch vehicles, and bulk launcher purchases. Another process to reduce costs further that was identified by the CSOS is "buy-on-orbit" procurement, a method of transferring total system performance responsibility to the contractor that requires less government oversight.[84] The CSOS touts the EELV program as an outstanding example of how the military can successfully leverage the commercial sector; its primary recommendation is to stay the course on EELV.[85] Potential military risks in this area stem from factors such as competition with the private sector for launchers and pads, having fewer vehicles optimized for military payloads, and unclear future options for both military and commercial RLVs. Perhaps the most potentially significant long-term military risks are associated with RLVs and arise from several factors: NASA rather than DOD has the lead for developing new RLVs, it is unclear whether NASA's current efforts will produce any operational commercial or military vehicles, and RLVs would seem to be better suited for many projected military missions than for most commercial or civil uses.

Launch Ranges. Ranges are a good example of an area where the CSOS could not find a big "pot of gold" for the military due to increased commercial activity. The Air Force currently spends about $600-700 million annually to operate and maintain the nation's primary launch facilities: the Eastern and Western Ranges at Cape Canaveral Air Station and Vandenberg Air Force Base, respectively.[86] The Air Force's Range Standardization and Automation (RSA) program is a $1.2 billion comprehensive effort scheduled for completion in 2006 that is designed to eliminate obsolete equipment, standardize equipment within and between the two ranges, and reduce the number of personnel required for operations (two thirds of the operators today are contractors rather than military or civil service personnel).[87] Once the RSA is completed, the Air Force looks forward to annual savings of $30-60 million (approximately 5-8 percent of annual operation costs). The CSOS recommends pressing ahead with the RSA but what is perhaps most interesting is how little support the report gives to proposals to commercialize range activities. This runs counter to the general trend toward increased commercialization in most industrial sectors worldwide, the fact that commercial launches have already edged ahead of government launches (and this gap is expected to increase), and NASA's apparent success to date in commercializing shuttle operations and maintenance through the United Space Alliance. Bucking these trends, the CSOS recommends that the Air Force "retain responsibility for flight safety, launch decision authority and range scheduling[.]". . . due to "its responsibility for public safety, its independence of private interests, and industry's concerns with liability issues."[88]

Remote Sensing. Commercial remote sensing is a complex area that requires the USG to carefully balance several conflicting goals. It is currently next to impossible to assess all the potential ways in which high-resolution commercial remote sensing will create military opportunities and risks due to the nascent state of this industry and its highly interdependent nature. Inter alia, military effectiveness will depend upon the quality, timeliness, and types of products offered; military efficiency will be based on the optimal mix between commercial and government systems. Under the Land Remote Sensing Policy Act of 1992 and Presidential Decision Directive (PDD)-23 of March 1994, it is now the policy of the United States to create incentives to develop a high-resolution commercial remote sensing industry. By attempting to dominate this market, the U.S. hopes to preserve its defense industrial base and workers trained in this sector, leverage commercial systems for government uses, and shape global standards on acceptable use via mechanisms such as shutter control.[89] Three U.S. firms—Space Imaging, EarthWatch, and OrbImage—are developing high-resolution commercial remote sensing systems (Ikonos, QuickBird, and OrbView, respectively) and they face significant foreign competition from systems such as SPOT, the Indian Remote Sensing (IRS) satellites (marketed by Space Imaging), and EROS (an Israeli-U.S. joint venture).[90] According to the CSOS, the Air Force spends $10 million annually on commercial imagery (this includes the innovative Eagle Vision activities); the report recommends that spending be increased to $80 million annually for each year in the FYDP.[91]

Two congressionally mandated studies reemphasize just how complex and difficult remote sensing issues have become for the USG. Many of the findings and recommendations from the commissions studying the NRO and NIMA go well beyond those in the CSOS by placing a great deal of emphasis on commercial imagery and the Intelligence Community's (IC) tasking, processing, exploitation, and dissemination (TPED) process. According to the NRO Commission report, for example, the USG: "could satisfy a substantial portion of its national security-related imagery requirements by purchasing services from" U.S. firms; it "must" develop a "clear national strategy that takes full advantage of the capabilities of the U.S. commercial satellite imagery industry;" and it should create a system similar to DOD's industrially funded airlift account to help efficiently focus government systems "on targets where their unique capabilities in resolution and revisit times are important, while commercial systems would be used to provide processed 'commodity' images."[92]

The NIMA Commission report goes even further. It found the IC to be "collection centric," "that NIMA was not a good, dependable business partner," and recommended creating a "central commercial imagery fund" to help mitigate problems resulting from the fact "that national technical means (NTM) imagery appears to be 'free' to government agencies, while use of commercial imagery generally requires a distressingly large expenditure of (largely unplanned, unprogrammed) O&M [operation and maintenance] funds."[93] The commission recommended that the central commercial imagery fund start at about $350 million annually for "raw imagery and vendor's value-added offerings."[94] They expect that this figure will rise substantially throughout the FYDP, and were very "distressed by an announcement promising $1 billion for commercial imagery purchase, which subsequently proved to be so much fiction."[95] The NIMA Commission saved its harshest critique for NIMA's TPED shortcomings. These shortcomings "increasingly strains at the fabric of the NIMA organization as a whole" and undermine confidence "that NIMA currently has the system engineering experience, acquisition experience, appropriate business practices, and performance measures" to acquire a cutting-edge TPED system.[96] The commission concludes that NIMA's TPED efforts simply cannot "get there from here" and recommends:

> creation of an Extraordinary Program Office (EPO) armed with special authorities of the Director of Central Intelligence and the Secretary of Defense, augmented by Congress, and staffed beyond ceiling and above "cap" through an heroic partnership between industry, NIMA, and the NRO. The EPO, to be constituted within NIMA from the best national talent, shall be charged with and resourced for all preacquisition, systems engineering, and acquisition of imagery TPED—from end to end, from "national" to "tactical." The first milestone shall be completion of a comprehensive, understandable, modern-day "architecture" for imagery TPED. Other provisions of law notwithstanding, Congress shall empower the Director of the EPO to commingle any and all funds duly authorized and appropriated for the purpose of the "TPED enterprise," as jointly defined by the Secretary of Defense and the Director of Central Intelligence.[97]

Positioning, Navigation, and Timing (PNT). Although perhaps not quite as complex as remote sensing, the current *de facto* role of the Global Positioning Systems (GPS) as the global utility for PNT presents difficult policy challenges in balancing military and commercial interests. Moreover, because commercial PNT applications are already large (more than $8 billion annually)[98] and are expanding rapidly and in many different areas worldwide, it difficult to assess how the military might best leverage the commercial PNT sector. The current GPS constellation consists of 29 Block II, IIA, and IIR satellites launched between June 1989 and January 2001; the system costs over $280 million annually to operate and estimates for the total sunk cost in procuring and launching the current constellation is well over $10 billion.[99] The U.S. policy framework for PNT issues was formalized by National Science and Technology Council (NSTC)-6, "U.S. Global Positioning System Policy," in March 1996. To manage the system, NSTC-6 established the interagency GPS Executive Board (IGEB) that is chaired jointly by DOD and the Department of Transportation. The policy also reemphasized that the USG will continue to operate the GPS "on a continuous, worldwide basis, free of direct user fees;" established the intention to discontinue the use of SA by 2006 (SA was turned off on 2 May 2000); and directed the DOD to "continue to acquire, operate, and maintain the basic GPS" while developing "measures to prevent hostile use of GPS and its augmentations to ensure that the United States retains a military advantage without unduly disrupting or degrading civilian uses."[100]

The USG is attempting to reassess and rebalance various equities as the GPS is modernized to provide significant improvements in its civil, commercial, and military capabilities. In May 2000, President Clinton put more emphasis on the system's growing civil and commercial uses than on its military roots and applications when he described the discontinuation of SA as "the latest measure in an ongoing effort to make GPS more responsive to civil and commercial users worldwide. . . . This increase in accuracy will allow new GPS applications to emerge and continue to enhance the lives of people around the world."[101] Turning off SA has already produced an order of magnitude improvement in accuracy for civil and commercial users; when combined with the two new civil signals (L2 and L5) that are scheduled to first come on line beginning in 2003 and 2005, these sectors clearly seem poised for further accelerating growth. The L2 Coarse/Acquisition (C/A) code is designed for general use in non-safety critical applications and will help to improve "standalone accuracy as low as 8.5 meters (95 percent) compared with approximately 22.5 meters (95 percent) with L1 alone."[102] The second new civil code, L5, is a "safety-of-life" signal designed primarily for aircraft navigation, but "it will also serve as a robust third signal for all users."[103]

Naturally, DOD's perspective on GPS modernization emphasizes the military utility of the system. The U.S. military is already critically dependent on GPS for a wide range of applications and this dependence will only grow over time. For example, most modern U.S. precision-guided munitions (PGMs) use GPS guidance for at least some phase of their flight from weapons release to impact.[104] According to March 2000 testimony by Mr. Keith Hall, Assistant Secretary of the Air Force for Space and Director of the NRO: "While sustainment of the constellation is a top priority, navigation warfare (Navwar) requirements and inherent system vulnerabilities have driven the need to modernize."[105] Current plans call for DOD to invest more than $2.7 billion through fiscal year 2005 to operate, maintain, and upgrade the system.[106] In addition to the two new civil signals, the modernized system will also have new military codes (M-code) "that will 'reuse' portions of the radio spectrum already assigned to the L1 and L2 frequencies while remaining spectrally distinguishable from the L1 and L2 C/A-codes."[107] It is unclear, however, whether this resuse approach will be flexible and robust enough to enable the U.S. military to use GPS effectively even when the enemy is attempting to jam the system.[108]

CONCLUSION

Spacepower is a complex, multidimensional concept that clearly deserves the current attention it is receiving. It should be studied in comprehensive ways that allow analysis of all the many factors that contribute to its efficacy. For the near-term, the links between spacepower and the commercial space sector should be studied most carefully. Carefully examining these linkages will point to how the military can best use commercial space assets and also highlight the areas where it will require dedicated military systems. Although space is not an economic center of gravity today, it may emerge as one in the coming decades. It is less clear, however, that traditional "flag follows trade" arguments will lead to an increased military space presence or provide the best way to protect space assets. Looking beyond just economic considerations, there appear to be a growing number of strategic factors that are creating pressure for increased militarization and probably weaponization of space. To date, military space developments have been the single most important contribution to the global reconnaissance, precision strike RMA that first emerged in the Gulf War. As current political, fiscal, and technological challenges are surmounted, it is likely that space—like every other environment humankind has opened—will become weaponized and will emerge as an independent RMA.

NOTES

[1] *The NRO at the Crossroads* (Washington, D.C.: National Commission for the review of the National Reconnaissance Office, 1 November 2000). *The Information Edge: Imagery Intelligence and Geospatial Information in an Evolving National Security Environment* (Washington, D.C.: Independent Commission on the National Imagery and Mapping Agency, December 2000). *Report of the Commission to Assess National Security Space Management and Organization* (Washington, D.C.: Commission to Assess National Security Space Management and Organization, 11 January 2001, hereinafter Space Commission Report). All three reports are available on-line at http://www.space.gov. In addition, in May 2001 under National Security Presidential Directive (NSPD)-5, President Bush ordered a comprehensive review of U.S. intelligence capabilities to be conducted by both internal and external panels that was originally scheduled for completion in September but was delayed following the terrorist attacks of 11 September 2001. See Vernon Loeb, "U.S. Intelligence Efforts to Get Major Review," *Washington Post,* 12 May 2001, 3; and Walter Pincus, "Intelligence Shakeup Would Boost CIA," *Washington Post*, 8

November 2001, 1; and Greg Miller, "Congress to Probe Intelligence Community," *Los Angles Times*, 26 January 2002.

The most important previous groups and their key space policy recommendations include: the 1954-55 Technological Capabilities Panel (TCP) (establish the legality of overflight and develop spy satellites); the President's Science Advisory Committee (PSAC) led by Science Advisor James Killian in 1958 (create the National Aeronautics and Space Administration [NASA]); the SAMOS Panel led by Science Advisor George Kistiakowsky in 1960 (create the NRO); the review led by Vice President Lyndon Johnson in April 1961 (race the Soviets to the Moon for prestige); Vice President Spiro Agnew's 1969 Space Task Group (establish NASA's post-Apollo goals); the U.S. Air Force's (USAF) 1988 Blue Ribbon Panel led by Maj Gen Robert Todd (integrate spacepower into combat operations); NASA's 1991 Augustine Commission (emphasize scientific exploration over shuttle operations); and the USAF's 1992 Blue Ribbon Panel led by Lt Gen Thomas Moorman (emphasize space support to the warfighter, establish the Space Warfare Center).

The Space Commission Report is the broadest-ranging and most important product of the three commissions in 2000. The Space Commission was chaired by Secretary of Defense Donald Rumsfeld and included 12 other members with a broad-range of very high-level military space expertise. They are (listed with the top "space" job they formerly held): Duane Andrews (Deputy Undersecretary of Defense for Command, Control, Communications, and Intelligence); Robert Davis (Undersecretary of Defense for Space); Howell Estes (Commander, U.S. Space Command); Ronald Fogleman (Air Force Chief of Staff); Jay Garner (Commander, Army Space and Strategic Defense Command); William Graham (President's Science Advisor); Charles Horner (Commander, U.S. Space Command); David Jeremiah (Vice Chairman of Joint Chiefs of Staff); Thomas Moorman (Air Force Vice Chief of Staff); Douglass Necessary (House Armed Services Committee staff); Glenn Otis (Commander, Army Training and Doctrine Command); and Malcolm Wallop (Senator). See John A. Tirpak, "The Fight for Space," *Air Force Magazine* 83 (August 2000): 61.

The legislation authorizing the commission was clearly action-oriented and spelled out its duties as follows: "The Commission shall, concerning changes to be implemented over the near-term, medium-term, and long-term that would strengthen United States national security, assess the following: (1) the manner in which military space assets may be exploited to provide support for United States military operations. (2) The current interagency coordination process regarding the operation of national security space assets, including identification of interoperability and communications issues. (3) The relationship between the intelligence and nonintelligence aspects of national security space (so-called "white space" and "black space"), and the potential costs and benefits of a partial or complete merger of the programs, projects, or activities that are differentiated by those two aspects. (4) The manner in which military space issues are addressed by professional military education institutions. (5) The potential costs and benefits of establishing any of the following: (A) An independent military department and service dedicated to the national security space mission. (B) A corps within the Air Force dedicated to the national security space mission. (C) A position of Assistant Secretary of Defense for Space within the Office of the Secretary of Defense. (D) A new major force program, or other budget mechanism, for managing national security space funding within the Department of Defense. (E) Any other change to the existing organizational structure of the Department of Defense for national security space management and organization."

See sec. 1622 of *National Defense Authorization Act for Fiscal Year 2000* (Public Law 106-65; 113 Statute 814; 10 *US Code* 111 note).

In October 2000, Congress added an amendment directing the commission to study (6) the advisability of—

(A) various actions to eliminate the de facto requirement that specified officers in the United States Space Command be flight rated that results from the dual assignment of officers to that command and to one or more other commands in positions in which officers are expressly required to be flight rated;

(B) the establishment of a requirement that, as a condition of the assignment of a general or flag officer to the United States Space Command, the officer have experience in space, missile, or information operations that was gained through either acquisition or operational experience; and

(C) rotating the command of the United States Space Command among the Armed Forces.

See sec. 1091, Additional Duties for Commission to Assess United States National Security Space Management and Organization; sec. 1622(a) of the *National Defense Authorization Act for Fiscal Year 2000* (Public Law 106-65; 113 Statute 814; 10 US Code 111 note).

The key recommendations of the Space Commission Report called for: raising the priority of national security space to a vital national interest; creating a Presidential Space Advisory Group; instituting closer and more regular coordination between the Secretary of Defense and the Director of Central Intelligence; creating an Under Secretary of Defense for Space, Intelligence, and Information; creating a new four-star billet for the Commander of Air Force Space Command that is separate from the Commander in Chief of U.S. Space Command and the North American Aerospace Defense Command; designating the Air Force as the Executive Agent for space within the Department of Defense (DOD) and amending Title 10 of the United States Code to assign the Air Force responsibility to organize, train, and equip for prompt and sustained offensive and defensive air and space operations; assigning the Undersecretary of the Air Force as the Director of the National Reconnaissance Office and the Acquisition Executive for space; and establishing a Major Force Program to consolidate the space budget. (Space Commission Report, xxxi-xxxv). Not surprisingly, Secretary Rumsfeld recently accepted nearly all of these recommendations in his required assessment of the Space Commission Report for Congress. The only major change was that he did not request legislation to establish an Under Secretary of Defense for Space, Intelligence, and Information. See Donald

H. Rumsfeld, letter to Honorable John Warner, Chairman, Committee on Armed Services, United States Senate, 8 May 2001; Donald H. Rumsfeld, National Security Space Management and Organization Memorandum, Office of the Secretary of Defense, 18 October 2001; and Lt Col Peter Hays and Dr. Karl Mueller, "Going Boldly—Where? Aerospace Integration, the Space Commission, and the Air Force's Vision for Space," *Aerospace Power Journal* 15, no. 1 (Spring 2001): 34-49.

[2] This paper uses spacepower as one word; it is also commonly expressed as two words. Air Force Chief of Staff Thomas D. White first used the word *aerospace* in 1958, and the concept that air and space form a seamless operational medium has been the foundational component of Air Force thinking about space ever since. Unfortunately, however, the Air Force is primarily talking to itself by using this word in this way because none of the other Services or DOD offices use the word aerospace according to the Air Force's definition. Aerospace, for example, is only used as an adjective describing industry in the Space Commission Report and the word does not even appear in the DOD's current space policy statement (Department of Defense Directive 3100.10, *Space Policy*, 9 July 1999).

[3] Prior to the opening of the space age, the United States, in particular, was very reluctant to define where space begins. The Eisenhower Administration's secret but highest priority space policy as expressed in NSC-5520 of May 1955 was designed to distinguish between aerial and satellite overflight and to established the legitimacy and legality of the latter. This policy called for using the civilian face of the United States' International Geophysical Year scientific satellite program as a "stalking horse" to establish the precedent of legal overflight in order to open up the closed Soviet state to photoreconnaissance via the secret WS-117L spy satellite system. The term *stalking horse* is taken from R. Cargill Hall's "Origins of U.S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program*, ed. John M. Logsdon, vol. 1, *Organizing for Exploration* (Washington, D.C.: NASA History Office, 1995), 213–29. The United States has not subsequently revisited the issue of where space begins in light of the changed geopolitical context and declassification of satellite reconnaissance. By using unclassified sources, primarily at the Eisenhower Library, Walter A. McDougall was the first to break through the veil of secrecy surrounding early U.S. space policy in *. . .the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985). His book won the Pulitzer Prize for History in 1986.

[4] Barry D. Watts, *The Military Use of Space: A Diagnostic Assessment* (Washington, D.C.: Center for Strategic and Budgetary Assessments, February 2001); Steven Lambakis, *On the Edge of Earth: The Future of American Space Power* (Lexington: University Press of Kentucky, 2001; Everett C. Dolman, *Astropolitik: Classic Geopolitics in the Space Age* (London: Frank Cass, 2002); and Robert Preston, et al., *Space Weapons: Earth Wars* (Santa Monica: RAND Corporation, 2002).

[5] Military use of commercial satellites was a major issue in the 1998 Army After Next wargame and space weaponization, deterrence and preemption, and space-to-

Earth force application were all critical parts of the Air Force's Schriever 2001 and Future Concepts 2001 wargames. See, for example, "Air Force gains insights from first space wargame," Air Force News Archive, available from http://www.af.news/Jan2001/n20010129_0124.shtml.

[6] Many U.S. Government documents list three rather than four space sectors. Upon closer examination, however, these documents reveal the important contributions of each of the four sectors discussed above. For example, the most recent National Space Policy discusses civil, national security (defense and intelligence), and commercial sectors. National Science and Technology Council, "Fact Sheet: National Space Policy" (Washington, D.C.: The White House, 19 September 1996). The term "space sectors" was first used as an organizing typology in President Jimmy Carter's 1978 National Space Policy. National Security Council, "Presidential Directive/NSC-37: National Space Policy" (Washington, D.C.: The White House, 11 May 1978).

[7] Space Commission Report, 10-14.

[8] This section and the next are adapted from Peter L. Hays, James M. Smith Alan R. Van Tassel, and Guy M. Walsh, eds., *Spacepower for a New Millennium: Space and U.S. National Security* (New York: McGraw-Hill, 2000), 3-6.

[9] Satellites in Low Earth Orbit (LEO) fly in the region from less than 100 miles to several hundred miles altitude and complete each orbit in approximately 90 minutes. Polar LEO is ideal for many spysat and weather applications because from this orbit satellites can look down on all parts of the Earth several times each day as the Earth rotates beneath and they also can be aligned in Sun Synchronous Orbits that arrive overhead the same location at the same time each day. Satellites in Semi-Synchronous Orbit are located at approximately 12,500 miles altitude and complete an orbit every 12 hours. Geostationary Orbit (GSO) is located approximately 22,300 miles above the equator, a location where the satellites' orbital velocity matches Earth's rate of rotation and the satellite appears to remain motionless above the same spot—a very valuable attribute for communications and SIGINT satellites. NPOESS is a system that is currently being jointly developed by the National Oceanic and Atmospheric Administration (NOAA) and DOD that will merge their separate meteorological satellite systems into one system scheduled for its first launch in 2005. The AEHF program is developing the successor to the Milstar system and currently plans its first launch in 2005. The WGS is scheduled to launch a satellite in 2004. It is designed to bridge the gap between the current DSCS and GBS systems and a future advanced wideband system. For more information, see the Air Force Association's "Major Military Satellite Systems" webpage at http://www.afa.org/magazine/space/satellite_systems.html.

[10] *Long Range Plan: Implementing USSPACECOM Vision for 2020* (Peterson AFB, Colo: U.S. Space Command, Director of Plans, March 1998), 19-20. Space control or "counterspace operations" are defined in much greater detail in Air Force Doctrine Document (AFDD) 2-2 *Space Operations*: "**Counterspace operations consist of those operations conducted to attain and maintain a desired degree of space superiority by allowing friendly forces to exploit space capabilities while**

negating an adversary's ability to do the same. Counterspace operations include two elements – offensive and defensive counterspace, both predicated on space surveillance and other intelligence. Air, space, land, sea, information, or special operations can perform counterspace functions.

Offensive counterspace (OCS) operations preclude an adversary from exploiting space to his advantage. Should policy allow, OCS actions may target an adversary's space system, forces, and information links, or third-party space capabilities supporting those forces, using lethal or nonlethal means. Possible methods include the use of deception, disruption, denial, degradation, and destruction of space capabilities. The "Five Ds" represent a continuum of options, from spoofing the enemy to hard-kill of a space asset. However, there are tradeoffs along the continuum. At the destruction end of the continuum, airmen can be confident that an adversary's space asset and the effect it produced have been eliminated. However, there may be undesirable collateral effects, such as added debris threats in orbit, or negative world opinion. At the deception end of the continuum, airmen may have less confidence in achieving the desired effect, but have more confidence in not producing any adverse collateral effects.

- **Deception employs manipulation, distortion, or falsification of information to induce adversaries to react in a manner contrary to their interests.**
- **Disruption is the temporary impairment of some or all of a space system's capability to produce effects, usually without physical damage.**
- **Denial is the temporary elimination of some or all of a space system's capability to produce effects, usually without physical damage.**
- **Degradation is the permanent impairment of some or all of a space system's capability to produce effects, usually with physical damage.**
- **Destruction is the permanent elimination of all of a space system's capabilities to produce effects, usually with physical damage**.

Assets designed for the OCS mission may be used to conduct or support counterair, countersea, counterland, counterinformation, or strategic attack missions by performing offensive counterspace actions where the adversary's vulnerable node is a space system.

Defensive counterspace (DCS) operations preserve US/allied ability to exploit space to its advantage via active and passive actions to protect friendly space-related capabilities from enemy attack or interference. Although focused on responding to man-made hostile intent, DCS actions may also safeguard assets from unintentional hazards such as space debris, RF interference, and other natural occurring events. Defensive counterinformation (DCI) operations and force protection measures may be employed in support of DCS.

- **Active defense seeks to detect, track, identify, characterize, intercept, or negate adversary threats and unintentional hazards to friendly space capabilities.**
- **Passive defense seeks to ensure the survivability of friendly space assets, and the information they provide.**

Space situational awareness (SSA) forms the foundation for all counterspace and other space actions. It includes traditional space surveillance, detailed reconnaissance of specific space assets, collection and processing of space intelligence data, and analysis of the space environment. It also encompasses the use of traditional intelligence sources to provide insight into adversary space operations. (Emphases in original.) Air Force Doctrine Document 2-2 *Space Operations* (Maxwell AFB, Ala.: Air Force Doctrine Center, 27 November 2001), 9-10.

[11] Lt Col David E. Lupton, *On Space Warfare: A Space Power Doctrine* (Maxwell AFB, Ala.: Air University Press, June 1988).

[12] Robert S. Dudney, "Washington Watch: The New Space Plan," *Air Force Magazine* 81, no. 7 (July 1998): n.p.; on-line, Internet, 13 December 2000, available from http://www.afa.org/magazine/0798watch.html.

[13] Ibid.

[14] General Howell M. Estes, III, "The Promise of Space Potential for the Future," prepared remarks to the United States Space Foundation's 1997 National Space Symposium, Colorado Springs, Colo., 3 April 1997; on-line, Internet, 11 December 2000, available from http://www.defenselink.mil/speeches/1997/s19970403-estes.html.

[15] *Long Range Plan*, 4-5, 33.

[16] On the sea change caused by growth in the commercial space sector, see Frank G. Klotz, *Space, Commerce, and National Security* (New York: Council on Foreign Relations Press, 1998); Gen Thomas S. Moorman Jr., "The Explosion of Commercial Space and the Implications for National Security," *Airpower Journal* 13, no. 1 (Spring 1999): 6–20; and John M. Logsdon and Russell J. Acker, eds., *Merchants and Guardians: Balancing U.S. Interests in Global Space Commerce* (Washington, D.C.: Space Policy Institute, George Washington University, May 1999). The idea that the "flag follows trade" is from Klotz, 15-20.

[17] "There appears to be no demand from the operators of commercial communications satellites for defense of their multibillion-dollar assets." John M. Logsdon, "Just Say Wait to Space Power," *Issues in Science and Technology* (Spring 2001), n.p.; on-line, Internet, 24 April 2001, available from http://www.nap.edu/issues/17.3/p_logsdon.htm.

[18] General Ronald R. Fogleman and the Honorable Sheila E. Widnall, *Global Engagement: A Vision for the 21st Century Air Force* (Washington, D.C.: November 1996), 8. Emphasis in original.

[19] Klotz, 55; and Lt Col Paul L. Bailey, "Space as an Area of Responsibility," *Air Chronicles*, Winter 1998, on-line, Internet, 13 December 2000, available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj98/win98/waywin98.html.

[20] Quoted in Otto Kreisher, "The Move into Space," Air Force Magazine 82, no. 4 (April 1999): n.p.; on-line, Internet, 11 December 2000, available from http://www.afa.org/magazine/0499space.html.

[21] General Richard B. Myers, "Integrating Space in an Uncertain Era," prepared remarks to the Air Force Association Space Symposium, Los Angeles, 13 November 1998; on-line, Internet, 13 December 2000, available from http://www.aef.org/symposia/myers.html.

[22] Quoted in Peter Grier, "The Investment in Space," *Air Force Magazine* 83, no. 2 (February 2000): n.p.; on-line, Internet, 11 December 2000, available from http://www.afa.org/magazine/0200onvestment.html.

[23] Gen. Richard B. Myers, "Space Superiority Is Fleeting," *Aviation Week & Space Technology*, 1 January 2000: n.p.; on-line, Internet, 13 December 2000, available from http://www.awgnet.com/avaiation/newmillen/aw54.htm.

[24] General Michael E. Ryan and the Honorable F. Whitten Peters, *Global Vigilance, Reach & Power: America's Air Force Vision 2020* (Washington, D.C.: Department of the Air Force, June 2000).

[25] Air Force Chief of Staff General Merill McPeak moved away from the aerospace concept in June 1992 by changing the Air Force mission statement by adding the words "air and space." During the tenure of General Michael E. Ryan as Chief of Staff, however, the Air Force returned to the aerospace concept. For the period of General Ryan's tenure, the Air Force emphasized that there are physical differences between the atmosphere and space but defined aerospace as a seamless operational medium comprised of both physical domains. See, for example, Air Force Doctrine Document 2-2 *Space Operations* (Maxwell AFB, Ala.: Air Force Doctrine Center, 23 August 1998), 1 or *Global Vigilance, Reach & Power*. As reflected in recent speeches and the 27 November 2001 edition of AFDD 2-2, General John P. Jumper, the current USAF Chief of Staff, has chosen to return to using "air" and "space" as separate words rather than continuing to use the term "aerospace."

> Let me start off by talking a little bit about air and space versus aerospace. I carefully read the Space Commission report. I didn't see one time in that report, in its many pages, where the term "aerospace" was used. The reason is that it fails to give the proper respect to the culture and to the physical differences that abide between the physical environment of air and the physical environment of space.
>
> We need to make sure we respect those differences. So, I will talk about air *and* space. I will respect the fact that space is its own culture, that space has its own principles that have to be respected. And when we talk about operating in different ways in air and space, we have to also pay great attention to combining the effects of air and space because in the combining of those effects, we will leverage this technology we have that creates the asymmetrical advantage for our commanders.

Prepared Remarks of General John P. Jumper at Air Force Association National Symposium, Los Angeles, CA, 16 November 2001. Available from http://www.aef.org/symposia/jump1101.asp.

In this context, it is very important to note that the other Services and the Office of the Secretary of Defense have never fully accepted the Air Force's definition of aerospace or ceded all operations in this area to the Air Force. For a comprehensive analysis of the aerospace concept's deep roots in airpower theory see Maj Stephen M. Rothstein, "Dead on Arrival? The Development of the Aerospace Concept, 1944-1958," Master's thesis, School of Advanced Airpower Studies, (Maxwell AFB, Ala.: Air University Press, 2001). For a critique of the aerospace concept see Lt Col Peter Hays and Dr. Karl Mueller, "Going Boldly—Where? Aerospace Integration, the Space Commission, and the Air Force's Vision for Space," *Aerospace Power Journal* 15, no. 1 (Spring 2001): 34-49.

[26] General Eberhart did not put much emphasis on commercial space developments and did not even mention the term COG in his 8 March 2000 testimony to the Senate Armed Services Committee Strategic Subcommittee (available from http://www.spacecom.af.mil/usspace/cinc8mar00.htm); or in his 4 April 2000 keynote speech to the United States Space Symposium (available from http://www.spacecom.af.mil/usspace/cinc0404.htm). USSPACECOM picked up the CND mission in 1999 and became responsible for CNA on 1 October 2000. It is not yet clear how the command will organize to perform these new missions. One proposal is for a unified subcommand but that option along with others is the subject of a yearlong study scheduled for completion on 1 October 2001. See George I. Seffers, "Cyberwar Ops May Unify," *Federal Computer Week*, 30 October 2000, 12.

[27] John A. Tirpak, "The Fight for Space," *Air Force Magazine* 83, no. 8 (August 2000): n.p.; on-line, Internet, 13 December 2000, available from http://www.afa.org/magazine/august2000/0800space.html.

[28] Quoted in William B. Scott, "Cincspace: Focus More on Space Control," *Aviation Week & Space Technology*, 15 November 2000, n.p.; on-line, Internet, 19 April 2001, available from http://www.infowar.com/MIL_C4I/00/mil_c4I_111500b_j.shtml.

[29] Futron Corporation, *Satellite Industry Guide* (Bethesda, Md.: Futron Corporation, October 1999).

[30] Ibid., x.

[31] United States GDP figures are available from the Commerce Department's Bureau of Economic Analysis at http://www.bea.doc.gov/bea/ARTICLES/2001/08august/0801GDP.pdf. Aerospace does not qualify as a separate subset within manufacturing but manufacturing of *all* durable goods accounts for only 9.4 percent of GDP.

[32] "The *Fortune* 500 List," is available from http://www.fortune.com/. The *Fortune* 500 list for 2001 is based on data from 2000. Most major aerospace corporations do not report space-only revenues or categorize this part of their business in consistent ways.

[33] Ibid. and Space Commission Report, 11.

[34] $572.945 billion for the energy sector versus $186.081 billion for the aerospace sector. And, again, this represents the *all* the revenues from aerospace corporations rather than the fraction attributable to space activities.

[35] "Comparison of Aerospace Market Valuation to Top 25 U.S. Companies—End of CY 1999," Slide 31 of "Space Industry 2000 Study" presentation by Industrial College of the Armed Forces.

[36] Elaine Gresham, "SIA/Futron Satellite Industry Indicators Survey: 1999/2000 Survey Results," Futron Corporation Slide Presentation to the Office of Net Assessment, the Pentagon, 21 November 2000, slide 6.

[37] Phil McAlister, "1999 Year in Review," Futron Corporation Slide Presentation to Office of Net Assessment, the Pentagon, 21 November 2000, slide 12.

[38] Ibid., slide 10; and Marco Antonio Cáceres, "Expendables Face Tough Market," *Aviation Week & Space Technology*, 15 January 2001, 145. 2001 was the slowest year for space launches in nearly 40 years with only 58 successful orbital launches. "Tsyklon booster launches with cargo of six satellites," *Spaceflight Now*, 28 December 2001. Available from http://www.spaceflightnow.com/news/n0112/28tsyklon/.

[39] Ibid. and *Satellite Industry Guide*, xiii-xvi.

[40] Gresham, slide 5.

[41] Ibid., 2-4.

[42] Colonel David A. Anhalt, "The Changing Nature of Military Advantage in Satellite Communication," Presentation Slides for USSPACECOM, 26 October 2000, slide 11. Slide derived from Mel Mandell, "120,000 Leagues Under the Sea," *IEEE Spectrum*, April 2000, 50.

[43] Ibid. DWDM uses different wavelengths of laser light within each strand of fiber. The capacity of one strand of fiber using DWDM is 1000 Gigabits per second (Gbps). The Hughes Network Systems Spaceway wireless broadband (Ka-band) system is scheduled to begin operation over North America in 2002 using two Boeing 702 GEO comsats and have a capacity of 10 Gbps.

[44] Gresham, slide 5.

[45] *Satellite Industry Guide*, 3-17.

[46] McAlister, slide 3.

[47] Rep. Christopher Cox (R.-Calif.) led a six-month long House Select Committee investigation that produced the "U.S. National Security and Military/Commercial Concerns with the People's Republic of China" Report that was released on 25 May 1999. The report is available from http://www.house.gov/coxreport.

[48] Satellite builders claim that their exports dropped 59 percent in 2000 and that since March 1999 their share of the global market declined sharply (from 75 percent to 45 percent). Not surprisingly, they place most of the blame for this decline squarely on their problems with export controls. See Evelyn Iritani and Peter Pae, "U.S. Satellite Industry Reeling Under New Export Controls," *Los Angeles Times*, 11 December 2000, 1. According to *Space News*, 2000 marked the first time that U.S. firms were awarded fewer contracts for GEO comsats than their European competitors (they show the Europeans ahead 15 to 13). See Peter B. de Selding and Sam Silverstein, "Europe Bests U.S. in Satellite Contracts in 2000," *Space News*, 15 January 2001, 1 and 20. This issue has attracted a great deal of attention in the trade press and elsewhere. See, for example, Representative Dana Rohrabacher, "Reconciling

Commerce with National Security," *Space News*, 12 April 1999; Peter B. de Selding and Warren Ferster, "NATO Allies Decry New U.S. Export Policies," *Space News*, 26 April 1999, 1, 28; Warren Ferster, "Senators Propose Even Tougher Export Reviews," *Space News*, 7 June 1999, 1, 28; Ray A. Williamson, "Time to Repair the Damage to Industry," *Space News*, 14 June 1999, 26; Vernon Loeb, "Satellite Firms Chafe at New Export Controls," *Washington Post*, 12 May 1999, 6; Andrew Pollack, "Export Rules are Said to be a Threat to Satellite Industry," *New York Times*, 1 August 1999; and James Hackett, "Satellite Industry Ensnared," *Washington Times*, 5 August 1999, 17. One particularly difficult, but perhaps overlooked, dimension of this problem is the fact that only about 20 percent of the space launch insurance business is based in the U.S. and the State Department's rules now make it very hard and time consuming for U.S. space businesses to conduct meaningful negotiations with foreign insurers.

[49] Gresham, slide 5.

[50] Ibid.

[51] The 5 August 1994 National Space Transportation Policy is available from http://www.hq.nasa.gov/office/codez/nstc4.html.

[52] Lockheed-Martin was the prime contractor for the X-33 and Orbital Sciences Corporation was the prime for the X-34. Both of these RLV programs ran into very significant technical and programmatic challenges, raising questions whether either system might replace the Space Shuttle or lead to an operational commercial variant. Anticipating increasing demand for launch vehicles, the Air Force is helping to provide funding for two EELV development programs rather than following the normal process of selecting a single system for development. In October 1998, the Air Force awarded $500 million each to the Boeing Delta IV and the Lockheed-Martin Atlas 5 EELV programs. Both contractors are investing approximately twice as much of their own money (approximately $1 billion each) in these families of medium-to-heavy boosters. The first government EELV payloads are scheduled for launch beginning in 2002. See William B. Scott, "EELV Funding: Is It Enough?" *Aviation Week & Space Technology* 1 March 1999, 27.

[53] About $1.2 billion was spent on the X-33 program since it began in 1996 ($350 million from Lockheed Martin and $912 million from NASA). See Peter Pae, "Lockheed Asks Air Force to Fund X-33 Craft Revival," *Los Angeles Times*, 14 April 2001; Frank Morring, "NASA Eyes Military Role in Aerospace Push," *Aviation Week & Space Technology*, 23 April 2001, 36; and Brian Berger and Jeremy Singer, "USAF Plans Major Funding for a Space Plane by 2004," *Space News*, 24 September 2001, 4.

[54] The seven companies attempting to develop commercial RLVs are: Kelly Space and Technology, Kistler Aerospace Corporation, Pioneer Rocketplane, Rotary Rocket Company, Space Access LLC, Vela Technology Development, and Lockheed Martin Skunk Works. See McAlister, slide 7. In January 2001, officials from Kern County, Calif. threatened to seize Rotary Rocket assets and auction them off to pay property taxes owed by the company. "Rotary Rocket's Assets Seized,"

on-line, Internet, 3 January 2001, available from http://www.space.com/news/roton_auction_000102_wg.html.

[55] Paul Meller, "Europe Plans Full Inquiry on G.E.-Honeywell Deal," *New York Times*, 9 May 2001.

[56] "EU Kills GE-Honeywell," on-line, Internet, 28 August 2001, available from http://cnnfn.cnn.com/2001/07/03/europe/ge_eu/.

[57] Current GPS policy is spelled out in Office of Science and Technology Policy and the National Security Council, "Fact Sheet: U.S. Global Positioning System Policy," (Washington, D.C.: The White House, 29 March 1996).

[58] See, for example, Brig Gen Simon Peter Worden, "The Air Force and Future Space Directions: Are We Good Stewards?" *Aerospace Power Journal* 15, no. 1 (Spring 2001): 50-57; and Lt Gen Bruce Carlson, "Protecting Global Utilities," *Aerospace Power Journal* 14, no. 2 (Summer 2000): 37–41. For a more detailed development of this argument with a focus on distinctions between the role of armies and navies, see Brig Gen Simon P. Worden, "Space Control for the 21st Century: A Space 'Navy' Protecting the Basis of America's Wealth," in Hays et al., *Spacepower for a New Millennium*, 225–38.

[59] Several of these individuals were quite prolific; the following list represents their best known works: Alfred Thayer Mahan, *The Influence of Sea Power upon History, 1660-1783* (Boston: Little, Brown, 1980); Julian S. Corbett, *Some Principles of Maritime Strategy*, ed. by Eric J. Grove (Annapolis: Naval Institute Press, 1988. First published 1911); Giulio Douhet, *The Command of the Air*, ed. by Richard H. Kohn and Joseph P. Harahan (Washington, D.C.: Office of Air Force History, 1983. First published 1921); William Mitchell, *Winged Defense: The Development and Possibilities of Modern Airpower—Economic and Military* (New York: Dover, 1988. First published 1925); and John A. Warden III, *The Air Campaign: Planning for Combat* (Washington, D.C.: National Defense University Press, 1988). On the importance of these works see, Jon Tetsuro Sumida, *Inventing Grand Strategy and Teaching Command: The Classic Works of Alfred Thayer Mahan Reconsidered* (Washington, D.C.: Woodrow Wilson Center Press, 1997); Philip S. Meilinger, ed. *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, Ala.: Air University Press, 1997); and David R. Mets, *The Air Campaign: John Warden and the Classical Airpower Theorists* (Maxwell AFB, Ala.: Air University Press, April 1999).

[60] Virtually all of these concepts are applied throughout the Chief of Staff-directed yearlong study by Air University that is published as *SPACECAST 2020* (Maxwell AFB, Ala.: Air University, 1994). See also, for example, Arnold H. Streland, "Clausewitz on Space: Developing Military Space Theory through a Comparative Analysis," Air Command and Staff College Research Paper, April 1999; and Charles H. Cynamon, "Protecting Commercial Space Systems: A Critical National Security Issue," Air Command and Staff College Research Paper, April 1999.

[61] In 1997, then-CINCSPACE Howell M. Estes III attempted to remedy the lack of a comprehensive space-power vision or theory by commissioning Dr. Brian R. Sullivan to write a book on space-power theory. This project was taken over by

James Oberg and published as *Space Power Theory* (Washington, D.C.: Government Printing Office, 1999). On the enduring nature of strategy and problems with developing space-power theory, see also Colin S. Gray and John B. Shelton, "Spacepower and the Revolution in Military Affairs: A Glass Half-Full," in *Spacepower for a New Millennium*, 239–58; and Colin S. Gray, *Modern Strategy* (Oxford: Oxford University Press, 1999), 243–67. The 2001 publications by Watts, Lambakis, and especially Dolman (*The Military Use of Space*, *On the Edge of Earth*, and *Astropolitik*) will undoubtedly go a long way towards filling the yawning spacepower theory gap in the literature.

[62] Hays and Mueller. "Going Boldly—Where?" 37.

[63] Lt Col Dennis M. Drew, "Of Leaves and Trees: A New View of Doctrine," *Air University Review* 33, no. 2 (January–February 1982): 40–48; Lt Col Charles D. Friedenstein, "The Uniqueness of Space Doctrine," *Air University Review* 37, no. 1 (November–December 1985): 13–23; and Col Kenneth A. Myers and Lt Col John G. Tockston, "Real Tenets of Military Space Doctrine," *Airpower Journal* 2, no. 4 (Winter 1988): 54–68.

[64] The Air Force published AFM 1-6 on 15 October 1982, and its release was designed to coincide closely with the stand-up of Air Force Space Command on 1 September 1982. For a detailed critique of AFM 1-6, see Peter L. Hays, "Struggling towards Space Doctrine: U.S. Military Space Plans, Programs, and Perspectives during the Cold War," unpublished Ph.D. dissertation, Fletcher School of Law and Diplomacy, Tufts University, May 1994, 400–422.

[65] Friedenstein, 21, 22.

[66] Myers and Tockston, 59. A more up-to-date and outstanding blueprint for developing space doctrine is provided by Maj Robert D. Newberry, *Space Doctrine for the Twenty-First Century* (Maxwell AFB, Ala.: Air University Press, October 1998).

[67] Turner first presented his ideas in a paper, "The Significance of the Frontier in American History," at a gathering of historians in Chicago, site of the World's Columbian Exposition, an enormous fair to mark the four-hundredth anniversary of Columbus' voyage.

[68] Cited in New Perspectives on the West, on-line, Internet, 20 May 2001, available from http://www.pbs.org/weta/thewest/people/s_z/turner.htm.

[69] Ibid.

[70] The original *Star Trek* series aired from 1966-68. Creator Gene Roddenberry originally sold the series concept to the NBC network as *Wagon Train* in space. Science fiction has probably been more important in shaping our perceptions of spacepower than any other single factor. Gerard K. O'Neill, *The High Frontier: Human Colonies in Space* (New York, Morrow, 1977).
Report of the National Commission on Space, *Pioneering the Space Frontier: An Exciting Vision of Our Next Fifty Years in Space* (New York: Bantam Books, 1986).
See, for example, Senator Bob Smith, "The Challenge of Space Power," *Airpower Journal* 13, no. 1 (Spring 1999): 32-39.

[71] Gerard K. O'Neill founded the Space Studies Institute at Princeton University in 1977 and is probably most famous for *The High Frontier*. Representative works in this tradition include James E. Oberg and Alcestis R. Oberg, *Pioneering Space: Living on the Next Frontier* (New York: McGraw-Hill, 1986) and Robert Zubrin, *Entering Space: Creating a Spacefaring Civilization* (New York: Jeremy P. Tarcher/Putnam, 1999). Carl Sagan cofounded the Planetary Society in 1980 and was one of the most famous and articulate spokesmen for planetary science; *Pale Blue Dot: A Vision of the Human Future in Space* (New York: Random House, 1994) was one of the last major books before his death in 1996. Frank White, *The Overview Effect: Space Exploration and Human Evolution* (Boston: Houghton Mifflin, 1987).
[72] McDougall, 4.
[73] Ibid., 460-61.
[74] Available from the Center for Strategic and Budgetary Assessments website, http://www.csbaonline.org/2Strategic_Studies/1Revolution_in_Military_Affairs/Revolution_Military_Affairs.htm.
[75] Ibid.
[76] Ibid.
[77] Gray and Shelton, "Spacepower and the Revolution in Military Affairs," in *Spacepower for a New Millennium*, 239–58. Emphasis in original.
[78] Headquarters Space and Missile System Center, Developmental Planning Directorate and Headquarters Air Force Space Command, Directorate for Plans and Programs, *Final Report: Commercial Space Opportunities Study* (Los Angeles AFB, Calif.: Commercial Exploitation Planning Office, 16 February 2000).
[79] Ibid., quotation from ES-4.
[80] Space Commission Report, 72.
[81] CSOS, ES-5, 3-2.
[82] Estimating actual costs-per-pound-to-orbit for various launch vehicles is a cottage industry and such calculations are well beyond the scope of this paper. Two outstanding recent discussions of basic problems with spacelift and current launch programs are found in Oberg, 87-95; and Watts, *The Military Use of Space* 55-63.
[83] CSOS, 3-2.
[84] Ibid., 3-5.
[85] Ibid., 3-4.
[86] Ibid.
[87] Ibid., 3-6, 3-9; and Lieutenant General Lance Lord, "Range Modernization: The Rest of the Story," *Space News*, 22 March 1999, 13.
[88] CSOS, 3-8.
[89] PDD-23 is explained in a press release and fact sheet released on 10 March 1994 (available from http://www.fas.org/irp/offdocs/pdd23-2.htm). The press release quoted Vice President Al Gore on the many advantages of improved resolution for benign civil applications and environmental monitoring and the importance of the $15 billion total annual worldwide market for remote sensing data and applications that were expected to develop by the year 2000. The fact sheet covers the specifics

of PDD-23 in considerable detail. Significant restrictions on commercial U.S. remote sensing systems remain in effect including licensee requirements to:

Maintain a record of all satellite taskings for the previous year and allow the USG access to this record.

Refrain from making changes to satellite operational characteristics without formal approval from the Department of Commerce.

Limit data collection and distribution when the Secretaries of Defense or State determine that national security, international obligations, and/or foreign policy may be compromised. The actual decision to limit data will be made only be the Secretary of Commerce in consultation with the Secretaries of Defense and State. (This restriction is known as shutter control).

Use only USG approved encryption devices for the purpose of denying unauthorized access to others during periods when national security, international obligations, and/or foreign policy may be compromised. The data downlink format must allow USG data access during these periods.

Notify the USG in advance of intent to enter into significant or substantial agreements with new foreign customers.

PDD-23 also allows for the transfer of "turnkey" advanced capability U.S. remote sensing systems on a case-by-case basis, subject to significant diplomatic steps that may include a formal government-to-government agreement. The most stringent restrictions are placed on the sale of sensitive components, subsystems, and information on the U.S. Munitions List for U.S.-unique remote sensing capabilities. These transfers will be made only on the basis of a government-to-government agreement.

To date, shutter control has not been formally requested or invoked. For the campaign against terrorism in Afghanistan, NIMA has established *de facto* shutter control by signing an "agreement of assured access" with the Space Imaging Corporation, reportedly for $1.9 million per month. Under the terms of this agreement, Space Imaging is not to sell or share its Afghanistan theater imagery with anyone except the USG until 5 December, and the contract may be extended beyond that date. Kerry Gildea, "NIMA Extends Deal with Space Imaging for Exclusive Imagery Over Afghanistan," *Defense Daily*, 7 November 2001, 2; and "Eye Spy," *The Economist*, 10-16 November 2001. This agreement opens many interesting issues related to the utility of limiting information dissemination for public diplomacy, the media, and exploitation of enemy information channels. It also raises the issue of whether this agreement using market mechanisms has set a precedent that might well make it more difficult to invoke formal shutter control in the future. For background and analysis on this issue see, Lt Col Peter L. Hays and Lt Col Roy F. Houchin, II, "Commercial Spysats and Shutter Control: The Military Implications of U.S. Policy on Selling and Restricting Commercial Remote Sensing Data," paper prepared for the USAF Institute for National Security Studies, 1 October 1999.

[90] The first commercial one-meter resolution remote sensing system became operational following the successful launch of the Ikonos 2 satellite aboard a Lockheed-Martin Athena II booster from Vandenberg AFB on 24 September 1999.

See Vernon Loeb, “Spy Satellite Will Take Photos for Public Sale,” *Washington Post*, 25 September 1999, 3. The Ikonos system can provide resolutions of 0.82 meters ground sample distance per pixel for digitized panchromatic images and four meters for multispectral images. EarthWatch’s QuickBird 1 was launched aboard a Cosmos 3M ELV from Plesetsk on 21 November 2000 but failed to reach the proper orbit and was presumed destroyed. Jason Bates, “QuickBird Loss Hits Firm, Remote Sensing Industry,” *Space News*, 4 December 2000, 3. ImageSat (formerly West Indian Space)—a joint venture between two Israeli companies (Israel Aircraft Industries and Electro-Optics Industries) and Core Software of Pasadena, California—successfully launched its EROS A1 0.82-meter resolution system (that is derived from Israel’s Ofeq 3 spysat) aboard a Start 1 ELV from Svobodni, Siberia on 5 December 2000. ImageSat “does not believe it is subject to U.S. jurisdiction regarding export licenses.” See “West Indian Space Changes Name to ImageSat, Announces Product Offerings,” *SPACEandTECH Digest*, on-line, Internet, 23 January 2001, available from http://www.spaceandtech.com/digest/sd2000-22/sd2000-22-007.shtml; and ImageSat’s website, http://www.imagesatintl.com. In December 2000, the National Oceanic and Atmospheric Administration (NOAA) awarded the first two half-meter resolution licenses to Space Imaging and EarthWatch. The half-meter licenses “contain a provision that calls for a 24-hour delay from collection of an image to distribution to a customer.” See Jason Bates, “U.S. approves Licenses for Two Imaging Satellites with Half-Meter Resolution,” *Space.com*, 18 December 2000, on-line, Internet, 19 December 2000, available from http://www.space.com/businesstechnology/business/satellite_licenses_001212.html.

EarthWatch’s corporate roots go back to WorldView Imaging (the first licensee for a high-resolution commercial system) and Ball Aerospace. Space Imaging’s lineage includes the Eosat, Lockheed-Martin, and Raytheon corporations. In addition, from the 1950s until losing a $4.5 billion NRO Future Imagery Architecture (FIA) contract to Boeing in 1999, Lockheed had been the NRO’s primary spysat contractor. See Tim Smart, “Lockheed Loses Big U.S. Contract,” *Washington Post*, 8 September 1999, E1. OrbImage is a corporate affiliate of the Orbital Sciences Corporation. On the security implications of high-resolution commercial remote sensing see Yahya A. Dehqanzada and Ann M. Florini, *Secrets for Sale: How Commercial Satellite Imagery Will Change the World* (Washington, D.C.: Carnegie Endowment for International Peace, 2000); Gerald M. Steinberg, “Dual Use Aspects of Commercial High-Resolution Imaging Satellites,” Security and Policy Studies No. 37, (Bar-Ilan University, Israel: Begin-Sadat Center for Strategic Studies, February 1998); and Vipin Gupta, “New Satellite Images for Sale,” *International Security* 20 (Summer 1995): 94-125.

[91] CSOS, 3-13.

[92] Report of the National Commission for the Review of the National Reconnaissance Office, *The NRO at the Crossroads* (Washington, D.C.: National Commission for the Review of the National Reconnaissance Office, 1 November 2000), quotations from pages 67, 74, and 71.

[93] Report of the Independent Commission on the National Imagery and Mapping Agency, *The Information Edge: Imagery Intelligence and Geospatial Information in an Evolving National Security Environment* (Washington, D.C.: Independent Commission on the National Imagery and Mapping Agency, December 2000), quotations from pages viii, 60, and 33.
[94] Ibid., 56.
[95] Ibid., 16. On DOD's pledge to buy $1 billion worth of commercial imagery over the FYDP see, for example, Warren Ferster, "U.S. to Buy Private Imagery for Intelligence," *Space News*, 12 April 1999, 1 and 34.
[96] *The Information Edge*, 89.
[97] Ibid., 90.
[98] CSOS, 3-14. Sales of GPS equipment and services are expected to exceed $16 billion by 2003. See Stephen G. Moran, "GPS Policy: Past Accomplishments and Future Opportunities," *Institute of Navigation Newsletter* 8, no. 4 (Winter 1998-99), on-line, Internet, 17 January 2001, available from http://www.ion.org/newsletter/v8n4.html.
[99] Block II satellites, the satellites that completed the first full-scale constellation, were built by Rockwell International and launched from February 1989 through October 1990. Rockwell International was also the prime contractor for Block IIA; these satellites have a design life of 7.3 years, contain two Cesium and two Rubidium atomic clocks (the primary driver of overall system accuracy), have Selective Availability (SA) and Anti-Spoof (A-S) capabilities, and were launched November 1990 through November 1997. Lockheed-Martin is the prime contractor for Block IIR satellites; these satellites have a design life of 7.8 years, contain three Rubidium atomic clocks and SA and A-S capabilities, and are designed with cross-links that allow up to 180 days of autonomous operations. Block IIR satellites were first launched in January 1997 and the most recent launch was on 30 January 2001. See United States Naval Observatory (USNO) Automated Data Service (ADS), "Block II Satellite Information," on-line, Internet, 31 January 2001, available from http://tycho.usno.navy.mil/gpscurr.html. "SA was a technique to reduce the accuracy of unaugmented, single-receiver GPS measurements. This was accomplished by altering (or 'dithering') the GPS satellite clock signals, and by modifying orbital elements of the broadcast navigation message. These alterations were done in a coded fashion, and could be removed by authorized users. This alteration caused horizontal position errors on the order of 100 meters (95%), and varied in a manner that prevented rapid averaging of positional data." SA was first implemented on 25 March 1990 on all Block II satellites. It was discontinued in September 1990 in order to provide better support to the U.S. and allied forces in Operation Desert Storm who had to rely on civilian GPS receivers because there were not enough military receivers capable of receiving the encoded precise positioning signal. SA was returned to standard level on 1 July 1991. With SA set to zero, users should "immediately expect better than 20 meter horizontal accuracy on the ground." The largest error sources are now solar disturbance of the ionosphere and the orbital parameters broadcast on the navigation message; if these

are controlled, "one may be able to achieve around 1-3 meter positioning." Discontinuation of SA will not eliminate the need for systems that use Differential GPS ("a technique to improve GPS accuracy by incorporating error corrections provided by a GPS monitoring station") such as the Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS). See Removal of GPS Selective Availability (SA), "GPS & Selective Availability Q & A," on-line, Internet, 31 January 2001, available from http://www.ngs.noaa.gov/FGCS/info/sans_SA/docs/GPS_SA_Event_QAs.pdf.

[100] Office of Science and Technology Policy and National Security Council, "Fact Sheet: U.S. Global Positioning Policy," (Washington, D.C.: The White House, 29 March 1996). Available from http://www.ostp.gov/html/gps-factsheet.html. USSPACECOM established the Navigation Warfare (Navwar) program to protect U.S. and allied military GPS use within an area of operations, prevent enemy exploitation of GPS, and preserve civil GPS service outside military areas of operations.

[101] The White House, Office of the Press Secretary, "Statement of the President Regarding the United States' Decision to Stop Degrading Global Positioning System Accuracy," 1 May 2000, available on-line from http://www.ostp.gov/html/0053_2.html.

[102] Ibid.

[103] A.J. Van Dierendonck and Chris Hegarty, "The New L5 Civil GPS Signal," *GPS World Online*, on-line, Internet, 24 January 2001, available from http://www.gpsworld.com/1000/1000inov.html. The JCS spells out basic military policy on PNT and the use of GPS as follows: "General Military Policy. In conducting military operations described in Joint Vision 2020, it is essential that PNT services be available with the highest possible confidence. These services must meet or exceed mission requirements. In order to meet these mission requirements, military operators may use a mix of independent, self-contained, and externally referenced PNT systems. DOD PNT users may use US civil PNT systems for peacetime operations where their use does not jeopardize DOD's ability to carry out its military mission. Civil PNT systems will not be used for combat, combat support, and combat service support operations. Use of foreign PNT systems is prohibited unless a specific memorandum of agreement (MOA) has been established with that respective nation. DOD ships and aircraft may use civil PNT system(s) in peacetime scenarios as long as the system(s) in use meet International Maritime Organization (IMO), International Civil Aviation Organization (ICAO), and/or FAA specifications. Global Positioning System. GPS is now and will continue to be the primary radio-navigation system source of PNT information for the Department of Defense. All DOD combatant users must acquire, train with, and use GPS systems capable of receiving the encrypted, military GPS signal, the Precise Positioning Service (PPS). The National Defense Authorization Act for FY 1994 (Public Law 103-160), as amended by National Defense Authorization Act for FY 1999 (Public Law 105-261), mandates that '. . . after September 30, 2005, funds may not be obligated to modify or procure any Department of Defense aircraft, ship, armored

vehicle, or indirect-fire weapon system that is not equipped with a Global Positioning System receiver.' DOD PNT users may use civilian GPS augmentations for peacetime operations where their use does not jeopardize DOD's ability to carry out its military mission. Examples include the US Coast Guard's Differential Global Positioning System (DGPS) and the Federal Aviation Administration's Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS), currently under development. It is essential for users to understand that these systems may not be reliable during conflict, as they do not incorporate the same level of security and survivability as military systems." *2000 CJCS Master Positioning, Navigation, and Timing Plan*, CJCSI 6130.01B (Washington, D.C.: Chairman of the Joint Chiefs of Staff, Department of Defense, 15 June 2000), A-1 through A-2, available from http://www.dtic.mil/doctrine/jel/cjcsd/cjcsi/6130_01b.pdf.

[104] The current and near-term inventory of GPS-enhanced PGMs includes the Conventionally Armed Air Launched Cruise Missile (CALCM), the Joint Air to Surface Standoff Missile (JASSM), the Joint Standoff Weapon (JSOW), and the Joint Direct Attack Munition (JDAM). See John A. Tirpak, "Brilliant Weapons," *Air Force Magazine* 81 (February 1998); available online at http://www.afa.org/magazine/0298brill.html. On GPS use in the Gulf War in 1991 and the Air War over Serbia in 1999, see Watts, "Military Use of Space," 41-46. In 1999, B-2 bombers using JDAMs and their GPS-aided targeting system were able to hit within approximately five meters of their intended target when bombing from 40,000 feet. In addition, JDAMs are relatively inexpensive for PGMs at less than $20,000 per round.

[105] Mr. Keith R. Hall, "Presentation to the Committee on Armed Services Subcommittee on Strategic Forces," Washington, D.C.: United States Senate, 8 March 2000, available on-line from http://www.nro.gov/speeches/sppo3-8.html.

[106] "GPS & Selective Availability Q & A."

[107] Michael Shaw, Kanwaljit Sandhoo, and David Turner, "Modernization of the Global Positioning System," *GPS World Online*, on-line, Internet, 18 January 2001, available from http://www.gpsworld.com/1000/1000shaw.html. Finding and securing permission to use portions of the frequency spectrum requires extensive domestic and international coordination (with agencies such as the Federal Communication Commission and the International Telecommunications Union) and can be among the most difficult and time-consuming aspects of developing an operational space system. L1 is located at 1575.42 MHz, L2 at 1227.60 MHz,

[108] Russia is marketing handheld GPS jammers with effective ranges of 80 and 192 kilometers. See Space Commission Report, 19-20; and Tom Wilson, "Threats to United States Space Capabilities," Paper Prepared for the Commission to Assess United States National Security Space Management and Organization, available from https://www.space.gov/commission/support-docs/article05/article05.html.