# SECURING THE HEAVENS:

# A PERSPECTIVE ON SPACE CONTROL

by

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## Disclaimer

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Major Burke E. “Ed” Wilson (BS, United States Air Force Academy; MS, Northeastern University) is a master space operation officer and acquisition professional. After graduating from the US Air Force Academy in 1985, he was assigned to Electronic Systems Division (ESD) at Hanscom AFB, MA where he served as a systems engineer in the Space Defense Operations Center system program office. While at ESD, he also served as the program manager for the ground-based MILSTAR communication terminal and several advanced technology development efforts, as well as completed his graduate degree in electrical engineering. During his next assignment at Onizuka AFB, CA, he supported satellite command and control operations, launch preparation and spacecraft engineering activities first for a national satellite program as an operations officer, then as chief of the advanced satellite management division. Next, Major Wilson served in the Overhead Collection Management Center, Ft. Meade, MD, first as a mission director and then as chief of the military support to operations division charged with mission planning and user support. He was then assigned as the executive officer to the acting director of the National Reconnaissance Office and later the military assistant to the Assistant Secretary of the Air Force (Space). Major Wilson is a recent graduate of Air Command and Staff College, as well as a distinguished graduate of Squadron Officer School. Upon graduation from the School of Advanced Airpower Studies, he will be assigned to HQ

USSPACECOM at Peterson AFB, CO.  Major Wilson is happily married to the former Lisa Johnson; they have a son, Burke, and a daughter, Jordan.

# *Abstract*

This study analyzes various ways in which the United States might best gain and maintain control of outer space. Ultimately, a strategic framework is proposed that offers improved awareness regarding the constraints, strengths, weaknesses, synergies and implications of candidate space control strategies. It accomplishes this by reviewing the milestone events associated with the last forty-plus years of space control history, assessing current trends and their inherent dilemmas, as well as cataloging the various means or methods of achieving space control. With these insights, a strategic framework is described that allows the strategist to better develop space control strategies at any level—strategic, operational or tactical.

The topic is timely given the nation's mandate to the US military to guarantee the ability to gain and maintain control of space in order to better shape the strategic environment and respond to any form of conflict. This mandate is especially challenging since the task—holding the "high ground" of space—must be accomplished without the benefit of weapons operating in the contested medium—space. Clearly, this is counter to the traditional manner by which militaries typically prepare, deploy and employ force to achieve superiority in a given medium of war. Given this dichotomy—the recognized importance of space in the current strategic environment with the limitations of a non-weaponized medium—the study is clearly relevant to the ongoing space control debate.

## Chapter 1

# Introduction

> *The United States must win and maintain the capability to control space in order to assure the progress and pre-eminence of the free nations. If liberty and freedom are to remain in the world, the United States and its allies must be in a position to control space.*
>
> —Gen Thomas D. White, Air Force Chief of Staff
> *Address to National Press Club, Nov 29, 1957*

> *Space forces are fundamental to sustaining US global commitments. The national C4ISR infrastructure that space forces support enables air, land and sea forces to be projected anywhere on the globe with the assurance that essential information will be available. The strategic significance of space to the nation's security and prosperity will continue to increase as the world evolves toward a global market. DoD's role in space during that evolution is to protect the nation's investment by protecting US space systems and assuring continued leadership in space.*
>
> —DoD Annual Report to the President and Congress (1998)

## Purpose

Unquestionably, the US military's ability to gain and maintain control of space is an essential component to the nation's mandate to shape the strategic environment and respond to any form of conflict. As seen above, the DoD has interpreted this unique role as one of protecting the nation's investment in space. However, the traditional manner by which militaries prepare, deploy and employ force to achieve superiority in a medium is not directly applicable to space—especially in an era of non-weaponization. Specifically, the US military has been directed to hold the high ground of space without the benefit of weapons operating in the contested medium—space. Given this dichotomy—the recognized importance of space in the current strategic environment yet the limitation of a non-weaponized medium—how should the US military gain and maintain 'space superiority,' when directed, in an era of non-weaponization in space?

## Background and Significance

The current US national space policy directs the DoD to "maintain the capability to execute the mission areas of space support, force enhancement, space control, and force application."[1] The inclusion of space control (ensuring free access to and passage in space) and force application (projection of firepower against surface targets from space) implies military missions using space-based weapons. However, the policy goes on to state that "*consistent with treaty obligations*, the United States will develop, operate, and maintain space control capabilities to ensure freedom of action in space, and, if directed, deny such freedom of action to adversaries."[2] In other words, the DoD must maintain the ability to establish 'space superiority' in any situation around the globe. However, the current administration has adopted a conservative interpretation of the ABM and Outer Space Treaties thereby limiting space-based weapons initiatives solely to research and development efforts (i.e., no pursuit of an operational system).[3] Therefore, the DoD is presented with a unique challenge—establishing 'space superiority' without the advantage of employing a space-based weapon in the contested medium. Undeniably, the US military will eventually be asked to respond to an actual or projected threat to a US or allied space system in the future. By formulating a strategic framework and investigating insights regarding how the military can respond to this eventuality, given these limitations, the dichotomy facing the military can be more effectively addressed.

## Roadmap

To address this question, a "building block" approach is used whereby foundational concepts are built to support follow-on analyses and recommendations. Three sections form the framework—Context, Concepts and Analysis/Conclusions.

First, the foundational elements of military space systems, terminology, orbitology and operations are highlighted in Chapter 2. Readers already knowledgeable of these space fundamentals may elect to skim this chapter. The *contextual* factors that have affected the military's need to control space are introduced in Chapter 3 by reviewing the importance of space, the historical precedents formed regarding space, and current perspectives regarding space control.

The *concepts* section is designed to provide an assessment of the space control landscape. To begin, Chapter 4 lays out several observations regarding space, as well as several unique dilemmas associated with space systems. It also reviews the current doctrine regarding the control of space and introduces a construct useful in understanding the myriad of space control issues. The 'tools of the trade' related to space control strategy are then introduced. Chapter 5 concentrates on the threats to space systems, whereas Chapter 6 addresses the range of options available to control these threats.

With these building blocks in place, Chapter 7 (the analysis/conclusion section) completes the study by highlighting key insights and proposing a unique perspective to assess both current and future space control issues. Appendix A outlines a more detailed strategy for developing and assessing space control strategies.

## Scope and Limitations

As stated, the current space control strategies are the focus of the paper. As such, there is limited discussion that relates to space-based weapons because of the existing technological and policy impediments. Likewise, the central role of space in the ongoing ballistic missile defense efforts is avoided entirely. Though critical to the national and international security debate regarding TMD, NMD and potentially GMD, they are only peripheral to this work.[4] Specific systems, organizations and budget details are rarely noted and, when they are, only for purposes of example—no comparisons or advocacy arguments are put forth. Instead, the emphasis is strictly on the strategic concepts related to the necessity to achieve and maintain control of space.

## Chapter 2

# Space Basics

> *Therefore, like it or not, space is a new theater of war that must be studied in that regard as thoroughly and carefully as any other lest we suddenly find ourselves confronted by the threat of physical force and violence from others who have taken it quite seriously.*
>
> —G. Harry Stine
> *Confrontation in Space, 1981*

From the warfighter's perspective, space assets are increasingly more useful as force multipliers—virtually every type of military operation, from small-scale conflicts to strategic nuclear war, leverages the capabilities delivered via space. As a result, control of space is rapidly becoming a necessity in modern warfare. However, space remains unfamiliar to many. This chapter highlights several key principles regarding the space domain—terminology, space systems, satellite orbits, as well as space operations. It is not intended to be an exhaustive tutorial on space, but rather provides the reader an adequate foundation to assimilate the various space control concepts explored later. *Readers already knowledgeable with these space fundamentals may elect to skim this chapter. The knowledgeable reader should at a minimum skim the "Defining a Space System" section since it describes a somewhat non-traditional perspective.*

## ABCs of Satellites

Man-made satellites revolve around the earth (or other celestial bodies) just as natural satellites such as the planets revolve around the sun and the moon revolves around the earth. A common analogy used to describe the physical phenomena of orbits is the act of swinging a bucket filled with water over your head. By generating enough velocity, the effect of gravity can be overcome. Without sufficient velocity, the water in the bucket will pour out. In our case, sufficient energy must be generated to put a satellite into orbit—potential energy to launch it and kinetic energy in the form of velocity to keep it in orbit.[5] Once in orbit, increasing a satellite's velocity will make it go into a higher orbit; decreasing velocity will drop it into a lower orbit. If the satellite goes too slow, it will "deorbit" and hit the earth.[6]

## A Discussion of Orbits

Obviously, the purpose for launching and operating a satellite is to perform some mission or function, which is more cost and/or performance effective if accomplished from space. Depending on the mission, certain types of orbits are more appropriate depending on their characteristics. Generally, satellite orbits are divided into four broad categories—three circular orbits and one elliptical orbit:

**Table 1: Common Orbital Regimes**

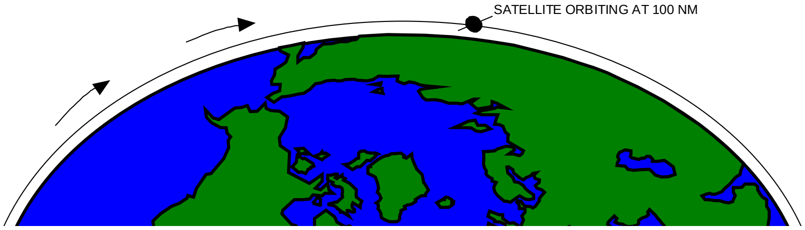
| ***Orbital Regime*** | ***Altitude*** | ***Orbital Period*** |
|---|---|---|
| Low Earth Orbits | 90-900 nm (150-1,500 km) | 1.5 – 2.0 hrs |
| Medium Earth Orbit | 900-22,300 nm (1,500-35,800 km) | 2.0 – 24.0 hrs |
| High Altitude Orbit | 22,300+ nm (35,800+ km) | 24.0+ hrs |
| Highly Elliptical Orbit | 200 x 22,800 nm | 12.0 hrs |

To better understand each orbital regime, let's examine its essential characteristics and the types of mission(s) conducted.

### Low Earth Orbits (LEO)

Satellites in LEO are very close to the earth's surface—Figure 1 depicts this graphically. These satellites travel at approximately 17,000 mph orbiting the earth about every ninety minutes. During this period, the satellite will only be capable of observing or receiving signals from a relatively small portion of the earth at any given instant—approximately 1.4 percent of the earth's surface at 100 nm as discussed earlier. Added to this limitation is the fact that satellites in LEO experience considerable drag due to the outer atmosphere.  To overcome these forces, satellites operating in LEO must continually reorient themselves and periodically increase their altitude.

**Figure 1. Notional Satellite Orbiting in Low-Earth Orbit (LEO)**



The obvious question is "why operate a satellite in this orbital regime given the challenges and limitations of low earth orbits?"  First, remote sensing missions such as high-resolution imagery and weather systems have traditionally been the primary occupants of LEOs.  Since optical resolution is a function of altitude (i.e., resolution decreases with the square of the altitude), imagery systems tend to trade-off the harshness of their LEO space environment, area coverage and resolution when determining their operating orbits.  A common orbit selected for imagery satellites in this trade-off process is the "sun-synchronous" orbit whereby the satellite passes over any given point on the earth at the same local solar time each day.[7]  The advantage gained from this is that the shadows cast by various objects will be the same over relatively short periods of time, if the object has not moved, knowledge that can be useful to analysts assessing imagery data.

Second, a satellite's altitude significantly impacts the ability to communicate via space. Specifically, the closer the satellite is to the earth, the smaller the satellite communication antennas used to transmit/receive signals; substantially less power is required to close the communication link. The growth of mobile communication systems such as the Iridium and Globalstar networks is built around this principle—a large constellation of satellites operating in LEO with relatively small antennas and lower power transmitters. It is interesting to note that the majority of these systems have elected to operate in the upper portion of the LEO region to avoid certain space environmental concerns such as drag.

Lastly, most manned space missions operate in LEO due to the limitations imposed by the today's reusable launch systems. Specifically, it requires enormous amounts of energy to launch space shuttles and other manned objects into space.

Clearly, a need exists to conduct operations such as remote sensing and communication in LEO. However, the relatively small field of view (or "footprint") and high-speeds relative to the ground means most LEO satellite systems must be augmented to achieve more global effects. Typically, relay satellites operating at higher altitudes, satellite crosslinks or extensive networks of worldwide ground stations are employed to transmit mission critical information to and from the LEO satellites to achieve optimum access.

### Medium Earth Orbits (MEO)

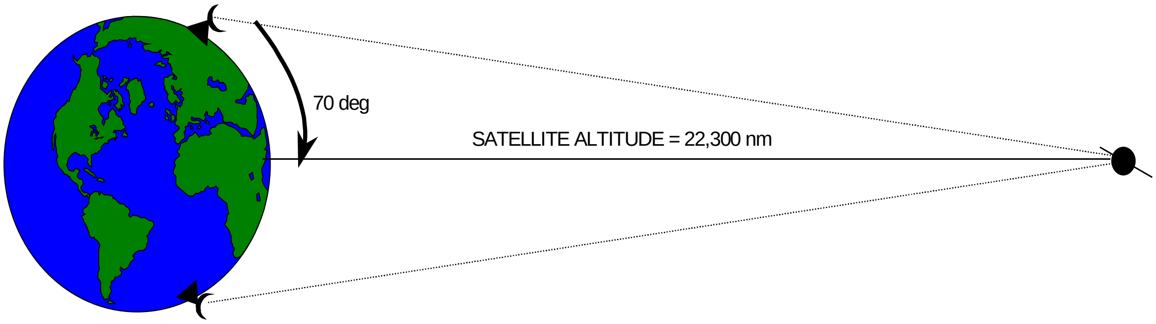
Though relatively sparsely populated, the MEO region is well suited for some communication and navigation missions. The orbit of choice has been the semi-synchronous orbit at approximately 12,500 nm in which satellites orbit the earth every 12 hours and repeat an identical ground track over the earth every 24 hours. The primary military mission conducted in this orbital regime is navigation using such systems as the US Global Positioning System (GPS) and the Russian GLONASS system.

## High Altitude Orbits

The most common high altitude orbits are the circular geostationary and geosynchronous (GEO) orbits at 22,300 nm. Satellites operating at this altitude appear to be relatively stationary to an observer on the earth—an extremely important characteristic. A *geostationary* orbit is an ideal case in which the orbital period is equal to the earth *and* its inclination is zero. The result is an orbit that stays fixed over the exact same point on the earth's equator (i.e., its ground track is a point). A *geosynchronous* orbit is one in which the orbital period is also equal to the Earth's, but the inclination is greater than zero. Therefore, the satellite does not appear to "hover" over a single point on the equator. Instead, the ground track appears as a vertical line or "figure eight" depending on the orbit's eccentricity (eccentricity is described in detail later). From an observer's perspective, the satellite moves slightly in the sky.

As stated, GEO satellites have the distinct advantage of maintaining a relatively common perspective of the earth, especially given the large expanses that are observable from 22,300 nm in space.[8] The relative constancy of the satellite in the sky and its ability to observe vast areas make GEO orbits ideally suited for a variety of communications, data relay, reconnaissance and ballistic missile early warning missions. A limitation worthy of note is the fact that most GEO satellites are incapable of effectively communicating with or observing objects on the Earth that are located above or below approximately 70 degrees latitude due to the Earth's flattening at the poles (see Figure 2).[9]

**Figure 2. Limits of Satellite in Geosynchronous Orbit**

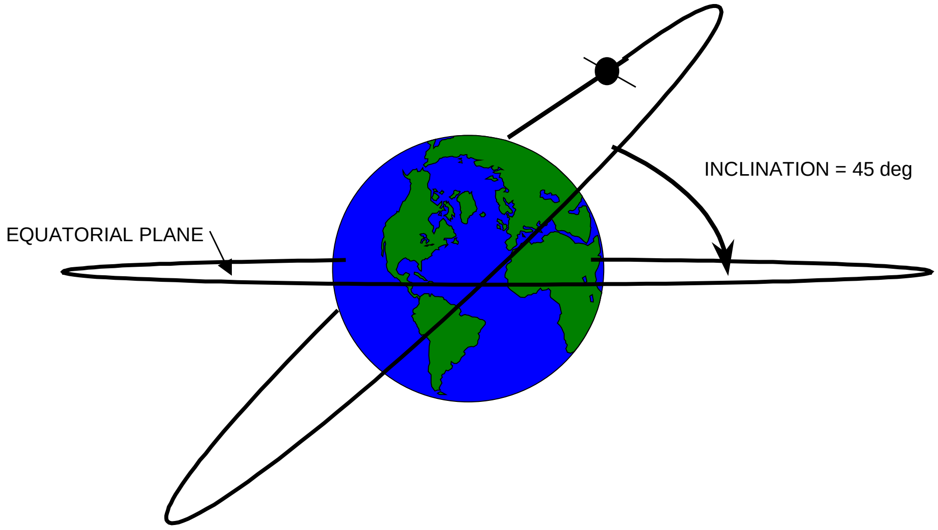


Beyond GEO altitude, satellites travel slower relative to the earth and appear to regress through the sky. With the exception of space exploration missions, relatively few satellites currently use this GEO+ altitude.[10]

## Orbitology 101

Before continuing the description of the remaining orbital regime, it is important to explain two fundamental orbital concepts. It may be obvious, but our categorization so far has been based strictly on a satellite orbit's altitude—simply the height of the satellite above the earth's surface. This is sufficient for a large set of orbits. However, two other characteristics are important to understanding a satellite's orbit—*inclination* and *eccentricity*—since both are critical components to any satellite's mission.[11] Envision a LEO satellite that orbits the earth directly over the Equator (i.e., it isn't inclined relative to the Equatorial plane, so it has a 0-degree inclination). This notional satellite will see only the terrain around the Equator and have no access to points further north or south such as New York, Moscow or Rio. However, if we incline our notional satellite's orbit by 45-degrees (see Figure 3), then it will eventually "see" all the terrain between 45-degrees North and South latitude because the earth is slowly rotating underneath the satellite's orbit at a rate of one revolution per day.

**Figure 3. Satellite Orbit Inclined 45-degrees to the Equator**

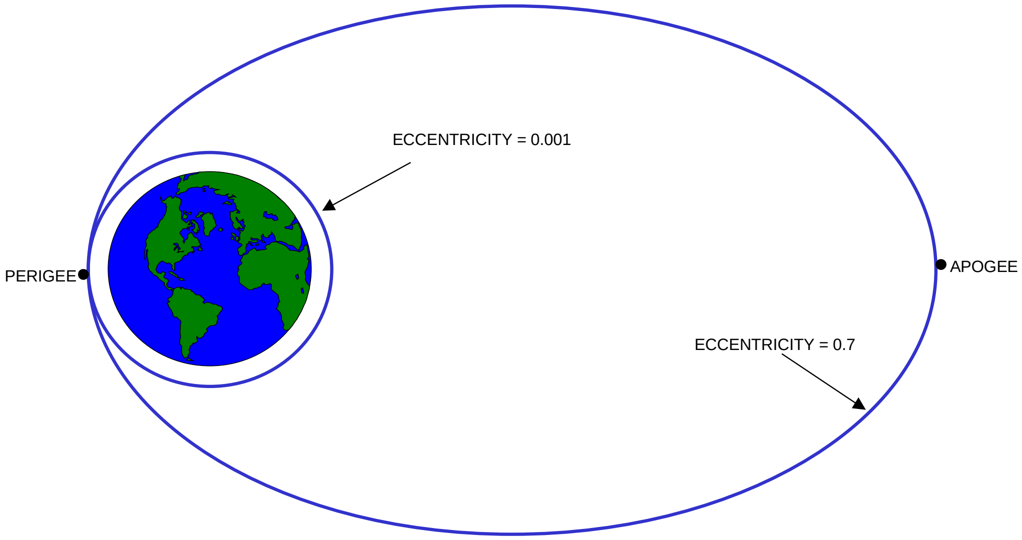


If we take this concept one step further and rotate the orbital plane to an inclination of 90-degrees (what is termed a "polar orbit"), everything between 90-degrees North and

South latitude—the entire globe—rotates underneath the orbit. Therefore, a satellite launched into our typical 90-minute LEO discussed earlier, yet inclined into a polar orbit, could image the entire earth's surface over a period of many days (remember a satellite in LEO orbit only "sees" a small portion of the earth's surface with each revolution).

The second fundamental concept deals with orbital eccentricity. It should be understood that, despite our use of circular orbits in describing notional orbits, no orbit is exactly circular. All orbits are at least somewhat less than perfect, or "eccentric." If you recall your Junior High School geometry days, eccentricity is a measure of how squashed a circle is—orbital eccentricity is identical. It is measured using the minimum and maximum altitudes a satellite achieves as it orbits the earth. For example, a LEO satellite with a "perigee" (minimum altitude) of 890 nm and an "apogee" (maximum altitude) of 900 nm has an eccentricity of 0.001—nearly circular. A satellite in a semi-synchronous orbit with perigee of 900 nm and apogee of 22,300 nm has an eccentricity of 0.7—quite elongated (see Figure 4). Both orbits are actually ellipses with the earth at the primary focus. As a satellite moves around an eccentric orbit, it goes faster near perigee than it does near apogee. As we will see, this characteristic is quite advantageous when an eccentric orbit is also inclined to the Equator.

**Figure 4.** **Comparison of Orbital Eccentricity (to scale)**



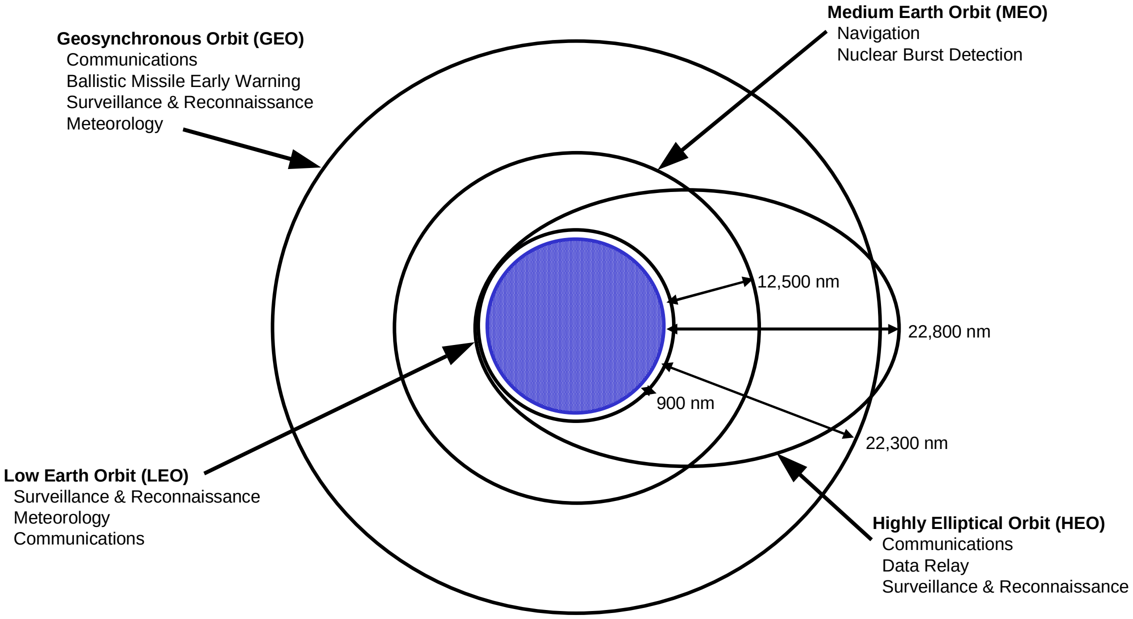
### Highly Elliptical Orbits (HEO)

A variation of the earlier semi-synchronous MEO orbit worth mention is the Molniya orbit. The orbit was first conceived and used by the Former Soviet Union to achieve better communication coverage across the predominantly northern Soviet landmass (remember the 70S-70N degree perspective limitation associated with geosynchronous orbits). By raising the inclination of the orbit to 63.4 degrees and adopting an elliptical orbit (200 x 23,800 nm), the result was a satellite orbit that spends over 80 percent of its time over the Northern Hemisphere and is readily available for missions such as early warning and communications.[12]

## Military Space Missions and Orbits

As implied, various military mission requirements lend themselves to specific types of orbits. As Figure 5 depicts, most military missions are aggregated in one of the four orbit regimes discussed previously.

**Figure 5. Traditional Orbital Regimes Used by the Military**



*Note: All orbits are shown with a zero degree inclination and as if viewed from above the North Pole (i.e., looking down on the Earth).*

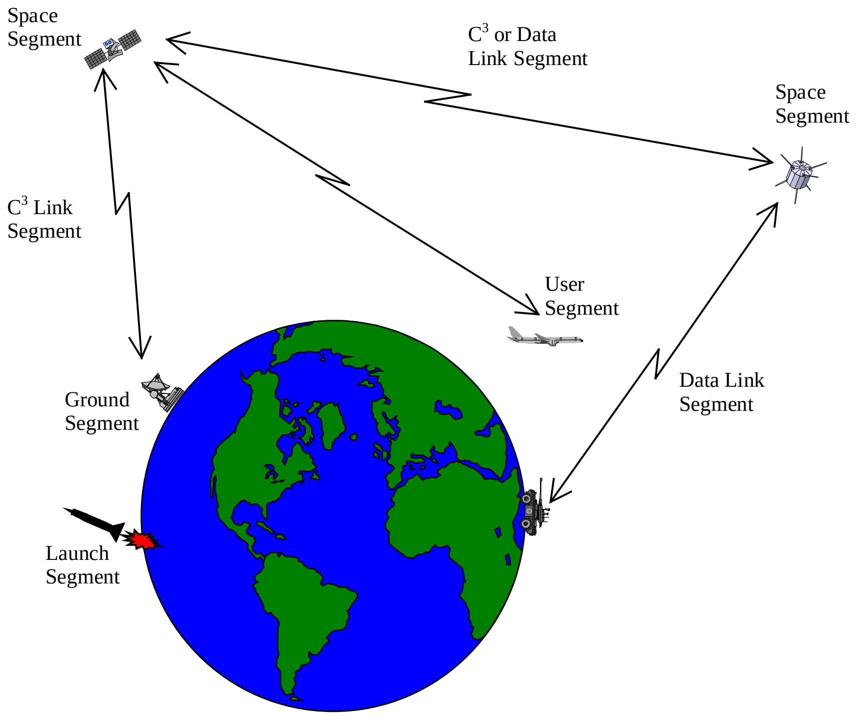
- Imaging and weather satellites perform best in LEO sun-synchronous orbits (near polar, retrograde) where the satellite passes over the same location at the same local solar time each day. Though commonly in LEO, remote sensing satellites that use non-optical sensors such as radar and infrared payloads can operate independent of the local solar time very effectively.

- Communications, data relay and early warning and some reconnaissance satellites are most likely to occupy GEO or HEO orbits to maximize coverage areas. The exception to the rule is the newest generation of LEO satellite constellations used for low power, mobile communications.
- Navigation satellites have traditionally used the semi-synchronous MEO to maximize global coverage and maintain stable orbits.
- Missions requiring frequent revisit time, small footprints and/or shuttle missions typically make use of the LEO regime.

## Defining A Space System

So far, we have focused solely on the spacecraft in orbit. As important as the satellite is to the conduct of any mission, it is only one part of a larger space system designed to operate as a whole. Traditionally, space systems have been described as consisting of three primary segments—ground, space and communication link—which is adequate for most purposes.[13] However, this description is somewhat simplistic for our purposes. Instead, we will use six primary segments to define and assess space systems—ground control segment, $C^3$ link segment, space segment, data link segment, user segment, as well as a launch segment (see Figure 6). Most conventional space systems will be comprised of all these segments, yet cases may exist where only a subset of these segments is applicable. However, an understanding of all six segments of this notional space system will be important as we examine the various space control concepts.

**Figure 6. A Notional Space System**



## Launch Segment

As implied in our discussion of orbits, all satellites must be “launched” or put in orbit by some external means. Launch systems consist of either expendable (rocket boosters) or reusable (space shuttle and a variety of reusable rockets) launch vehicles and some form of launch infrastructure. Traditionally, satellites have been launched from relatively large, fixed launch sites. However, the explosive growth in the commercial satellite market, combined with the smaller satellite components, has led to the development of a widening array of launch configurations—sea-based launch, air-launched boosters, etc.

From a military perspective, it is imperative that we understand the potential vulnerabilities of any launch segment and its impact to national security. Without question, the ability to launch critical military satellites and “replenish” on-orbit systems during hostilities is a major component of assured access.

## Ground Control Segment

Once on orbit, a satellite is autonomous in the sense that it requires no additional fuel, parts, etc.[14] However, satellites do require monitoring and control to maintain their functional "health" and must be directed to perform specific mission tasks. Each satellite has its own requirements regarding the amount of monitoring and intervention needed to turn systems on and off, execute maneuvers, maintain stable pointing and altitude, compensate for ever-changing temperatures due to the earth's shadow, keep proper spin rates, etc. Therefore, all space systems employ some form of ground control segment to ensure satellite health and effective operation. The more sophisticated space systems have such extreme $C^3$ demands that spacecraft will fail catastrophically within hours without the appropriate intervention from the ground segment. Other satellites can operate independently for weeks or months with little to no intervention.[15]

In most cases, a single ground $C^3$ architecture is responsible for one or more constellations of satellites. Typically, a primary mission control center is responsible for executing the complex calculations required to control each satellite, as well as orchestrate the constellation to accomplish its specific mission. Extensive $C^3$ networks made up of ground control sites and antenna stations are common with many of the older LEO systems. The details of antenna pointing, communication relay requirements, satellite state of health concerns, user position(s), frequency selection, mission data processing, etc. are deconflicted and executed by the ground control segment.

Without question, the ground control segment is of critical importance to the military strategist. In terms of friendly assets, the defense of relatively complex (and potentially vulnerable) resource(s) presents a unique challenge. One should also consider similar enemy assets as part of any offensive (i.e., negation) strategy.

## $C^3$ Link Segment

The commands generated by the ground control segment must be sent to the satellite(s) in orbit. Typically, this has been accomplished via a radio frequency (RF) communication link from the primary ground site directly to the satellite, indirectly through a separate relay satellite(s), or through a network of geographically dispersed ground relay stations. No matter what the means, a "link" exists between the ground controllers and the satellite. For our purposes, the $C^3$ link segment consists of the RF (or other) uplink/downlink signal(s) being sent to/received from the mission satellite. It may contain $C^2$ data being sent to the satellite by the ground controllers, as well as telemetry or mission data received by the ground segment from the satellite(s).

All satellite systems currently in operation make use of some form of $C^3$ link to maintain effective spacecraft operations. However, the degree of autonomy varies depending on the mission and type of spacecraft. The more complex satellites are only capable of relatively short periods of autonomous operation (e.g., a few hours) without some form of contact with ground controllers, while others can operate continuously for days or weeks without contact with the ground segment. If the maximum "out of contact" period elapses, the typical satellite response is to digress into a "safe" or "contingency" mode whereby the satellite commands itself into a stable, sun-pointing configuration to ensure all power and attitude control requirements are met. Mission operations typically cease during these periods until ground controllers redirect the satellite.

The importance of the $C^3$ link segment to the military strategist cannot be overlooked. If the ability to communicate via the $C^3$ link is denied or disrupted, the associated satellite(s) mission effectiveness will be affected. Depending on the mission type and characteristics, the effects may be regional or global since the space system could be impaired for all users. The worst case scenario would be the degradation or destruction of the satellite(s) itself due to an excessive "out of contact" period.

### Space Segment

Clearly, the space segment is the most recognized segment. With modern media images of shuttle missions, moonwalks and space exploration, we all have a concept of space and the environment in which satellites operate. The space segment—principally the satellites—is arguably the most complex and typically the most expensive segment of any space system. Each satellite is an intricate piece of hardware consisting of subsystems dedicated to attitude control, power generation, thermal control, propulsion, communications, as well as the primary mission payload such as remote sensing, navigation, communication, etc. As described, the satellite(s) will occupy a particular orbit as a means to accomplish its mission(s).

The importance of relay satellites to overall mission effectiveness is wothy of special attention. If a particular space system is reliant on one or more relay satellites to forward $C^3$ or mission data to the ground controllers or end users, it is clearly a critical node whereby a space system could be neutralized. This is especially pertinent if the relay satellite(s) is used to support multiple space systems.

Undeniably, any discussion related to space control immediately gravitates towards the space segment since it is central to the contested operating medium. However, it cannot be overemphasized that the space segment is only one of the many segments critical to the effective operation of a space system.

### Data Link Segment

No matter what the mission of a space system, data or information must be transmitted to the end user. Often (but not always), this involves a separate communication link to the user. For example, a telecommunications satellite will send or relay a signal to a broad area (e.g., direct broadcast system) or individual user (point-to-point communication). In the case of a reconnaissance satellite, the data is typically processed by a ground site and then disseminated to the end user in a more usable format.[16] This separate data link operates using decidedly different operating characteristics—frequency, direction, format, etc—when compared to the $C^3$ link segment described earlier. Similarly, the transmission of data or information to the user is sent directly via a RF communication link from the satellite to the user, indirectly through a separate relay satellite(s), or through a terrestrial communication network. For our purposes, the data link segment consists of the RF (or other) downlink of mission data to the user and uplink of data (if applicable) from the user to the mission satellite; it will usually only contain mission data.

As with the $C^3$ link, the importance of the data link to the military strategist can never be overlooked. If the ability to communicate via the data link is denied or disrupted, the overall space system's mission effectiveness is impacted. The uniqueness of this link makes it a separate and distinct asset. Therefore, defensive measures must be address on friendly assets, as well as vulnerabilities assessed against enemy assets.

### User Segment

The last segment in our notional space system is the user segment. It consists of the ground, naval and airborne assets that the space system(s) support. These assets typically include the equipment necessary to receive the mission data, any associated processing and display equipment, as well as the personnel responsible for receipt, processing, exploitation, dissemination and feedback as appropriate.

For the military strategist considering space control, the user segment offers yet another asset that must be defended and sustained to ensure mission success. The adversary’s user segment(s) also offers a variety of opportunities to deny access to the space domain. Finally, it should also be noted that the end user’s mission objectives are the final yardstick against which space system’s effectiveness is measured.

## Chapter 3

# Context Of Space Control

> *Man has always sought to expand his domain. In subduing the earth, man moved into the water, under the water, into the air, and into space as technology allowed. With him, man took war. Man will take war into space. It is not a matter of if; it is merely a matter of when.*
>
> — Lt Col Thomas Eller & Maj Charles Friedenstein
> *The Great Frontier: A Book of Readings for the US Air Force*
> *Academy Military Space Doctrine Symposium, 1-3 April 1981*

## Importance of Space

The assertion that war will inevitably move to space has been a common theme among civilian and military circles for decades. The general consensus has been that the projection of war into space is inevitable—only technology and international restraints slow the progress.

Today, space is integral to military operations, commercial enterprise and even the social well-being in most developed countries. In fact, many consider space to be a classic "center of gravity" due to its central role in modern society.[17] The simple fact that more than $250 *billion* will be invested in space by the year 2000 and that more than $1.2 *trillion* will be generated in global telecommunications revenue by 2005 lends tremendous credence to these assertions.[18] Former Commander in Chief, US Space Command, Gen Howell Estes aptly described the strategic importance of space:

> Satellites do far more today than just help us defend American interests. Commercial satellites keep our financial institutions connected…and beam the Super Bowl into our homes. Weather satellites tell us when violent storms threaten our homes and loved ones…and when to plan the family picnic. Imagery satellites monitor climate changes…and help farmers best use their land to grow food for our tables. The same GPS satellites that tell our military forces exactly where they are anywhere in the world also keep airliners on course…and map out directions for drivers on our highways.

He adds,

> Space provides us with so many services that we are now reliant on it. Simply put, space is becoming a vital national interest—in the information age we are entering, no less important than oil is to our world today. And just as availability of oil was used against this country during the oil embargo of the 70's, this new source of national strength also could be become a vulnerability.[19]

Today, the dependency-vulnerability relationship is a major concern because nations have been leveraging space for national security through reconnaissance, communications and early warning operations. Hence, the need for a means to "control" the activities in space—just as one controls activities in the other mediums of conflict.

## Space Control's Legacy

As stated, the concept of controlling the "third dimension"—the medium of space above the earth's surface—is not a new phenomenon.[20] Strategic visionaries dating back to Napoleon have conceptualized how one could control the vertical dimension. In general, theories and concepts regarding how best to exploit space militarily were the sole domain of visionaries until the unexpected launch of *Sputnik 1* on October 4, 1957. The historic launch employed an SS-6 "Sapwood" ICBM and changed these perspectives almost overnight. Embroiled in a Cold War, Americans were stunned by the fact that the Soviets were ahead in a new contest the media and Congress dubbed the "space race." An aide to Senator Lyndon Johnson captured the mood aptly,

> It really doesn't matter whether the satellite has any military value. The important thing is that the Russians have left the Earth and the race for the control of the universe has started.[21]

This new "threat" galvanized the nation with a new mindset regarding the control of space. The Air Force Chief of Staff, Gen Thomas D. White, summed this up in Nov 1957,

> …whoever has the capability to control the air is in a position to exert control over the land and seas beneath…in the future whoever has the capability to control space will likewise possess the capability to exert control of the surface of the earth.[22]

In the larger context of space, *Sputnik 1* established a legal precedent that the Eisenhower administration had been diligently seeking—the concept of "freedom of space." Similar to the unsuccessful "Open Skies" proposals that he presented to the Soviets in 1955, which had been crafted to allow reconnaissance aircraft overflights of each other's territory, "freedom of space" held tremendous potential for reconnaissance purposes.[23] President Eisenhower stressed that the US was not in a "space race" with the Soviets, opting instead to pursue space for "peaceful purposes for the benefit of all mankind." US space efforts were directed towards pure scientific research, civil applications (such as communication systems) and limited military support applications (such as automated reconnaissance satellites).[24] The latter mission of space reconnaissance was considered to be of "critical importance to US national security" because it had "high potential use as a means of implementing the open skies' proposal or policing a systems of international armaments control."[25] The administration was rewarded by its efforts in 1959 when the United Nations declared the "permissibility of the launching and flight of space vehicles…regardless of what territory they passed over during the course of their flight through outer space" with this caveat the new international law only applied to "peaceful" missions. The administration gladly accepted the new law by categorizing reconnaissance satellites as "peaceful" defensive support missions.[26] This string of events culminated in a national policy of "space sanctuary" which has endured, in varying degrees, over the past four decades to the present.

As our national leaders laid the foundation for space as a sanctuary, the military focused on how to control and exploit the new domain of space. By reviewing the myriad of military programs designed to counter the space threats, two dominant paths emerged as the military services pursued the requirement to control space: manned military weapon systems and terrestrial-based anti-satellite (ASAT) weapons. Both were viewed as truly viable options to negate the emerging space threat.

One of the first issues faced by the military was determining if there was a legitimate role for man in space. The first serious military initiative aimed at exploring this issue came as an outgrowth of future concept work conducted by the Bell Aircraft Company and the US Air Force in 1952. The most significant outcome of these studies was the weapon system 464L named "Dyna-Soar" (an engineering acronym for Dynamic Soaring)—considered to be the first manned military aerospace system. The Air Force's 1957 proposal called for using Dyna-Soar as a reusable shuttle to routinely perform orbital reconnaissance and provide an element of strategic deterrence as a nuclear bomber capable of speeds, ranges and altitudes that would make it essentially invulnerable.[27] Given the Eisenhower administration's unstated policies of minimizing the cost of space systems, avoiding "prestige" missions, and rejecting any form of offensive space activity that might place US reconnaissance satellites at risk, Dyna-Soar would soon face many obstacles. As technical and cost pressures increased, so did the political demands to terminate the program—ultimately Dyna-Soar was cancelled in December 1963.[28] Prior to its cancellation, the OSD (namely Defense Secretary Robert S. McNamara) directed the Air Force to create an additional designator for the Dyna-Soar program ("X-20") to highlight the experimental nature of the program's first phase. Shortly thereafter, Secretary McNamara cancelled the Dyna-Soar/X-20 program and reallocated the program funds to the OSD-sponsored Manned Orbiting Laboratory (MOL). Both programs were designed to determine the military role of man in space by assessing his unique capabilities in various military space activities and perform specific military missions.[29] Ultimately, the DoD considered these activities insufficient and comparatively too costly, which led to the termination of each program. The end of MOL signaled the close of the Air Force's efforts to create a separate military manned space program. The DoD was then directed by the administration to turn to NASA's Space Shuttle as its sole means of manned space flight. The space transportation system's primary emphasis would be launch support and, as with the first phases of Dyna-Soar and MOL, experimental efforts (vice the military missions of reconnaissance, interdiction, logistics and bombardment envisioned by the early airpower strategists and incorporated into these systems at various stages of their planned operations).

While the military manned space effort capability to "control" space, the second path—consisting of terrestrial-based anti-satellite weapons—is another story. As noted, the launch of *Sputnik I* created an emotional fear across the US, principally because of perceptions that the Soviets would launch nuclear weapons from space-based platforms. While the nation's leaders tried to dissipate these concerns by emphasizing their unfeasibility, these efforts were to no avail.

Fortunately, in response to the detonation by the Soviets of their first H-bomb on August 12, 1953, President Eisenhower had already directed that the Atlas ICBM development would be the nation's number one development priority.[30] Fortuitous as this 1955 decision may have been as a deterrent to nuclear warfare, this early ICBM development formed the initial foundation for the early ground-based ASAT, as well as the accelerated ICBM, SLBM and spacelift efforts that were soon to follow.[31]

Concurrent with the development of the manned space weapon systems, the military began to assess the potential merits of developing a terrestrial-based satellite "kill" capability. A series of automated programs soon emerged that also challenged the early "Freedom of Space" then "Space for Peace" themes being trumpeted in the late 1950's. The first such program was the Satellite Interceptor (SAINT)—conceptualized as a ground-based ASAT in 1959. It was quickly restricted to an R&D-only effort with the limited objectives of rendezvous and inspection (vice "kill").[32] The SAINT R&D program was followed in May 1962 by Program 505—an ASAT interceptor developed around the Army's Nike Zeus Anti-Ballistic Missile (ABM). Given the missile's limited range (less than 200 nm), Air Force leaders quickly sought approval to transition to a larger Thor IRBM-based option. Approved as Program 437, facilities on Johnston Island (which had been used for high-altitude nuclear test known as Project Fishbowl) soon served as the ground site for these new nuclear-tipped Thor anti-satellite missiles.[33] Despite the political sensitivities of deploying an ASAT designed to detonate a nuclear weapon in space, Project 437 was operational in various forms from May 1964 through April 1975. Therefore, Program 437 provided the US with its first step towards an operational capability to control space.[34]

In contrast, the Soviets focused their ASAT efforts during this period on a "co-orbital" interceptor launched into space by a liquid-fueled SL-11 booster. Once in orbit, ground controllers maneuvered the interceptor vehicle so that it would pass in close proximity of the target satellite. As it approached the target, the on-board guidance system took over. Once in range, an explosive charge detonated sending a cloud of shrapnel toward the targeted satellite destroying it. Over twenty developmental and operational tests were performed from 1968 through 1982 with mixed results.[35] Regardless, the mere existence of an operational Soviet ASAT served to galvanize tremendous support in the US for an operational space control capability.

With the demise of Program 437 and the reality of a Soviet ASAT threat, the US Air Force began to reconsider an air-launched option.[36] In 1971, initial efforts focused on an F-106 interceptor armed with a Standard Anti-radar Homing Missile carrying a small second stage and a terminal homing vehicle armed with either a conventional or nuclear warhead. Although the program, known as Project SPIKE was not developed, it laid the groundwork for a follow-on program—the Prototype Miniature Air-Launched System (PMALS).[37] PMALS consisted of an F-15 armed with a miniature homing intercept vehicle (MHV) carried on a modified short-range attack missile (SRAM).[38] A series of operational tests culminated in a successful demonstration on 13 September 1985, when a miniature homing vehicle struck and destroyed the P78-1 Solwind satellite in a 320 nm orbit. Initial deployment plans called for two F-15 squadrons and their ASAT missiles to be stationed at Langley AFB, VA and McCord AFB, WA. However, as with the other ASAT systems, political controversy, budget limitations and principally test restrictions led to the program's cancellation in March 1988.[39]

Concurrent with the PMALS initiative, political and military interest was on the rise regarding Anti-Ballistic Missile (ABM) systems that held the promise of protecting the

US from ballistic missile attacks. In 1983, President Reagan directed the start of the Strategic Defense Initiative (SDI)—or popularly known as the "Star Wars" program—consisting of both earth- and space-based ABM components. While the SDI efforts were geared towards ABM missions, they would have unavoidable effects on space control mission because the technologies for ballistic missile defense (BMD) and satellite attack overlap in critical areas. The surveillance and warning capabilities, space-based and terrestrial-based missiles and lasers, as well as particle beams, all could be considered dual-use technologies to some extent.[40] Therefore, there was no clear way to disentangle the ASAT issue from broader BMD considerations. Years of concern related to SDI's "destabilizing" effects, technical and budgetary feasibility, and military usefulness were punctuated by the demise of the Soviet Union in 1991. As a result, the SDI focus shifted to a more limited technology development program aimed at development of Global Protection Against Limited Strikes (GPALS) capability consisting of theater, national and global missile defense segments.[41]

Several powerful themes emerged in the early 1990's that resulted in a "sea change" in the arena of space control. First, the ever-present Cold War threat was abated with the fall of the Soviet Union. The lack of a consensus concerning a recognized, viable threat in space made it difficult to galvanize political, military and popular support for the development and employment of what many considered diplomatically "destabilizing" weapons. This aversion to space control initiatives—especially space-based weapons—was magnified by a negative bias among most of the international players. Second, the declining budgetary environment forced decision-makers to parcel out less resources among a growing number of competing interests and current crises. The result has been less support across the national security space community for space control capabilities as they competed against the traditional needs of the services. Lastly, the explosive growth in the commercial space systems sector, especially with regards to international consortia, has introduced an entirely new set of factors into the space control arena. Issues such as technology proliferation, competition in the international marketplace, discrimination between friend and foe once conflict begins, and a host of other issues have stemmed from the increasing dominance of the commercial sector in key areas of space. As a result, the decision to develop and employ weapons designed primarily for the control of space has become increasingly more complex.

## Summary

Three themes emerge from this (albeit) cursory review of the more prominent space control efforts over the last forty-plus years of spaceflight. First, the importance placed on space has been, and continues to be, central to modern society—especially the military. Hence, the need to control its use. Second, the existence of a known or perceived threat to space systems has traditionally been sufficient cause to galvinize support for action. In some cases, this action takes on an extremist character—such as nuclear-tipped ASAT missiles—despite more tempered diplomatic and budgetary concerns. Lastly, the historical means to “control” the medium of space has been the application of force against an adversary’s space-based assets. Little attention was paid to other "means” to control space.

# Chapter 4

## Space: Observations & Dilemmas

> *Space is a military medium which has not been exploited for combat. The reasons are largely political and financial. But those barriers are not holding back other nations. They are exploring the fundamentals of space combat systems and operations. The US is behind in thought, debate, and experimentation. Let us not be caught wanting by a space combat Pearl Harbor.*
>
> —Lt Col Michael R. Mantz, USAF
> *The New Sword: A Theory of*
> *Space Combat Power, 1995*

The importance of space is clear. Space has become a vital national interest upon which we are heavily reliant. In fact, it is difficult to imagine functioning without space—at home, at work or at war. For the military, space has been declared "inextricably linked" to a wide array of operations on land, sea and in the air. Additionally, tremendous attention is being focused on wholly migrating many other key military functions such as ISR, early warning, weapons guidance, communication and environmental monitoring to space.[42] As such, our dependence on space continues to grow—not only militarily, but socially and economically. Clearly, any threat to our use of space is a threat to our national security.

However, the uniqueness of space presents a more complex set of concepts. In this chapter, we will examine the central space control concepts and terminology, establish the attributes from which space derives its importance, as well as identify specific trends and dilemmas associated with the use of space systems.

## Space Control: Concepts & Terminology

As alluded earlier, the importance of space makes it necessary to exercise some form and degree of strategic control of space—similar to the need to control actions in the air, on the land, and on and beneath the sea. Unfortunately, when the strategist seeks guidance related to space control, there is little consensus regarding the terminology or concepts. There is clear recognition regarding the four basic mission areas of military space operations—force enhancement, force application, space control and space support. Table 2 provides generally accepted descriptions of each mission area.

**Table 2: Military Space Operational Mission Areas**

***Force Enhancement*** – operations conducted from space with the objective of enabling or supporting terrestrial-based forces.

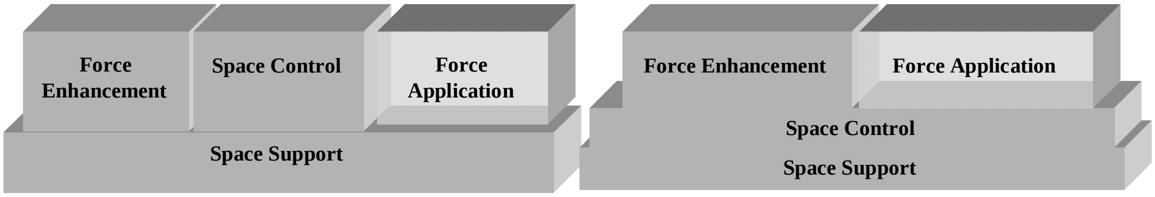
***Force Application*** – operations carried out by military weapon systems operating in space against terrestrial-based targets.

***Space Control*** – means by which space superiority is gained and maintained to assure friendly forces can use the space environment while denying its use to the enemy.

***Space Support*** – support operations carried out by terrestrial-based elements of military space forces to sustain, surge and reconstitute elements of a military space system or capability (these typically include various forms of spacelift and space operations).

The concept(s) consists of three relatively distinct mission areas focused on different variations of space combat are supported by a relatively robust space support infrastructure. Unfortunately, insights regarding the interaction between or the dynamics of the various mission areas is relatively scarce. In general, the relationship between the mission areas is perceived one of two ways as shown in Figure 7. As discussed below, the most effective way to approach military space—especially when considering the control of space—is the construct on the right.

**Figure 7. Common Military Space Perspectives**



Three primary documents describe the US military's understanding of space control—Air Force Doctrine Document 2-2 entitled *Space Operations,* US Space Command's *Long Range Plan*, and the draft Joint Pub 3-14 entitled *Joint Doctrine, Tactics, Techniques and Procedures for Space Operations*. Though there are many common themes, there is a clear discontinuity even at the most basic level regarding key terminology, concepts, focus and presentation. To avoid a long dialogue on the merits of each, Table 3 highlights the main points of emphasis in each manual, as well as a proposed space control perspective.

### Table 3: Space Control Objectives, Missions & Operational Concepts

| | *Space Operations* | *Long Range Plan* | *Joint Doctrine Pub* | *Proposed Space Control Perspective* |
|---|---|---|---|---|
| *Objective* | **Space Superiority** | **Control of Space** | **Space Superiority/ Space Control** | **Space Superiority** |
| *Mission* | **Defensive Counterspace**<br>**Offensive Counterspace** | | | **Space Control** |
| ***FUNCTIONS / ATTRIBUTES*** | | Assured Access | | Assured Access<br>*- Spacelift*<br>*- Space Operations* |
| | Survey | Space Surveillance | | Space Surveillance |
| | Protect (DCS)<br>*- Active / Passive* | Protect<br>*- Active / Passive*<br>*- Self-Protection* | Protection<br>*- Active / Passive* | Protection<br>*- Active / Passive*<br>*- Self-Protection* |
| | Prevent | Prevent | Prevention | Prevention<br>*- Diplomatic*<br>*- Legal*<br>*- Economic* |
| | Negate (OCS)<br>*- Lethal / Non-lethal*<br>- $D^5$ | Negate<br>- $D^5$ | Negation<br>- $D^5$ | Negation<br>*- Lethal / Non-lethal*<br>*- Direct / Indirect*<br>*- Permanent / Temporary*<br>- $D^5$ |

***(Source: Adopted in part from Doran, Toby G., 1Lt, USAF, "Toward Development of an Integrated Aerospace Doctrine," Wright-Patterson AFB, OH: Air Force Institute of Technology, These for Masters of Science in Space Operations, March 1999, #AFIT/GSO/ENY/99M-02, 86)***

Table 3 highlights both the commonality and divergence in the current space control documentation. For our purposes, a somewhat consensus perspective has been adopted. However, it is separate and distinct in many ways. To begin, *space superiority* will be used to describe the operational objective (or goal), while *space control* will be used to describe the mission (or means) executed to achieve it.

More specifically, *space superiority* will refer to the control of the medium of space. This control enables freedom of action without significant interference from an adversary (i.e., uninterrupted access to space and operation within space), as well as the ability to deny others the use of space. Two key components of space superiority are worthy of note. First, various forms and degrees of space superiority exist. This is because the medium of space can be controlled via a variety of methods each producing its own unique effects. For instance, jamming a communication or navigation signal in a region is unique in many ways—relatively localized effects, easily regulated with respect to time (continuous or intermittent) and can often be discretely employed to minimize collateral effects. By combining this and other space control means, a specific form and degree of space control can be achieved. Second, once achieved, space superiority serves as an enabler—a means to other ends. In other words, space superiority (i.e., controlling the medium of space) is of no utility in and of itself. Instead, the value of gaining and maintaining space superiority lies in the activities—terrestrial-based and space-based—that can be conducted with minimal, or ideally no, risk. For the military, these activities typically include information-based operations that rely on space-based assets. Therefore, space superiority will always be an essential prerequisite for success in modern warfare in the air, on the land, on and beneath the sea, and eventually in and from space.

The term s*pace control* will be used to refer to the means by which space superiority is gained and maintained. The term “control” has been adopted to emphasize the relatively complex nature of the task. The mission is not simply to counter an adversary’s military space force, but is focused on control of both the medium and use—hence the force, activities and information associated with it. As alluded to earlier, a variety of space control actions can be used to achieve the necessary space superiority. These actions can vary from relatively benign diplomatic and legal actions to economic sanctions to military force, with either terrestrial-based or space-based assets.

As depicted in Table 4, the proposed perspective includes five space control "functions" that are key to successfully conducting space control operations and ultimately attaining space superiority. They include two foundational functions—assured access and space surveillance—upon which all other activities are reliant to some degree. The three remaining functions—protection, prevention and negation—form the core space control mechanisms used to achieve the desired form and degree of space superiority. Each has "attributes" that describe the critical characteristics expected. For clarity, the space control functions are defined in Table 6 above.

**Table 4: Proposed Space Control Functions**

***Assured Access*** – refers to the functions needed to place objects in space (i.e., spaceflift) and conduct operations in space. *It should be noted that "assured access" is essentially those referred to in the mission area entitled "space support."* The object of spacelift is the delivery of space-based assets to (and potentially through or from) space in a reliable, flexible, cost-effective manner. Currently, spacelift assets include a mix of expendable launch vehicles (e.g., rockets) and reusable launch vehicles (e.g., shuttle). Future capabilities will include a larger variety of expendable and reusable launch vehicles, as well as space operational vehicles (SOVs) and space tugs designed to deploy, reconstitute, replenish, refurbish, augment and sustain space systems. On-orbit operations includes the traditional tasks of TT&C of satellites.

***Space Surveillance*** – In general, space surveillance refers to the surveillance and monitoring of all significant activities related to space. Specifically, it is the ability to quickly and accurately detect, track and characterize objects launched into space and other space-related activities, as well as the ability to notify the appropriate entities and disseminate information as warranted.

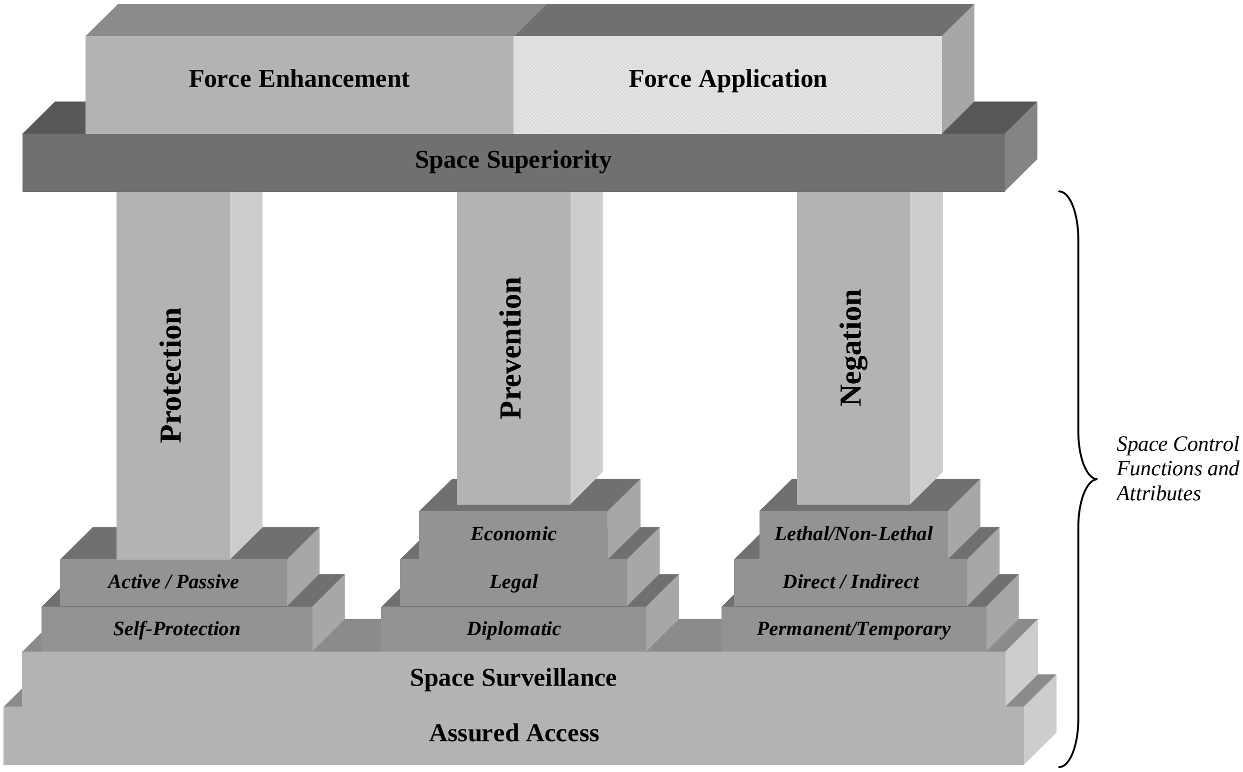
***Protection*** – refers to the self-protection capabilities, as well as the active and passive defensive measures used to counter both natural and man-made threats to space systems. Specifically, it includes the threat identification and warning systems; defensive measures such as robustness, hardening, mobility, maneuver, proliferation, etc.; mission impact assessment; and the ability to reconstitute and repair impaired space-based capabilities.

***Prevention*** – refers to the non-military means—diplomatic, legal and economic—used to deny an adversary the advantages of space-based capabilities. Examples include denying the use of space-based assets to an adversary through shutter control, economic sanctions, etc.

***Negation*** – refers to the use of military force to neutralize (i.e., deceive, disrupt, deny or degrade) or destroy an adversary's space-based capabilities. Specifically, it includes attacks on a space system's ground-based components, data link(s), satellites, user equipment and/or launch infrastructure to produce the desired effect. Actions can typically be categorized as lethal/non-lethal, direct/indirect and or permanent/temporary.

Next, it is important that the relationship and interactions between the five space control functions be understood. For this purpose, a space control construct is proposed as illustrated in Figure 8.

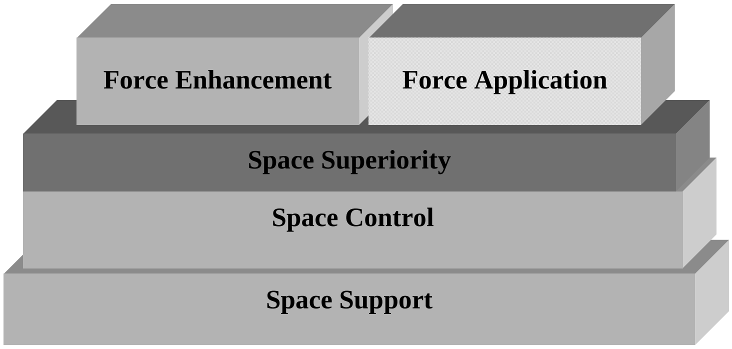
**Figure 8. Proposed Space Control Construct**



As shown, the foundation and pillars collectively form the mission area known as space control from which space superiority is achieved for the ultimate purposes of force enhancement and potentially force application in the future. From this construct it is clear that space control is most applicable in a contested environment (i.e., in the presence of a threat). The construct emphasizes the supporting nature of assured access (e.g., spacelift and space operations) and space surveillance across the full spectrum of space control activities. Additionally, it illustrates the relative independent nature of the core space control functions, yet effectively depicts the inherent interactions through the objective of space superiority. Ultimately, the form and degree of space superiority achieved will determine the effectiveness of the ongoing force enhancement and force application operations.

In essence, we have simply magnified the preferred military space perspective depicted earlier—the key being increased emphasis on both space control and space superiority in the strategic sense (see Figure 9).

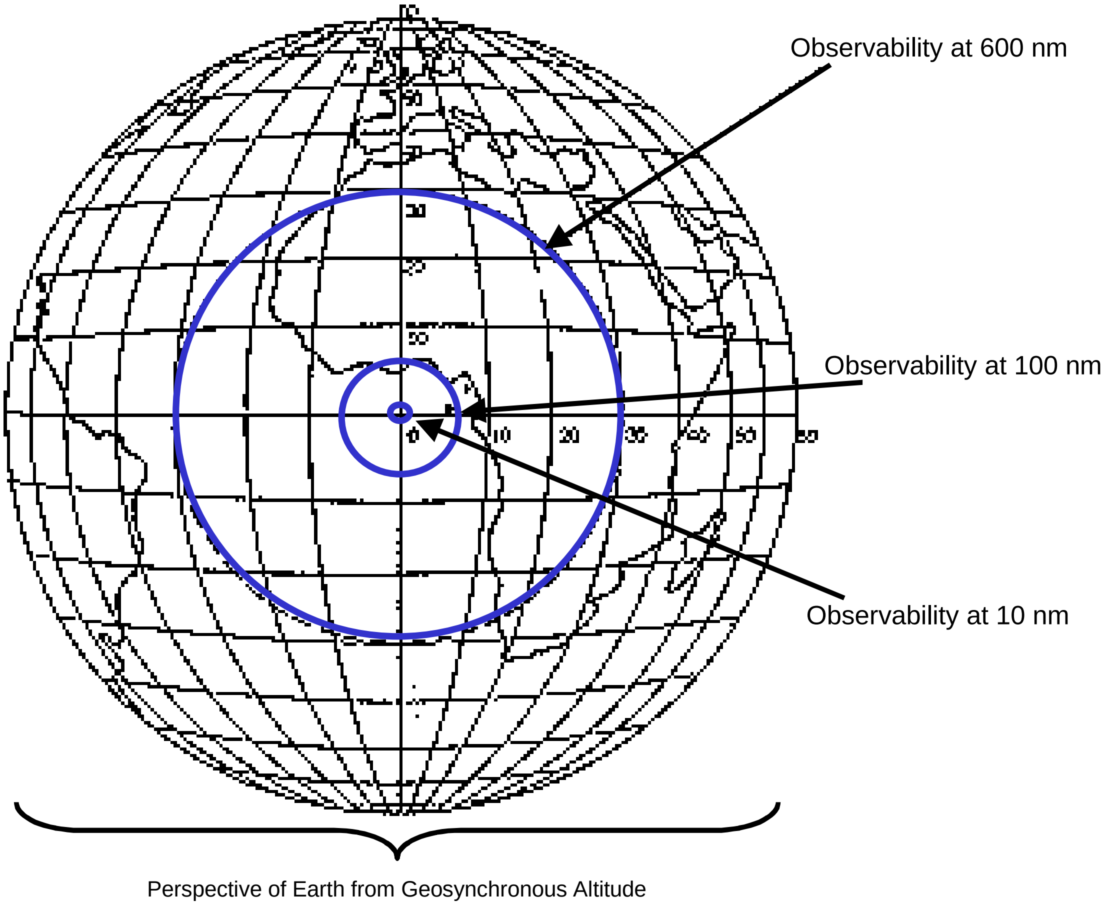
**Figure 9. Proposed Military Space Perspective**



## Space: The Ultimate High Ground

First, the evolution of space into a dominant force multiplier hinges on several unique characteristics. Most notable is the unmatched *perspective* one achieves from space. The vantage point of space offers clear benefits related to *observability*—the ability to "see" relatively vast areas of the earth—regardless of whether the mission is remote sensing (i.e., intelligence, surveillance, reconnaissance, early warning or environmental monitoring), communications, navigation, or force projection. For example, a satellite orbiting at only 200 nm above the earth (referred to as a "low-earth orbit") can "see" 2.7 percent of the earth's surface, while a satellite at 22,300 nm (a "geosynchronous orbit") can "see" 42.4 percent of the earth's surface. In comparison, an aircraft operating at the relatively extreme altitude of 10 nm can only "see" 0.14 percent of the earth's surface.[43] Figure 10 depicts this concept of perspective. However, coincident with this perspective is a high degree of *exposure*. If a satellite can "see" a terrestrial object, the object being observed on the ground can "see" the satellite. The effect of this characteristic is magnified since satellites orbit the earth in a fairly predictable manner and the fact that there is essentially no terrain or "cover" in space.[44]

**Figure 10. Perspective of Earth from Various Altitudes**



Second, space offers a *sovereign operating medium* for the vast majority of missions conducted from space due to international agreement such as the Outer Space Treaty and customary international law. The fact that satellites can operate freely over any point on the earth has always been, and will most probably always be, a critical element in the decision criteria to move functions, traditionally performed terrestrially, to space.

Third, the magnitude of space in terms of dimensions presents tremendous challenges—especially regarding its effect on orbits, missions and operations. Space is an *infinitely larger operating medium* when compared to our traditional terrestrial perspectives of air, land and sea. The result is a sense of *remoteness*. We can appreciate this expanse by considering that the distance from the earth to geosynchronous orbit is almost the same distance as a complete trip around the earth. Likewise, a simple one-degree separation at geosynchronous when viewed from the ground, a common practice to preclude communications interference, translates to approximately a 400 nm separation in orbit. It is important to note that relative distances and speeds are also dynamic in nature. Though somewhat cyclical in nature, activities such as new deployments, maneuver, perturbations and attrition can dramatically alter these spatial relationships. In summary, it should be evident that the expansive operating medium and dynamic nature of space requires a somewhat modified operating perspective related to distance, depth, speed and time.

Finally, these attributes combine to make space-based assets an unrivaled means for conducting a host of missions such as intelligence, surveillance, reconnaissance, early warning, communication, navigation, environmental monitoring and, potentially, force projection. These missions can be performed either solely from space or by complimenting terrestrial-based capabilities. As this list of missions shows, the principal military role of space has been, and is currently, one of *force enhancement* to ongoing terrestrial-based actions, policy-makers and others.[45] The Persian Gulf War—considered by many the apex of military space operations and dubbed the “first space war”—highlighted the prominence of the force enhancement role. General Donald J. Kutyna, the Commander of NORAD, US Space Command and Air Force Space Command during the Gulf War, noted that space played a “major role *in support* [italics added] of our land, sea and air forces” during Desert Storm.[46] It is also important to note that this support is almost exclusively *information-based*—electro-optical, radar and infrared imagery; a myriad of signals intercept data; long-haul and mobile communications traffic; positional and timing data; meteorological, cartographic and geodetic (MC&G) information. Should the fact that the principal military role of space is one of "support" be considered a negative? Absolutely not! In fact, many would contend that the "information revolution" only magnifies the importance of this military, as well as economic, political and social, support role. Retired General Thomas S. Moorman, Jr., former Air Force Vice Chief of Staff, describes how Operation Desert Storm transformed senior military leaders perspective regarding space. Space is like "air conditioning—everyone who needs and wants *information from space* [italics added] wonders how we ever got along without it."[47] Hence, the renewed political and military discourse regarding space control as a means to safeguard this emerging domain. As a result, the traditional constraints of technology and limits regarding space policy are being challenged in a new climate that recognizes the importance of space and the potential threats. Even the politically taboo topic of space-based weapons is receiving renewed consideration as a viable option for NMD. Regardless, it should be clear that although space is often referred to as the "fourth medium" of war, the center of mass regarding space-based assets, at least for the near-term, is one of information flow (e.g., *information-based, force enhancement*).

## Current Trends in Space

The potential of space in the wave of the ongoing information revolution has fueled several dramatic trends. While important in and of themselves, these trends are creating a unique operating environment for anyone tasked to secure "control" of space.

### Commercialization

The commercialization of space is one of the principal catalysts behind the explosion of space's functionality in modern society. Historically the domain of governments, space is rapidly becoming the domain of business. In fact, the technology edge, long the domain of the government, is being challenged, even surpassed in some instances, by commercial enterprises. General Thomas S. Moorman, Jr., enumerates a number of reasons for this change:

> Rapid evolution of information technologies such as the explosive growth in semiconductor technology, digital signal processing and voice compression;
> Progress in international space policy to include increasing deregulation of telecommunications services, allocation of new frequency spectrums to commercial satellite communications and allowance of higher imagery resolution for commercial remote sensing;
> Fundamental changes in the process and cost of satellite manufacturing;
> Increased reliability (if not decreasing costs) of space launches;
> Expanding global demand for satellite services driven by the information revolution.[48]

Consequently, a tremendous infusion of private capital has moved into space and space-related industry—current worldwide revenues from space are estimated to be $88 *billion* annually and are projected to grow to $117 *billion* by 2001. The primary driver for this phenomena is the commercial space sector with an annual growth rate of 20 percent, as compared to 2 percent for the government space sector.[49]

### Globalization

To raise the substantial capital that is required to acquire and operate modern space systems, space entrepreneurs are seeking financial collaborators and equity investors. As a result, there has been an explosion in the *number* and *complexity* of international affiliations in recent years. Table 5 provides a list of the more dramatic projects undertaken in just the last five years.

**Table 5: Major International Commercial Space Projects (1994-1999)**

***Launch***

Boeing Sea launch venture teaming Norwegian, American, Russian and Ukranian firms to produce a space launch system;
Lockheed Martin's joint venture with Russian firms RKK Khrunichev and RKK Energiia to market Proton launch vehicles;
The Starstem joint venture with the Progress Rocket and Space Complex and Areospatiale;

***Communication***

Globalstar's venture to jointly produce communications satellites with CAST in China;
The Celestri broadband communications systems involving USA's Motorola and France's Matra;

***Remote Sensing***

EarthWatch (US) equity investments from Hitachi (Japan), Nuova Teespazio (Italy) and McDonald, Dettwiler and Associates (Canada);
Space Imaging (US) equity investments from Mitsubishi Corp (Japan), Van Der Horst Ltd. (Singapore) and Space Imaging Europa (Greece), as well as contracts to distribute other indigenous imagery products produced by India (IRS series), Canada (Radarsat) and Japan (JERS);
Israeli Aircraft Industries (IAI) and Core Software Technologies (US) venture to develop the Earth Resource Observation Systems (EROS);
Chinese-Brazilian Earth Resources Satellite (CBERS) initiative;
US Air Force contract to France's Matra CAP Systems to build a mobile receiving and processing station for SPOT and other types of civilian imagery;
Russian civilian remote sensing providers contracting with Western imagery data distributors such as Jebco Information Services (England), Core Software (US) and Satellitbild (Seden) to help market imagery data;

***Marketing & Infrastructure***

TRW's cooperative arrangements with the governments of Korea and Taiwan;
Pratt and Whitney's marketing and co-development venture with Energomash.

***(Source: Tahu, G.J. et al, "Expanding Global Access to Civilian and Commercial Remote Sensing Data: Implications and Policy Issues," Space Policy (3 August 1998): 185, and Aldrin, Andrew J., "Technology Control Regimes and the Globalization of Space Industry," Space Policy (May 1998): 115)***

A quick review of the list offers several key insights. First, the diverse nature of the multinational collaboration not only includes government-to-government and commercial joint ventures, but also business relationships between governments and foreign commercial firms. Clearly, government organizations and commercial enterprises are becoming increasingly receptive to engaging international partners simply to amass the necessary resources in today's tight budgetary environment. In addition, the desire to establish global distribution networks (especially in the remote sensing sector) is fostering commercial relationships and strategic alliances among a larger, more intermingled set of players.[50] Lastly, it should be evident that many of the listed affiliations involve significant degrees of technology transfer and sharing between former Cold War “adversaries.”[51]

## Proliferation

The result is the proliferation of a new and powerful set of commodities such as remote sensing products, worldwide communication services and navigation aids available to a broader global marketplace.

Given the strong heritage of government dominance of remote sensing systems and their role in national security and military operations, the civilian and commercial market offers a striking example of these explosive growth trends at work. By contrasting Table 6 and 7, the growth in the number, diversity and capabilities of civilian and commercial remote sensing systems in recent years is clearly evident.

**Table 6: Civilian and Commercial Remote Sensing Space Systems (1960-1997)**

| Country | Satellite (Company) | Sensor (Resolution) | Available |
|---|---|---|---|
| *USA* | TIROS | MSI (1 km) | 1960 |
| | Landsat | MSI (30 m) | 1972 |
| *France* | SPOT | P (10 m); MSI (20 m) | 1986 |
| *Russia* | Resurs-O | P (1-2 m); MSI (4 m) | 1988 |
| | Resurs-F / Kosmos | P (2-30 m); MSI (5-8 m) | 1991 |
| | Mir / Priroda / Salyut | P (2-3 m); MSI (5-25 m); Topo (30 m) | 1991 |
| | Almaz | SAR (15 m) | Archive |
| *EU* | ERS-1 & 2 | SAR (30 m) | 1991 |
| *India* | IRS-ID | P (5.8 m); MSI 23.5 m) | 1991 |
| *Japan* | JERS 1 & 2 | SAR (18 m) | 1992 |
| | ADEOS | P (8 m) | 1995 |
| *Canada* | Radarsat | SAR (10 m) | 1995 |

P = Panchromatic; MSI = Multi-Spectral Imagery; SAR = Synthetic Aperture Radar

***(Source: Tahu, et al, 180, and Hubert George, “Remote Sensing of Earth Resources: Emerging Opportunities for Developing Countries,” Space Policy (February 1998): 34)***

## Table 7: Civilian and Commercial Remote Sensing Space Systems (1998-2001)

| Country | Satellite (Company) | Sensor (Resolution) | Available |
|---|---|---|---|
| *Brazil* | CBERS | P (20-80 m); MSI (20-80 m) | 1999 |
| | SSR-1 | MSI (100-400 m) | 2000 |
| Canada | Radarsat 2 | SAR (3 m) | 2000 |
| ESA | Envisat-1 | SAR (30-100 m); MSI (250 m–1 km) | 1999 |
| France | SPOT-4 & 5 | P (5 m); MSI (10-20 m) | 1998 |
| | Spot Image 3S | P (2.5 m) | 2001 |
| India | IRS-P4 | MSI (360 m) | 1999 |
| | IRS-P5 | P (2.5 m) | 2000 |
| | IRS-P6 | MSI (6-23 m) | 2001 |
| Israeli/US | EROS | P (1.5 m) | 1999 |
| Japan | ALOS | P (2.5 m) | 2000 |
| Korea | KOMPSAT | MSI (10 m) | 1999 |
| Ukraine | SICH | SAR (10-50 m) | N/A |
| US | Landsat 7 | P (15 m); MSI (30 m) | 1998 |
| | IKNONOS 2 (Space Imaging) | P (1 m); MSI (4 m) | 1999 |
| | Orbview-3&4 (ORBIMAGE) | P (1-2 m); MSI (4 m) | 1999 |
| | Resource 21 | MSI (10 m) | 1999 |
| | LightSAR | SAR (N/A) | 2000 |
| | TOPSAT | SAR (N/A) | 2001 |

P = Panchromatic; MSI = Multi-Spectral Imagery; SAR = Synthetic Aperture Radar

NOTE: In addition to the remote sensing systems noted above, Algeria, Argentina, Brazil, Chile, France, Germany, Israel, South Korea, South Africa, Thailand, the United Kingdom and United States have all initiated indigenous or government/commercial collaborative programs to develop small, inexpensive satellites.

***(Source: Tahu, et al, 182, and George, 34)***

Though we have only explored the proliferation in the remote-sensing sector, similar dynamics are at work across almost all of the other commercial and civil space sectors, especially communications, navigation and launch. The combination of commercialization, globalization and proliferation has spawned a revolution in the arena of space.

## Dilemmas Associated With Space

Though beneficial by almost any criteria, the revolution now underway with regard to space-based systems and products has created several contentious dilemmas. Individually none are unique to space, however, the full set of dilemmas presents a unique challenge if the objective is to "control" the medium of space.

### Dual-Use

The issue of "dual-use" is derived by the fact that space-based commodities have tremendous value to both the civil and commercial sector (as a means of social and economic enhancement), as well as the military sector (as a means of force enhancement). While not a threat themselves, the availability of these new products in the global market certainly poses a potential threat if they are transformed into some form of viable combat power by an aggressor(s). As technology, innovation and profit potential continue to drive the revolution in space, the ability of a nation, group or individual to project power—economic, social or military—by leveraging one, or all, of these space-based capabilities becomes increasingly easier.

Cruise missiles are just one example of how space-based capabilities are being leveraged in the world market. According to experts, cruise missiles are becoming "increasingly effective because of the availability of small turbojet engines with improved fuel consumption and reliability; improved, less expensive seekers, and cheap, accurate navigation through the US GPS or Russian GLONASS systems."[52] When combined with improvements in low observable technology such as heat signature reduction and radar-absorbing materials, and relatively high-resolution imagery products registered with detailed digital terrain elevation data (DTED) for targeting purposes, the proliferation of these types of weapons are viewed to be more ominous.[53]

Fortunately for the military sector, the dual-use nature of many space systems not only spawns potential new threats, but also creates a wealth of opportunities. Specifically, the commercial space industry's ability to increase performance, enhance reliability and lower the cost of space systems makes it a viable source to either complement, reduce or replace existing military space-based (and potentially terrestrial-based) capabilities. Additionally, as the maturing commercial space sector realizes greater efficiencies, they can be integrated into the nation's national security space arena.

## Codependency and Commingling

Despite optimistic projections, it is imperative that the issue of "codependency" be addressed whenever space system capabilities or practices are integrated into a military space mission.[54] Why? Simply put, the ability to influence the battlespace—principally the information flow from or through a given space system—can be severely limited if in a heavily codependent or commingled environment.

For example, a commercial communication satellite such as INMARSAT[55] has the potential to be employed by both friend and foe, military or civilian. Therefore, destroying or neutralizing this relatively vulnerable communications capability via traditional means such as destruction or electronic jamming, denies the enemy use of the space asset, but also negatively impacts friendly operations (the result of codependency) and/or non-military activities (the result of commingling). Hence, the traditional tact of military decision-makers to pursue more robust, dedicated military space systems that remain segregated from civil and commercial space systems.

From another perspective, certain military space-based systems, while being tremendous force enhancers to land, sea and air forces, can also be used to support civil and commercial users. The Global Positioning System (GPS) is a classic example of such a case.[56] Since the GPS satellite signal has been available—with few exceptions—on a worldwide, unrestricted basis there has been a tremendous growth around the world in civil, commercial and scientific use of GPS. This rapid growth presents non-US governments with a daunting dilemma—should they continue to integrate this integral component to the emerging Global Information Infrastructure (GII) into applications such as military systems, air traffic control systems, etc.? Or, should they seek alternatives? The distinct advantages of the system must be weighed against the fact that GPS is owned and operated by the military authorities of another government who, regardless of current policies, are in a position to deny the GPS signals in some future crisis.[57] From the US perspective, the dual-use nature of GPS to both the military and others clearly limits, to some degree, the types and level of denial tactics that can be employed due to the inherent codependency and commingling issues involved.[58]

## Third Party Space Systems

In addition to dual-use, codependency and commingling, the recent trends have magnified a long-standing issue in the space control arena—third party space systems. An example best illustrates the issue. During the recent conflict between NATO and Serbia over Kosovo, space-based sensors have provided a myriad of imagery products to NATO-member countries. Specifically, US national, civil and commercial, as well as a variety of other NATO-member nation's imagery systems, are all supporting the ongoing conflict.[59] However, let us assume the Serbs negotiate with a "third party"—in this case

Russia—to provide similar space-based imagery products in near real-time to their military forces, thereby increasing Serbia's situational awareness in the Kosovo region (and arguably their combat effectiveness). Certainly, NATO would object and attempt to deny these force enhancing imagery products to the Serbs. Yet, since Russia is an independent actor not directly involved in the conflict, what recourse can NATO (or the US) take?

The issue becomes more complex if the "third party" is an international commercial consortium instead of a traditional nation-state. The participation of international consortiums raise murky questions regarding jurisdiction, sovereignty and what space control options are realistic (i.e., diplomatically viable). For instance, what if both NATO and Serbia make use of imagery products generated by space systems owned and operated by an international consortium? With corporations based in both NATO-member countries and Serbia? These are tough issues that will certainly pose a challenge to the space control strategist.

So far, we have focused on dilemmas resulting primarily from the emerging trends in space. However, two dilemmas stand out as unique to the medium of space based on its physical environment—verification and collateral damage.

### Verification of Attack & Attacker

Determining the cause of an "anomaly"—when a satellite ceases to operate normally due to natural phenomena such as radiation, an on-board satellite failure, ground controller errors, or an intentional effort to damage the satellite or disrupt service—can often be difficult due to the remoteness of space. Unlike terrestrial assets, which typically afford an opportunity to "kick the tires" or to have a dialogue with an operator when trying to determine the cause of failure, the information available during a satellite anomaly is limited to the satellite's telemetry and associated ground equipment data. Ideally, the satellite effected would have on-board threat detection sensors to identify and report interference attempts. However, even with such sensors, verification of attack is a difficult task—let alone validation of the specific aggressor(s). This challenge is only magnified without such threat detection sensors, which is the norm in the commercial and civil space sectors.

Given the profit motive of most commercial space operators, there is little incentive to protect against what is perceived as a "non-threat." General Richard B. Myers, current Commander of NORAD, US Space Command and Air Force Space Command, aptly describes the majority perspective regarding space as an "international sanctuary for generating revenue." In his words, there is no business case for protection since industry assumes the "multinational aspect of space provides its own protection."[60] As a result, verification of attack and attacker will pose a significant challenge—especially on non-military space systems—until effective sensors are developed that require minimum space, weight and power (precious commodities in any spacecraft design).[61]

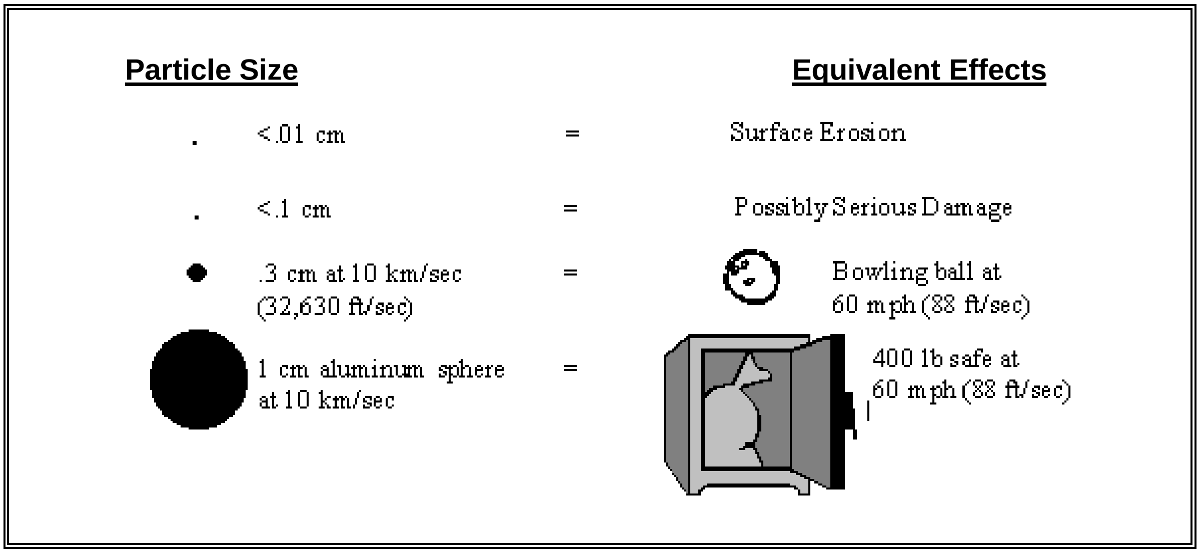
## Space Debris and Collateral Damage

Given the tremendous speeds experienced once in orbit, a collision with even a single piece of debris can be catastrophic. Fortunately, the "big sky" theory, whereby the sheer size of the operating medium decreases the probability of collision, has been alive and well in space. Collisions between satellites and space debris is a relatively rare occurrence. However, the forty-plus years of the world's spaceflight activities has left many non-operational spacecraft, empty rocket stages, as well as random artificial debris in orbit. Of these, space debris—non-functioning man-made objects orbiting the earth—is by far the most prevalent.[62] A NASA study characterized the situation in the following manner:

> The space environment is expected to become increasingly polluted as worldwide spacecraft launches increase and collisions between debris particles create more debris. This becomes all the more menacing considering that a 1-centimeter aluminum sphere (roughly the diameter of an aspirin tablet) traveling at an average speed of 22,000 miles per hour disperses the same kinetic energy when striking a spacecraft as would a 400-pound safe traveling 60 miles per hour.
>
> The National Security Council calculated, based on the estimated amount of debris in space in 1988, that a spacecraft the size of the space station would be hit by an object larger than 1 centimeter once in 20 years. The Council predicted that this possibility would increase to one hit every 2 years by 2010.[63]

Figure 11 depicts the kinetic energy effects when an object in space collides with particles of various sizes.

**Figure 11. Kinetic Energy and Debris Effects for Collision in Space**



*(Source: US General Accounting Office,"* **Space Program: Space Debris a Potential Threat to Space Station and Shuttle,"** *Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives, April 1990)*

Clearly, space debris can cause catastrophic results, yet it hasn't slowed the ongoing "gold rush" to space principally due to the "big sky" rationale. However, these effects introduce tremendous implications for planners considering engagements in space because studies and experiments have convincingly shown that literally thousands of fragments (debris) will result when projectiles collide with a satellite at orbital velocities. Depending on the orbital altitude of the ASAT engagement, the residual debris could pose a hazard to manned and unmanned spacecraft for years (or perhaps centuries depending on the altitude).[64]

# Chapter 5

# Identifying The Threats

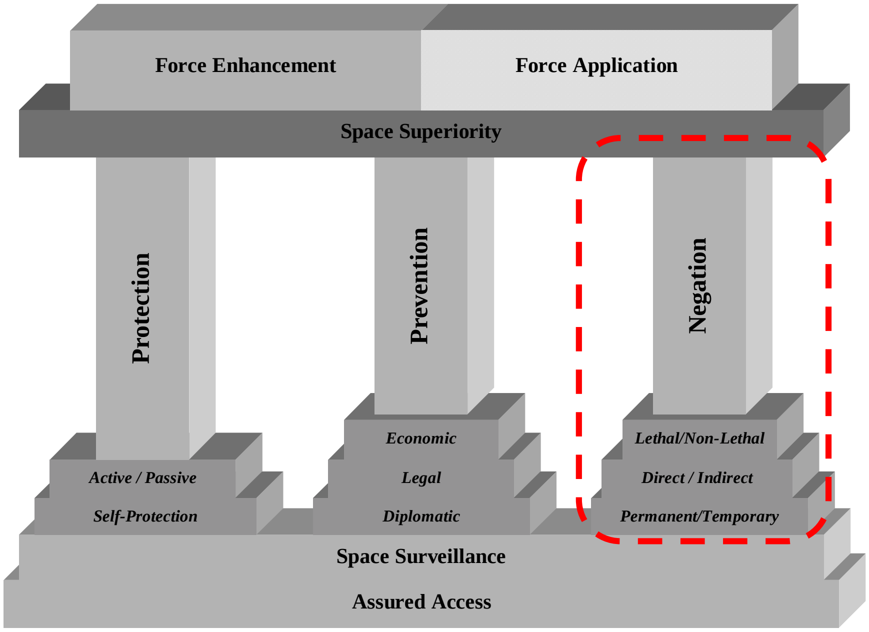
> *Space may be viewed as an attractive area for a show of force. Conflict in space does not violate national boundaries, does not kill people and can provide a very visible show of determination at a relatively modest cost.*
>
> —Former Astronaut, Lt Gen (ret) Thomas B. Stafford, USAF
> Battle for Space, *Curtis Peebles, 1983*

> *Advanced technologies can make third-class powers into first-class threats.*
>
> —Former Secretary of Defense, Hon Dick Cheney
> *US Space Command's "Long Range Plan," 1998*

This chapter addresses potential space system threats and the impact of these threats on the military's warfighting capability. As Lt Gen Stafford's statement reminds us, space is an attractive target for any adversary—large and small nations, non-state actors, paramilitary and terrorist groups or others. Clearly, the ever-expanding role of military space systems only increases the incentive of denying these benefits to an opponent in time of conflict, especially if the opponent's national security—military, economic and social—is dependent on them.

As noted earlier, the term "negation" is typically used to describe forcible measures aimed at the delay, deception, disruption, denial, degradation or destruction of a space system or its capabilities. Current doctrine emphasizes that the principal means of conducting such operations is through the "use of terrestrial-based forces such as air attacks against space system ground nodes or supporting infrastructure."[65] The focus is on a conventional military force used against a space system's terrestrial-based assets or, as in the past, direct attacks on the satellites themselves. In contrast, our assessment will consider both direct and indirect, permanent and temporary, as well as lethal and non-lethal, actions that can threaten each of the space system segments. Figure 12 depicts the focus of this chapter.

**Figure 12. Focus of Chapter 5**



## Attack on the Ground Control Segment

Based on the notional ground control segment described in Chapter 2, it should be clear that most space systems have critical ground facilities—satellite communications, data reception/transmission, command and control, as well as their supporting infrastructure—which should all be considered potential targets. The appeal of physically attacking or sabotaging these ground control assets is that existing military assets can be used. In general, space systems that are reliant on a single ground site or asset will always be more susceptible to attack, especially if its destruction or neutralization will lead to the loss of an entire range of space capabilities.

The worst case scenario for the defender is an adversary with a thorough knowledge of key space systems who is in a position to identify the most critical ground control facilities—especially single points of failure—for attack and/or sabotage. As the National Air Intelligence Center notes, this case may become a reality since "many fixed US satellite communications, data reception, and control facilities are described in open source material."[66]

A variety of conventional (or nuclear) strike options are available including air, naval, ground and/or special operations forces. The location, protection and vulnerability of a specific ground control target(s) will dictate the type of assets and tactics employed. Clearly, forward-deployed ground control segment assets will typically be primary targets. Critical ground control assets located inside areas such as the US and larger nations would most likely be attacked by long-range bombers, cruise missiles, special operations forces/agents or potentially ICBM/SLBMs.[67]

While effective, the tactics identified so far have been primarily direct in nature. In many instances, fixed ground control segments are heavily dependent upon central support systems—principally power and communications, but potentially water—for continuous operation. This dependency, combined with the real-time nature and vulnerability of many space systems, makes them extremely susceptible to indirect attacks that disrupt, degrade or destroy these central support systems. Like direct attacks, thorough knowledge of the targeted space system is a tremendous force multiplier to a state, group or individual planning an indirect attack. Clearly, this type of attack has the potential to render a targeted space system non-operational either temporarily (disruption of power) or long-term (destruction of critical support systems) depending on the objectives and effectiveness of the attack.

Attacks or sabotage by terrorists and paramilitary groups present a real and lasting threat to any space system's ground control assets. As with conventional attacks, the ground control assets must be accessible to the enemy and critical to the continuing operation of the space system. However, terrorist attacks have the potential to be particularly effective because they can be disguised to avoid the identification of overt aggression or a particular nation.[68] These characteristics make sabotage an ever-present threat to any space system. This is particularly true in free and open societies such as the US and Western Europe.

## Attack on the Space Segment

The space segment inevitably receives the most attention in almost any space control discussion due to the advanced technologies, hence cost, involved. A variety of anti-satellite (ASAT) concepts exist which promise to disrupt, deny, degrade or potentially destroy targeted satellites. Regardless of the attack mechanism, it should be understood that ASAT-relevant technologies are proliferating. Fortunately, development and employment of ASAT capabilities requires not only the weapons, but detailed information about the physical characteristics and orbits of the satellites to be attacked. Typically, this information is derived from a network of space tracking sensors, which is required to deliver the precise targeting information. Whether the network information is developed indigenously or purchased on the open market, accuracy and cost are key constraints.[69]

### Direct Attack

Direct attack is the surest means to destroy or neutralize a satellite, but also one of the most complex and expensive. For our purposes, the direct attack mechanisms will be categorized as either "interceptors" (often referred to as kinetic energy weapons (KEW)) or "directed-energy weapons" (DEW).

*Interceptors:* Interceptors typically include direct-ascent ASATs, co-orbital ASATs, space mines and various kinetic-energy ASAT concepts. The complexity of an interceptor is a function of its kill mechanism, relative velocity during engagement, how close it must get to the target to effect a kill, as well as whether the interceptor is ground-, air-, sea- or space-based.[70] Armed with conventional or nuclear warheads, interceptors effectively kill a satellite by a direct one-on-one engagement. Clearly, a conventionally armed interceptor requires very precise targeting information during the attack sequence to ensure proximity to the target satellite prior to the terminal guidance system completing the intercept. In contrast, nuclear-armed interceptors enjoy a much larger kill radius—on the order of tens to hundreds of miles—and can simply be targeted at a point in space.[71] Conventional warheads rely on physical damage to generate a "kill." However, a nuclear detonation (NUDET) in space kills by electromagnetic pulse and radiation effects vice the well-known blast effects on the ground. Nuclear effects due to exposure to x-rays, gamma rays and neutrons (as well as trapped radiation that lingers above the atmosphere) include electronic upset, electronic burnout and mechanical damage.[72] For example, a single high-altitude 1.4 megaton nuclear test over the Johnston Island launch site in 1962 known as Project Fishbowl produced widespread collateral damage. Seven satellites were damaged by the NUDET—some immediately due to the initial EMP and radiation, while others decayed over time as they repeatedly passed through areas of intense radiation trapped in the Van Allen Belt.[73] Understandably, great strides have been made in spacecraft electronic hardening since this period. Nonetheless, collateral effects must be considered no matter what the attack mechanism and regardless of who employs an ASAT in space.

A sampling of the more prominent interceptor employment configurations is shown in Table 8.

## Table 8: Types of Interceptors (KEWs)

**Low-altitude direct-ascent ASAT** interceptor is launched on a booster from the ground, sea or air into a suborbital trajectory that is designed to intersect that of a LEO satellite.

**Low-altitude co-orbital ASAT** interceptor is launched from the ground into an orbit from which they maneuver to intercept a LEO satellite.

**High-altitude, short-duration ASAT** interceptor is launched from a large space launch vehicle into a temporary parking orbit from which the interceptor maneuvers to engage a higher altitude (MEO, HEO, and GEO) satellite, typically within 1-12 hours.

**Long-duration orbital ASAT** interceptor is launched into a storage orbit, where it awaits the command to engage a target satellite. Various concepts include space mines, orbiting interceptors, space-to-space missiles and space-based guns.

***(Source: National Air Intelligence Center,* Threats to US Military Access to Space, *Wright-Patterson AFB, OH, Document #NAIC-1422-0984-98, 13-14)***

*Directed-Energy Weapons:* The more sophisticated directed-energy (DE) ASAT concepts are also ground-, air-, sea- and space-based. The clear advantage of DE ASATs, when compared to the interceptor's traditional single shot/single kill constraint, is the ability to engage multiple targets. Additionally, DE weapons offer the ability to instantly engage a targeted satellite once it is in view thereby greatly reducing or completely eliminating any warning or reaction time. The disadvantage of these weapons is their requirement for enormous amounts of power, precise targeting information and extremely accurate pointing systems.

A sampling of the more prominent DE ASAT employment configurations is shown in Table 9.

## Table 9: Types of Directed Energy (DE) Weapons

**High-powered ground-based lasers (GBLs)** aimed at satellites in LEO could damage thermal control, power generation or potentially structural components, as well as degrade electro-optical (EO) sensors.

**Low-power anti-sensor lasers** (often referred to as "*dazzlers*") could blind or damage specific satellite EO sensors theoretically at any altitude. Relatively low power would potentially be required—assuming the laser operates at the same wavelength—since it would be amplified by the EO sensor.

**High-powered airborne lasers (ABLs)** employed against LEO satellites could potentially damage satellite components. The airborne platform allows the DE weapon to operate above inclement weather, which has the potential to negate a GBL's effectiveness.

**Space-based lasers (SBLs) or neutral particle beam weapons** pose a unique threat to other satellites. Without the need to overcome atmospheric dispersion or attenuation and the potential to move much closer to the target satellite, relatively low power lasers could be used to achieve similar effects as a much larger terrestrial-based laser. It is conceivable that large SBLs could be used to rapidly engage multiple satellites and ballistic missile post-boost vehicles at very long ranges.

**RF weapons** that emit intense beams of high frequency radio energy are another option. Concepts include both narrowband, centered between 100 MHz and 100 GHz, as well as ultrawide band, nominally between 100 MHz and 1 GHz. Conceptually multiple-shot, long-range, ground-based systems and multiple- or single-shot, short-range, space-based systems are feasible.[74]

***(Source: National Air Intelligence Center,* Threats to US Military Access to Space, *Wright-Patterson AFB, OH, Document #NAIC-1422-0984-98, 15-16)***

### Indirect Attack

Several other attack mechanisms offer alternatives to directly engaging the target satellite(s) by using conventional or nuclear weapons. The remote nature of satellite $C^3$ (i.e., limited telemetry, relayed communications, time-sensitive nature of satellite operations) makes indirect attacks a potent threat, especially to unprotected space systems. Vulnerability is only the first issue. As noted earlier, identification and verification of both the attack and attacker pose significant challenges in this environment. In other words, even if one suspects foul play, it may be difficult to prove it. The recent Galaxy IV anomaly is a case in point. After losing pager service to approximately 90 percent of North America's estimated 45 million pager customers and wreaking havoc with a host of media enterprises reliant on the satellite communications, it took several weeks to completely rule out "foul play" as a cause of the failure.[75]

For our purposes, three means of indirect attack against the space segment will be considered—sabotage, spoofing and information-based attacks.

*Sabotage*: Throughout a space systems development and operation, sabotage of satellite subsystem hardware and software at the assembly plant, subcontractors, testing facilities or launch site presents an ever-present possibility. This form of attack is particularly attractive to an adversary because it is relatively cheap, may go unnoticed for extended periods and has the potential to affect multiple assets.

*Spoofing*: Once in orbit, "spoofing" (the injection of false commands into the $C^3$ link) is a real threat. The objective is to either take control of the target satellite(s) either permanently or temporarily, or make the satellite(s) or ground controller(s) take an inappropriate action based on the false data injected thereby jeopardizing mission operations. The electronic intrusion by "Captain Midnight" into the Home Box Office (HBO) broadcast serves as a reminder that "spoofing" can be effective against an unwary target. Using a large satellite dish equipped with a strong transmitter, the intruder successfully interrupted HBO's broadcasting with a transmission of his own rebellious message regarding the scrambling of satellite broadcasts.[76]

*Information-based Attack*: In this age of information dependence, command and control warfare ($C^2W$) capabilities are becoming recognized as a potent means to deny an adversary key capabilities to include space-based assets. In fact, government estimates show approximately 120 countries and groups have or are developing information warfare systems. Additionally, there are currently over 30,000 "hacker-oriented" web sites on the Internet making hacking more accessible to the technically challenged.[77] As the capability to attack $C^2$ and information systems matures, the ability to gain and maintain control of an adversary's satellite(s) could conceivably become a reality. Whether done remotely or through an electronic connection like the Internet, such an attack could easily degrade or potentially destroy an entire space system if not detected and countered quickly. In the same manner as "spoofing," information attacks could be used to selectively deactivate specific spacecraft subsystems or cause malfunction during critical periods.

## Electronic Attack against the C$^3$ Link and Data Link Segments

Just as the ground control and space segments present lucrative targets for an adversary's negation efforts, both the C$^3$ and data links afford potentially profitable targets. As discussed previously, the C$^3$ link is comprised of the C$^2$ data, telemetry and potentially mission data being exchanged between the ground segment and satellite(s). If interrupted, mission operations are typically degraded to some degree and, if disrupted long enough, can pose significant risk to the satellite(s) survival.

Attacks on these critical C$^3$ links typically take the form of electromagnetic jamming aimed at disrupting, degrading or denying the use of the C3 link(s) through interference of the signal(s). A high-altitude NUDET creates the most extreme, wide-ranging jamming effects.

### Electromagnetic Jamming

Most military and commercial satellite systems are susceptible to some form of electronic jamming. As with any form of electromagnetic jamming, the object is to saturate the RF medium with electronic noise at the same RF band being used to communicate. Similarly, whether jamming a satellite's uplink or downlink signal(s), the jammer must operate in the same RF band to effectively jam the target satellite system.[78] However, the jammer's transmitter power requirements may vary considerably. Generally, uplink jammers must be as powerful as the emitter associated with the link being jammed. Because downlink jammers are located much closer to the target, as compared to the space-based emitter with which they are competing, they can often be much less powerful and still be effective.[79] Likewise, the higher the frequency, the more narrow (or directed) the communications signal becomes, hence making it more difficult to jam. In other words, as the target signal's frequency increases, the RF beam becomes narrower, forcing the jammer to move closer to the receiver or transmitter.[80]

Compared to uplink jammers, downlink jammers are generally much easier to effectively employ since very low power jammers may be suitable. For example, a NASA satellite data reception facility was recently jammed by a malfunctioning car alarm in the ground control site's parking lot. However, as in this particular case, the effects will typically be restricted to a local area—from tenths to hundreds of miles, depending on the power of both the jammer and downlink signal.[81]

### Exoatmospheric Nuclear Detonation

In addition to jeopardizing the satellites themselves, NUDETs are a constant threat to satellite $C^3$ and data links due to the associated scintillation (distortion of radio waves) and absorption/blackout (denial of communications) effects. High-altitude NUDETs (i.e., greater than 18 nm) present a significant challenge to space systems since they produce large amplitude electromagnetic pulse (EMP) fields over hundreds of miles across a large broad-band frequency range extending from direct current (DC) to 100 MHz. Disruption due to scintillation or absorption/blackout can last from seconds to days depending on the communication frequency (the higher the frequency, the shorter the duration of the interruption), proximity to and intensity of the NUDET.[82] For example, a one-megaton high-altitude NUDET test performed on August 1, 1958 approximately forty-eight miles above Johnston Island triggered extensive magnetic effects. According to the Atomic Energy Commission report, the magnetic storm blacked out radio transmissions across most of the Pacific Ocean "from Tokyo to California" for several hours.[83]

## Attack on the User Segment

Negation efforts targeted at the user segment typically receive limited attention in space control strategy discussions primarily due to the large number of targets involved. However, the increasing reliance on and diversity of user equipment make this a potentially lucrative target to deny an adversary the use of space-based assets. Traditional attack mechanisms involve direct conventional strikes against key $C^3$ centers and communication nodes or jamming the data downlink as just described. In fact, these tactics can be very effective against a vulnerable target that is relatively accessible. For example, a variety of ground-based and airborne jamming devices are currently available to disrupt the GPS or GLONASS signal thereby denying access to critical navigation aids in a relatively small region.[84] The challenge is producing the desired effect when there are hundreds, or thousands, of user sets receiving networked or broadcast data across a large area, or when a specific user target is the goal. In these instances, more indirect attacks such as sabotage and information-based attacks against user sets and computer networks may be more effective. For example, corrupting a series of military GPS or

GLONASS user sets via corruption of the microcode associated with a specific block upgrade to a GPS or GLONASS user's set could potentially produce similar effects.

## Attack on the Launch Segment

Traditional space launch facilities are also susceptible to attack or sabotage by an adversary. The launch infrastructure currently required to boost even the smallest satellites into orbit is extremely complex, hence generally vulnerable to attack. The US military's reliance on essentially two launch complexes—Vandenberg AFB, CA and Patrick AFB, FL—is frequently cited as a potential risk to the military's assured access to space. Clearly, current or future space systems that require initial population of constellations or replenishment could be adversely impacted for extended periods (months and potentially years) by a single or limited number of incidents/attacks at US space launch facilities—especially those requiring relatively scarce "heavy lift" capabilities. In practice, investigations related to launch failures can take months to identify the specific cause of failure. Meanwhile, the specific type of launch vehicle involved may be grounded depending on the risk of reoccurrence. Emergency call-up procedures can help mitigate this risk, but the central theme regarding a relatively limited, complex (i.e., vulnerable) launch infrastructure remains a stark fact.

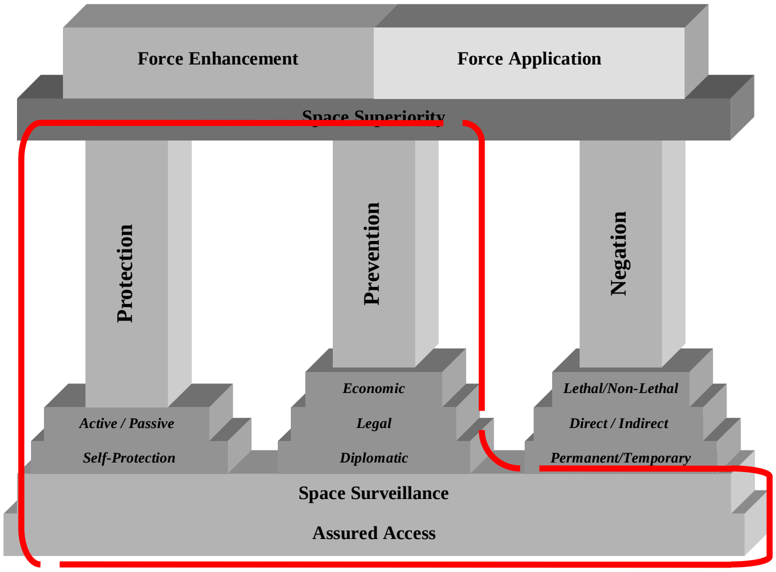
## Chapter 6

# Controllng The Threat

> *The US must continue to mix offensive and defensive measures to ensure freedom of action on-orbit for friendly forces and to prevent enemies from using space for purposes inimical to US interests. The US military can deny access to space solely through offensive action, but the ability to control space to enhance the combat effectiveness of terrestrial forces requires measures to protect US space systems.*
>
> – Marc J. Berkowitz, Director OSD Space Policy
> *Signal, May 1992*

As discussed, the very nature of space systems makes all of them vulnerable to some extent. Given enough time and effort, a variety of strategies are available to the determined foe to destroy or neutralize any space system. The challenge at this juncture is to understand the array of strategies to minimize a space system's vulnerability. Traditionally, these vulnerabilities, as well as the response(s) to aggressive acts in space, are addressed exclusively in military terms. However, a clear need exists to explore the broader range of options which are typically available to the strategist—economic, diplomatic, information and military. This chapter, though not exhaustive, introduces this diverse set of concepts. Figure 13 depicts the focus of this chapter.

**Figure 13. Focus of Chapter 6**



## Space Surveillance

As emphasized earlier, the ability to survey and monitor (i.e., detect, identify and characterize) space systems and developing space threats is absolutely vital to any space control capability. In fact, it should be considered a foundational element to any action—whether defensive or offensive in nature—being considered in space. Space surveillance and reconnaissance, just as its terrestrial namesake, is a continual process whereby the current "order of battle" (e.g., a space order of battle) is developed and maintained. The process of tracking and cataloging active satellites from among the nearly 9,000 trackable objects in space is challenging due to the remote nature of the medium, as well as the fact that satellites frequently make unannounced maneuvers, are launched without prior notification and are acted upon by environmental effects such as drag.[85] The solution is to use an integrated system of radar and optical trackers whereby precise observations are constantly made and correlated by complex computer algorithms. For example, satellites in GEO are typically tracked using primarily optical sensors due to their relatively higher altitude—a process constrained by both weather and lighting conditions. The result is somewhat less accurate tracking information and a degraded ability to target/engage with confidence. In general, the lower the satellite's altitude the greater the variety of surveillance sensors, such as radar, that can be used.

The space surveillance problem also includes the task of monitoring the indications and warnings (I&W) information associated with potential enemy space control actions. As depicted previously, the broad range of threats combined with an ever-increasing list of potential adversaries makes this task extremely challenging. Whether this classic intelligence function is accomplished using space-based or terrestrial-based assets, its performance is critical to one's ability to deter, preempt or decisively react to an aggressor's space control actions.

## Assured Access

The second foundational element to space control is the unimpeded use of space consisting of "on-demand" spacelift and on-orbit operations.[86] Given the remote nature of space operations, assured access serves as the "lifeblood" regardless of the mission or space sector—military, civil, commercial or national. On-demand spacelift enables the initial population of satellite constellations in peacetime, the reconstitution of space systems in times of conflict, and potentially the recovery and repair of malfunctioning spacecraft in the future. Similarly, these on-demand on-orbit operations, which includes establishing and maintaining some measure of $C^3$, are essential to the effective and efficient conduct of satellite operations.[87]

## Prevention

Prior to and concurrent with any space control action, a variety of preventive measures—diplomatic, legal and economic options—are typically pursued to achieve the desired outcome without military escalation.[88] The challenge becomes one of understanding the effects of such actions in an increasingly complex strategic environment.

### Diplomatic and Legal Options

Negotiation in the form of arms limitations and agreements form a means to limit the threat to space systems. The inherent problem, as in the case of ballistic missile or nuclear weapons arms negotiations, is the difficulty of compliance verification and technology proliferation. In the case of space, verification is further complicated by the fact that almost any rudimentary space launch vehicle (SLV) can be relatively easily modified to have an ASAT or long-range ICBM capability. Albeit, the ASAT or ICBM may not have a high-degree of precision, it still poses a significant threat to both space and terrestrial targets if equipped with an effective warhead.[89] The same complications are true for high-powered directed energy weapons such as a Ground-based Laser (GBL) or Airborne Laser (ABL), which can easily be redirected heavenward to serve a space control role.

As for technology proliferation, a series of international technology control regimes including the Wassenaur Agreement, International Traffic in Arms Regulations (ITAR) and, most importantly, the Missile Technology Control Regime (MTCR) are aimed at limiting the international exchange of space-related technology. Each has shown promise in reducing the ranks of states willing to export space-related, hence ballistic missile, technology.[90] However, experience has shown that a number of countries (such as Russia, China and North Korea) remain willing to sell missiles and associated technology both to increase their influence in regional affairs and to generate hard-currency earnings.[91] Additionally, globalization is rapidly changing the nature of the traditionally state-centric space technology development arena. As noted previously, cooperation has turned from government-to-government cooperation for science and prestige to commercial production for profit whereby technology transfer takes on a whole new dimension.

Negotiating agreements in other areas such as banning the interference of space assets of another nation has proved useful. Essentially, these types of agreements hinder an adversary’s efforts to develop and test such aggressive space control capabilities in peacetime. They therefore establish a limit to how far an action can go before it is labeled as provocative. Without such an agreement, an adversary could routinely interfere with satellite operations through electronic attack. In masking potentially aggressive intentions, the enemy has also decreased the effectiveness of the targeted space systems.[92]

Clearly, these types of diplomatic and legal measures do not address all the dimensions of the space system vulnerability issue. For instance, these types of limitations and agreements, while valuable, are wholly focused on peacetime activities.

Another common weakness is their narrow focus on space-based assets. Unfortunately, little attention is paid to decreasing the vulnerability of the ground, user or launch segments. Finally, these types of diplomatic efforts are generally state-to-state agreements. The commercialization of space is rapidly driving the need to change this perspective. A case in point is the upcoming launch of CaribStar—a commercial satellite designed to broadcast radio programming throughout the developing world. Unfortunately, the CaribStar satellites broadcast in L-band on the same radio frequency that is used for military and civilian flight testing in the US. Though not intended to serve the US, CaribStar's powerful L-band broadcast has the potential to cause "irreparable injury" to America's flight test program, which could cause up to $4 billion in additional costs due to delays, reconfigurations and additional testing. The CaribStar corporation is attempting to reconcile the problem before launching the culprit satellite. However, it is interesting to note that if the Pentagon "seeks legal recourse," there is currently no precedent for such legal action.[93] Since the future will be increasingly shaped by advances in commercial satellite technology, similar types of conflicts related to access rights, overflight, technology controls and military uses can be expected to increase.

### Economic Options

Likewise, the nature of the traditional state-to-state mechanisms used on the economic front is changing. "Positive" economic sanctions such as foreign aid, loan guarantees, foreign internal defense (FID) efforts and technology sharing arrangements can still be applied successfully; just as "negative" economic sanctions involving embargoes and trade restrictions—especially those focused on pertinent technologies—are useful in a state-to-state context. However, the aforementioned revolution in space is rapidly changing the international economic landscape of space—particularly in the remote sensing, communication and navigation sectors.

As discussed, commercialization, globalization and proliferation have led to the increased availability of a growing set of space-based products to a much broader market. From a classic economic perspective, the dominant mechanism for restricting goods in this type of "free market" environment is price. To deny access to an adversary, an obvious tactic is to buy up the space-based commodity in question or negotiate exclusive access rights. However, the increasing availability of most space-based products and services on the open market makes this an expensive course of action—especially in a lengthy crisis. In addition, the free market dynamics will most likely react in such a manner to nullify the ability of a single nation to effectively deny an adversary such products.[94] The information-based nature of these commodities only magnifies this inability to fence in or control such space-based products given the diverse means to distribute data.

Interestingly, if one assumes like quantity and quality of a particular space-based commodity is available in a free market scenario (i.e., communication bandwidth, electro-optical images, launch manifesting, etc.), the value becomes one of access and response time—both to the military and businessman. Therefore, the ability to maintain priority in what appears to be a resource constrained environment becomes paramount. LCDR Todd Black, USN, provides just such a perspective in the following scenarios:

> This general [free market] approach certainly results in a proliferation of systems available to the consumer and the military, which should thus be able to continue contracting for the communication capacity it needs. However, while the allure of additional bandwidth is considerable, there is no guarantee that the US military will be able to use a system as it desires. For example, Iridium does not have the ability to provide priority service; in other words, it operates on a first-come, first-serve basis. If the US military were to rely on such a system during a crisis, it might find itself competing with CNN or even its adversary for use of the limited number of access channels. Market forces will probably drive providers to ensure all subscribers to a system have an equal chance at access. Giving priority service to any one subscriber, even if that user can pay for the luxury, would drive other customers away. Business would be reluctant to pay for a service that could be withdrawn at any moment in favor of a military client.
>
> On the other hand, free access to the GPS system is now a given; if one has the appropriate receiver, one can obtain the locating data. In 1996 the Clinton administration announced its intention to discontinue Selective Availability by 2006. This would allow anyone to obtain the very accurate locating information presently provided only to the military and certain authorized users.[95]

## Shutter Control

The concept of "shutter control" is an interesting case study that spans the diplomatic, legal and economic spheres. Shutter control is when a nation (the US in this case) maintains the ability to impose restrictions on the collection and/or dissemination of commercial remote sensing satellite data. Introduced in 1992, shutter control serves as the “cornerstone” of current US policy related to commercial high-resolution imaging satellites.[96] Its aim is to restrain commercial imaging when operational security and force protection issues warrant. Though considered a viable means of limiting certain remote sensing data if a nation dominates the international marketplace, questions abound regarding its effectiveness as alternative foreign sources of data become available. Additionally, excessive use of shutter control will likely be frowned upon by other nations as they become more reliant upon commercial remote sensing information for commercial and national security purposes (similar to GPS concerns discussed earlier). Needless to say, shutter control will certainly be cumbersome to implement for any extended period of time given the scope of international security interests (globalization), the increasing number of commercial remote sensing ventures (commercialization), the variety of sensors in orbit (proliferation), and the fact that the US military and intelligence community will increasingly use commercial imagery (codependency).[97]

## Protection

A host of defensive measures can be taken to meet a threat—whether passive or active. They span the spectrum and can be terrestrial-, link- or space-based. Without exception, all involve additional cost to the space system’s price tag. Hence, the reluctance to infuse a wide array of defensive measures into all space systems. Instead, a balancing act generally takes place to determine which defensive measures are appropriate depending on mission priority, system characteristics, known or projected threats, etc.

### Physical Security

The most traditional means of both deterring and defending the ground segment against attacks—conventional, terrorist or sabotage—is physical security. Proper site location and design can minimize susceptibility to these types of attack (i.e., avoiding congested urban areas, increasing physical security measures, etc). Likewise, physical security measures are essential during the development and testing of all space system components such as spacecraft subsystems, launch vehicle components, ground communication equipment and software to reduce the probability of sabotage and industrial espionage.

Attention must also be given to how missions are conducted and the types of information made available to the public. Simple measures such as access security (passwords, software gates, encryption, virus check, etc), equipment design (distinctive features, etc) and security classification policies are all important. In addition, details critical to space system survivability and operability such as specific orbit parameters, communication frequencies and operational capabilities must be protected with appropriate security measures.

### Hardening

Although little can be done to protect any component of a space system from a nuclear detonation in close proximity, it is possible to harden against long-range prompt and delayed radiation and EMP effects. Techniques such as incorporating Faraday cages, surge-arrestors, waveguide-cutoffs, filters and fiber optic technologies are used to significantly improve ground site protection against a NUDET. Similar hardening techniques are used in spacecraft electrical components to overcome the EMP and radiation environment.[98] To minimize the absorption and scintillation effects, military communication systems such as the MILSTAR space system make use of higher frequency (e.g., EHF), redundant message transmissions and/or error correction coding schemes.

The effects of DEW against satellites are just beginning to emerge with results from test firings such as the first Mid-Infrared Advanced Chemical Laser (MIRACL) at White Sands, New Mexico in October 1997.[99] However, a variety of techniques have often contemplated to minimize DEW effectiveness against satellites. Special shutters or filters have been proposed to reduce the vulnerability of sensitive sensor systems such as optics and infrared sensors to laser illumination. Additionally, ablative materials such as those using graphite derivatives hold the potential of protecting sensitive spacecraft components.[100] However, shielding against particle beam weapons does not hold as much promise given the particles penetration ability.

Despite the potential effectiveness of these measures, the central issue is typically cost, especially when dealing with commercial or civil systems whose principal motive is delivering maximum performance at lower cost in light of what is perceived as remote contingencies.[101]

## Mobility & Maneuverability

As with any military force, movement always reduces vulnerability. As such, mobile ground-, air- and sea-based ground control and user segment elements decrease the risk of catastrophic failure. Assuming their location and movement remain undetected, mobile terrestrial assets can be effective counters to the threats of direct conventional and nuclear attack, as well as sabotage and terrorist activities.

Clearly, the challenge of mobilizing the ground control and user segments depends on the mission and characteristics of the space system. The worst case being a real-time, space-based imagery system because it typically consists of spacecraft in LEO that require frequent, yet complex $C^2$ updates to be uplinked; relatively vast amounts of raw data to be downlinked and processed into usable form; as well as a means to disseminate imagery products to a diverse user segment. The combination of these requirements means mobilizing even a portion of these systems requires the extensive application of cutting-edge communication/processing technologies and manning by highly-trained personnel—a sure recipe for high cost. In contrast, the simplest case is the higher altitude systems (i.e., MEO, GEO, HEO) carrying out less complex missions requiring limited $C^3$, processing or data dissemination.

Providing a satellite maneuver capability—either on command by controllers or off-board sensors, or autonomous action by on-board sensors—decreases vulnerability to a variety of threats.[102] Assuming sufficient warning is provided, maneuverable satellites should be able to evade or reduce the effects of conventional and potentially nuclear direct-ascent ASATs, co-orbital interceptors, space mines, as well as electronic attack(s) on the $C^3$/data link(s).[103] The disadvantages of satellite maneuverability include the additional complexity associated with executing evasive maneuvers, opportunity cost of additional satellite life or mission potential due to the additional fuel allocated to maneuvers, as well as the inevitable impact to mission operations before, during and after a threat-induced maneuver.

## Robustness

Ensuring a satellite system is robust (in the sense of being redundant) complicates an adversary's efforts in many ways. A strategy of proliferation—space, ground, link(s) and user segments—is the most common means to achieve satellite system redundancy. Essentially, the enemy's targeting problem becomes overwhelming if critical elements such as satellites, user equipment, ground control terminals and $C^3$/data links are sufficiently proliferated. For example, a space system consisting of a few high-value satellites and a single ground control node is, in most cases, considered more vulnerable than one consisting of dozens of "cookie cutter" satellites being controlled via a network of ground control sites. The first case offers an adversary a relatively limited number of targets on which to focus counterspace efforts. In contrast, the latter case has a more distributed nature (i.e., too many targets) making it more difficult to attack effectively. In general, the idea is to avoid single-point nodes by which the enemy can inflict serious damage. The net effect is to force an adversary to expend more counterspace resources countering an increasing number of redundant targets thereby lengthening the period—perhaps by a vital margin—in which the space segment remains viable.[104] Therefore, proliferation and networking are two effective means to increased robustness.

As with any conventional military system, the potential for attrition must also be accommodated. Whether this involves spare satellites, ground control back-up equipment or sufficient user terminals, maintaining sufficient reserves is a key element to any space system's robustness. Replenishment of the terrestrial-based segments will involve the normal logistic infrastructure associated with military forces. However, replenishment of satellite(s) can present a challenge. Spare satellites can be pre-positioned in space to replace those lost to enemy action or other causes. Though effective from a responsiveness perspective, redundancy of this kind is costly. Alternatively, spare satellites can be queued for rapid launch and initialization/checkout (on the order of days to months depending on the type and complexity of the system) using military or commercial launch facilities.

### Autonomy

Traditionally, autonomy refers specifically to the space segment's ability to operate without the "man-in-the-loop" thereby reducing the workload to support a satellite, as well as decrease its vulnerability to both natural and man-made threats. Autonomous operation typically includes such functions as the health and status monitoring (HSM), autonomous navigation (AUTONAV), on-board mission processing (OMP), fault detection, isolation and resolution (FDIR), as well as on-board mission planning and scheduling.[105] Autonomy can also refer to the ability to detect, characterize and react to impending threats. The advantage of each form of autonomy is that the "leash" between historically fixed, complex ground sites and the satellite(s) is broken. In other words, the space system becomes less dependent on a potentially vulnerable ground control segment. Additionally, more autonomy holds the potential of enabling more direct interface(s) with the end user. The disadvantages include initial complexity (hence cost) of developing and implementing autonomous capabilities and the inherent lack of trust or confidence in these types of capabilities by space system operators due to the loss of direct satellite control.[106]

### Concealment & Deception

The age-old concept of concealing one's location and disposition most assuredly translates to space systems. Operational security (OPSEC) related to terrestrial-based activities is essential to concealing potential vulnerabilities of any space system. Establishing and maintaining secure contingency communication frequencies, using high-frequency (e.g., low probability of intercept) communications, and deploying mobile assets to remote operating sites are typical examples of terrestrial OPSEC methods.

On-orbit assets can also employ a variety of methods to conceal or deceive the enemy. Since there is truly "no place to hide" in space, physically reducing the likelihood of detection seems to hold the most promise for concealment. Designing satellites with low radar cross sections (RCS), radar absorbing material, reduced optical signatures and/or the ability to communicate via crosslinks holds tremendous promise in defeating enemy space surveillance systems, as well as overcoming targeting and terminal guidance sensors.

As in any medium, deception in the medium of space can take many forms. One of the classic examples of deception was the US imagery reconnaissance system known as CORONA, which began operations in the mid-1960s. Given the hostile international climate to overflight reconnaissance (e.g., the Soviet and Chinese fury over ongoing U-2 reconnaissance flights), it was imperative that the US conceal the development and employment of the CORONA overhead intelligence system. The solution was to "hide" the entire CORONA program behind the very public scientific space mission dubbed

DISCOVERER. Public press releases highlighted DISCOVERER's exploration of space environmental conditions via an assortment of scientific missions, which included the launching of mice, primates and an assortment of radiometric experiments. Behind this very public cover story, the CORONA space system collected critical photographic intelligence of "denied areas" such as the Soviet Union, China and their allies.[107]

### Active Defensives

Assuming a satellite is equipped with adequate sensors to warn of attack such as on-board or off-board radar and laser sensors, various countermeasures may be used. These countermeasures could potentially take the form of decoys, radar-jamming devices (ECM) and/or infrared flares depending on the threat. As with conventional countermeasures, the aim would be to deceive or deflect the attacker's guidance system or warhead. Concepts involving more active countermeasures with an autonomous ability to "shoot back" or defensive "escorts" would be the logical extension to the case for active defenses. High cost and the impairment of mission operations are often cited as the weaknesses of these concepts.

### Orbit Selection

As discussed earlier, orbit selection is a complex process in which operational requirements, launch constraints, mission efficiency and (on occasion) survivability are weighed against each other. Given the nature of the ground-based ASAT threats, a need exists to maximize the warning time when space systems are under attack. One strategy is to maximize this warning time by raising the satellite's orbit beyond the known (or potential) threats. Depending on the attack mechanism being employed (direct-ascent, co-orbital, etc) and the target satellite's orbital altitude, warning times could be on the order of tens of minutes to tens of hours.[108] Regardless, the advantage gained is less vulnerability to all categories of direct-ascent ASAT threats since increased warning time translates to enhanced countermeasure opportunities such as maneuver. Increasing the altitude of any spacecraft beyond LEO may also move it beyond the lethal range of some directed energy weapons, as well as complicate the detection and tracking problem for the adversary. The associated cost is commonly measured in terms of decreased mission effectiveness (depending on the mission requirements) and additional costs to achieve orbit (e.g., larger launch vehicle).

In addition to the survivability concept of “higher is better,” orbital spacing is an important consideration especially when dealing with spacecraft in GEO.[109] To prevent a single conventional or nuclear threat from destroying or neutralizing multiple satellites, high-priority assets in GEO must be spaced sufficiently far apart.

### Reconstitution

Reconstituting essential space capabilities once hostilities begin is critical to the modern military force’s ability to carry on the fight effectively. Reconstitution efforts typically focus on the space segment with the emphasis placed on reliable, responsive and flexible launch capabilities to ensure rapid replacement or augmentation of existing military systems.[110] Other solutions include on-orbit storage, satellite repositioning and supplemental launch capabilities (e.g., commercial options). While valuable in themselves, reconstitution of the other space system segments is also key to any reconstitution strategy. Restoring lost or degraded ground control sites, C3 links, user data equipment, etc. are all critical to the effective sustained operations. Regardless of the solution, rapid response in meeting short-notice crises and contingencies is the objective.

## Negation

While not completely exhaustive, Chapter 5 (“Identifying the Threat”) describes the wide array of military force that could be employed to neutralize or destroy a targeted space system. In short, it forms the negation “toolbox” available for offensive space control operations against the full range of targets and effects. Therefore, no additional examination is provided in this section. However, one concept worthy of consideration given its potential to dramatically change the outcome of any engagement in space is preemption.

### Preemption

No matter what the medium—land, sea, air or space—the ability to gain the initiative in combat is a long-held military axiom. In space, taking preemptive action against an enemy’s critical space systems has the potential to provide the aggressor with this initiative. Whether aimed at disarming an opponent of his counterspace capabilities, disrupting space-based $C^3$ or simply "blinding" the adversary's ability to observe the battlespace, preemption can be a significant force multiplier.

Due to the somewhat cyclical nature of space-based assets in orbit, a patient aggressor armed with the appropriate space surveillance information and offensive space control capabilities has the potential to inflict serious damage against an unwary foe. If the space dependency-vulnerability situation is severe enough, a well-conceived, preemptive attack against a foe's high-value space systems could potentially inflict the space equivalent of Pearl Harbor. Multiple simulated wargames and information-intensive field experiments have revealed just such a potential to US defense leaders. The milestone event to many occurred in 1997 during the "Army-After-Next" wargame. The following excerpt summarized the findings as follows:

> The wargame scenario, set in 2020, involved a neighboring state invading Ukraine. To inhibit anticipated Western intervention, the attacker immediately destroyed many US satellites. This complicated "Blue" team decision-making, because intelligence and communications channels were disrupted severely. Ultimately, the invader detonated numerous nuclear weapons in orbit, disabling almost all US and allied spacecraft.
>
> "In the opening engagement, they took out most of our space-based capabilities. Our military forces just ground to a halt," declared one of the game's participants.
>
> "We learned a lot," said Lt Gen Edward G. Anderson, III, commander of the Army Space and Strategic Defense Command. "Space capabilities became high-value targets for the enemy. It's very easy to set off a nuclear bomb in space—no casualties," but the resulting electromagnetic pulse devastates spacecraft sensors and electronics. In a brief time, US forces had lost overhead imaging, communications, navigation and weather satellites.[111]

While most of these scenarios are staged far into the future, the lesson is clear—the force-enhancement, information-based support provided to military air, land and sea operations can be severely degraded or totally denied unless sufficient warning of and protection against preemptive attacks is provided.

# Chapter 7

## Conclusion: A Strategy For Success

*When blows are planned, whoever contrives them with the greatest appreciation of their consequence will have a great advantage.*

—Frederick the Great
*cited in US Space Command's*
*Long Range Plan, 1998*

*A strategist should think in terms of paralyzing, not of killing.*

—B.H. Liddell Hart
*Strategy, 1954*

*We will need to recognize that the US lead in space will not go unchallenged. We must coordinate the civil, commercial and national security aspects of space, as use of space is a major element of national power*

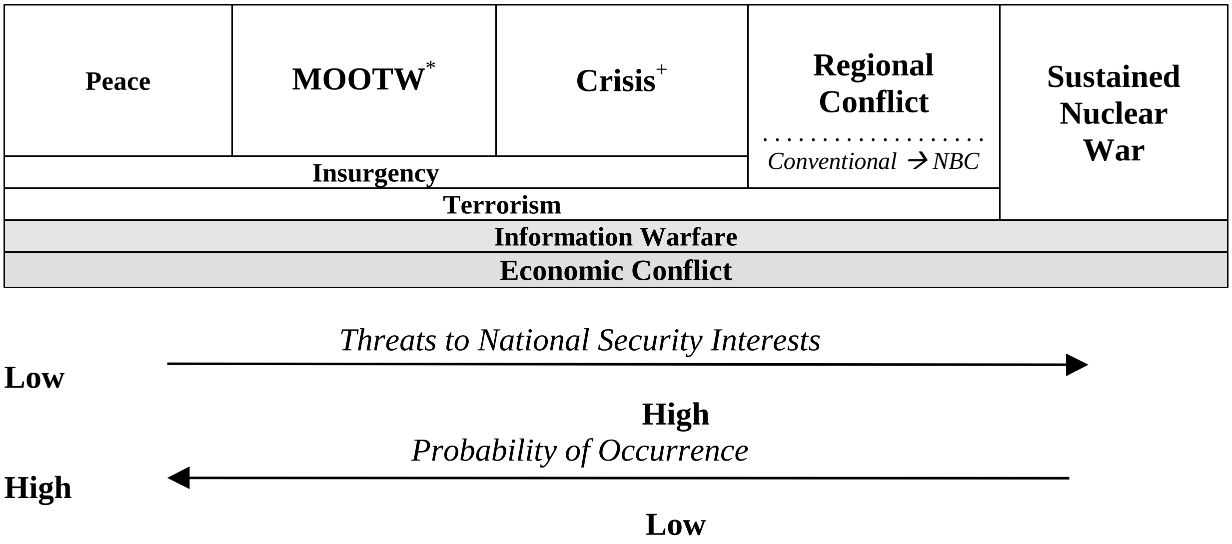
—National Defense Panel (1997)

In review, two themes have emerged throughout each of the chapters: the uniqueness and importance of space. Clearly, characteristics such as vastness, observability, speed, exposure, remoteness and the inherent nature of space make it a unique operating environment requiring a somewhat modified operating perspective. Additionally, the merging of powerful trends such as commercialization, globalization and proliferation with regards to space systems and technology have created an assortment of dilemmas including dual-use, commingling, codependency and third party issues fundamentally unique to space—especially when the application of force is being considered. At the same time, our dependence on the information collected from and disseminated through space for force enhancement, as well as the growing dimensions of economic and social enhancement, make it critically important to modern society as a whole. For the military, a new form of warfare is rapidly emerging in an environment dominated by information (i.e., electronics). Space is at the center of this evolution. Reconnaissance satellites are routinely used to identify targets before and assess results after military strikes, navigation systems provide accurate positional data to deployed forces and stand-off weapons, and communications satellites pass command and control information between and among military forces and national command authorities. These and a host of other force enhancement missions are essential components provided by space systems in this new emerging form of war.[112] The challenge is how to best leverage space for these missions, thereby increasing our dependence on it, without provoking the intrinsic vulnerabilities.

## Range of Space Control Options

The first key is to ensure a range of offensive and defensive capabilities exists. As emphasized, the traditional mindset of "blowing up satellites in space" in response to aggressive actions is quickly becoming an unrealistic option in many situations due to international pressures, fears regarding collateral damage, issues such as codependency and commingling, etc. Instead, it is imperative to consider the nature and intensity of the conflict at hand—whether peace, crisis or war—because it is the strategic environment that will dictate what actions are deemed appropriate.[113] Therefore, no matter what space control actions—offensive or defensive—are under consideration, it is helpful to frame it within the spectrum of conflict (see Figure 14).

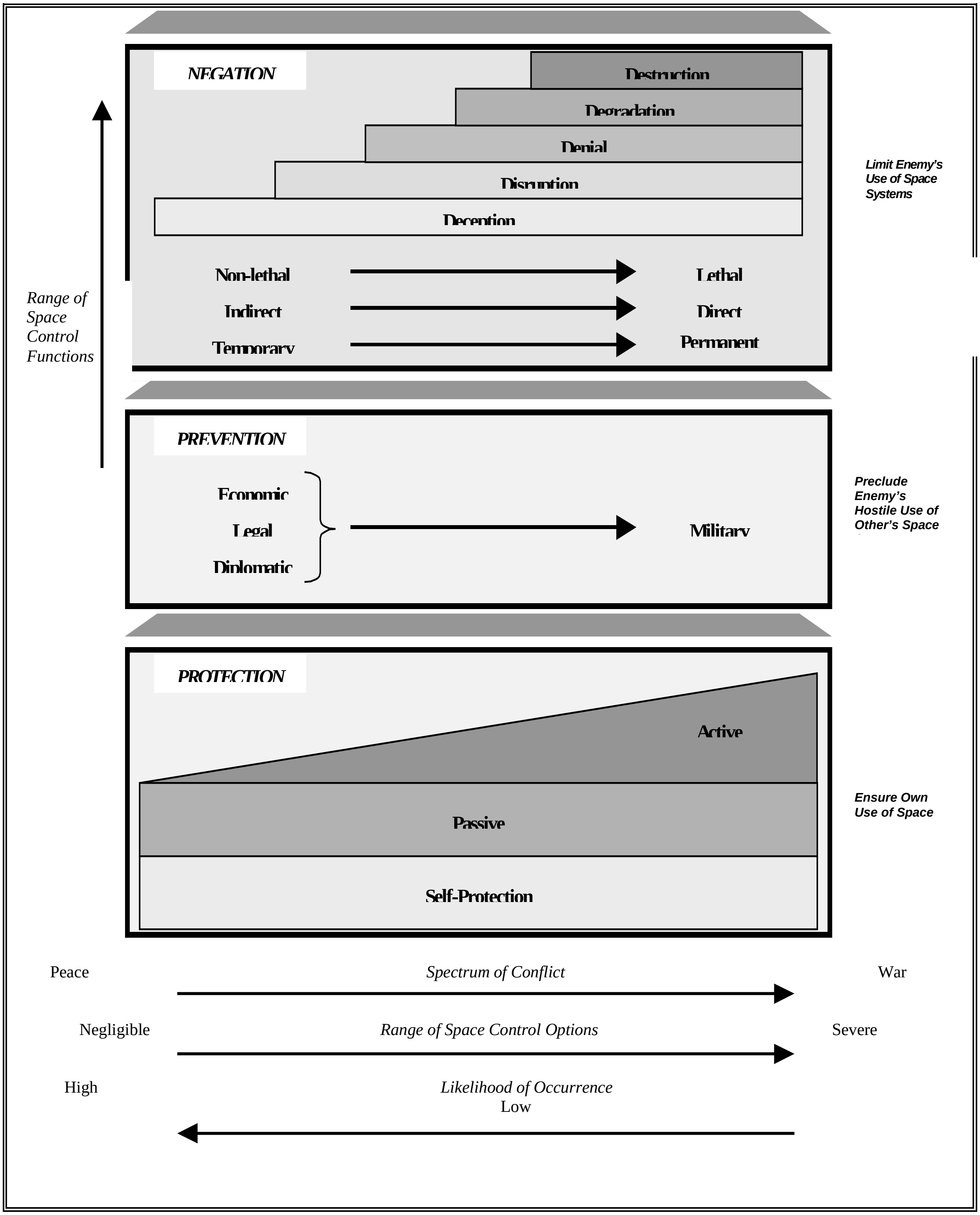
**Figure 14. Spectrum of Conflict**



*Notes:* * *"MOOTW" refers to military operations such as Peacekeeping, Humanitarian Operations, Counternarcotic Operations, Restoring Civil order, Disaster Relief and Enforcement of Sanctions.*
\+ *"Crisis" refers to military operations such as Peace enforcement, Forced Entry NEOs, Punitive or Preemptive Strikes, and Establishing and Maintaining Security Zones.*

Using this perspective, several pertinent insights can be made related to space control strategy. First, it should be apparent that most space control options will be influenced by both the nature and intensity of the conflict similar to the various forms of conventional military force. For example, the more severe space control operations such as active defensive measures and lethal attacks will be deemed inappropriate in the lower spectrums of conflict. However, measures such as passive defense and diplomatic action take on increasing importance as deterrent and threshold events in such an environment. Next, both an economic and information dimension exist across the entire spectrum of conflict. As described, key aspects of both are increasingly dependent on the medium of space. For this reason, space-based assets continue to be relevant militarily, economically and socially throughout the spectrum of conflict, whereas specific forms of military force may be inappropriate or constrained in certain types or levels of conflict. As a result, space control strategy must be considered uniquely. Figure 15 illustrates one perspective regarding the relationship between the spectrum of conflict and space control.

**Figure 15. Space Control Options in Context[114]**



This perspective emphasizes the inevitable limits that will most probably be placed on negation options aimed at destruction of an adversary's space-based capabilities.[115] Rather, the need for a broad range of options is clear. With respect to negation, these capabilities must offer alternatives across the spectrum: non-lethal to lethal, temporary to permanent, as well as indirect to direct. In today's interdependent environment, it seems most prudent to stress the negation capabilities that are temporary and reversible in nature. Additionally, the ability to localize effects offers tremendous incentives. For example, the ability to deny an adversary the use of INTELSAT in a region through temporary jamming would be preferred given the localized, reversible effects over destruction of a consortium-owned satellite or control facility.

However, the need for a range of options is not limited to only the function of negation—both protection and prevention form important elements to one's ability to conduct effective space control options. As discussed in Chapter 6, prevention efforts such as negotiating arms limitations, restricting technology proliferation and banning space interference can be effective in precluding aggressive use of space and establishing threshold events. Additionally, various forms of economic action such as positive or negative sanctions, access limitations and space system priority can be critical during times of peace and lower intensity conflicts. Naturally, the diplomatic, legal and economic options will give way to more military actions (e.g., negation) as the nature and intensity of the conflict increases.

Protection forms the third essential pillar in our space control construct. An important aspect of protection illustrated in Figure 15 is the fact that no matter what the nature or intensity of a conflict, both self protection and passive measures will be viable space control actions due to the long-accepted right to self-defense. Therefore, measures such as physical security, hardening, robustness, concealment and orbit selection are widely accepted as non-provocative defensive measures. In contrast, the more active defenses such as decoys, ECM and potentially autonomous “shootback” and defensive “escorts” are clearly more provocative. Their use will most likely be predicated on the need for some level of confidence regarding the verification and characterization of the aggressive action.

Therefore, a range of effective space control capabilities must be available in both the “horizontal” dimension related to space control options (reference Figure 15), as well as the “vertical” dimension related to the range of space control functions. From a military perspective, we must resist our natural tendency to think in terms of “bombs on target” or destructive options. Instead, concerted effort and resources must also be applied to the more flexible and non-provocative options. The result will be a more significant range of space control options available when required.

If successful, we will also reap the benefits of deterrence. The US can clearly demonstrate improved capability and increased commitment so important to deterrence by developing and sustaining a broader range of space control options. Assuming these capabilities and commitment are communicated effectively, a more effective deterrent posture should be the result.

## An Information Perspective

Emphasizing a broader range of space control options is even more logical given today’s primary role in space is information-based, force enhancement. As noted previously, the current threat is not generally space systems themselves, but the information collected from and disseminated through space. Therefore, today's focus should be an information-centric perspective versus one of force projection. In other words, space control strategy in the current strategic environment will be conceived and assessed with the objective of attacking and defending the *information* advantage achieved via space.[116]

Adopting an information-centric perspective also facilitates the understanding of the implications of space control actions in multiple dimensions—across space sectors (commercial, civil, military and national) and among domestic and international politics, economics, military and social/information domains. For instance, the dual-use issues associated with GPS infringe upon almost all of these areas. Hence, understanding both the effects and implications across all of these dimensions due to the interruption of GPS-provided information is essential.

## Space Superiority: The Critical Prerequisite

Space superiority has been central to this study. Like air superiority to the airman and sea control to the sailor, space superiority (i.e., control of the medium of space) will always be an essential prerequisite for warfare in the air, on the land, on and beneath the sea, and eventually in and from space. Today, it is the critical prerequisite that enables space-based capabilities to be converted into effective combat power (e.g., force enhancement). In the future, space superiority will also be the critical prerequisite that enables direct force projection from space. Without it, modern military forces cannot expect success especially if operating against a foe who enjoys space-based capabilities guaranteed by a more dominant form of space superiority.

## Implications

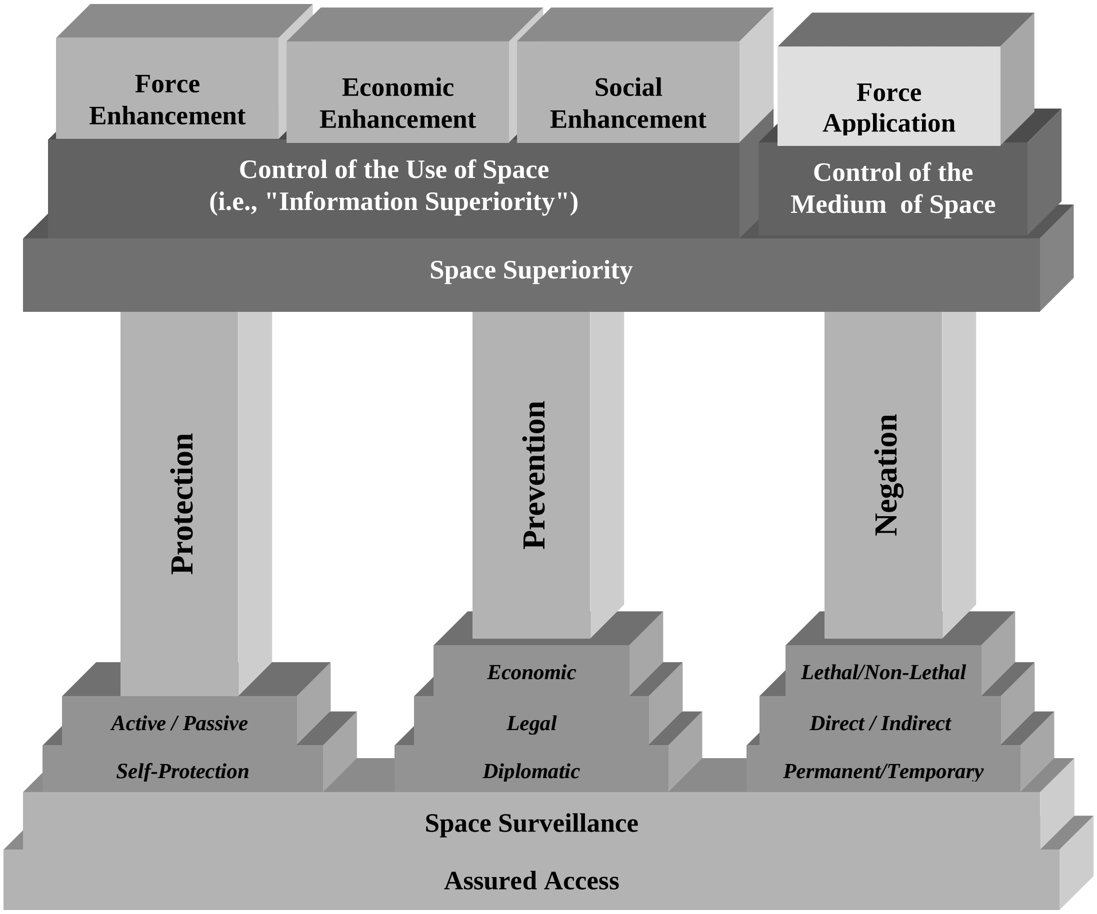
Several key insights are strikingly apparent when reviewing the various constructs, frameworks and perspectives that have been presented. First, it is clear that space control is not only about military force to achieve the desired ends. Rather, a variety of space control options consisting of diplomatic, legal and economic, as well as information-based means can also be employed to achieve the desired effects. Likewise, all space control actions can have dramatic effects on non-military entities such as commercial and civil space, domestic and international politics, culture, economics and technology. These effects can be felt locally, regionally and even globally due to the nature and importance of space. In reverse, the space control domain is influenced by all of these factors, plus the perceived or known existence of a threat to space systems.

Second, the critical importance of space superiority has been demonstrated in shaping not only the military's ability to conduct operations (e.g., force enhancement and force application), but also its role in ensuring both economic and social enhancement in today's modern society.

Lastly, the information aspect to space operations is critical—especially the space control mandate. Addressing space systems in more discrete segments helped emphasize this fact. Given that today's most prominent role in space is information-based, force enhancement, the importance of controlling information becomes readily apparent.

By applying these insights, the original space control construct can be modified as depicted in Figure 16.

**Figure 16. Follow-on Space Control Construct**



This follow-on space control construct provides interesting "food for thought" when pondering the current dynamics and future potential of space. It continues to highlight the critical nature of space superiority and the multi-faceted nature of space control means used to achieve and sustain it. Additionally, it emphasizes the unique information dimension principally associated with force, economic and social enhancement. Clearly, the imperative is controlling the use of space in these areas. In contrast, the future mission of force application will be predicated to a much greater degree on control of the medium. That is not to say that force application operations will not be dependent on intelligence, battle management, and C3 information. However, the nature of space superiority will be weighted more heavily towards a need to control the medium of space versus the current emphasis on controlling the use of space.

Regardless, developing and assessing space control strategies in this increasingly complex strategic environment will only become more challenging. Toward this end, a framework is proposed in Appendix A that provides a relatively simple, yet intuitive, approach for developing effective space control strategy. Though not a "cookbook recipe" or "prescribed solution," the framework should aid both the space expert and novice in conceiving and evaluating space control strategies.

## Steps to an Effective Space Control Strategy

The problem confronted by the strategist is how to effectively link the ultimate ends (i.e., inherently political objectives and goals) with the specific means of space control. More precisely, the problem is how to orchestrate the space control functions—assured access, space surveillance, protection, prevention and negation—to achieve the desired degree and form of space superiority. A framework is proposed that provides a relatively simple, yet intuitive, approach for developing effective space control strategy. Though not a "cookbook recipe" or "prescribed solution," the framework should aid both the space expert and novice in conceiving and evaluating space control strategies.

### Step #1: Understand the Strategic Environment

First, the strategic environment must be characterized as it relates to space control. Ideally, a grand strategy will be overtly communicated which encompasses the national political, economic and military objectives being sought. In practice, this may not be the case. In either case, orchestrating the instruments of national power—political, economic, information and military—in a manner that achieves the national security objective(s) is paramount. It is at this highest level that the coordination must take place regarding the utility of space control options and the associated implications on the other instruments of national power—both domestically and internationally must be coordinated. Factors such as the perceived threat, domestic and international politics, economics, culture and technology will influence both the national grand strategy, as well as the resulting space control options that evolve. Factors especially critical to the success of any space control strategy are the identification and characterization of the enemy threat to space systems, discernment of relevant constraints that may limit the nature or intensity of space control options, and finally the resources being made available—both terrestrial-based and space-based—for space control purposes.

### Step #2: Develop Top-Level Space Control Strategy[117]

To begin, clear space control objectives must be distilled that define "what" outcome (or effect) is to be achieved in support of the national security objectives. It is important to emphasize that, despite the distinct military character, all dimensions—military, economic, information and political—are essential to formulating an effective strategy. In fact, the trends towards greater commercialization, globalization and proliferation, hence situations involving codependence, commingling, dual-use and third parties makes the need for this awareness even more consequential. The impact of achieving the desired effects must be assessed with regard to these factors not only regarding the adversary, but also the potential impacts domestically and internationally and across all space sectors—commercial, civil, national and military. Ideally, the achievement of the collective set of space control objectives will result in the desired form and degree of space superiority.

Next, it must be determined, in broad terms, "where" diplomatic, legal, economic actions or military force should be applied to achieve the desired effects. Often expressed as a "center of gravity" (COG), the nature of and trends in space make this assessment somewhat more complex than the traditional military estimate. As implied, both military and non-military, as well as offensive and defensive, considerations will influence this assessment. Additionally, the strategist must determine whether the enemy COG(s) is/are inherently vulnerable thus susceptible to attack or a key strength relatively invulnerable to attack. This determination will shape the nature of space control options (i.e., direct or indirect, lethal or non-lethal, etc). In either case, the adversary must be dependent on the COG(s) if the objective is to cause incapacitation or adverse effects. Again, the implications resulting from codependence, commingling, dual-use and third party situations must be addressed across all the space sectors, both domestically and internationally.

Finally, it must determined "how" the proposed space control action(s) are to achieve the desired effects. In other words, how will the effected actors—adversary, domestic and international players—react to the diplomatic, legal, economic action(s) and/or military force applied? Considerations such as the nature, magnitude and timing of the action(s) must also be addressed.

### Step #3: Refine the Capabilities, Targets and Tactics

With a firm grasp of the strategic environment and a sound top-level space control strategy, it is necessary to refine the specific capabilities required, targets to be effected and tactics to be employed.

*Identify & Characterize Specific Capabilities*: First, the specific capabilities both available and required must be delineated. Identifying the critical *enablers* is the first step. Specifically, identifying what "means" are available in terms of space control systems, resources, key personnel, etc. and the "character" of these events in terms of accuracy, location, firepower, range, speed, visibility, etc. Additionally, the critical *constraints* must be identified early in the strategy development process. Specifically, known environmental and operational considerations that may effect the rules of engagement (ROE). In the context of space, these considerations take on a somewhat grander scale because both terrestrial and space, as well as local, regional and global restrictions can dramatically change one's perspective regarding space control options. Additionally, enemy offensive and defensive capabilities must be identified and characterized. Factors such as the nature and capacity of the enemy's space-based resources, tactics and intent must be considered.

*Develop Specific Targets*: Next, appropriate targets must be selected by which the desired effects can be achieved. Ideally, proper target selection, when combined with sound tactics and capabilities, will lead to the achievement of the required state of space superiority. Using the traditional military analogy, the tendency is to equate space control targets with "aimpoints" in an effort to produce the desired effects—deception, disruption, denial, degradation or destruction. However, as the construct developed earlier highlights, space control is not just about "$D^5$" (i.e., a narrow portion of negation), but spans a much broader set of principles. Instead, the full spectrum of space control functions—protection, prevention and negation—should be used against the appropriate target(s) to achieve the desired effect(s).

Traditional space control targets span the entire space system—launch, ground control, $C^3$ and data links, space and user segments. As discussed in Chapter 5 and 6, all space systems are vulnerable to some degree, the challenge is identifying both the strengths and weaknesses, as well as the critical dependencies. Characterizing each target in terms of how the system is used, its contribution to the overall military capabilities, as well as physical details such as ground site location, existence of mobile assets, orbital data, communication frequencies, existence of encryption and anti-jamming capabilities, will greatly facilitate conventional targeting and weaponeering solutions. Naturally, non-traditional "targets" will include those associated with diplomatic, legal and economic (e.g., prevention) efforts.

*Develop Specific Tactics*: Finally, the detailed tactics, or "how" the effects should be achieved, are developed. For the military, specific modes of attack (e.g., negation) and appropriate defensive measures (e.g., protection) are the focus. A key to success in both is ensuring synergy with the other forms of military force being employed, as well as the various diplomatic, legal, economic and especially information-based operations. Without proper coordination, the potential exists to neutralize or destroy vital information sources or targets being exploited for intelligence or other purposes. The result is increased potential for "collateral damage" in the information domain. In addition, considerations such timing, tempo, the need for verification and assessment, and potentially the requirement for deniability must be assessed.

### Step #4: Assessing Candidate Space Control Strategies

A dilemma of sorts exists when attempting to assess a proposed space control strategy. Simply put, there is little historical precedent regarding success or failure in the space control domain, and what little historical evidence does exist is typically classified due to the sensitivity of such operations. Therefore, a somewhat different approach has been used to provide a "measuring stick" for use in assessing various space control strategies. While not exact, it does provide insight regarding the complexity and risk associated with candidate space control strategies.

# Figure 17. The Space Control Spectrum

| | **“Best Case”** | **“Worst Case”** |
|---|---|---|
| • ***Strategic Environment*** | | |
| - Domestic & International Political Support: | *Popular* | *Fragile* |
| - National Commitment: | *Resolute* | *Weak* |
| - Perceived Enemy Threat: | *Passive, Negligible* | *Aggressive, Asymmetric Peer Competitor* |
| • ***Top-Level Space Control Strategy*** | | |
| - Objectives – National, Military & Space Control: | *Clear, Attainable, Synergistic* | *Uncertain, Unrealistic, Disjointed* |
| - Nature of Strategy: | *Flexible, Comprehensive* | *Rigid, Myopic* |
| • ***Targets, Tactics & Capabilities*** | | |
| - Capabilities: | *Available, Dedicated, Technologically Superior* | *Limited, Delegated, Tech Inferior* |
| - Targets: | *Accessible* | *Inaccessible* |
| | *Vulnerable* | *Secure, Robust, Concealed, Hardened, Autonomous, Reconsitutable* |
| | *Discrete* | *Commingled, Codependent* |
| | *Concentrated* | *Disbursed, Distributed* |
| | *Static* | *Mobile,* Maneuverable |
| | *Distinct*[*]*, Single-Role* | *Ambiguous*[*]*, Dual-Use* |
| - Tactics: | *Coordinated, Verifiable* | *Uncoordinated, Non-verifiable* |
| | *Focused, Precise* | *Graduated, Sporadic* |
| | *Deniable* | *Attributable* |
| | *Preemptive* | *Reactionary* |

Notes: * - “Distinct” refers to targets that are clearly and solely affiliated with military or national security interests, whereas “ambiguous” refers to commercial, civil, consortium, third party or potentially a mix of one or more of these affiliations.

\# - Coordination with other space control, military, economic, diplomatic and information operations is critical to avoid efforts counter to each other.

The approach is a “space control spectrum” that distinguishes the key elements pertinent to any space control strategy.  As seen in Figure 17, the “best case” and “worst case” is characterized according to the strategy development process.[118]  The elements associated with strategy Steps #1 and #2 are more subjective given their strategic nature. However, the specifics identified in Step #3 provide a more solid framework for detailed assessment at the operational and tactical levels.

# *Bibliography*

## Books

The Aspen Strategy Group. *Anti-Satellite Weapons and US Military Space Policy*. Washington D.C.: University Press, 1986.

Bate, Roger R., Donald D. Mueller and Jerry E. White. *Fundamentals of Astrodynamics*. New York: Dover Publications, Inc., 1971.

Clausewitz, von Clausewitz. *On War*. Edited and translated by Michael Howard and Peter Paret. Princeton, NJ: Princeton University Press, 1976.

Emme, Eugene M. *he Impact of Air Power: National Security and World Politics*. New York: D.Van Nostrand Company, Inc., 1959.

Forgen, Jensen, et al. *Design Guide to Orbital Flight*. New York: McGraw-Hill Book Co., Inc., 1962.

Giffen, Robert B., Col, USAF. *US Space System Survivability*. Washington D.C.: National Defense University Press, 1982.

Glasstone, Samuel and Dolan, Philip. The Effects of Nuclear Weapons. Washington D.C.: US Department of Defense and US Department of Energy, 1977.

Hart, B.H. Liddell. *Strategy*. London, England: Faber & Faber, Ltd., 1991.

Hayes, Peter. *Space Power Interests*. Boulder, Colorado: WestviewPress, 1996.

Kutyna, Donald J., Gen (ret), USAF. “Indispensable: Space Systems in the Persian Gulf War,” *The US Air Force in Space: 1945 to the 21st Century*. Washington D.C.: USAF History & Museum Program, Proceedings from the Air Force Historical Foundation Symposium held at Andrews AFB, MD on 21-22 September 1995, dated 1998.

Luongo, Kenneth N. and Wander, Thomas W, *The Search for Security in Space*. Ithaca, NY: Cornell University Press, 1989.

Manno, Jack. *Arming the Heavens: The Hidden Military Agenda for Space 1945-1995*. New York: Dodd, Mead & Co, 1984.

Mason, Tony. *Air Power: A Centennial Appraisal*. Washington, D.C.: Brassey’s Ltd, 1994.

Muolo, Michael J., Maj, USAF. *Space Handbook: A War Fighter’s Guide to Space—Volume One*. Maxwell AFB, AL: Air University Press, December 1993.

Peebles, Curtis, *High Frontier: The US Air Force and the Military Space Program*. Washington D.C.: US Government Printing Office, Air Force History and Museums Program, 1997.

Ruffner, Kevin C. *CORONA: America’s First Satellite Program*. Washington D.C.: CIA History Staff Center for the Study of Intelligence, 1995.

Stares, Paul B. *The Militarization of Space: US Policy, 1945-1984*. Ithaca, NY: Cornell University Press, 1985.

_____. *Space and National Security*. Washington, D.C.: The Brookings Institute, 1987.

Wiesel, William E. *Spaceflight Dynamics*. New York: McGraw-Hill Book Company, 1989.

## Periodicals

Aldrin, Andrew J. "Technology Control Regimes and the Globalization of Space Industry." *Space Policy* (May 1998) Vol 14, No 2.

Barnes, Richard J.H., and Gibson, Roy. "An International Look at Global Navigation Satellite Systems." *Space Policy* (August 1998) Vol 14, No 2, May 1998.

Covault, Craig. "Atlas, Proton Kick Off Busy 1999 Schedules." *Aviation Week and Space Technology* (22 Feb 99) Vol 150, No 11.

DeBlois, Lt Col Bruce. "Space Sanctuary: A Viable National Strategy." *Airpower Journal* (Winter 98) Vol XII, No 4.

Fulgham, David A. "Cheap Cruise Missiles A Potent Threat," *Aviation Week & Space Technology* (6 September 1999) Vol 139, No 10.

Grundhauser, Lt Col Larry K. "Sentinels Rising: Commercial High-Resolution Imagery and Its Implications for US National Security." *Airpower Journal* (Winter 98) Vol XII, No 4.

Mann, Paul. "Support Gathers Steam for National Missile Defense." *Aviation Week & Space Technology* (22 March 1999) Vol 150, No 15.

Moorman, Gen (ret) Thomas S., Jr. "The Explosion of Commercial Space and the Implications for National Security." *Airpower Journal* (Spring 1999) Vol XIII, No. 1.

Scott, William B. "Space Chief Warns of Threats to US Commercial Satellites." *Aviation Week & Space Technology* (12 April 1999) Vol 150, No 15.

_____. "US Adopts 'Tactical' Space Control Policy," *Aviation Week & Space Technology* (29 March 1999), Vol 150, No 13.

_____. "Wargames Underscore Value of Space Assets for Military Ops." *Aviation Week & Space Technology* (28 April 1997) Vol. 146, No. 18.

Seffers, George I. "Pentagon Threatens to Block Satellite Launch." *Space News* (26 April 1999) Vol. 10, No. 16.

Sparaco, Pierre. "French Satellite Details Air Strike Damages." *Aviation Week & Space Technology* (12 April 1999) Vol 150, No 15.

Tahu, G.J. et al. "Expanding Global Access to Civilian and Commercial Remote Sensing Data: Implications and Policy Issues." *Space Policy* (3 August 1998) Vol 14, No 3.

Thomson, Allen. "Satellite Vulnerability: A Post-Cold War Issue?" *Space Policy*, Vol 11, Winter 1995.

Zoglin, Richard. "Grounding Captain Midnight." *Time* (4August 1986).

## Reports

Caton, Maj Jeffrey L. *Rapid Space Force Reconstitution: Mandate for US Security*. Maxwell AFB, AL: Air University Press, December 1994.

Erhard, Maj Thomas P. “Making the Connection: An Air Strategy Analysis Framework.” Maxwell AFB, AL: Air University Press, April 1996.

Houchin, Lt Col Roy F. “The Rise and Fall of Dyna-Soar: The USAF’s First Hypersonic Program.” Maxwell AFB, AL: School of Advanced Air Power Studies, 1998.

Mantz, Michael R., Lt Col, USAF. *The New Sword: A Theory of Space Combat Power*. Maxwell AFB, AL: Air University Press, May 1995.

Mims, Jim, et al. *Satellite Autonomy Study Final Report.* Kirtland AFB, NM: Phillips Laboratory, Plans and Programs Directorate, June 1995.

National Air Intelligence Center. *Threats to US Military Access to Space.* Wright-Patterson AFB, OH: Document #NAIC-1422-0984-98.

Nosenzo, LCDR Thomas E. “You Can’t Spell Space Control ‘ASAT’ Anymore.” NWC, Newport, RI, 6 March 1996.

Remillard, Stephen K. “Debris Production in Hypervelocity Impact ASAT Engagements.” Thesis for Master of Science (Space Operations) at Air Force Institute of Technology. Wright-Patterson AFB, OH: 30 November 1990.

US General Accounting Office. "Space Program: Space Debris a Potential Threat to Space Station and Shuttle." Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives. April 1990.

Van Zandt, J.R. “Debris from Kinetic Kill ASAT Engagements.” Bedford, MA: The MITRE Corporation, June 1990.

## Manuals and Other Publications

Department of the Air Force. Air Force Doctrine Document 2-2, *Space Operations*, dated 23 August 1998.

Department of the Air Force. *Global Engagement: A Vision for the 21st Century Air Force.* Washington D.C., 1998.

National Aeronautics and Space Act of 1958, Public Law 85-568, Sec 102(6), 29 July 1958.

US Space Command. *Long Range Plan: Implementing USSPACECOM Vision for 2020*, March 1998.

White House. *Fact Sheet: National Space Policy.* 19 September 1996.

## Electronic Publications

Black, LCDR Todd J. “Commercial Satellites: Future Threats or Allies?” On-line. Internet, 9 February 1999. Available from http://www.nwc.navy.mil/press/REVIEW/1999/winter/art5-w99.htm.

Christensen, John. “Bracing for Guerilla Warfare in Cyberspace,” CNN Interactive. On-line. Internet, 12 April 1999. Available from http://www.cnn.com/TECH/specials/hackers/cyberterror/.

Estes, Gen Howell M., III. “Protecting America’s Investment in Space,” dated 17 May 1998. On-line. Internet, 2 April 1999. Available from http://www.spacecom.af.mil/usspace/.

Herbert, Douglas. “PanAmSat Runs Down: Embattled Satellite Service Reports Battery Problems, Fears Client Loss,” 19 November 1998. On-line. Internet, 22 March 1999. Available from http://www.cgi.cnnfn.com/hotstories/companies/9811/19/panamsat;.

INTELSAT Homepage. On-line. Internet, 21 April 1999. Available from http://www.intelsat.com/csc/faqs.html.

Myers, Gen Richard B. “Achieving the Promise of Space—The Next Step,” Speech delivered to the Air Force Association Warfighting Symposium, Orlando, FL on 4 February 1999. On-line. Internet, 2 April 1999. Available from http://www.spacecom.af.mil/usspace/.

_____. “Implementing Our Vision for Space Control,” Speech given to the US Space Foundation in Colorado Springs, CO, on 7 April 1999. On-line. Internet, 16 April 1999. Available from http://www.spacecom.af.mil/usspace/speech15.htm.

_____. Written Testimony presented to the Senate Armed Services Committee Strategic Forces Subcommittee at Peterson AFB, CO on 22 March 1999. On-line. Internet, 2 April 1999. Available from http://www.spacecom.af.mil/usspace/.

Space Warfare Center. Computer-Based Training Module entitled “An Introduction to Orbital Mechanics.” Compact Disc. Colorado Springs, CO: BETAC Corp., Space Applications and Technologies Division, 1 February 1998.

## Notes

[1] White House, Fact Sheet: National Space Policy, 19 September 1996, 4.

[2] Ibid., 5.

[3] Recent legislation was approved by a decisive 97-3 vote in the Senate to codify, as US policy, a commitment to deploy an effective NMD system "as soon as technologically possible," which is capable of defending territory of the US against limited ballistic missile attack "whether deliberate, accidental or unauthorized." Known as the National Missile Defense Act of 1999 (S257), it reverses years of unwillingness by the Democratic filibustering and threats of veto. Two amendments—the first stipulating that NMD remains subject to the regular budget process and the second that the US remains committed to the nuclear reduction negotiations with the Russians—avoided a Presidential veto threat. Additionally, the recent North Korean, Pakistani and Iranian ballistic missile testing seems to have galvanized bipartisan support for the NMD efforts. The bill is currently awaiting approval by the administration. Source: Paul Mann, "Support Gathers Steam for National Missile Defense," *Aviation Week & Space Technology* (22 Mar 99): 29.

[4] "TMD" refers to Theater Missile Defense, "NMD" to National Missile Defense and "GMD" to Global Missile Defense.

[5] A good reference for understanding the dynamics of space systems is Roger R. Bate, Donald D. Mueller and Jerry E. White, *Fundamentals of Astrodynamics* (New York: Dover Publications, Inc., 1971).

[6] After a satellite is launched into space, gravity pulls on the object and causes it to be attracted towards the earth. However, the launch velocity and lack of friction outside the atmosphere causes the object to try to pull away from the earth. Since the forces of gravity and the speed of the satellite remain the same, the forces combine to form a "closed loop path" called an orbit. In some cases, when a satellite is launched it will have enough speed to escape the earth's gravity completely—escape velocity which is greater than 25,000 mph. In other cases, gravity will cause it to fall back to earth at speeds less than 17,500 mph. Source: Space Warfare Center (SWC), Computer-Based Training Module entitled "An Introduction to Orbital Mechanics" (Colorado Springs, CO: BETAC Corp., Space Applications and Technologies Division, 1 Feb 98), Chapter 3 dealing with specific orbits.

[7] To achieve this characteristic, the orbit is inclined over 90 degrees (termed a retrograde orbit) taking advantage of the oblateness of the earth to synchronize the orbit with its relative ground track.

[8] In 1944, Arthur C. Clarke recognized that three satellites in geosynchronous orbit could provide "global coverage" for communication purposes.

[9] SWC, n.p.

[10] A relatively new exception to this rule is the "supersynchronous" high-transfer orbit with an apogee of greater than 22,300 nm. It is occasionally used, instead of the classic geosynchronous transfer orbit, whereby the satellite's orbit is brought down to GEO altitude. Source: "Atlas, Proton Kick Off Busy 1999 Schedules," *Aviation Week and Space Technology* (22 February 1999): 30.

[11] Robert B. Giffen, Col, USAF, *US Space System Survivability* (Washington D.C.: National Defense University Press, 1982), 6-13. Much of the description related to both inclination and eccentricity has been drawn extensively from Col Giffen's work since it is one of the best (i.e., simplest) descriptions of these important concepts presented in laymen's terms.

[12] The Soviets found that launching into a 63.4-degree inclination avoided the typical rotation of the perigee caused by the oblateness of the earth. Instead, the relative position of perigee and apogee resulted in a stable orbit with apogee constantly occurring over the Northern Hemisphere. Source: SWC, n.p.

[13] Air Force Doctrine Document 2-2, *Space Operations*, 23 August 1998, describes "space systems" as consisting of three elements: space, terrestrial and link. Space includes "all components for which astrodynamics is the primary principle governing movement" such as satellites, space shuttles, etc. Terrestrial includes all "land, sea and airborne (C3) equipment" such as ground stations, communication nodes, as well as all operations personnel. The link includes "communication between the space element and the terrestrial-based element" such as data link signals.

## Notes

[14] This is not to imply that "repair" or "replenishment" missions are not possible or may become the standard. However, with very few exceptions (such as the repair of the Hubble telescope) most satellites operate without physical intervention once on-orbit.

[15] Giffen, 17.

[16] The trend for data dissemination is to make large volumes of information available in a virtual database environment. The user accesses the data on demand thereby reducing or eliminating the requirement to forward large volumes of data directly to the user. This concept is often referred to as "demand pull"; the corollary is a "requirement push" scenario in which high-priority data is forwarded without request (typically data associated with critical, time-sensitive data such as threat warning). Whether the data is relayed in the traditional manner or made available in a virtual database and accessed by the user, the reality is long-haul communication via satellite will most probably be involved either directly or indirectly at some point in the communication architecture.

[17] Similar statements made by Gen Richard B. Myers, USAF in Written Testimony presented to the Senate Armed Services Committee Strategic Forces Subcommittee at Peterson AFB, CO on 22 March 1999, and Gen Howell M. Estes, III, USAF in a variety of speeches and testimony during tenure as CINCSPACE. All sources on-line, Internet, 2 April 1999, available from http://www.spacecom.af.mil/usspace/.

[18] Estes, 1, and Richard B. Myers, Gen, USAF, "Achieving the Promise of Space—The Next Step," Speech delivered to the Air Force Association Warfighting Symposium, Orlando, FL on 4 February 1999, 2; on-line, Internet, 2 April 1999, available from http://www.spacecom.af.mil/usspace/.

[19] Howell M. Estes, III, Gen, USAF, "Protecting America's Investment in Space," dated 17 May 1998, 1; on-line, Internet, 2 April 1999, available from http://www.spacecom.af.mil/usspace/.

[20] As early as the 1950's, senior Air Force leaders were publicly stating the potential of "controlling" the "third dimension" of space. An address by Gen Thomas D. White, Chief of Staff of the US Air Force, to the National Press Club in Washington D.C. on November 29, 1957 makes this point clear. In fact, this address is considered by many to be a "classic" doctrinal statement in the early post-Sputnik era. Source: Eugene M. Emme, *The Impact of Air Power: National Security and World Politics* (New York: D.Van Nostrand Company, Inc., 1959), 496-498.

[21] Curtis Peebles, *High Frontier: The US Air Force and the Military Space Program* (Washington D.C.: US Government Printing Office, Air Force History and Museums Program, 1997), 9.

[22] Emme, 498.

[23] Peebles, 4-5 and 10. The "Open Skies" proposals were made at the July 1955 Geneva Four Power Summit Conference and were viewed as means to legitimize the overflights of the Soviets closed society. Shortly after the Geneva Conference, President Eisenhower approved the first, of many, U-2 overflights on July 4, 1956.

[24] National Aeronautics and Space Act of 1958, Public Law 85-568, Sec 102(6), 29 July 1958. Additionally, the act clearly stated that "activities peculiar to or primarily associated with the development of weapon systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of the Department of Defense." For the first time, the act clearly established, in both law and policy, a separate and independent military space program. Source: Thomas S. Moorman, Jr., Gen (ret), USAF, "The Explosion of Commercial Space and the Implications for National Security," *Airpower Journal*, Vol XIII, No 1 (Spring 1999): 8.

[25] Excerpt from an August 1958 National Security Council directive issued by the Eisenhower Administration. Another NSC policy directive (June 1958) sought to establish a "political framework which will place the uses of US reconnaissance satellites in a political and psychological context most favorable to the United States." The last of the related NSC policy directives (December 1959) described the military space missions which were considered to be peaceful uses of outer space. Source: Peebles, 10.

[26] Peebles, 11.

[27] Roy F. Houchin, Lt Col, USAF, "The Rise and Fall of Dyna-Soar: The USAF's First Hypersonic Program," (Maxwell AFB, AL: School of Advanced Air Power Studies, 1998), 1-2. Dyna-Soar was the first true aerospace bomber concept to be advanced by the military. Once built, the Dyna-Soar program was envisioned to operate at orbital altitudes of 300,000 feet and a speed of 15,000 mph making it wholly suited for reconnaissance, interception, logistics, bombardment or ASAT missions.

[28] Houchin, 18.

## Notes

[29] Peebles, 20-22.

[30] US Air Force Space Warfare Center, *Space Reference Guide*, Chapter 1, 1-5.

[31] The early US space launch vehicles were based on IRBM first stages such as the Juno 2, Thor Able, Thor Delta, Thor Epsilon and Thor Agena. The Thor boosters later evolved into the successful Delta boosters. For larger payloads, boosters began to be developed from the first stages of larger ICBMs such as the Atlas and Titan II developments. Source: *Space Reference Guide*, Chapter 1, p. 1-8.

[32] Paul B. Stares, *The Militarization of Space: US Policy, 1945-84* (Ithaca, NY: Cornell University Press, 1985), 53.

[33] The Kennedy Administration struggled with the political sensitivities associated with developing a nuclear-tipped anti-satellite weapon. Curtis Peebles describes the decision to pursue Program 437 as follows: "In late 1963, Kennedy Administration officials met to review the technical feasibility and political sensitivity of Program 437. In attendance: Robert McNamara, Harold Brown, Undersecretary of State U. Alexis Johnson, Director of the US Information Agency Edward R. Murrow, and Col. Harry E. Evans, Chief of the Research and Development Division of the JCS. In the official 437 history, Evans recalled:

> *Most of the civilian leadership of both the State and Defense Departments were very nervous about even having a program of research and development for something like 437, let alone the prospect of having such a system operationally ready and manned by "blue suiters." Certainly the aspect of detonating a nuclear weapon in space was politically unattractive to them.*

As the discussion continued, most seemed to be against what was viewed as a political liability. Up to this point, Murrow had been quietly smoking a cigarette. Now he interrupted the discussion with a brief comment:

> *If the Soviets place a bomb in orbit and threaten us and if this administration has refused to develop a capability to destroy it in orbit, you will see the first impeachment proceeding of an American President since Andrew Johnson*
>
> .

Evans recalled that about two minutes of total silence followed Murrow's remark. Finally, McNamara said testily, 'Well, it doesn't cost much, and the JCS want it, so let's approve 437." Source: Peebles, 61-62.

[34] Program 437 featured a novel operational profile—capable of intercepting satellites as high as 700 nm and within a cross range of 1,500 nm of Johnston Island. Because of timing constraints, the missile had a launch window of plus or minus one second. Therefore, two Thor interceptors would simultaneously countdown—one primary and a back-up. Once launched, the Thor would follow a ballistic trajectory to the intercept point at which time a radio signal would arm and detonate a 1.0-1.5 megaton nuclear warhead with a "kill" radius of five miles. Source: Stares, 120-123, and Peebles, 62.

[35] Kenneth N. Luongo and Thomas W. Wander, *The Search for Security in Space* (Ithaca, NY: Cornell University Press, 1989), 39-41.

[36] The term "reconsider" is used because the Air Force had developed initial capabilities to intercept satellites using air-launched rockets in the late 1950's. First, a B-58 unsuccessfully launched a missile at the Discoverer 5 satellite in September 1959. However, on 13 October 1959, a B-47 launch a Bold Orion missile at Explorer 6. Many consider this to be the "first interception of a satellite" since the missile passed within four miles of Explorer 6. Source: Peebles, 65.

[37] Michael J. Muolo, Maj, USAF, *Space Handbook: A War Fighter's Guide to Space—Volume One* (Maxwell AFB, AL: Air University Press, December 1993), 42.

[38] The ASAT missile would be released from the F-15 while in a steep climb. Once the solid-rocket SRAM burned out, separation would occur and the second stage Altair III rocket would ignite. A guidance system would direct the second stage to the intercept point where, after second stage burnout, the miniature vehicle would be released and steered to collide with the target satellite scoring a "kill." Source: Gray, 7 and Peebles, 65-66.

[39] Luongo, 67.

[40] The Aspen Strategy Group, *Anti-Satellite Weapons and US Military Space Policy* (Washington D.C.: University Press, 1986), 31.

[41] Muolo, 152.

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[42] Department of the Air Force, *Global Engagement: A Vision for the 21st Century Air Force* (Washington D.C.), 7.

[43] Using the following formula, the percentage of the earth's surface visible from a satellite or aircraft at altitude h (in nautical miles) can be calculated:

$$A = [\ (1 - (3444 \div (3444+h))) \div 2\ ] \times 100$$

Forgen Jensen, et al., *Design Guide to Orbital Flight* (New York: McGraw-Hill Book Co., Inc., 1962), 771-773.

[44] This characteristic will have significant implications as space-based weapons are developed and employed. The inability to "hide" these systems in space complicates one's ability to protect them—especially since the initial systems will most probably be 'fragile' as compared to the relatively robust ground-based ASAT threats. Hence, many players in the international community can be expected to perceive them as 'first strike' weapons (outside the TMD/NMD/GMD debate) since it is questionable whether they will be capable of surviving to conduct 'second strike' operations. Source: Bruce DeBlois, Lt Col, USAF, "Space Sanctuary: A Viable National Strategy," *Airpower Journal*, Vol XII, No 4 (Winter 98): 4.

[45] Current US space doctrine recognizes four distinct mission areas—space control, force application, force enhancement and space support. Air Force Doctrine Document 2-2, *Space Operations*, 23 August 1998, states "space force operations focus on controlling the space environment, applying force, conducting enabling and supporting operations for terrestrial-based forces, and supporting space forces." (7) The mission areas of space control, force application, force enhancement and space force support are clearly captured in this statement. Likewise, the current National Space Policy directs the DoD to "maintain the capability to execute the mission areas of space support, force enhancement, space control, and force application." Source: The White House, *Fact Sheet: National Space Policy*, 19 September 1996, 4.

[46]Donald J. Kutyna, Gen (ret), USAF, "Indispensable: Space Systems in the Persian Gulf War," *The US Air Force in Space: 1945 to the 21st Century* (Washington D.C.: USAF History & Museum Program, Proceedings from the Air Force Historical Foundation Symposium held at Andrews AFB, MD on 21-22 September 1995, dated 1998), 103.

[47]Thomas S. Moorman, Jr., Gen (ret), USAF, "The Explosion of Commercial Space and the Implications for National Security," *Airpower Journal*, Vol XIII, No. 1 (Spring 1999): 6-7.

[48] Moorman, 9-10.

[49] Moorman, 10.

[50]G.J. Tahu ,et al, "Expanding Global Access to Civilian and Commercial Remote Sensing Data: Implications and Policy Issues," *Space Policy* (3 August 1998): 185.

[51]Aldrin, Andrew J., "Technology Control Regimes and the Globalization of Space Industry," *Space Policy* (May 1998): 115.

[52]David A. Fulgham, "Cheap Cruise Missiles A Potent Threat," *Aviation Week & Space Technology*, Vol Vol 139, No 10 ( 6 September 1999): 54. Note: The US Global Positioning System (GPS) and Russian Global Navigation System (GLONASS) are the two dominant space-based navigational systems currently in operation. New systems are under consideration such as that being proposed by the European Space Agency.

[53] Fulgham, 54-55. The author notes that "cruise missiles are ideal for radar cross-section reduction because they have few of the traditional problem areas such as landing gear, weapons pylons, cockpits and large intake cavities. That makes it cheap and easy to treat these vehicles with low observable materials." Additionally, the use of turbojet and turbofan engines in cruise missiles has solved many of the infrared problems associated with first generation ramjets and fuels with metal additives used for increased power.

[54] LCDR Nosenzo introduced the term "co-dependency" in 1996. While not widely used in the space arena, it is a very effective description and has been adopted in this paper. Source:Thomas E. Nosenzo, LCDR, USN, "You Can't Spell Space Control 'ASAT' Anymore," NWC, Newport, RI, 6 March 1996, 1.

[55] INTELSAT, the International Telecommunication Satellite Organization, is a 200+ nation telecommunication cooperative, which offers voice, data, video and INTERNET communications on a world-wide basis. Currently, the constellation consists of nineteen communication satellites in geostationary orbits including INTELSAT V- through IX-series spacecraft. Source: INTELSAT Homepage, n.p.; on-line, Internet, 21 April 1999, available from http://www.intelsat.com/csc/faqs.html.

[56] The NAVSTAR Global Positioning System (GPS) is a constellation of orbiting satellites that provedes navigation data to military and civilian users all over the world. The system is operated and

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controlled by members of the 50th space Wing loacted at Schriever AFB, CO. The constellation typically consists of twenty-four spacecraft, which currently include Block I-, IIA- and IIR-series satellites.

[57]Richard J.H. Barnes, and Roy Gibson, “An International Look at Global Navigation Satellite Systems,” *Space Policy* (August 1998): 190.

[58] In fact, US space policy signed by the Clinton administration in March 1996 directs the DoD to provide the GPS signal free-of-charge on a worldwide basis, as well as to deactivate the selective availability feature by 2006.

[59] Pierre Sparaco, “French Satellite Details Air Strike Damages,” *Aviation Week & Space Technology* (12 April 1999): 26-27.

[60] Richard B. Myers, Gen, USAF, “Implementing Our Vision for Space Control,” Speech given to the US Space Foundation in Colorado Springs, CO, on 7 April 1999, n.p.; on-line, Internet, 16 April 1999, available from http://www.spacecom.af.mil/usspace/speech15.htm.

[61] An Air Force Research Laboratory manager summed up the view of most in the commercial space sector by stating, “they’ll be glad to put [a sensor] on their satellites—just as long as it has zero volume, zero weight, requires no power and generates revenue.” Source: William B. Scott, “Space Chief Warns of Threats to US Commercial Satellites,” *Aviation Week & Space Technology* (12 April 1999): 51.

[62] William E. Wiesel, *Spaceflight Dynamics* (New York: McGraw-Hill Book Company, 1989): 261. He adds, “Explosions in orbit have left thousands of macroscopic objects in orbit as spent upper stages detonate, sometimes years after reaching orbit.”

[63] US General Accounting Office, *Space Program: Space Debris a Potential Threat to Space Station and Shuttle*, Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives (April 1990): 2.

[64]J.R. Van Zandt, “Debris from Kinetic Kill ASAT Engagements” (Bedford, MA: The MITRE Corporation, June 1990): 3. Van Zandt cites the Delta 180 experiment in which an interceptor was purposely collided with the second stage of it Delta booster. A total of 381 fragments of 10 cm or greater were generated by this hypervelocity impact. Additionally, Capt Stephen K. Remillard, USAF, theorizes thousands of fragments 1 cm or less will be produced in such collisions. Specifically, he states the following:

When a projectile collides with a satellite at orbital velocities, the outcome of the collision is determined largely by the relative masses of the projectile and target. If the projectile and target are roughly the same size (within a factor of 100) a catastrophic collision will result. This means that all of the target and all of the projectiles are converted to debris. Otherwise, some amount of debris will be generated as a function of the mass and velocity of the projectile. A more massive, or faster moving, projectile will generate more debris, all other factors being equal.

The detailed calculations of a notional ASAT attack predict approximately 40,000-70,000 pieces of debris (less than 1 cm) could be generated depending on relative size, speed and orientation of attack, as well as spacecraft design features such as component positioning and materials. Source: Stephen K. Remillard, “Debris Production in Hypervelocity Impact ASAT Engagements,” Thesis for Master of Science (Space Operations) at Air Force Institute of Technology (Wright-Patterson AFB, OH: 30 November 1990): 14.

[65] Air Force Doctrine Document 2-2, *Space Operations*, 23 August 1998, 8.

[66] National Air Intelligence Center, *Threats to US Military Access to Space* (Wright-Patterson AFB, OH, Document #NAIC-1422-0984-98): 8.

[67] NAIC, 8.

[68] Robert B. Giffen, Col, USAF, *US Space System Survivability* (Washington D.C.: National Defense University Press, 1982): 29.

[69] Orbital information on a host of satellite systems to include alleged intelligence collection satellites is easily obtained from amateur observers via the INTERNET and other sources. Though relatively rudimentary methods are employed, the worldwide association of amateur satellite observers offers a (albeit not completely reliable) cheap alternative. Countries concerned about the reliability of the amateur satellite observer data would most likely supplement the data with indigenously derived tracking information or purchase it commercially from more developed sources such as Russia. NAIC, 6 and 12. Allen Thomson’s “Satellite Vulnerability: A Post-Cold War Issue?,” *Space Policy* (Winter 1995): 19-30,

also offers a convincing argument related to the proliferation of direct-ascent ASAT technologies and the specific capabilities required to field such ASAT systems.

[70] NAIC, 13.

[71] Giffen, 27.

[72] Bruce G. Blair, *Strategic Command and Control: Redefining the Nuclear Threat* (Washington D.C.: The Brookings Institue, 1985): 201-207, and NAIC, 12.

[73] Samuel Glasstone and Phillip J. Dolan, *The Effects of Nuclear Weapons* (Washington D.C.: Published by US Department of Defense and US Department of Energy, 1977): 45-48. The nuclear test cited was the third attempt on July 9, 1962 referred to as Starfish in which a 1.4 megaton NUDET occurred at an altitude of 248 nm over the South Pacific.

[74] NAIC, 15-16.

[75] The failure was ultimately determined to be a "computer glitch" which allowed the satellite to rotate out of position. The Galaxy IV blackouts also "shut down the first feed of a CBS evening news broadcast, disrupted cable transmissions and decommissioned thousands of banking networks across the country that operate automated teller machines. Motorists trying to refuel at fast-pay pumps at gas stations across North America suddenly found the spigots shut." Source: Douglas Herbert, "PanAmSat Runs Down: Embattled Satellite Service Reports Battery Problems, Fears Client Loss," 19 November 1998, 1-2; on-line, Internet, 22 March 1999, available from http://www.cgi.cnnfn.com/hotstories/companies/9811/19/ panamsat;.

[76] Richard Zoglin, "Grounding Captain Midnight," *Time* (4 August 1986): 47. The article detailed how "Mr. John MacDougall, 25, a part-time engineer at a satellite transmission facility in Ocala, FL and owner of a home-dish dealership pleaded guilty to electronic intrusion. His unauthorized interfering signal interrupted an ongoing HBO broadcast with the message '…'" Obviously, proactive actions are routinely taken to prevent similar intrusions of military, civil and commercial satellite systems. However, the incident demonstrates how a relatively knowledgeable individual with rudimentary equipment can spoof an unprotected target. Translating this experience into a scenario with a well-informed, well-equipped aggressor does not take a leap of faith.

[77] John Christensen, "Bracing for Guerilla Warfare in Cyberspace," CNN Interactive, n.p.; on-line, Internet, 12 April 1999, available from http://www.cnn.com/TECH/specials/hackers/cyberterror/. Estimates regarding countries and groups pursuing information warfare systems is cited from a US Government Accounting Office (GAO) report. Figures related to hacker-oriented web sites is drawn from comments by Rob Clyde, a representative of Axent Technology—a computer security firm.

[78] An adversary employing uplink jammers is most likely targeting the satellite's command receivers or potentially a RF-based sensor onboard the satellite. As stated, uplink jamming is considerably more difficult due to the relatively large transmit power requirements. However, the effects have the potential to be either regional or global depending on the spacecraft mission and characteristics. An adversary employing downlink jammers is most likely targeting ground-based satellite data receivers—either receivers associated with the ground control segment (i.e., integral to control of the space segment) or the receivers deployed in the user segment (i.e., communication terminals, navigational aids, early warning alert equipment, etc). In other words, both ground controllers and end users can be the target of downlink jammers.

[79] NAIC, 10.

[80] Giffen, 30.

[81] NAIC, 10.

[82] Space Warfare Center, Space Reference Guide, Chapter 21, 21-1 – 21-3.

[83] Glasstone, 45-48. Three additional high-altitude NUDET tests were performed in 1958 as part of Project Argus (Aug 27, Aug 30 & Sep 6), which confirmed the original findings. According to Jack Manno, *Arming the Heavens: The Hidden Military Agenda for Space 1945-1995* (New York, NY: Dodd, Mead & Co., 1984): 56, the Presidential Science Advisor, James Killian, prepared a report outlining the findings regarding nuclear explosions in space. Three types of effects were produced "significant to military planning: high-energy radiation effects in space, worldwide radio noise, and intensification of the ionosphere." He adds,

> The extent of each of these effects was determined by the power of the bomb blast, the geographical placement and altitude, and the amount of fission products released. Some of the

important effects could be deliberately created and targeted to occur where chosen. There were two important limits to the effects: First, they could be produced over the equatorial and temperate zones but not in the polar regions. Second, although the intensity of the effects increased with the power of the bomb, too great an explosion would cause the earth's magnetism to 'burst,' so that radiation was not trapped by the lines of magnetic force and no discrete belt formed.

[84] The Russians are actively peddling a small GPS jamming system on the open market in an effort to generate revenue. Source: Scott, William B., "Space Chief Warns of Threats to US Commercial Satellites," *Aviation Week & Space Technology* (12 April 99): 51.

[85] Richard B. Myers, Gen, USAF, Written Testimony presented to the Senate Armed Services Committee at Peterson AFB, CO, 22 March 1999, 4; on-line, Internet, 2 April 1999, available from http://www.spacecom.af.mil/usspace/.

[86] US Space Command, *Long Range Plan: Implementing USSPACECOM Vision for 2020*, March 1998, 22-23. The LRP highlights three "key tasks" related to assured access—transporting mission assets to, through and from space; operating on-orbit assets; as well as servicing and recovering on-orbit assets. For our purposes, the service and recovery has been omitted since it does not appear to be a near-term capability.

[87] Satellite operations run the gambit from "cradle to grave" by supporting tasks such as spacecraft initialization after launch; actual mission execution; conduct of housekeeping activities; calibrations and other tests; deorbiting operations; etc.

[88] The current US National Space Policy states that "these [space control] capabilities may also be enhanced by diplomatic, legal and military measures to preclude an adversary's hostile use of space systems and services." Interestingly, 'economic' activities are omitted from this statement. Source: The White House, *Fact Sheet: National Space Policy*, 19 September 1996, 5.

[89] Thomas Mahnken and Janne Nolan maintain that "converting an SLV into a long-range ballistic missile involves replacing the SLV's payload with a warhead and reentry vehicle." They note that the warhead must be "both small and light enough to be carried by missile (that is, in the neighborhood of 500 to 1,000 kg). While creating a chemical or biological warhead of such dimensions is not difficult, fielding a compact nuclear weapon is much more so." They emphasize that there are diverse political motivations for developing ballistic missiles and SLVs. Specifically, "ballistic missiles (and space systems in general) are symbols of national power and prestige in many developing states. Such programs often inspire patriotic and nationalistic sentiment, demonstrating both technical capacity and industrial sovereignty." Additionally, some states "build an aerospace production base to generate revenue through arms exports and to expand their scientific and technical infrastructure…states may hope to reap the benefits of space technology while also retaining an option to deploy ballistic missiles." Finally, at the strategic level, "ballistic missiles [built on a foundation of SLVs] can serve as the means to exert coercive leverage against regional rivals or to deter US intervention in local conflicts. By possessing the ability to strike neighboring adversaries, states may hope to coerce the former into denying requests for access to the region by US forces." Source: Chapter entitled "Challenges Posed by Space-Launch and Missile Proliferation" in Peter Hayes, *Space Power Interests* (Boulder, Colorado: Westview Press, 1996): 12-18.

[90] Andrew J. Aldrin, "Technology Control Regimes and the Globalization of Space Industry," *Space Policy* (May 1998): 118.

[91] Mahnken and Nolan highlight the fact that the "cornerstone" of US missile nonproliferation efforts remains the 1987 MTCR. As Mahnken and Nolan detail,

MTCR is a set of coordinated export policies designed to limit the spread of missiles capable of delivering a 500-kg payload to a distance of 300 km. The MTCR export restrictions include a ban on the sale of missile production facilities and a strong presumption to deny exports of complete delivery systems, including complete rocket systems, such as ballistic missile systems, space launch vehicles and sounding rockets, drones and remotely-piloted vehicles; rocket engines; guidance sets; thrust vector controls; and warhead safing, arming, fuzing and firing mechanisms (Category I systems). In addition, the export of dual-use missile components (Category II systems) is to be judged on a case-by-case basis.

They add that the MTCR faces a number of limitations to its ability to slow the diffusion of missile technology. Reasons include the fact that a cartel limiting the supply of prescribed technologies only raises the incentive for cheating by both members and non-members; restrictions on supply channels tend to foster new sources of supply; significant differences in enforcement standards both within and among

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MTCR members; and the relatively limited nature of the MTCR (currently less than thirty members). Source: Hayes, 19-20.

[92] Robert B. Giffen, Col, USAF, *US Space System Survivability* (Washington D.C.: National Defense University Press, 1982): 35.

[93] George I. Seffers, "Pentagon Threatens to Block Satellite Launch," *Space News* (26 April 1999): 3. Seffers adds the DoD is now deciding how best to proceed (if required)—whether to go through US or international courts. Undeniably, the ability of a commercial enterprise to operate autonomously in a "sovereign" medium presents an interesting challenge when opposed by a nation-state.

[94] Todd J. Black, LCDR, USN, "Commercial Satellites: Future Threats or Allies?" 7; on-line, Internet, 9 February 1999, available from http://www.nwc.navy.mil/press/REVIEW/1999/winter/art5-w99.htm.

[95] Black, 6.

[96] Shutter control was introduced in 1992 by the Land Remote Sensing Policy Act and built upon in Presidential Decision Directive INSC-23 (PDD-23), entitled "US Policy on Foreign Access to Remote Sensing Space Capabilities" dated 9 March 94. Source: Larry K. Grundhauser, Lt Col, USAF, "Sentinels Rising: Commercial High-Resolution Imagery and Its Implications for US National Security," *Airpower Journal*, Vol XII, No 4 (Winter 98): 74.

[97] Grundhauser, 75.

[98] Giffen, 35-36.

[99] *Defense Daily*, 17 October 1997, 3.

[100] Paul B. Stares, Space and National Security (Washington D.C.: The Brookings Institute, 1987): 79.

[101] This mindset is only magnified given commercial industry's effectiveness in providing radiation-hardened spacecraft components designed to effectively operate in the extremely severe space environments (principally solar radiation effects).

[102] Almost all satellites have some ability to "move" or orient themselves for proper attitude control, power collection, etc. "Maneuverability" in the context of space control usually refers to the ability to make relatively large movements in space—either "in-track" or "cross-track" relative to the satellite's orbit—for the purpose of evading a threat.

[103] Warning time is principally a function of the quality of the space surveillance system employed, satellite's orbit type (especially altitude) and character of the threat.

[104] Stares, 80.

[105] Jim Mims, et al, *Satellite Autonomy Study Final Report* (Kirtland AFB, NM: Phillips Laboratory, Plans and Programs Directorate, June 1995): 1 and 14.

[106] Mims, 1-2. The Satellite Autonomy Study Final Report cites the major benefits of implementing satellite autonomy as "reduced operations cost resulting from a decrease in manpower requirements, protection against inadvertent operator errors, increased satellite survivability and threat assessment, reduction in contact time and frequency of contacts, and reduction of data stream for Telemetry, Tracking and Communication (TT&C) functions." Risks or disadvantages include "programmatic constraints, hardware and software failures, potential high cost of implementing autonomous features in ground and space segments, operators' lack of confidence in autonomous satellites, and not being in direct control of the satellites."

[107] Kevin C. Ruffner, *CORONA: America's First Satellite Program* (Washington D.C.: CIA History Staff Center for the Study of Intelligence, 1995): xiii and 10-11. It should be noted that the US did not acknowledge that it used "satellite systems and imagery for intelligence purposes" until 1978. At that time, it was only in reference to verification of arms control treaties under the term "national systems." It was not until the early 1990's that officials have talked openly about the existence of overhead reconnaissance systems and their intelligence uses.

[108] The Aspen Strategy Group, *Anti-Satellite Weapons and U.S. Military Space Policy* (Washington D.C.: University Press of America, 1986): 10-12. The study cites the Soviet co-orbital ASAT as an example of a threat to LEO systems, which required two orbital revolutions to "catch up" to the target satellite to allow the radar homing sensor to guide the pellet-type warhead within lethal range. In contrast, the US air-launched miniature homing vehicle targeted directly thereby minimizing its "attack sequence" to only 10-20 minutes thereby minimizing the target satellite(s) ability to maneuver out of danger. Moving a satellite to GEO adds 3-6 hours to the flight time alone of a terrestrial-based ASAT using a standard rocket booster.

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[109] Though relatively distances are extreme in GEO, the somewhat static nature regarding the satellites positions presents a potentially lucrative target in space.

[110] Caton, Jeffrey L., Maj, USAF, Rapid Space Force Reconstitution: Mandate for US Security (Maxwell AFB, AL: Air University Press, December 1994). Maj Caton highlights the need for responsiveness, reliability and flexibility, which (in addition to cost) are traditionally cited as the characteristics of an effective launch system. In summary, he proposes "rapid-response spacelift" and "light satellites (lightsats)" as the best solutions to the inherent problems of reconstituting US space-based assets. The basic premise is that US space assets are too complex due to a host of reasons (mindset of quality over quantity, evolution of space launch assets from ICBMs, over-commitment to existing space launch systems such as Titan and Space Shuttle), which prevents a better solution to emerge. He offers the Russian space launch capability/mindset as the preferred solution—less complex satellite systems geared toward the ability to "surge" using a robust spacelift capability. For example, the Soviet Union conducted 29 satellite launches within a 69-day period during the Falklands War—an order of magnitude improvement over US launch rates.

[111] Scott, William B., "Wargames Underscore Value of Space Assets for Military Ops," *Aviation Week & Space Technology* (28 April 1997): 60. Similar findings were highlighted regarding the dependency-vulnerability situation in wargames/experiments conducted by the Army "Task Force 21" and US Strategic Command—especially related to NUDETs in space.

[112] Often, the concept of a "high-value asset" (HVA) is applied to space due to its military significance. In other words, it is proposed that space (or space-assets) be treated like other HVAs such as aircraft carriers, JSTARS, AWACS, etc. The intent being to provide the similar types of defensive posture to critical space assets as afforded these other HVAs. For example, the armada of surface, subsurface and air assets which typically makes up the carrier battle group (CVBG) is dedicated primarily to the defense of the carrier itself. The reasoning being that the importance of critical space assets warrants the commitment of similar defensive resources. Unfortunately, the rapid evolution in space, the military's increasing reliance on commercial space capabilities, and the dynamic geopolitical environment make this task extremely difficult.

[113] Carl von Clausewitz offers timeless counsel regarding the need to clearly understand the strategic environment: No one starts a war—or rather, no on in his senses ought to do so—without first being clear in his mind what he intends to achieve by that war and how he intends to conduct it. The former is its political purpose; the latter its operational objective. The is the governing principle which will set its course, prescribe the scale of means and effort which is required, and make its influence felt throughout down to the smallest operational detail. Source: Carl von Clausewitz, *On War*,edited and translated by Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1976), 579.

[114] Figure 15 is similar in some respects to Figure III-1 entitled "Space Combat Operations" in the draft Joint Pub 3-14.

[115] The Hon John J. Hamre, current Deputy Secretary of Defense, emphasized this point recently when he stated, "we could spend an enormous amount of money on space destruction capabilities that our leaders would never authorize us to use, for fear of international [backlash] and the problems it might create." Source: William B. Scott, "US Adopts 'Tactical' Space Control Policy," *Aviation Week & Space Technology* (29 March 1999): 35.

[116] This view holds true in the absence of true force application capabilities (e.g., direct space-to-ground force projection). However, once force application capabilities are developed and deployed, this information-centric perspective will have to become more "hybrid" in nature incorporating elements of both information and force application.

[117] The basic structure of the strategic planning steps is drawn in part from Erhard, Thomas P., Maj, USAF, "Making the Connection: An Air Strategy Analysis Framework" (Maxwell AFB, AL: Air University Press, April 1996).

[118] The concept as presented is similar in some respects to Tony Mason's "Air Power Pendulum" presented in *Air Power: A Centennial Appraisal* (Washington, D.C.: Brassey's Ltd, 1994), xiii. However, the proposed space control spectrum is wholly focused on the unique aspects of space control versus airpower and is much more detailed (i.e., assesses factors in a more tactical manner).