After thirty-five years, space systems remain an integral part of national security. Desert Storm—which some regard as the first space war—represented the first widespread use of military space systems by common soldiers, sailors, marines, and airmen. It was also a harbinger of future military operations in which dependence on space-based force enhancement will continue to grow. This dependence by the Armed Forces on space systems reveals a vulnerability that an enemy with knowledge and expertise could exploit and concentrates on an ignored threat: countries with little or no space capability. The exploitation of space dependency can greatly benefit an unsophisticated foe by dramatically degrading our efficiency in combat.

Retaining the current international character of space will remain critical to achieving national security goals.

—National Security Strategy, July 1994
Dependence

Military space operations were extensive as early as 1963. Both the United States and the Soviet Union used space capabilities to observe strategic weapon systems, and that helped provide for a stable nuclear detente strategy. The use of space by the military has not been limited to strategic nuclear applications but has covered the conflict spectrum. A science adviser to President Reagan noted that “even in a very limited war, we would have an absolutely critical dependence on space today.” Indeed, space systems have played a crucial role in a number of limited operations: El Dorado Canyon (Libya, 1986), Earnest Will (the Persian Gulf, 1988), and Just Cause (Panama, 1989), to name a few.

Probably the best known military use of space occurred during Desert Shield/Desert Storm, when it greatly enhanced coalition effectiveness. Space systems provided support for navigation, weather, missile defense, communications, reconnaissance and surveillance, and target acquisition. As we face increasing global responsibilities with smaller forces, our ability to accomplish military missions will depend ever more on such force-enhancing support from space.

The dependence on a specific space system is linked not only to the availability of alternate means of performing system tasks, but also to the effectiveness and efficiency of those means. Since space systems and their alternate means can be affected by out-side forces, however, military dependence on space—the so-called space dependency link—is dynamic in a combat environment; that is, subject to constant change in its magnitude.

Vulnerability

The ultimate objective of military space operations is the effective employment of space capabilities in support of land, sea, and air operations to gain and maintain a combat advantage throughout the operational continuum and across the three levels of war.

—Joint Pub 3-14, Space Operations

Two studies conducted by the Ford administration in 1976 concluded that the United States was growing dependent on satellites for various functions, with little provision for satellite survival during wartime. While the studies concentrated on satellite vulnerabilities, it is important to look at vulnerabilities in joint surface forces (including air forces) that result from dependence on space. The extent of our space dependency link is based on three criteria: the types of space systems vital to ongoing operations, the extent of their use among our forces, and an enemy’s ability to affect system performance (see figure 1).

Both the United States and its adversaries can influence the first criterion—the importance of a given space system to ongoing operations. We may affect it in our selection of force structure which, in turn, dictates the availability and quality of alternate means of performing system tasks. Since these alternate means may include assets from other countries, dependence on space systems extends to coalition operations. At least eight U.S. and coalition civilian satellites were called upon during Desert Storm to augment U.S. systems. It can be expected that such systems would be “fair game” for enemy antisatellite (ASAT) efforts during wartime.

An enemy can influence these criteria by conducting operations that increase dependence on a given space system. This may include physically destroying alternate means of task performance or simply concentrating their efforts to increase U.S. use of satellites. The second criterion—scope of application—is influenced only by the United States. Once again, our force structure is the key player since it dictates the amount of surface-based equipment that is acquired and the level at which it is used. Space systems are well ingrained in our forces, as illustrated by three applications from Desert Storm: communications, navigation, and intelligence. Over a thousand single-channel, manportable satellite radio units were issued at small unit level. All told, satellites provided 85–90 percent of intratheater and intertheater communications. Also, thousands of global positioning system (GPS) receivers were used by coalition ships, planes, and ground forces.

Figure 1. Criteria for Evaluating Space System Vulnerability

<table>
<thead>
<tr>
<th>Criteria</th>
<th>U.S. Forces</th>
<th>Enemy Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of Space Systems in Use</td>
<td>Force Structure</td>
<td>Concentrate Attacks to Increase Specific Dependence</td>
</tr>
<tr>
<td></td>
<td>Availability/Quality of Alternate Means</td>
<td></td>
</tr>
<tr>
<td>Extent of Space System Application</td>
<td>Force Structure</td>
<td>Cannot Influence</td>
</tr>
<tr>
<td></td>
<td>Training</td>
<td></td>
</tr>
<tr>
<td>Enemy Means to Affect System Performance</td>
<td>Protection</td>
<td>Attack Ground Systems</td>
</tr>
<tr>
<td></td>
<td>Countermeasures</td>
<td>Electronic Warfare</td>
</tr>
<tr>
<td></td>
<td>ASAT Attacks</td>
<td></td>
</tr>
</tbody>
</table>

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troops to navigate in unfamiliar and featureless terrain. Finally, each service supported an ongoing initiative called Tactical Exploitation of National Capabilities (TENCAP), which allowed joint-force tactical units to receive and sort intelligence data directly from space.6

The third criterion—enemy ability to affect system performance—can be influenced by both ourselves and adversaries. The United States can affect the enemy’s ability to attack friendly space systems by using countermeasures for satellites.7 These protective measures fall under the “space control” mission area. The objective is defending friendly space assets and denying an enemy use of his own. Currently, the popular view of space control emphasizes its role in the larger category of “information warfare.” As such, space control strategies are geared toward the protection and denial of “information warfare” as such, space control strategies are geared toward the protection and denial of satellite data than physical attacks on space system assets.8

An enemy might weigh the vulnerability of a space system to determine if the U.S. space dependency link could be impacted. How can an enemy take advantage of such vulnerabilities?

Exploitation

[Satellites] would be so valuable to the overall order of battle that any opponent would have to take them into account in his overall battle plan and try to exploit any possible weakness.9

Attacking our space systems could provide an enemy with excellent leverage by degrading our combat efficiency and effectiveness. An enemy who is not dependent on space systems (civil or military) can target ours with no fear of retaliation in kind. In such a case no space deterrence exists for the United States.

Enemies with no space capabilities can lease them. America may con- duct diplomatic space control by encouraging states not to provide space support to foes. This occurred during Operation Desert Shield when France, working in collaboration with the coalition, agreed not to sell SPOT multispectral imagery data to Iraq.10 But cutting off access to space data may not be effective for U.S. space assets more attractive to an enemy. This may

apply even to systems that have open access, such as GPS. Simply put, if the enemy cannot use space or must use it at a disadvantage, he can only gain by knocking space systems out.

The equipment and tactics required for attacks on ground systems by conventional, special operations, and terrorist forces are readily available. The equipment for certain ground-based, air-based, and sea-based electromagnetic jamming also is obtainable from many countries, especially the former Soviet Union (FSU). Methods of attack against the space segment include direct ascent and coorbital weapon systems and directed energy beams that can disrupt or destroy satellites.11 FSU has demonstrated electromagnetic phenomena that affected space operations: widespread ionization, electromagnetic pulse (EMP), and artificial auroras.12 Of particular interest was the “argus effect,” named for the shell formed around the earth by beta particles after a nuclear detonation. Trapped radiation from the test explosion with the largest yield, Starfish Prime which had a 1.4 megaton warhead, inadvertently damaged at least three satellites.

ballistic missiles can optimize the apogee for ASAT effectiveness

The overall ASAT system concept was proven by the 10th Aerospace Defense Squadron at Johnston Island in 1964–1975.13 Successful operation of this unit required years of research and testing. The many challenges for an enemy to develop and operate such a system can be divided into three areas: tracking and targeting, delivery, and warhead.

Tracking and targeting a satellite is often considered an expensive process that requires an immense infrastructure and highly qualified technical personnel. However, the Kettering group, an informal network that monitors space activities, has proven that it can be done using common and inexpensive electronics with minimal training. For example, in 1978 a 12-year-old student at Kettering Boys School, with the aid of his physics teacher (a Kettering group member), predicted within a 24-hour range when the Cosmos 954 satellite would reenter the atmosphere. The

Figure 2. High Altitude Nuclear Tests, 1958–62

<table>
<thead>
<tr>
<th>Test Series/Date</th>
<th>Test Name</th>
<th>Warhead Yield</th>
<th>Explosion Altitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOTSTACK</td>
<td>1 Aug 58</td>
<td>Teak</td>
<td>megaton range</td>
</tr>
<tr>
<td></td>
<td>12 Aug 58</td>
<td>Orange</td>
<td>megaton range</td>
</tr>
<tr>
<td>ARGUS</td>
<td>27 Aug 58</td>
<td>Argus 1</td>
<td>1–2 kiloton</td>
</tr>
<tr>
<td></td>
<td>30 Aug 58</td>
<td>Argus 2</td>
<td>1–2 kiloton</td>
</tr>
<tr>
<td></td>
<td>1 Sep 58</td>
<td>Argus 3</td>
<td>1–2 kiloton</td>
</tr>
<tr>
<td>FISHBOWL</td>
<td>9 Jul 62</td>
<td>Starfish Prime</td>
<td>1.4 megaton</td>
</tr>
<tr>
<td></td>
<td>20 Oct 62</td>
<td>Checkmate</td>
<td>submegaton</td>
</tr>
<tr>
<td></td>
<td>26 Oct 62</td>
<td>Blightlifeprime</td>
<td>submegaton</td>
</tr>
<tr>
<td></td>
<td>1 Nov 62</td>
<td>Kingfish</td>
<td>submegaton</td>
</tr>
</tbody>
</table>

Source: Defense Nuclear Agency.
group also was credited with discovering the then-secret Soviet launch facility at Plesetsk in 1966 as well as tracking Soviet spy satellites that were observing the 1967 Arab-Israeli War. In both cases the tracking was done without modern calculators and personal computers. Today, an enemy can purchase commercial software packages to calculate orbital mechanics and can access the computer Internet to obtain the orbital parameters of satellites. Using this information, tracking and targeting a nuclear ASAT within its effective radius (usually measured in miles) is certainly feasible.

Once a target is selected, a delivery vehicle must place the warhead in a given effect radius. Not including countries with established missile programs (namely, the United States, countries of the former Soviet Union, France, China, and Great Britain), there are at least 22 states with active ballistic missile programs. Ballistic missiles can be developed to optimize the apogee for ASAT effectiveness. Technological hurdles to the development of missile systems may be overcome with the help of FSU workers for hire. NPO Energomash, Russia’s leading developer of liquid-fueled rocket engines, lost much of its experienced staff in September 1993.

Hiring expertise could also help develop space hardware for the final guidance and control of warheads. But generating a satellite bus was another task accomplished by a group of amateur radio enthusiasts who designed, constructed, and operated six satellites. Built mostly in their garages, the first orbiting satellite carrying amateur radio equipment (OSCAR 1) was launched in December 1961. The design and performance of the OSCAR series have improved over time, yet the majority of the work is still done by amateurs using their own resources.

The final challenge to operating a nuclear ASAT is acquiring a warhead. Though difficult, developing or procuring nuclear weapons is feasible enough that our national security strategy lists their proliferation as a major concern. A recent Air Force study estimated that in 1993 as many as 10 countries were capable of producing nuclear weapons.
This could increase to 25 by 2003. A separate probe by a government proliferation study team estimated that eight third world countries would be added to the list by 2000.

**Effects**

*Spending billions in space makes little sense if the assets are unusable in wartime.*

An attack on our space assets could impact every element of national power—political, diplomatic, economic, and military. During conflict, a priority of any commander is to prepare the battlespace for combat operations—that is, to "stack the deck" to his advantage. An enemy has much to gain by exploiting the dependency link between our terrestrial forces and force-enhancing space systems. An assault on U.S. military space systems is a force multiplier for an enemy.

If prepared, the Armed Forces could probably operate in remote theaters without the aid of space systems. However, based on the increasing strength of space dependency links, they would have problems operating under the immediate and unexpected loss of critical space support, which would give at least temporary advantage to an enemy. That edge could increase by synchronizing attacks on space systems with assaults on terrestrial forces. While this may not enable an enemy to triumph militarily, it may cause loss of life and materiel sufficient to bring our withdrawal.

**Bang for the Buck**

The most effective and least defensible method of attack against space systems is the high-altitude detonation of a nuclear device. Depending on the yield of the warhead, a nuclear ASAT could attack multiple satellite systems with one detonation. Such an attack would have temporary and permanent effects on U.S. forces. Depending on the design and operating radio frequency of the target, temporary effects could last minutes, hours, or days. These effects can be used to great advantage. If an enemy plans an offensive with the high-altitude nuclear environment in mind (for example, EMF atmospheric ionization), it can opt to outfit troops with low-tech equipment and procedures that would be unaffected by such an attack. Devices such as signal flags, compasses, and presurveyed attack routes could be turned into enemy force enhancers that exploit GPS navigation and satellite communication links that are suddenly severed. An enemy could thus strengthen the synergistic synchronization effects of his terrestrial attack.

A nuclear ASAT can destroy or damage satellites in its kill radius. As a consequence of the inadvertent satellite damage caused by the **Starfish Prime** nuclear test, it was obvious that nuclear ASATs would have limited usefulness because of unavoidable collateral damage they would inflict on other U.S. satellites. While such damage may concern us, it is of great benefit to a country which is not space dependent. Without penalties—for collateral damage, an enemy can pursue indiscriminate area targeting that allows less sophisticated targeting and delivery systems for its ASAT.

The permanent damage to satellites may introduce secondary damage mechanisms that would benefit an enemy. Even though space is vast, many of the useful orbits to support given areas on earth are heavily populated by satellites. This “bunching” could allow secondary satellite kills through debris fratricide. This could have a cascading effect as new collisions create more debris. The bottom line is that an enemy need not possess space forces to be a space threat.

The use of any nuclear device is likely to have significant political implications. While it may be acceptable to direct such a device at inanimate objects, the indiscriminate nature of ASAT may not be acceptable to neutral countries whose space systems and related economic links may be impacted. But faced with an enemy who has a low regard for world opinion (a Saddam Hussein or Mu’ammar Qadhafi), these factors may have little effect on enemy strategy. Given that reality, how can we best prepare against such a threat?

**Countermeasures**

In considering countermeasures against threats to space systems, the objective is to assess all elements of a system for vulnerabilities and provide survivability measures. Proliferation and reconstitution measures can then be added to ensure continuous capability on all levels of conflict.
to produce instantaneous failure in cir-
cuits today is two orders of magnitude
less than in the 1970s. Worse, domestic
vendos who produce radiation-toler-
ant semiconductors fell from twenty in
1990 to four in 1995. DOD investment
in radiation-hardening technology also
dropped, from $50 million in 1989 to
$20 million in 1995. 20

reconstitution through space launch

offers promise as a countermeasure

Equipment hardening and auton-
omy can reduce electromagnetic and
radiation interference from ASAT at-
tacks. However, hardening counter-
measures would only protect from
blast and debris damage. Also, the
ability to maneuver may be of little
use since there would be only a few
minutes for ground operators to ob-
serve the ASAT launch, assess intent,
determine its target, and command the
target satellite to avoid the impact
area. But such maneuver capability may
be useful for an untargeted satel-
lite to avoid a fratricide threat resulting
from a successfully targeted satellite.

The use of on-orbit spares (prolif-
eration) confronts the enemy with
more potential targets. However, since
some of these spares may have to be in
orbits similar to the target satellites to
be effective, they may also be vulnera-
ble to fratricide.

Reconstitution through space launch
launch offers promise as a countermea-
sure. As one analyst observed, “reconsti-
tuting essential space assets after hostili-
ties begin may be the only method of
ensuring that critical systems survive.” 21
While reconstitution would not be ef-
fective in preventing an enemy’s initial
operations, it would allow for satellites to
be reintroduced into the battlespace,
possibly in support of U.S. counterof-
ensive operations. Finally, one of the best counter-
measures, training, is not directly re-
lated to space systems. Future joint
and coalition training should instill
unexpected interruptions of space sys-
tems support. Our forces should iden-
tify and practice alternate means of
conducting operations which normally
include space dependency links.

The military use of space is a dou-
ble-edged sword with strengths as well
as vulnerabilities. Faced with growing
responsibilities and decreasing forces,
our ability to accomplish missions will
depend more and more on force-en-
hancing support from space. The result-
ing vulnerability may be affected by both
the United States and a potential
evergy. Developing counter-
measures to threats against our space
systems may enable us to avoid a need-
less loss of lives and equipment on the
battlefield of the future.

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