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THE NEED FOR A DEDICATED SPACE VEHICLE FOR DEFENSIVE COUNTERSPACE OPERATIONS

by

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Abstract

This paper investigates the defensive counterspace function as defined in Air Force Doctrine Document 1 and considers whether an on-orbit capability is needed for its fulfillment. The discussion begins with the examination of threats to space systems, how they are likely to be attacked and the means with which to counter those attacks. The examination focuses on the space element and determines that a space-based defensive capability will be needed to protect orbital assets in the future. The defensive potential of ground-based systems and self-defending spacecraft are determined to be inadequate, leading to the conclusion that a dedicated, mission specific vehicle design is the best option for fulfilling the defensive counterspace function. Finally, preliminary considerations of vehicle design and mission capability indicate that the first iteration of this vehicle should be ground-stationed, reusable, and prepared to launch into earth orbit in time of heightened tensions or war to carry out the defensive counterspace mission.

Chapter 1

Introduction

Over the last two centuries, the United States has expanded and sustained its national power through the commercial exploitation of the land, sea and air in succession. "The surge of commercial development in space systems…over the last decade is analogous to historical U.S. economic expansion over land, on the seas, and in the air. As the freedom to operate in each of these mediums became essential to the nation's economic well-being, it was necessary to protect the associated lanes of commerce,"[1] creating the need for an army, a navy, and an air force. The United States is now facing the need to protect and defend its use of space for commercial, public, and military purposes. As US dependence on space and the number of nations with access to space increase, the nation must think long and hard about how its space systems will be threatened in the future, what the best methods might be to deter and defeat those threats, and how the methods might best be employed.

In examining threats to our space systems and ways to protect against them, this paper argues that defense of US space systems in the future will have to be conducted in the space medium, and that a vehicle specifically designed to defend on-orbit assets is the best way to accomplish this function. It then briefly examines some of the preliminary design and employment choices that must be made to develop this vehicle.

Background

As the turn of the century approaches, the US Air Force becomes more focused on transitioning from an "air and space force" to a "space and air force."[2] With this transition the Air Force is beginning to see space not just as a vital domain for supporting terrestrial forces, but also as an arena that may soon be subject to military actions. This stance is not unreasonable given the extent to which the public and private sectors of the US economy and the Armed Forces presently depend on space systems, and that dependency is only expected to grow in the future.

Although national leadership is reluctant to admit openly that space forces might someday be necessary to protect US government and commercial space assets,[3] national security policy implies that the US is headed in that direction.

> Uninhibited access to and the use of space is essential for preserving peace and protecting U.S. national security….Our space policy objectives include deterring threats to our interest in space and defeating hostile efforts against U.S. space assets if deterrence fails,….[4]

This statement allows that we will continue to defeat hostile threats to our space systems using terrestrially based assets as long as those threats remain terrestrially based. However, once threats to satellites move into the realm of space, we will be forced to consider the migration of military capabilities into that arena as well.

While current civilian leaders do not want to address the issue of military capabilities beyond support missions in space, the US military already acknowledges that it expects someday to be fighting in space. *Joint Vision 2010*, the Department of Defense (DOD) vision statement for the 21st century, states that "(w)e must have information superiority: the capability to collect, process and disseminate an uninterrupted flow of information while exploiting or denying the enemy's ability to do the same."[5] Collection and dissemination of information is increasingly dependent on space systems. The Air Force vision statement, *Global Engagement*, is more direct. “The threats to Americans and American forces from the use of space by adversaries are rising while our dependence on space assets is also increasing. The medium of space is one which cannot be ceded to our nation’s adversaries. The Air Force must plan to prevail in the use of space.”[6] The implication is clear. We must be prepared to actively defend access to and use of space for commercial and military purposes.

Definitions

In order to establish a common framework around which this discussion can take place, some terms associated with operating in space should be defined at the outset. The most important terms are defined briefly here, while expanded definitions and additional terms are found in the glossary.

A **space system** is a “system with a major functional component which operates in the space environment.”[7] It has three elements: the space element, commonly known as a satellite; the terrestrial element, or ground-based assets and operations; and the link element, the means by which the space and terrestrial elements pass information back and forth.[8] Any of the three elements could be attacked to destroy or degrade a space system’s effectiveness, so it is important to consider each in protecting and defending space systems from attack.

“**Space control** is the means by which we gain and maintain space superiority.”[9] It is achieved through **counterspace operations**, which are “operations conducted to attain and maintain a desired degree of space superiority by the destruction or neutralization of enemy forces.”[10] Counterspace operations can be further divided into offensive and defensive counterspace operations. **Offensive counterspace operations** (OCS) "destroy or neutralize an adversary's space systems or the information they provide,"[11] while **defensive counterspace operations** (DCS) "consist of active and passive actions to protect our space-related capabilities from enemy attack or interference."[12]

Limitations and Assumptions

Certain limitations and assumptions have been made in order to focus the discussion around the operational and tactical issues of the DCS mission and to avoid policy issues.

The primary limitation of the study was the determination to use only unclassified data in developing the topic. This decision was prudent because it greatly eased the circumstances under which the paper was developed and is not crippling because classified data which might be applicable deals primarily with the capabilities and vulnerabilities of current and planned US space systems. Although such information would add real world examples to the discussion of techniques and tactics, it is not crucial to the development of the thesis.

A further limitation was the decision to avoid a discussion of the political, legal and ethical considerations involved in the weaponization of space. This topic is discussed at great length in many forums, public and private, and it is not the intent of the study to add to that debate. The considerations here are limited to the technical and operational advantages and disadvantages of a DCS system.

Finally, in the examination of design and employment considerations for a defensive counterspace vehicle, some technology related assumptions are required. Although not all of the technologies needed for the development of a vehicle with the capabilities described herein are fully developed at this time, the assumption is that their development is a reasonable expectation in the foreseeable future. This assumption is made based on the reporting of technology efforts found in the open literature.[13]

With the background, definitions and limitations of the topic identified, the first step in examining the need for a satellite defense is to understand how space systems can be threatened, both now and in the future.

Notes

[1] William B. Scott, "Pentagon Considers Space As New Area of Responsibility," *Aviation Week & Space Technology* 146, no. 12 (24 March 1997): 54.

[2] Department of the Air Force, *Global Engagement*, 7.

[3] William B. Scott, "USSC Prepares for Future Combat Missions in Space," *Aviation Week & Space Technology* 145, no. 6 (5 August 1996): 51-2.

[4] The White House, *National Security Strategy*, 14.

[5] Department of Defense, *Joint Vision 2010,* 10.

[6] *Global Engagement*, 7.

[7] Air Force Doctrine Document (AFDD) 2-2 (Draft), *Space Operations*, February 1997, 24.

[8] Although not always the case in the past, the link today is almost exclusively a two-way electronic data transmission link. Early US photo reconnaissance satellites ejected film canisters from orbit, which reentered the atmosphere, were recovered in mid-air and developed on the ground.

[9] AFDD 2-2 (Draft), 6.

[10] Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, September 1997, 47.

[11] Ibid.

[12] Ibid., 48.

[13] This includes past and present efforts of the Air Force, Army, SDIO, BMDO, NASA, private industry and foreign entities.

Chapter 2

Threats to Space Systems

There would be no need to consider the defense of space systems if they were not threatened to begin with. In understanding how space systems are threatened today and how they are likely to be threatened in the future, a determination for or against the need to employ defensive measures to specifically protect satellites on orbit can be made.

As is stated earlier, any of the three elements of a space system can be attacked to reduce or destroy its effectiveness. The attack can come in one of four ways: denying launch of the satellite (attacking the terrestrial element); denying command and control of the satellite (attacking the link or the terrestrial element); denying use of the collected data (attacking the link or the terrestrial element); or denying use of the satellite (attacking the space element).[1] An "attack" does not require an attempt to do physical damage to any of the elements, it can be any action taken against any element to prevent free and uninhibited use of the space system or its products. Potential means of attack against each of the elements of a space system are listed in Table 1.

Space Element

The space element is open primarily to physical attack, since there is little other means of affecting the satellite once it is in orbit. These attacks are prosecuted by systems generally known as "antisatellite weapons", or ASATs. An ASAT's purpose is the destruction, disruption, degradation or disabling of a satellite.[2] It is a system made up of several elements including the weapon itself, the delivery vehicle, the tracking and control network and a damage assessment element.[3] There are several kinds of ASATs.

Table 1. Threats to Space Systems

Element	Means of Attack	
	Physical	**Political/Diplomatic**
Space	Projectile weapons Beam weapons Electromagnetic pulse Space mines	Regulation Negotiation
Terrestrial	Traditional military attack Sabotage	Deny access/use Demonstrations
Link	Jamming Intrusion Electromagnetic pulse	Regulation Negotiation

Projectile Weapons

Projectile Weapons rely on physical contact to damage or destroy a satellite. This is done either by maneuvering an object of some mass with sufficient accuracy to impact the satellite, using the object's kinetic energy to inflict damage, or by maneuvering a vehicle into the vicinity of the target satellite before detonating a warhead and counting on blast and shrapnel effects to inflict damage. The first is called a kinetic kill vehicle (KKV) and the second is a fused/shrapnel device. The US developed ASAT of the 1980's was an F-15 launched KKV device, while the Soviet Union developed a co-orbital shrapnel weapon launched on an SL-11 booster between the late 1960's and early 1980's.[4] These are the only two ASAT systems whose development has been confirmed. Neither is currently operational, nor is development on either continuing.

Beam Weapons

Beam Weapons are focused and directed forms of electromagnetic energy including lasers, focused sunlight, neutral particle beams, high-power microwaves and plasma.[5] Beam weapons may be ground or space-based and can cause physical destruction, damage to sensors, disruption of on-board systems or degradation of performance[6] depending on the type, location and power of the weapon. Development of weapons of this type takes substantial time and resources, but the Russians have a ground-based laser of disputed capability at Sary Shagan,[7] and the US is currently doing experimental work on satellite-busting lasers.[8]

Electromagnetic Pulse (EMP)

Although EMP is a form of electromagnetic energy like a beam weapon, and can damage satellites in a similar fashion, it is treated separately here because EMP can cause substantial damage to satellites without being focused and directed, and because weapons of this type are rather cheap and simple to produce. A very effective EMP weapon can be created by placing a nuclear device atop a space traversing (for low altitude satellites) or orbit capable (for higher altitude satellites) ballistic missile and detonating it at a predetermined time. The radiation from a nuclear explosion in space would affect satellites as far as 1000 km away.[9] Russia already has this capability with the ABM system it employs around Moscow,[10] but one only needs compare the list of nuclear nations with those capable of space launch for a short list of those who could have such a capability in the near future.[11]

Space Mines

A space mine is an orbiting object with an explosive device which is launched and placed in an orbit near the satellite of an adversary. The explosive can be detonated at some future time, destroying the nearby satellite. In this sense the space mine is similar to the fused/shrapnel device, but is a more latent and long term threat that may be more difficult to detect from the ground.[12] Mines are useful primarily in geosynchronous orbits, where their proximity to other satellites gives little cause for alarm.[13] Placing a mine near a satellite in another orbit would "immediately telegraph enemy intentions,"[14] and would hence fall into the category of a more recognizable shrapnel type weapon.

Political/Diplomatic Attack

Although less dramatic, space systems may be attacked politically or diplomatically through negotiation, or through attempts to disrupt, degrade or negate the system through international regulation. The most obvious example deals with the allocation of the communications frequency spectrum through the Federal Communications Commission or the International Telecommunications Union. The expansion of the global telecommunications market has increased demand for parts of the frequency spectrum once used exclusively by the military. This forces the military to deal with restrictions and interference problems in these bands.[15]

Terrestrial Element

The terrestrial element includes all of the functions, operations and facilities which are accomplished or located on the ground. This includes the manufacturing and launch capability, ground control and data processing facilities, and any other associated infrastructure. It also includes the space element itself prior to launch, since the satellite can be considered just another (very important) piece of ground equipment until it is placed into orbit. For at least the immediate future, a satellite is a more accessible target on the ground than it is in space. A space system's terrestrial element can be attacked in ways traditionally used to attack other ground targets.

Physical Attack

The ground elements are vulnerable to the wide range of means of attack at the disposal of the modern military: conventional land, sea or air attack, nuclear strikes, terrorism, guerilla warfare, sabotage and attack by special forces.[16]

Political/Diplomatic Attacks

Attacks of this sort may be focused at the system as a whole or just at the terrestrial element. Countries or other organizations may attempt to deny use of a system by preventing access to territory, resources or utilities for ground-based infrastructure. In addition, political pressure may be brought to bear against the use of a space system via public demonstrations, rallies and protests,[17] or the organization of international opinion against such use. Although denial of access may be of diminishing concern to the US with much of its space launch and control within national borders and an increasingly global space system command and control capability from within the continental United States, public opinion continues to carry great leverage.

Link Element

Attacking the link element of a space system is enticing because it can be done with relative ease and can prevent or degrade system use without leaving physical evidence.

This provides an element of deniability in such attacks,[18] or the ability to deny that the attacks were intentional. The link element can be attacked in several ways.

Jamming

Just like the jamming used to disrupt or degrade the electromagnetic signals of terrestrial systems, jammers can be employed against satellite links as well. These actions can be inadvertent or purposeful, but there is evidence to suggest that US communications satellites have been subject to intentional jamming in the past.[19] Jamming can focus on the links that are used to transmit data between the space and terrestrial elements, which has a direct impact on the mission of the space system, or it can focus on disrupting the tracking, telemetry and commanding link, indirectly affecting mission accomplishment. The viability of jamming as a means of attack depends on line-of-sight restrictions and the degree to which a space element can act autonomously.[20]

Intrusion

Intrusion is directed at the system as a whole, and focuses on gaining access to the system under the guise of an authorized user, much as "hackers" attempt to do with computer networks. Once access has been gained, the intruder can insert signals and commands into the system, exploiting information, disrupting operations or degrading performance. This "spoofing," as it's called, can be very discrete and deniable.[21]

Threat Viability

Having briefly considered possible means of attacking a space system, one must look at each method and determine the likelihood that US space systems will be attacked in this manner in the future. Although a thorough analysis of each threat and corresponding defense is necessary for a comprehensive assessment of defensive counterspace operations, the analysis can be restricted here because interest is limited to the need for a space-based DCS capability. Since this is the case, some of the threats can be removed from consideration because a space vehicle is inherently incapable of acting against them or because there exists other means of countering this threat that are already available, more feasible, or more politically palatable.

As such, the political/diplomatic means of attack need not be considered, since they are traditionally countered with political and diplomatic methods in response. It is also quite obvious that a defensive counterspace capability would be much less effective in applying the political leverage that a carrier battle group, an airborne division, or wing of combat aircraft might apply in the event that the show or use of force becomes necessary.

Next, we remove from consideration any aspects of defending a space system's terrestrial element from attack by the enemy's terrestrial forces. Adequate and efficient forces currently exist in the Armed Services for such tasks, so development of a new capability for this purpose is not required. The ability to defend terrestrial targets from space is not of interest here. In other words, a space-based vehicle would not be expected to attack and defeat an earth-based jammer, because adequate means to accomplish this task presently exist in the Armed Forces. Likewise, any pre-emptive attacks that might be made from space on terrestrial threats are removed from consideration.

What remains are physical threats aimed at the space element itself and spaceborne threats to the link element (see Table 1). In determining the utility of a space-based satellite defense, potential defensive measures to counter each of these remaining threats must be examined.

Notes

[1] Michael R. Mantz, *The New Sword: A Theory of Space Combat Power* (Maxwell AFB, AL: Air University Press, 1995), 42-44.

[2] Steven R. Petersen, *Space Control and the Role of Antisatellite Weapons* (Maxwell AFB, AL: Air University Press, 1991), 37.

[3] Major Martin E.B France, Chief, Spacelift Vehicles Branch, Headquarters Air Force Space Command, via e-mail, 27 January 1998.

[4] Petersen, 37.

[5] Mantz, 20.

[6] James G. Lee, *Counterspace Operations for Information Dominance* (Maxwell AFB, AL: Air University Press, 1994), 31.

[7] Lee claims that the laser has the ability to damage satellites up to orbital altitudes of 1200 km, while Jeff Hecht, "Stray Rays Open Way for Ban on Satellite-Busting Lasers," *New Scientist* 130, no. 1776 (27 April 1991): 18, states that only a "modest sized" laser was found, inferring that it has no such capability.

[8] Hecht, 18. As recently as October 1997, the US Army's ground-based Mid-Infrared Advanced Chemical Laser (MIRACL) at White Sands illuminated an aging Air Force satellite in orbit. Charles Aldinger, "U.S. Military Hits Satellite with Light Beams," *Reuters News Service*, 21 October 1997, on-line, Yahoo!, 4 March 1998. Available from http://204.71.177.75/headlines/971021/news/stories/.

[9] Thomas G. Mahnken, "Why Third World Space Systems Matter," *Orbis* 35, no. 4 (Fall 1991): 574.

[10] Petersen, 38.

[11] These nations include:

Spacefaring Nations	***Nuclear Nations***
United States	United States
Russia	Russia
European Union (ESA)	UK
China	France
Japan	China
India	India
Israel	Pakistan
	Israel

[12] Department of the Air Force, *New World Vistas: Air and Space Power for the 21st Century. Space Applications Volume*, 117.

[13] Geosynchronous orbits are desired orbits for communications and surveillance missions, among others. There are already many satellites in these orbits and the true purpose of a space mine could be hidden in the guise of one of these benign systems.

[14] Robert B. Giffen, *US Space System Survivability* (Washington, DC: National Defense University Press, 1982), 39.

[15] The FCC is auctioning frequency bands for commercial use as a means of raising funds for the Federal government, while astronomers are trying to keep electromagnetic interference from mobile phones out of the radio astronomy bands. "Crowded Air," *Air*

Notes

Force Times 57, no. 50 (14 July 1997): 28, and Toni Feder, "Radio Astronomers Are Anxious to Head Off Satellite Interference at Millimeter Wavelengths," *Physics Today* 51, no. 2 (February 1998): 63.

[16] Petersen, 61, Table 5.

[17] Ibid.

[18] Ibid., 71.

[19] Mahnken, 575-6.

[20] Lee, 30.

[21] Ibid., 32.

Chapter 3

Defensive Counterspace Operations

Since the threats to a space system have been narrowed to those against which space-based measures might be effective, it is now important to consider the best ways to defeat these threats, the essence of defensive counterspace operations. In general, defensive operations consist of two activities, recognizing the threat and defeating the threat. Important considerations in employing space protection systems are location of the attacking platform, location of the target, location of the defender, type of weapon used, possibility of countermeasure and timing of the attack.[1] These considerations will help determine the time available to recognize and respond to the threat, as well as the best technique for defeating it.

Air Force Doctrine Document 1 identifies two general aspects of the DCS mission, active and passive measures.

> The objective of active counterspace defense measures is to detect, track, identify, intercept, and destroy or neutralize enemy space and missile forces. The objective of passive counterspace defense is to reduce the vulnerabilities and increase the survivability of friendly space forces and the information they provide. These may include operations such as designing survivability features into satellites, satellite maneuver, emission control and decoys.[2]

Passive DCS includes aspects of recognition and negation as well. In fact, detection, tracking and identification, perhaps to a different degree of precision, are necessary for some passive defensive measures as much as they are for offensive ones.[3]

Recognizing the Threat

Recognizing physical threats to space systems consists of the AFDD 1 defined elements of detection, tracking and identification. These elements may be performed in any number of ways, by multiple systems and organizations or by a single, integrated system.[4] There are several factors which must be considered in recognizing a threat.

In most cases, recognition must occur rapidly. Although space is a difficult place in which to hide, determining the purpose of an orbiting object quickly can be difficult.[5] The characteristics of the orbit or emission signature of a satellite can provide clues, but the true purpose may be difficult to detect if the controlling agency wishes to conceal it. Furthermore, although the mission of a satellite or ground system may be understood, it may not be prudent or possible to employ defensive measures until the enemy system has initiated its attack. In the case of beam weapons, this leaves no response time, in the case of projectiles or mines, potentially only slightly more. In any case, it is vital that a threat be recognized quickly so that appropriate activities begin to defeat or negate the threat.

Passive detection of a threat is also important,[6] because it hides the fact that the target is aware of impending attack and is prepared to take active or passive measures to defeat the attack. Passive detection can also serve to mask the presence or alert state of DCS systems that may be employed to assist the target.

Defeating the Threat

Defeating the threat does not necessarily connote direct engagement of the attacking entity; active or passive measures can be taken.[7] A list of possible techniques that might be employed to defeat threats to space system space and link elements is included as Table 2.

Table 2. Defensive Techniques for Defeating Space and Link Threats

Element	Defensive Technique	
	Passive	***Active***
Space	Maneuver Stealth/Deception Survivability	Physical engagement Spoofing
Link	Autonomy Encryption Frequency hopping Nulling	Physical engagement

Passive Space Element Protection

Several methods can be employed in the passive defense of space elements. Maneuvering the target to avoid an attack is one of the simplest passive techniques. Considerations such as when to perform the maneuver, the direction of the maneuver and the violence of the maneuver will vary based on the type of threat. Projectile weapons might require rapid and violent maneuvers as the weapon approaches while a space mine could be avoided with a series of slower evasive maneuvers over a longer period of time. Maneuver is not particularly effective against beam weapons, since the beams travel near the speed of light. In this case, maneuver might consist solely of staying out of effective range of the weapon. A potential disadvantage to maneuver is that it requires fuel, and a space vehicle with such a maneuvering capability is likely to pay a heavy penalty in weight and mission capability.[8]

Another passive technique is the use of stealth, camouflage or deception in employing a space system. This could involve the vehicle design, vehicle emissions, vehicle operations or the use of decoys. A satellite might employ stealth in its design and construction much as an aircraft does to avoid radar detection. This would increase the cost and decrease the efficiency of the satellite, but it would not defeat other detection and tracking techniques.[9] By controlling the emissions from a space vehicle, one could disguise or cloud its purpose from an adversary and make the satellite more difficult to track. A further means of deception could be the use of decoys that mimic the physical and operational characteristics of a given satellite. These decoys might be objects designed to confuse specific tracking and targeting systems, deployed near the satellite in times of higher alert much like the flares aircraft use to confuse IR sensored anti-aircraft missiles.[10] They could also be reasonable duplications of the true satellite, deployed with the system as a long term protection measure. Stealth and deception have the potential to be effective against all physical threats to the space element with the exception of electromagnetic pulse, which damages and destroys indiscriminately.

Other passive techniques include attempts to make the satellite or entire space element survivable in the face of the attacks it is likely to see. Armor protection as it is understood in traditional military systems, thick, heavy layers of material used to protect against projectile impacts, is not practical for space systems.[11] The speed at which objects travel in order to achieve and maintain earth orbit provides even the smallest object with enough energy to cause catastrophic damage to any object it might impact.[12] There may be, however, means by which to provide analogous protection against beam and EMP weapons. Aerosols which diffuse beams, beam deflectors, reflective coatings and satellites hardened against the effects of electromagnetic energy could provide a means of survivability against such attacks.[13]

Sparing, storing satellites on the ground or holding them in reserve on-orbit for rapid employment in the event that they are needed, is a means of making space assets survivable at the system level. Such a scheme would simply replace damaged or destroyed satellites with new ones on a one-for-one basis. Although storing spares on-orbit would expose them to the same threats faced by operational satellites, the launch industry is talking of a launch-on-command capability with response times of six hours for satellites in low earth orbit. This would allow sparing on the ground.[14]

Another means of ensuring survivability at the system level is the use of a distributed system. A distributed space system would employ many small, relatively low capability satellites rather than fewer, highly capable satellites to perform the same overall mission. This would reduce the system impact if one or more of the satellites were damaged or destroyed, at the same time reducing the value of any given satellite. The Iridium communications system is an excellent example of a distributed satellite system.[15] Advancing technology may mean that systems with larger numbers of smaller, less-capable satellites are more cost effective to produce and to replace when obsolete as well.[16] A drawback to this architecture is that while it is attractive for some systems, it is not a prudent design choice for others given cost or mission considerations.[17]

Passive Link Protection

Several viable techniques exist for protecting the link element of space systems. The first technique simply involves making the satellite more autonomous and less dependent upon communications with the ground to accomplish its mission. Although this is becoming more feasible as technology advances, it does nothing to address the threat to systems for which communication with the ground is not just required for maintaining proper functioning of the satellites, but is integral to the mission itself, as with communications and navigation satellites. Indeed all current space systems exist to support ground activities, meaning essential data must be transferred to the ground at regular intervals in support of the mission.

Another technique for protecting the link involves encrypting the link, which protects it from intrusion, both for the purpose of unauthorized use and the purpose of gaining control of the system to disrupt or degrade use. Although this may protect the system from intrusion, it does not ensure that the link can be maintained with authorized users, which can be disrupted through jamming. The effects of jamming and other link disrupting measures can be reduced or negated through the use of frequency hopping and nulling,[18] which allow the link to be maintained in spite of efforts to the contrary.

Other Passive Techniques

There are of course indirect means that can be used to protect the space and link elements from physical attack. These could be viewed more along the lines of deterrent factors and include things like leasing capabilities or buying data or services of space systems from other countries; participating in a multi-national consortium that owns and operates a satellite system; legally protecting space systems via international law, treaties and conventions; or using manned presence to dissuade attack.

These techniques basically include the insertion of another factor that acts as a deterrent, primarily that of international pressure. International law accepts the destruction of another country's space system as an act of self defense against a second country, but sees the destruction of a third country's satellite, which might be providing information to the adversary, as an act of aggression.[19] As with all deterrent methods, these factors can be highly effective in periods of peace or low intensity conflict, but lose effectiveness in wartime situations as the stakes increase.

Active Space Segment Protection

Here we consider means which might be used to actively defend against physical threats to the space element. This active defense encompasses the intercept and destroy or neutralize steps of counterspace defense.

One cannot underestimate the importance or the difficulty of the intercept step of the process. It entails positioning the defensive system in the right place and time to be able to destroy or neutralize the threat and as previously mentioned, includes factors such as the location of the target, location of the threat, type of weapon employed and the warning time of attack. The need to intercept also drives basing decisions, space- or ground-based, and whether or not individual satellites should be expected to defend themselves or should depend on dedicated defensive vehicles.[20]

Not surprisingly, many of the techniques employed to threaten satellites and their links can be used to protect them as well. Those techniques include the use of projectile and beam weapons to attack and destroy the threatening system; EMP weapons to disrupt the electronics; the use of jamming or "spoofing" to actively disrupt a threat's targeting, tracking, or telemetry and commanding systems or to cause it to attack the wrong target; and attacks on the ground based elements of the offensive system. All of these methods have employment considerations of their own.

Preemptive Defense

Taking preemptive actions in the defense of space systems, that is, engaging threats before they initiate attacks, holds certain advantages, just as it does in other forms of warfare. However, as is the case with all preemptive acts, if action is taken in time of peace, it can be construed as an act of war and will almost certainly initiate hostilities. In preemptive attack, the space and terrestrial elements of the offensive system are the most logical points of attack, since it is difficult to affect the link long term.

Attacking the space element of an ASAT system may be possible as early as the launch phase or when the ASAT is on orbit in a deployed (rather than employed) mode, before the threat to a specific satellite system develops.[21] Some have even considered the disabling or degrading of a space object through physical access to the satellite, in essence, vandalizing it on-orbit to prevent it from being employed in an OCS mission.[22] Needless to say, this is a risky proposition, akin to employing an orbiting bomb squad!

Air Force Basic Doctrine states that "airpower is most vulnerable on the ground."[23] The same can be said for spacepower at the present time, because few means currently exist to threaten satellites on orbit. However, because orbiting bodies move in a predictable manner, they are ultimately more vulnerable in use than is airpower. Still, attacking ground infrastructure may be the best way to disable a space system.

There are four ways to deny the use of space systems by attacking ground-based resources: deny space launch by attacking launch vehicles, launch sites and the space industry; deny command and control of orbiting satellites by attacking command and control centers or ground terminals; deny the tracking and observation of objects in space by attacking the tracking system; or deny use of space data by attacking ground terminals, the link, or the data in the link.[24] These ground-based assets are vulnerable to attack from any nation with a global engagement capability, and does not involve or require the use of a defense-oriented space vehicle.

There are a variety of measures that can be employed to protect and defend space systems. Although they do hold some sway, diplomatic/political means and physical means that focus on the enemy ground infrastructure to fulfill the DCS mission will not be effective in the future. A variety of physical threats will be brought to bear on the space element of space systems, and the threats will have to be countered on-orbit.

Notes

[1] Michael R. Mantz, *The New Sword: A Theory of Space Combat Power* (Maxwell AFB, AL: Air University Press, 1995), 49-50.

[2] Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, September 1997, 48.

[3] If a target satellite were to attempt to maneuver out of the way of a KKV, it would need to detect, track and identify the KKV in order to recognize the object, determine that it was, in fact, threatened by the vehicle, and maneuver to avoid it.

[4] NORAD's Space Surveillance Network (SSN) is a system of 25 ground-based sites using phased array and conventional radars and electro-optical sensors to detect, track, and identify space objects. United States Space Command. *On Orbit*. On-line. Internet, 28 February 1998. Available from http://www.spacecom.af.mil/usspace/.

[5] NORAD currently has 2.5 minutes to detect a missile launch and determine if it is a threat to US territory. William B. Scott, "Cheyenne Mountain Reshapes for Future Missions," *Aviation Week & Space Technology* 144, no. 2 (18 March 1996): 54. It would take substantially more time to determine the exact trajectory of an orbital object, its mission and likely target.

[6] Major Martin E.B France, Chief, Spacelift Vehicles Branch, Headquarters Air Force Space Command, via e-mail, 27 January 1998.

[7] There is, in fact, disagreement between AFDD 1, which labels maneuver as a passive measure, and AFDD 2-2 (Draft), which calls it an active measure; the AFDD 1 definitions are used here. As an example, a passive technique for defeating a KKV might be to maneuver the target as the weapon approaches to cause it to miss the target, while an active technique might be employing some device to intercept and destroy the KKV before it impacts the target.

[8] Department of the Air Force, *New World Vistas: Air and Space Power for the 21st Century. Space Applications Volume*, 117.

[9] *New World Vistas* concludes that the cost of incorporating stealth into satellite designs is not justifiable, even if stealth for satellites proves effective. *New World Vistas. Summary Volume*, 46.

[10] Decoys might be effective against isolated attacks, but can be defeated through attrition.

[11] *New World Vistas. Space Applications Volume*, 115.

[12] Although it is relative velocity, speed and direction, not absolute velocity of objects that is important in the lethality considerations of KKVs, only minor differences in orbital characteristics are sufficient to create the high relative velocities needed to make KKVs effective.

[13] Mantz, 53.

Notes

[14] Warren Ferster, "Industry Moves Toward a Launch-on-Demand Capability," *Defense News*, 13-17 October 1997, 88. The Air Force currently has a launch on demand capability for GPS with a response time of 60 days. In a space warfare scenario, response time would undoubtedly need to be faster.

[15] Iridium calls for 66 satellites plus 6 spares spaced in 420 nautical mile orbits and six orbital planes to provide worldwide personal telecommunications. *The Iridium System.* On-line. Internet, 28 February 1998. Available from http://www.iridium.com/.

[16] "Space Lift: Suborbital, Earth to Orbit, and On Orbit," *AirPower Journal* 9, no. 2 (Summer 1995): 48.

[17] Robert B. Giffen, *US Space System Survivability* (Washington, DC: National Defense University Press, 1982), 41.

[18] Frequency hopping involves switching communications frequencies of the transmitter and receiver in a synchronized fashion while nulling uses an adaptive antenna to sense the presence of a jammer and to adjust beam patterns to avoid reception of the jamming signal. DOD's Milstar II satellite communications systems employs all three methods of link protection and although effective, these techniques are expensive and inefficient with respect to bandwidth utilization.

[19] James G. Lee, *Counterspace Operations for Information Dominance* (Maxwell AFB, AL: Air University Press, 1994), 5.

[20] Mantz, 26.

[21] Ibid., 27.

[22] Ibid., 67.

[23] AFDD 1, 19.

[24] Mantz, 38-42.

Chapter 4

Fulfilling the Defensive Counterspace Mission

Having explored the possible with respect to offensive and defensive counterspace operations, it is time to concentrate more on the realm of probabilities, to consider not just how it might be done, but how it is likely to be done. Considerations include when and how space systems might be attacked and by what means. Only after these questions have been addressed can conclusions be drawn as to whether or not a space-based defensive counterspace capability is prudent, and what form the capability should take.

Likely Means of Attack

Offensive counterspace operations are likely to range from no action in a state of benign peace up through the attempted physical destruction of satellites or ground infrastructure during time of war.[1] Further, OCS directed at the space element can only be orchestrated by nations that, as a minimum, have a space launch capability.[2] Additional technical sophistication is required to develop the more discriminate space attack weapons. Figure 1 charts the required technology state and likelihood of employment as a function of conflict intensity for physical attacks on the space and link elements. Political means, which require no advanced technology to implement, can be pursued across the entire spectrum of conflict. Justification for the placing of each technique is included in the Appendix.

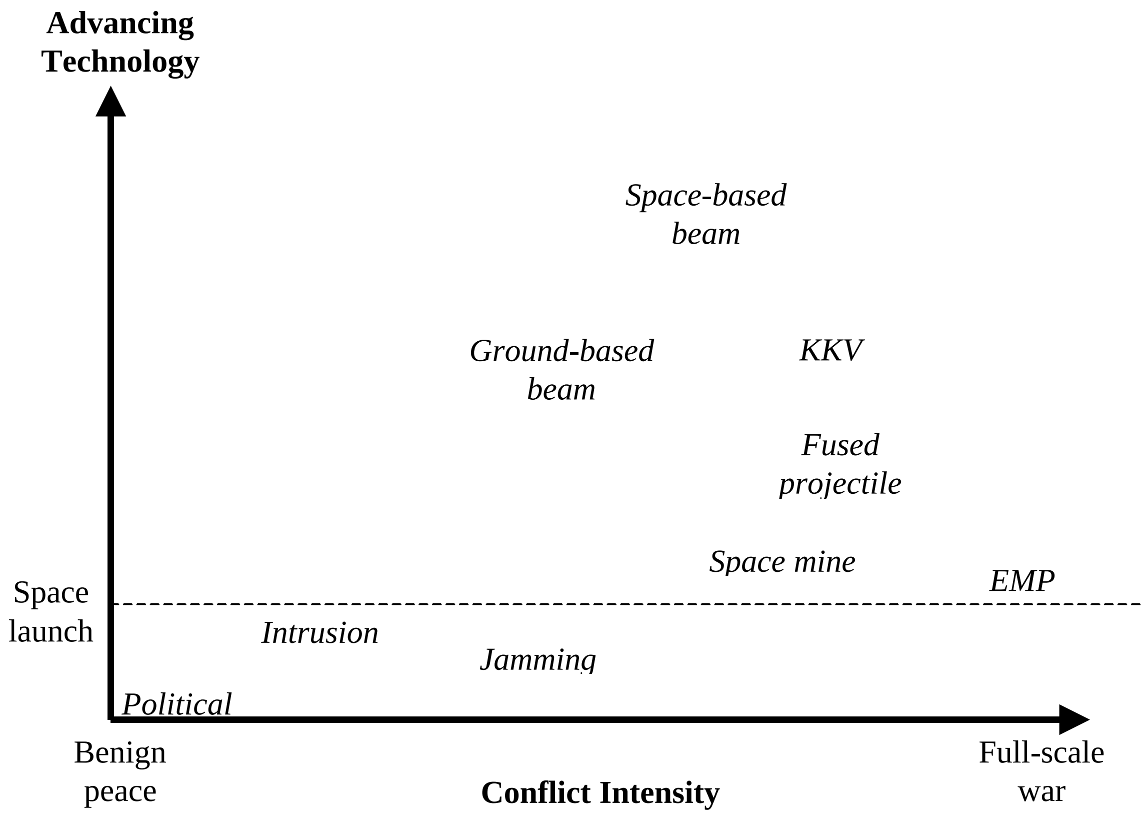

Figure 1. Adversary's Ability to and Likelihood of Attacking Space Systems

The offensive counterspace schemes likely to be employed by an adversary are a function of its technological sophistication and the intensity of the conflict. Adversaries without a space launch or medium range missile capability cannot attack using any of the techniques which pose the biggest threat to the space element of a space system. A further consideration is the effectiveness of the various defensive techniques in defeating these threats. Table 3 charts the effectiveness of the *space-based* defensive techniques for each of the space and link element threats. Those techniques marked with a small letter (x) identify methods of moderate effectiveness, while, methods marked with a large, bold letter (**X**) have the potential to be highly effective.

Table 3. Satellite Threat—Defense Correlation

Space-based Defense	Threat							
	Jam	Intrude	EMP	Mine	Fused projectile	Ground beam	KKV	Space beam
Autonomy	x	x	x					
Encryption		X						
Frequency hop	X	x						
Nulling	X							
Hardening			x			x		x
Protective Shields/coatings			x			X		X
Stealth/deception				x	X	x	X	x
Aerosols						X		X
Maneuver			x	x	X		X	
Jamming/spoofing			x	x	X		X	X
Physical Engagement			X	X	X		X	X
Sparing			x	X	X	x	X	x
Distributed system			X	X	X	x	X	x

An examination of this table leads to several conclusions about the defense of space systems from space. First of all, the use of sparing and distributed systems cannot be overlooked as effective means of ensuring space system survivability.[3] Unfortunately, these techniques are not the panacea they may first appear to be. A distributed constellation design is practical and cost effective for some systems, but not for others.[4] Sparing in the face of hostile attacks could very well require too many spares for too many systems and too much short notice launch capability, making it a logistical and financial impracticality on a grand scale. Further, national policy clearly states that uninhibited access to space is vital to US national security.[5] This includes not just US military and government systems, but US commercial space assets and likely the assets of our allies as well. Although the requirement to protect these systems is likely to fall to the US military, the military will not have a say in space system design considerations which might enhance survivability. As a result decisions made with respect to distributed design and sparing philosophy for commercial space systems are likely to be made based on market and budget considerations rather than survivability concerns.

Further, although many of the other techniques are effective to varying degrees, the surest means of defense in all cases is that of physical engagement directed at the offensive counterspace system. This conclusion is not surprising given that it falls in line with a fundamental principle of war, be it on land, at sea, in the air, or in space, the principle of the offensive.[6] An active defense such as physical engagement is offensive in spirit, and both complements and is complemented by many of the other defensive techniques like the use of deception, maneuver and jamming.

A final conclusion would be that the most difficult threat to counter in protecting the physical integrity of the system is the EMP threat, since it is most easily generated by nuclear weapons, is effective at long ranges, and therefore, offers little hope in the way of "passive" defenses. There are, however, several factors working against the employment of such a weapon in the first place. First of all, since such a weapon is not discriminate in its effects, the use of a device would result in the damage or destruction not only of the targeted system, but of many others in the vicinity. These others may be the systems of neutral countries, allies, or the adversary's own systems. Secondly, the use of a nuclear weapon in any medium signals an escalation of a conflict to its highest level, and invites not only the scorn of the international community, but retaliation with similar weapons, which might, also, be directed at other than space-based targets. Although potentially the most effective of all the anti-satellite weapons in a narrowly defined sense, it is also likely to be the weapon of last resort.

How then, is a space system likely to be attacked if the attack is to focus on the space segment? The conclusion of this analysis is that such an attack will come from a weapon with localized effects, in the near term either a space-mine, fused projectile, ground-based directed energy weapon, or kinetic kill vehicle. In the longer term, this will expand to include space-based beams. The best means of defense will be a combination of passive and active counterspace defense measures.

Implementation

Having decided that both passive and active defense measures are necessary, the question becomes how best to implement and employ a capability to detect, track, identify, intercept and destroy or neutralize threats to the space element of space systems. There are three possibilities; use a ground-based system, give satellites their own self-defense capability, or develop a dedicated space vehicle to perform the mission.

A completely ground-based system could not be expected to adequately perform the defensive counterspace mission. Although it might perform well in the detection, tracking and identification aspects of the mission,[7] such a system would be severely hampered in interception and destruction. Limitations would be apparent because a ground-based system would have trouble responding to threats to satellites that do not overfly the geographic area of the deployed system, and because the time factor involved in launching a defense mission in time to intercept an attack would be very short.[8]

Self protection takes a satellite designed for a specific mission and adds more subsystems like sensors to detect radar and laser illumination, jamming, impacts and other telltale signs of imminent or on-going attack.[9] Subsystems designed to defeat these attacks must be included as well, subsystems to increase maneuvering capability, added shielding, additional control complexity, and things like decoys, aerosol dispensers and jammers. Hybrid, self-defending designs of this nature have never proven adequate in the history of warfare, and should not be expected to operate effectively in space. Just as trucks, merchant vessels, and transport aircraft have never been able to defend themselves adequately against tanks, submarines and fighter aircraft, a communications, earth sensing or weather satellite would not be able to defend itself against a purpose built satellite killer. In addition, just as with sparing and distributed systems, convincing commercial and allied manufacturers to incorporate these costly and capability-robbing subsystems into their spacecraft would be difficult.

Given the deficiencies of the first two implementation techniques, the remaining option is the employment of a dedicated defensive counterspace vehicle (DDCV). Analogies exist in other military disciplines. Commercial shipping has long required escort protection in time of war, just as history records the hard lessons of the US Army Air Corps strategic bombing campaign, in which "self-defending" bombers were ultimately forced to depend on escort fighter protection in the face of a determined German air defense.[10] There are some problems with this analogy, however, in that while merchant shipping and bombers can be massed and routed in ways that provide tactical benefit, satellites are slaves to their mission and defined orbit, so that a form of "escort" cannot include the massing of satellites or selecting orbits to maximize the benefits of protection. This leads to the conclusion that this type of protection might require one-for-one escort for satellites that require protection. Additionally, given the long term nature of space missions, long term employment of a DDCV or sufficient advance warning would be necessary to ensure that the vehicle was in position to deter or defeat attacks.

Vehicle Capabilities

Seeing that a dedicated vehicle is the best option for fulfilling the defensive counterspace mission, some consideration must be given to desirable capabilities of the DDCV. Most of the capabilities revolve around cold, hard realities like range, response time and killing power, but there are more esoteric qualities as well.

A DDCV must be able to fulfill all aspects of the AFDD 1 defined DCS mission; detect, track, identify, intercept and destroy or neutralize. It must be able to perform all of these functions independently, or as part of an integrated DCS network, similar to the role of the fighter aircraft in an integrated air defense system. The vehicle could receive information from outside sources as to the nature and location of threats, but would then use its own on-board systems to complete the mission, requiring some form of on-board detection, identification, tracking and targeting system.

Given the ability to acquire and track threats, the vehicle would also need to be able to intercept these threats, that is, put itself in a position to neutralize or destroy the threat before it can damage or destroy friendly space assets. Such a capability has two facets, presence and reach.

The concept of presence means being at the right place at the right time, and is a function of response time (getting there quickly) and duration (staying there long-term). Response time will drive, among other things, basing and alert considerations. A vehicle that maintains a high state of readiness on the ground would need to be launched in times of heightened tensions while one that maintains a ready state on orbit, at a space station for instance, could respond more quickly and routinely. Space-based vehicles can avoid or reduce the potential delay of a ground-based system waiting for an appropriate launch window, either of the satellite to be protected or the offending system. The "forward basing" of space control assets, stationing them on orbit close to the threat in a state of readiness, would make a DDCV more responsive, but also more open to attack.[11]

Of course threats to space systems may be evident over extended periods of heightened tensions or in long term wartime scenarios, which would require a vehicle with the ability to remain on station for long periods of time or to be relieved at regular intervals. This idea of presence has a flavor of Mahanian seapower, with the need to remain on station and revisit regularly more akin to the idea of sea control than it is to air superiority.[12] This idea of "showing the flag" with a space presence capable of military action, in addition to positioning forces in the best manner to defend space assets, would have the complementary effect of deterring attacks on space systems.

The second aspect of an interception capability is the ability to reach the orbits where space systems operate. Since the mission of a space system drives its orbital requirements, and, in general, "clustering" individual satellites for the purpose of defense is not practical, some orbits are more important than others. These are the orbits where space systems tend to congregate. Some of the more important orbits are geosynchronous, semi-synchronous, sun-synchronous and low altitude polar orbits.[13] Table 4 lists orbital characteristics used for some common space missions.

Table 4. Orbits of Common Space Missions

Mission	Orbit Type	Altitude	Inclination
Communications	Geostationary	GEO	Equatorial
Navigation	Semi-synchronous	MEO	Mid-latitude
Weather	Sun-synchronous	LEO	Near Polar
Surveillance	Geosychronous	GEO/HEO	Near Equatorial
Reconnaissance	Sun-synchronous	LEO	Near Polar

These orbits varying greatly in ease of attainability and the severity of the background environment,[14] yet a defensive counterspace vehicle should be capable of protecting all of them, either locally with short range active and passive techniques or from long ranges, as might be necessary with satellites at higher orbital altitudes. This is the final capability required of a DDCV, its ability to protect itself and other satellites from attack, and to do so with both passive and active means.

Some of the passive techniques a DDCV might be expected to employ include deploying or serving as a shield to protect threatened satellites from beam weapons, dispensing aerosols for the same purpose, deploying decoys to trick enemy detection, tracking, identification and interception systems, and physically maneuvering a friendly satellite to avoid approaching threats.

Active defensive techniques might include systems designed to jam and spoof offensive weapons, forcing them to break off the attack or miss the intended target, and some means by which to physically engage the threat, either by coating its sensors with opaque materials,[15] or employing a system to damage or destroy it. At the current time, a fused projectile or KKV would be the most likely candidate. Tests conducted under the

SDI program in 1990 led to the conclusion that 20 pound KKVs were entirely feasible, with some engineers believing that vehicles as small as five pounds were possible.[16] A DDCV could carry many such weapons. Some type of beam weapon would be of importance in the future, since it is likely to have a much longer range and greater probability of success.[17] Space-based lasers and KKVs were to be the key weapons of the "Star Wars" program of the 1980's and work continues on them today. Although it might be questionable as to whether or not they could provide an effective defense against scores of ballistic missiles, even a mediocre missile defense system of this type would make an excellent ASAT, and therefore, space defense, system.[18]

It makes sense to employ these techniques from a dedicated vehicle rather than the satellites themselves not only because of the drawbacks mentioned earlier, but also because a DDCV could be upgraded over time with better and more effective equipment for defending against evolving threats, as well as for new systems that might be needed to counter future offensive systems. Trying to retrofit other satellites on-orbit with upgraded systems would be costly, time-consuming and impractical.[19]

The most logical means of fulfilling the DCS mission is a space vehicle designed specifically for the task. Ground schemes could not be global or sufficiently responsive, and outfitting each satellite to defend itself is too costly and impractical. Only a special purpose vehicle can combine appropriate subsystems with required performance.

Notes

[1] James G. Lee, *Counterspace Operations for Information Dominance* (Maxwell AFB, AL: Air University Press, 1994), 32.

[2] Michael R. Mantz, *The New Sword: A Theory of Space Combat Power* (Maxwell AFB, AL: Air University Press, 1995), 8.

[3] The Air Force Science Board's 1995 *New World Vistas* study recommended the use of distributed space system architectures for future military space systems. Department

Notes

of the Air Force, *New World Vistas: Air and Space Power for the 21st Century. Space Applications Volume*, vii.

[4] Steven R. Petersen, *Space Control and the Role of Antisatellite Weapons* (Maxwell AFB, AL: Air University Press, 1991), 74.

[5] The White House, *National Security Strategy*, 14.

[6] Joint Publication 1, *Joint Warfare of the Armed Forces of the United States*, 10 January 1995, III-1.

[7] The current US systems for detecting space launches and tracking orbital objects perform quite well, although the launch detection system does depend on Defense Support Program (DSP) satellites, and not ground sensors, for global near real-time launch detection.

[8] *New World Vistas* recommended the development of ground-based directed energy weapons. *New World Vistas. Summary Volume*, 46. Although ground-based beams might be useful for offensive counterspace missions, they could not be expected to accomplish the defensive mission for the reasons discussed in the text.

[9] Petersen, 72.

[10] *The United States Strategic Bombing Survey. Summary Report (European War).* (1945; reprint, Maxwell AFB, AL: Air University Press, 1987), 16.

[11] Petersen, 75-6.

[12] Dennis Poulous, Schafer Corp., telephone conversation with author, 6 November 1997.

[13] Petersen, 21.

[14] Low altitude, low inclination orbits are relatively easy to achieve and have a relatively benign background radiation environment. High inclination, low altitude orbits also require relatively little energy to achieve, but are exposed to more severe radiation in the vicinity of the poles. High altitudes require substantially more energy to achieve, and are outside of the protection of the Van Allen belts, resulting in a much more severe radiation background.

[15] Mantz, 69.

[16] James R. Asker, "Kinetic Interceptor Test Indicates 20-lb Space Weapons Are Possible," *Aviation Week & Space Technology* 133, no. 7 (13 August 90): 73.

[17] The Alpha hydrogen-fluoride laser currently being developed by TRW for BMDO would have a lethal range of 4,000 – 5,000 km from a 1,300 km orbit. Joseph C. Anselmo, "New Funding Spurs Space Laser Efforts," *Aviation Week & Space Technology* 145, no. 16 (14 October 96): 67.

[18] Petersen, 51.

[19] Robert B. Giffen, *US Space System Survivability* (Washington, DC: National Defense University Press, 1982), 36.

Chapter 5

Preliminary Design and Employment Considerations for a Dedicated Defensive Counterspace Vehicle

Knowing all that should be required of a DDCV, one begins to consider how these capabilities play into the design and employment of the vehicle. Although the ultimate design and employment decisions can only be made following a thorough analysis of the mission to be performed, available technology and cost of the system, there are certain aspects that will dominate considerations from the start.

The first consideration addresses orbital presence. Should DDCVs be deployed into fixed orbits, much like current systems, or should they be deployed and employed to varying orbits as the need arises? The first method would be akin to establishing defensive outposts in space, in strategically significant orbits near vital systems. It would require DDCVs in many different orbits to provide continuous coverage for all friendly space systems, a sort of an SDI system for defensive counterspace. The DDCVs would still likely need to maneuver in order to best defend specific satellites on a threat-by-threat basis, to deploy decoys or to maneuver for physical engagement. Further, this permanent presence would make the DDCVs difficult to service and upgrade. These vehicles would more likely require replacement rather than servicing.

The second orbital presence scheme would entail inserting DDCVs into specific orbits at certain times as the threat dictates. Multiple vehicles would be required to handle multiple threats, but this form of employment would also provide a more flexible response, and allow easier upgrade of the DDCVs as the threat evolves. This scheme is analogous to the USAF doctrinal concept of the Air and Space Expeditionary Force.[1]

Given the need for rapid reaction time in order to be in a position from which to employ defensive measures, a corollary to the first design consideration is the best means of "basing" the vehicle. Should it be stationed in orbit, perhaps at an orbiting space station, ready to react to identified threats, or should it be stationed on the ground, in some state of alert, ready to respond? In either case, it is not logical to assume that the vehicle will be able to launch on indication that some form of OCS action has begun. By then it will be too late to intervene in all but a few cases.

The co-orbital ASAT weapon developed by the Soviets throughout the 1970's was designed to be launched from the ground, rendezvous with the target within two revolutions, and detonate, destroying the target.[2] If a DDCV were alerted and ready to react when the launch was detected, it would have at most 3 hours to intervene before destruction of the target.[3] When one accounts for the time needed to detect the launch, calculate the expected orbit, and deduce the mission and target of the threat before "scrambling" the DDCV, neither stationing mode could be expected to consistently arrive on time to defend a specified target.[4] Other weapons such as beams, direct ascent ASATs and orbital KKVs would allow for even less response time.

In each case one must assume that a DDCV has been deployed into a defensive position based on intelligence and/or heightened tensions before attacks are initiated. As a result the best basing option for the near term is likely to be on the ground, since ground-basing would be less costly and technically challenging. Some concerns remain to be conquered in providing low cost, reliable orbital access,[5] but work on these issues is in progress.[6] Although a space station basing scheme might be feasible, political factors come into play. For the international space station currently in development, it is unlikely that an overt US military presence for this purpose would be acceptable to US partners, and the cost and political baggage of a second, military-oriented station is not likely to be justified.

Another big design consideration will be whether to make the DDCV manned or unmanned. This topic is likely to be contentious and turns as much on subjective opinion as on objective analysis. Those coming from an operational airpower background are likely to argue strongly for a manned vehicle, while those from the current satellite industry might be more inclined to argue unmanned. The crux of the arguments revolves around issues such as the flexibility and adaptability provided by man in the loop vs. the limitations placed on operations, cost and weight penalties associated with a man-rated system, and the environments in which the vehicle will be expected to operate.

Another significant consideration will be whether to make the DDCV reusable. Reusable systems carry with them the cost of designing for reusability, personnel and infrastructure needed for refurbishment, and the need for some type of controlled return.[7] Reusability can be cost effective, and factors to consider in making the reusable vs. expendable trade include expected mission model and launch rate, cost savings in manufacturing expendable *v.* reusable vehicles, payload and operational reductions caused by the weight of the recovery system, cost of facilities, infrastructure and operations supporting reusability.[8] Given the complex and expensive tracking, targeting and weapons subsystems that one would expect to equip a DDCV, a high launch rate and expected decreases in launch and ground operating costs,[9] a reusable vehicle would likely be the better design choice.

One of the most important tendencies that must be resisted in the design of a DDCV is the temptation to create a multi-mission space vehicle that has as one of its roles the defensive counterspace mission. History is replete with examples of systems developed with the noble goal of fulfilling multiple missions, which either failed in their required roles, were disproportionately expensive, or both. The most recent examples are the Air Force/Navy TFX aircraft development of the 1960's, which became the Air Force F-111 while the Navy abandoned it altogether, and the Space Shuttle, which has never come close to its initial launch rate and cost goals. Although many argue that the Space Shuttle's poor turn rate and high cost are a function of its reusability, others argue that the Shuttle's high cost is more a function of its multi-role design, acting as cargo carrier and orbiting manned expeditionary vehicle.[10] When tempted by thoughts of a multi-role space vehicle that can perform tactical missions as well as delivering ordinary payloads, one ought to keep in mind that an aircraft designed to perform the air superiority and cargo roles would do neither satisfactorily.

All things considered, a ground-based, reusable vehicle dedicated solely to the DCS mission and outfitted with a range of tracking, targeting, and active and passive defensive subsystems holds the best hope for a DDCV in the near future. Whether or not such a vehicle should be manned is still too unclear to determine at this time. The final determination will rest on rigorous design study and technological progress.

Notes

[1] Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine,* September 1997, 71.

Notes

[2] Department of Defense, *Soviet Military Power* (Washington, D.C.: Government Printing Office, 1985), 55.

[3] This assumes a 20 minute boost and injection phase and two 90 minute orbits before the target is intercepted.

[4] Energy efficient maneuvers between similar orbits take at least 45 minutes without considering wait time and phasing requirements to arrive at the desired location in the orbit. One must also assume that the adversary would time the attack to minimize acceptable DDCV response time.

[5] John R. London III, *LEO on the Cheap: Methods for Achieving Drastic Reductions in Space Launch Costs* (Maxwell AFB, AL: Air University Press, 1994), 151.

[6] NASA currently has a contract with Lockheed–Martin to develop the X-33 single-stage-to-orbit (SSTO) vehicle, and there are many commercial ventures pursuing the same end.

[7] Airplane like reusable space systems carry aerodynamic surfaces and supporting structures throughout the entire mission, which are used only in the last few moments of flight. London, 45-6. Lockheed-Martin's VentureStar vehicle will use a lifting body to achieve a Shuttle-like return to earth without the penalties of large aerodynamic surfaces. *VentureStar. Breaking the Cost Barrier*. On-line. Internet, 1 March 1998. Available from http://www.venturestar.com/.

[8] London, 101.

[9] The VentureStar program is developing a fully reusable, single-stage-to-orbit vehicle that, according to company and NASA claims, will reduce launch costs from $10,000 per pound to $1,000 per pound within the next decade. This vehicle is also expected to be quickly turned for relaunch using aircraft style servicing. *VentureStar. Breaking the Cost Barrier*

[10] London, 45.

Chapter 6

Conclusions

All three elements of US commercial and government space systems are threatened with physical and political attack today, and the physical threats will only become more varied and effective with time. Although current and future land, sea, air and special operations forces are likely to be able to protect the ground and link elements of our space systems into the foreseeable future, the space element will be threatened in ways that cannot be countered with land, sea, air or special operations forces. They will require a measure of protection on-orbit. In other words, the US must prepare to prosecute the defensive counterspace mission in space.

The DCS mission is best fulfilled by a dedicated defensive counterspace vehicle specifically designed for the mission, and equipped with systems that it can use to passively and actively defend itself and other satellites from attack. This concept of the efficacy of single purpose designs for military missions has proven itself in the past on land, at sea, and in the air, and there is no reason or evidence to believe that it should not hold in space as well. Near term design and employment considerations for a DDCV point to a concept that is on ground versus orbit alert, reusable rather than expendable, and equipped with sophisticated on-board systems that will allow it to detect, track, identify, intercept and destroy or neutralize space threats.

The Air Force is currently studying the acquisition and employment of a space vehicle with many attributes which would make it suitable for use as a DDCV. The Military Spaceplane Demonstrator System will develop and demonstrate technology and operational concepts for a multi-role, reusable space system and "forms the foundation of a new reusable military space architecture."[1] This system has several components, of which the Space Maneuver Vehicle (SMV) is the most likely to fulfill the DCS mission. It is slated to fill other roles as well.[2] While it is prudent to explore each of these missions and capabilities as part of concept exploration and technology development, it is also important to state once again that an operational system with too diverse a mission capability is likely to be costly and inefficient.

Although a DDCV may be justified as an operational requirement, national and international policy on the use of weapons in space will ultimately play a part in any fielding decision. Some of the capabilities of a vehicle designed and developed with the defensive counterspace mission in mind could easily be used offensively as well. In addition, the need to perform the defensive role effectively might require preemptive strikes on threatening space systems. Such attacks could certainly be labeled as "offensive" by an adversary and perceived as such by the international community. These considerations must also play a part in future acquisition decisions.

Ultimately however, as the National Security Strategy clearly states, "(u)ninhibited access to and the use of space is essential for preserving peace and protecting U.S. national security.… Our space policy objectives include deterring threats to our interest in space and defeating hostile efforts against U.S. space assets…."[3] Sooner or later, providing that protection will call for a dedicated defensive counterspace vehicle.

Notes

[1] Department of the Air Force, Air Force Materiel Command System Fact Sheet, *Military Spaceplane (MSP) Demonstrator System*, 1 November 1997.

[2] Department of the Air Force, Air Force Materiel Command Fact Sheet, *Space Maneuver Vehicle (SMV)*, 1 November 1997.

[3] The White House, *National Security Strategy*, 14.

Appendix A

Use of Various Offensive Counterspace Weapons

Weapon	Technology Considerations	Use Considerations
Political	• None required	• Always a potential
Jamming	• Little sophistication required	• Intention deniable short term
Intrusion	• Understanding of system and intel required	• Deniable
EMP	• Requires at least space launch and nuclear weapon capability	• Indiscriminant • Escalation • International opinion
Space Mine	• Simple for space-faring nations	• Covert until detonated • Good primarily in GEO
Fused Projectile	• Reasonable technical challenge • Perfected by USSR	• High probability of kill • Added orbital debris
Ground-based Beam	• Difficult to perfect • US and USSR have at least experimented	• Deniable • Relatively secure from attack • Requires LOS to satellite
KKV	• Challenging at orbital velocities • Perfected by US	• High probability of kill • No fusing/explosives • Added orbital debris
Space-based beam	• Extreme technological challenge • None yet perfected	• Partially deniable

Glossary

AFDD	Air Force Doctrine Document
ASAT	Anti-satellite weapon
BMDO	Ballistic Missile Defense Organization
DCS	Defensive Counter Space
DDCV	Dedicated Defensive Counterspace Vehicle
DoD	Department of Defense
EMP	Electro-Magnetic Pulse
FCC	Federal Communications Commission
GEO	Geosynchronous Earth Orbit
HEO	Highly Elliptical Orbit
ITU	International Telecommunications Union
KKV	Kinetic Kill Vehicle
LEO	Low Earth Orbit
MEO	Mid Earth Orbit
NASA	National Aeronautics and Space Administration
OCS	Offensive Counter Space
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
USAF	United States Air Force

anti-satellite weapon. Any system whose purpose is the destruction, disruption, degradation or disabling of a satellite.[1]

counterspace operations. Operations conducted to attain and maintain a desired degree of space superiority by the destruction or neutralization of enemy forces. The main objectives of counterspace operations are to allow friendly forces to exploit space capabilities, while negating the enemy's ability to do the same.[2]

defensive counterspace operations. Active and passive actions to protect space-related capabilities from enemy attack or interference.[3]

offensive counterspace operations. Operations conducted to destroy or neutralize an adversary's space systems or the information they provide at a time and place of one's choosing through attacks on the space, terrestrial or link elements of space systems.[4]

space control. The means by which space superiority is gained and maintained.[5]

space power. The capability to exploit civil, commercial, intelligence, and national security space systems and associated infrastructure to support national security strategy and national objectives from peacetime through combat operations.[6]

space system. A system with a major functional component which operates in the space environment.[7] It has three elements: the space element, the terrestrial element, and the link element.

Notes

[1] Steven R. Petersen, *Space Control and the Role of Antisatellite Weapons* (Maxwell AFB, AL: Air University Press, 1991), 37.

[2] Air Force Doctrine Document (AFDD) 1, *Air Force Basic Doctrine*, September 1997, 47.

[3] Ibid., 48.

[4] Ibid.

[5] Air Force Doctrine Document (AFDD) 2-2 (Draft), *Space Operations*, February 1997, 6.

[6] Ibid., 24.

[7] Ibid.

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