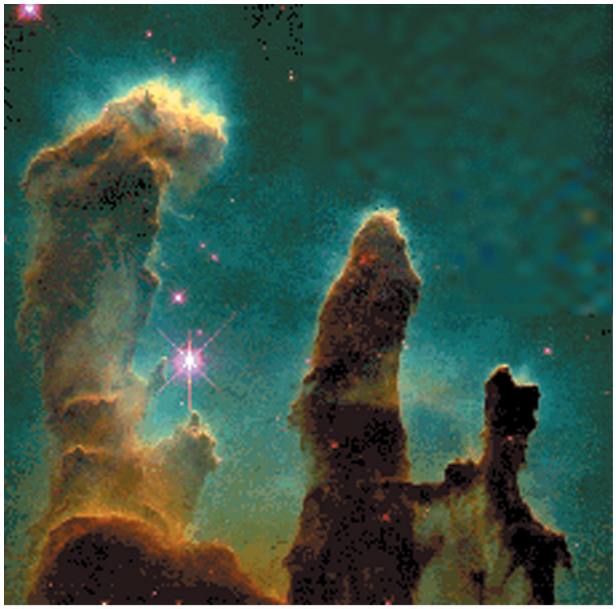
II. Space: Today and the Future

The security and economic well being of the United States and its allies and friends depend on the nation's ability to operate successfully in space. To be able to contribute to peace and stability in a distinctly different but still dangerous and complex global environment, the U.S. needs to remain at the forefront in space, technologically and operationally, as we have in the air, on land and at sea. Specifically, the U.S. must have the capability to use space as an integral part of its ability to manage crises, deter conflicts and, if deterrence fails, to prevail in conflict.

With the dramatic and still accelerating advances in science and technology, the use of space is increasing rapidly. Yet, the uses and benefits of space often go unrecognized. We live in an information age, driven by needs for precision, accuracy and timeliness in all of our endeavors—personal, business and governmental. As society becomes increasingly mobile and global, reliance on the worldwide availability of information will increase. Space-based systems, transmitting data, voice and video, will continue to play a critical part in collecting and distributing information. Space is also a medium in which highly valuable applications are being developed and around which highly lucrative economic endeavors are being built.

A. A New Era of Space

The first era of the space age was one of experimentation and discovery. Telstar, Mercury and Apollo, Voyager and Hubble, and the Space Shuttle taught Americans how to journey into space and allowed them to take the first tentative steps toward operating in space while enlarging their knowledge of the universe (Figure 4). While these programs were underway, the U.S. defense and intelligence communities were building and using satellites to conduct reconnaissance, warn of missile launches, chart the weather and allow commanders to



Source: Jeff Hester and Paul Scowen (Arizona State University) and NASA
Figure 4: Hubble space telescope image of the Eagle Nebula, 7,000 light years from the Earth

We are now on the threshold of a new era of the space age, devoted to mastering operations in space.

communicate with their forces and to precisely locate objects in time and space. These programs were driven by the urgent need for information about threats to vital interests of the United States. During this era, the commercial space industry matured gradually as it learned to develop reliable communications satellites to carry voice, data and video over continents and oceans.

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1. The Role for Space

There are four sectors of space activity: civil, commercial, defense and intelligence.

Civil Space Sector

The civil space sector is approaching a long-standing goal of a permanent manned presence in space with the deployment of astronauts to the International Space Station. The U.S. has shouldered the largest share of development and funding for this effort. Because it is an international program, however, its benefits for scientific research, experimentation and commercial processes will be widely shared. The number of countries able to participate in manned space flight has grown substantially. In addition to the U.S. and the USSR (now the Russian Federation), 21 other countries have sent astronauts into orbit in U.S. and Russian spacecraft. The People's Republic of China has announced its intention to become the third nation to place human beings in orbit and return them safely to earth.

Other research and experiments in the civil sector have many applications to human activity. For example, civil space missions to understand the effects of the sun on the earth, other planets and the space between them, such as those conducted by the Solar Terrestrial Probe missions, will help in the development of more advanced means to predict weather on earth.

The growth of the space industry today, and its hallmark in the future, will be space-based services.

Commercial Space Sector

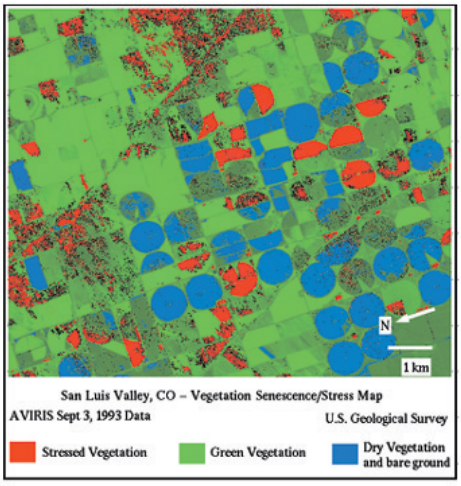
Unlike the earlier space era, in which governments drove activity in space, in this new era certain space applications, such as communications, are being driven by the

commercial sector (Figure 5). An international space industry has developed, with revenues exceeding $80 billion in 2000. Industry forecasts project revenues will more than triple in the next decade. Whereas satellite system manufacturing once defined the market, the growth of the space industry today, and its hallmark in the future, will be space-based services.

Source: United States Coast Guard
Figure 5: Coast Guard rescue of the crew aboard the cruise ship Sea Breeze I relied on space-based communications and navigation

The space industry is marked by stiff competition among commercial firms to secure orbital locations for satellites and to secure the use of radio frequencies to exploit a global market for goods and services provided by those satellites. International consortia are pursuing many space enterprises, so ascertaining the national identity of a firm is increasingly complex. The calculations of financial investors in the industry and consumer buying habits are dominated by time to market, cost and price, quantity and quality. It is a volatile market. Nevertheless, as a result of the competition in goods and services, new applications for space-based systems continue to be developed, the use of those products is increasing and their market value is growing.

Space-based technology is revolutionizing major aspects of commercial and social activity and will continue to do so as the capacity and capabilities of satellites increase through emerging technologies. Space enters homes, businesses, schools, hospitals and government offices through its applications for transportation, health, the environment, telecommunications, education, commerce, agriculture and energy (Figure 6). Space-based technologies and services permit people to communicate, companies to do business, civic groups to serve the public and

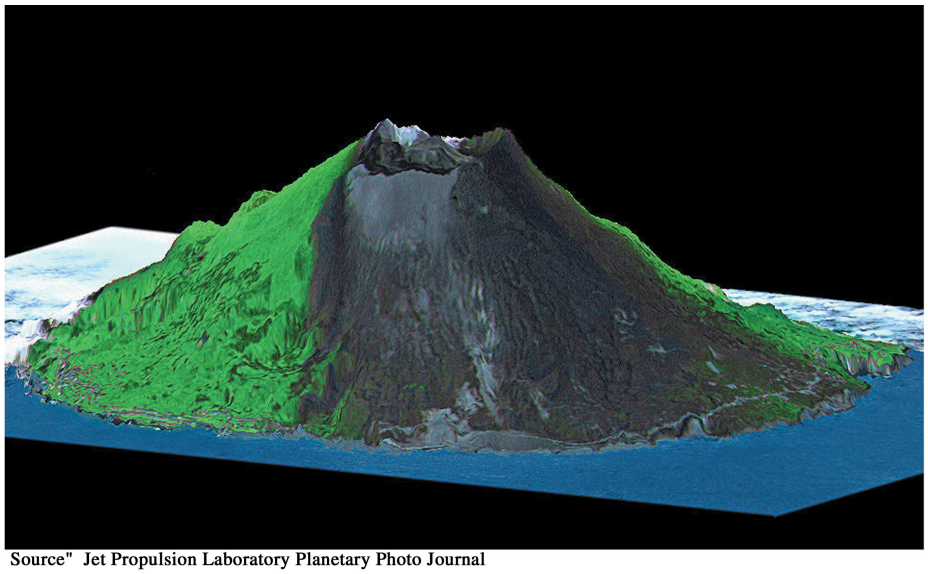


Source: USGS Spectroscopy Laboratory
Figure 6: Revolutionary satellite imaging products, simulated by this false color image, will enable new farming methods

The commercial revolution in space has eliminated the exclusive control of space once enjoyed by national defense, intelligence and government agencies.

scientists to conduct research. Much like highways and airways, water lines and electric grids, services supplied from space are already an important part of the U.S. and global infrastructures.

The most telling feature of the new space age is that the commercial revolution in space has eliminated the exclusive control of space once enjoyed by national defense, intelligence and government agencies. For only a few thousand dollars, a customer today can purchase a photograph of an area on earth equal in quality to those formerly available only to the superpowers during the Cold War. Commercial providers can complement the photographic images with data that identify the location and type of foliage in an area and provide evidence of recent activity there. They can produce radar-generated maps with terrain elevations, transmit this information around the globe and combine all of it into formats most useful to the customer (Figure 7). This service is of increasing value to farmers and ranchers, fisherman and miners, city planners and scientists.



Source" Jet Propulsion Laboratory Planetary Photo Journal

Figure 7: Radar satellite imagery can detail natural phenomena in three dimensions, such as the eruption of this Japanese volcano on the populated island of Miyake-Jima.

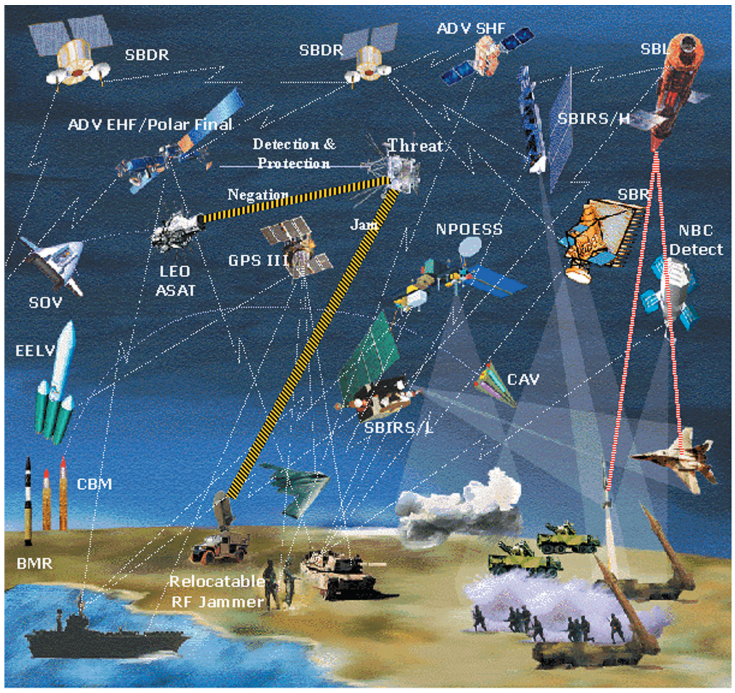
Defense Space Sector

Space-related capabilities help national leaders to implement American foreign policy and, when necessary, to use military power in ways never before possible. Today, information gathered from and transmitted through space is an integral component of American military strategy and

operations. Space-based capabilities enable military forces to be warned of missile attacks, to communicate instantaneously, to obtain near real-time information that can be transmitted rapidly from satellite to attack platform, to navigate to a conflict area while avoiding hostile defenses along the way, and to identify and strike targets from air, land or sea with precise and devastating effect. This permits U.S. leaders to manage even distant crises with fewer forces because those forces can respond quickly and operate effectively over longer ranges. Because of space capabilities, the U.S. is better able to sustain and extend deterrence to its allies and friends in our highly complex international environment.

Space is a medium much the same as air, land or sea.

Space is not simply a place from which information is acquired and transmitted or through which objects pass. It is a medium much the same as air, land or sea. In the coming period, the U.S. will conduct operations to, from, in and through space in support of its national interests both on earth and in space (Figure 8). As with national capabilities in the air, on land and at sea, the U.S. must have the capabilities to defend its space assets against hostile acts and to negate the hostile use of space against U.S. interests.



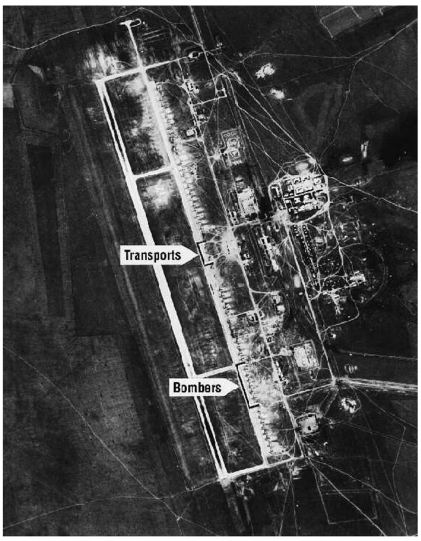
Source: Headquarters Air Force Space Command
Figure 8: Space systems will transform the conduct of future military operations

Intelligence Space Sector

Intelligence collected from space remains essential to the mission of the Intelligence Community, as it has been since the early 1960s. Then the need to gain access to a hostile, denied area, the USSR, drove the development of space-based intelligence collection. The need for access to denied areas persists. In addition, the U.S. Intelligence Community is required to collect information on a wide variety of subjects in support of U.S. global security policy.

Today, the U.S. Intelligence Community is required to collect information about many nations, organizations and even individuals.

The Intelligence Community and the Department of Defense deploy satellites to provide global communications capabilities; verify treaties through "national technical means"; conduct photoreconnaissance; collect mapping, charting, geodetic, scientific and environmental data; and gather information on natural or man-made disasters (Figure 9). The U.S. also collects signals intelligence and measurement and signature intelligence from space. This intelligence is essential to the formulation of foreign and defense policies, the capacity of the President to manage crises and conflicts, the conduct of military operations and the development of military capabilities to assure the attainment of U.S. objectives.



Source: National Reconnaissance Office, Corona Image of Dolon Airfield

Figure 9: Space-based image of a military airfield in the former USSR.

Modernizing the National Security Space Sector

The defense and intelligence space activities together comprise the national security space sector. The Department of Defense and the Intelligence Community are undertaking substantial and expensive programs to replace virtually their entire inventory of satellites and launch vehicles over the next decade or so. These programs are estimated to cost more than $60 billion during this period (Figure 10). Following are examples of space programs undergoing modernization:

- Intelligence collection systems designed in the late 1970s and early 1980s are scheduled for replacement in the near future. There are plans to improve the process for moving intelligence collected from these satellites to the users, both political and military.

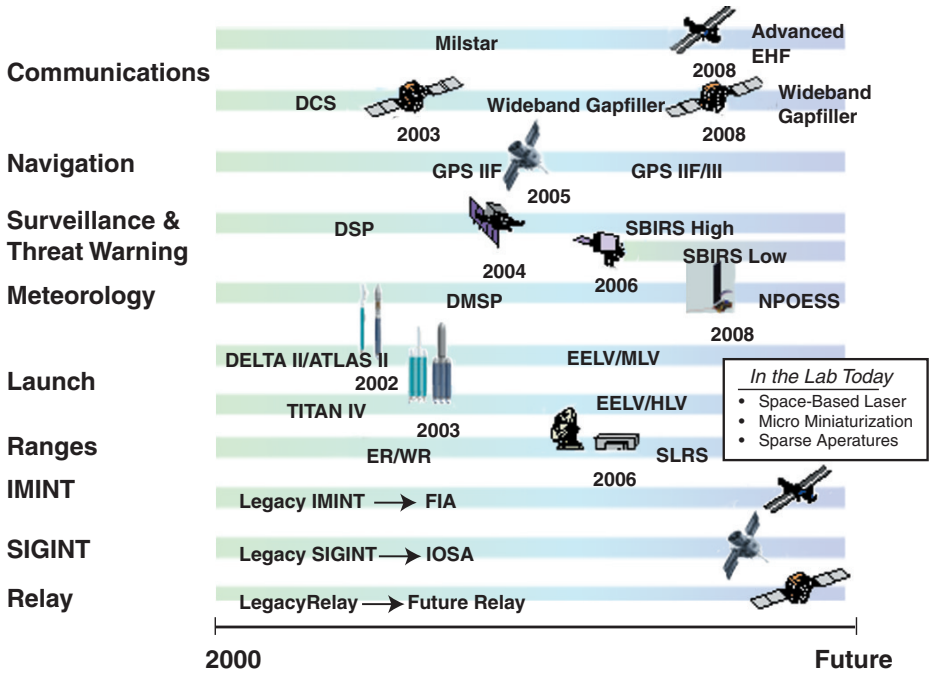
- The military will deploy the next generation Global Positioning System (GPS), which will provide both military and civilian users with position, location and navigation with greater precision and reliability while improving the value of the system for military operations.

- Weather satellites operated by DoD are to be merged in a program jointly conducted with the National Oceanic and Atmospheric Administration (NOAA) and NASA, which will improve weather and environmental monitoring.

- To meet the military's growing reliance on information, all military communication satellites are planned to be replaced with more capable systems.

- Deployment of the Space-Based Infrared System (SBIRS) will improve the ability to detect ballistic missile launches. SBIRS will also provide significant contributions to missile defense and intelligence missions.

- The Space Based Laser program plans to demonstrate the technology to destroy a ballistic missile from space.



Source: Headquarters Air Force and National Reconnaissance Office

Figure 10: An extensive modernization program is underway for national security space systems

International Dimension

Opportunities in space are not limited to the United States. Many countries either conduct or participate in space programs dedicated to a variety of tasks, including communications and remote sensing. Although no country has a comprehensive space program to rival that of the United States, a growing number of nations have more limited programs or take part in international collaborative efforts in order to improve their own national security, commercial and civil space capabilities. Collaborative efforts are making space knowledge, technology, capabilities and applications increasingly available worldwide.

The U.S. will be tested over time by competing programs or attempts to restrict U.S. space activities through international regulations. In some countries such as Russia, China and India, “commercial” space programs are operated and controlled by the government, not private industry. In others, Israel, France and Japan, for example, the government has a strong

influence over space companies, but these countries have a commercial space industry as well. Public and private entities in these and other countries are becoming competitive in the international market.

2. Toward the Future

Mastering near-earth space operations is still in its early stages. As mastery over operating in space is achieved, the value of activity in space will grow. Commercial space activity will become increasingly important to the global economy. Civil activity will involve more nations, international consortia and non-state actors. U.S. defense and intelligence activities in space will become increasingly important to the pursuit of U.S. national security interests.

The Commissioners appreciate the sensitivity that surrounds the notion of weapons in space for offensive or defensive purposes. They also believe, however, that to ignore the issue would be a disservice to the nation. The Commissioners believe the U.S. Government should vigorously pursue the capabilities called for in the National Space Policy to ensure that the President will have the option to deploy weapons in space to deter threats to and, if necessary, defend against attacks on U.S. interests.

B. Vulnerabilities and Threats

Space systems can be vulnerable to a range of attacks. These include disruption activities that temporarily deny access to space-derived products; activities that completely destroy a satellite system—the ground stations, launch systems or satellites on orbit; and those with the potential to render space useless for human purposes over an extended period of time. Launch systems are fragile. A launch failure can stop the U.S. from employing entire classes of boosters for extended periods of time. For example, after successive Titan failures in 1985 and 1986 and the Challenger Space Shuttle disaster in 1986, the nation experienced a 21-month hiatus in its ability to launch heavy national security payloads.

The political, economic and military value of space systems makes them attractive targets for state and non-state actors hostile to the United States and its interests. In order to extend its deterrence concepts and defense capabilities to space, the U.S. will require development of new military

capabilities for operation to, from, in and through space. It will require, as well, engaging U.S. allies and friends, and the international community, in a sustained effort to fashion appropriate "rules of the road" for space.

1. Assessing the Threat Environment

The U.S. is more dependent on space than any other nation. Yet, the threat to the U.S. and its allies in and from space does not command the attention it merits from the departments and agencies of the U.S. Government charged with national security responsibilities. Consequently, evaluation of the threat to U.S. space capabilities currently lacks priority in the competition for collection and analytic resources.

The U.S. is more dependent on space than any other nation.

The Intelligence Community has begun to improve its collection strategy for threats in and from space. Its analytic efforts, however, need to give more attention to the technical and operational forms a threat might take. The Intelligence Community needs to account fully for the implications of technology proliferation and services available on the open market to those entities that could threaten U.S. space capabilities. Political and military leaders need to appreciate the nature of the threat and should seek and receive from the Intelligence Community the necessary information on the space-related threat.

Failure to develop credible threat analyses could have serious consequences for the United States. It could leave the U.S. vulnerable to surprises in space and could result in deferred decisions on developing space-based capabilities due to the lack of a validated, well-understood threat. Surprise, however, is not limited to the possibility of an attack on U.S. systems. The U.S. also could be surprised by the emergence of new technological capabilities in the hands of potential adversaries. Or, the U.S. could be surprised in the international arena by economic or arms control proposals it does not anticipate, or the importance of which it does not fully appreciate, because of insufficient knowledge about the technical or operational capabilities of current or future negotiating partners.

2. Existing and Emerging Threats

The ability to restrict or deny freedom of access to and operations in space is no longer limited to global military powers. Knowledge of space systems and the means to counter them is increasingly available on the international market. Nations hostile to the U.S. possess or can acquire the means to disrupt or destroy U.S. space systems by attacking the satellites in space, their communications nodes on the ground and in space, or ground nodes that command the satellites.

Small nations, groups or even individuals can acquire from commercial sources imagery of targets on earth and in space. They can acquire accurate timing and navigational data and critical weather information generated by government-owned satellites. Improved command and control capabilities are available through the use of commercial communications satellites. Even launch capabilities can be contracted for with legitimate companies, and a number of smaller nations are developing their own space launch vehicles. The reality is that there are many extant capabilities, such as those described below, to deny, disrupt or physically destroy space systems and the ground facilities that use and control them.

Attacking Ground Stations

One of the more accessible ways to disrupt space systems is by attacking the associated satellite ground stations. This can be accomplished by a variety of means, ranging from physical attack to computer network intrusion.

Denial and Deception

Countries can attempt to defeat the reconnaissance function of satellites by obtaining sufficient information about the satellites' orbital and sensor characteristics. This information can be used to either deny access to the reconnaissance targets at critical times or to carry out deception efforts to confuse and complicate their signatures. As more information is made available concerning reconnaissance satellite characteristics, denial and deception are made easier and information collection more difficult.

Jamming Satellites on Orbit

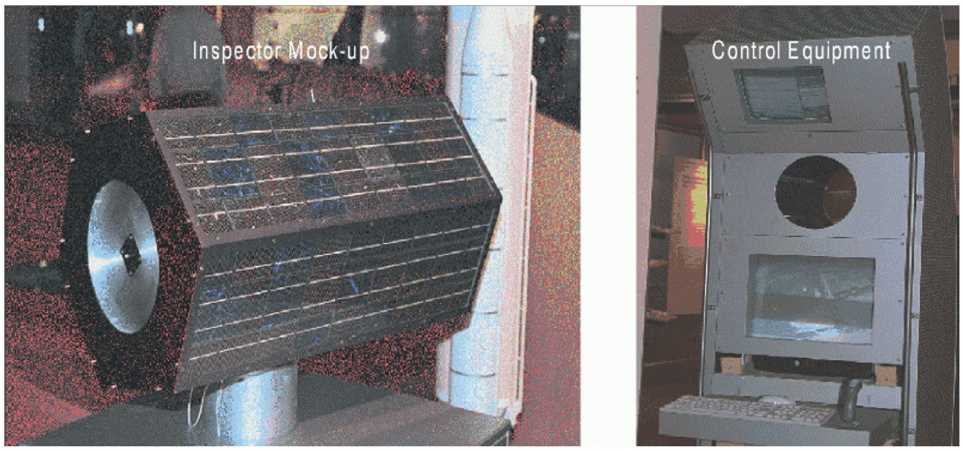
Commercial satellite ground communications equipment has electronic jamming capabilities that can easily be used to disrupt the functions of some satellites. Many countries also have military jamming capabilities, including Russia and China as well as Iran, Cuba, Iraq and North Korea. Most U.S. commercial and civil satellites lack built-in protection measures

and are vulnerable to such attacks. Recent examples of satellite jamming include Indonesia jamming a transponder on a Chinese-owned satellite and Iran and Turkey jamming satellite TV broadcasts of dissidents. More sophisticated technologies for jamming satellite signals are becoming available. For example, Russia is marketing a handheld GPS jamming system (Figure 11). A one-watt version of that system, the size of a cigarette pack, is able to deny access to GPS out to 80 kilometers; a slightly larger version can deny access out to 192 kilometers. Both are compact and powerful enough to jam an aircraft's GPS receiver signal, which could disrupt military missions or create havoc at a civilian airport.

Source: National Air Intelligence Center
Figure 11: Russian handheld GPS jammers are available commercially worldwide.

Microsatellites

Advances in miniaturization and the proliferation of space technologies create opportunities for many countries to enter space with small, lightweight, inexpensive and highly capable systems that can perform a variety of missions (Figure 12). Microsatellites and nanosatellites, weighing from 100 kilograms to 10 kilograms, respectively, are examples of the advances in miniaturized space system technologies. Microsatellites can perform satellite inspection, imaging and other functions and could be adapted as weapons. Placed on an interception course and programmed to home on a satellite, a microsatellite could fly alongside a target until commanded to disrupt, disable or destroy the target. Detection of and defense against such an attack could prove difficult.



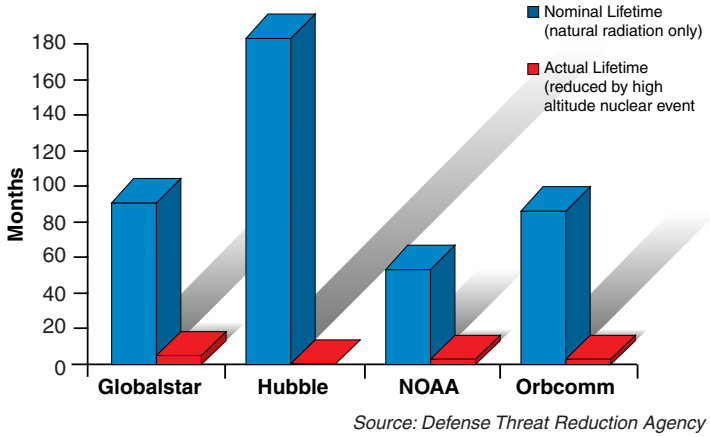
Source: National Air Intelligence Center

Figure 12: Many countries use microsatellites today for missions such as on-orbit inspection and remote sensing.

Technology transfer programs exist to train nations in the development and deployment of microsatellite systems. Commercial entities offer to teach customers how to design, develop, launch and operate small satellites, some as small as a portable compact disc player. Services have been provided to France, the United Kingdom and the United States, and technology transfer programs have been conducted with China, South Korea, Portugal, Pakistan, Chile, South Africa, Thailand, Singapore, Turkey and Malaysia. Companies in the United States and the United Kingdom, as well as other countries including Russia, Israel, Canada and Sweden, are involved in maturing microsatellite technology.

Nuclear Detonation

Perhaps the most devastating threat could come from a low-yield nuclear device, on the order of 50 kilotons, detonated a few hundred kilometers above the atmosphere. A nuclear detonation would increase ambient radiation to a level sufficient to severely damage nearby satellites and reduce the lifetime of satellites in low earth orbit from years to months or less. The lingering effects of radiation could make satellite operations futile for many



Source: Defense Threat Reduction Agency

Figure 13: Impact of a nuclear detonation on the lifetime of satellities

months. Even nuclear detonations in the 10-kiloton range could have significant effects on satellites for many months (Figure 13). To execute this mission, all that is needed is a rocket and a simple nuclear device. Countries such as Iran, North Korea, Iraq and Pakistan possess missiles that could carry warheads to the necessary altitudes and either have, or are believed to be developing, nuclear weapons.

3. Reducing Vulnerability

As harmful as the loss of commercial satellites or damage to civil assets would be, an attack on intelligence and military satellites would be even more serious for the nation in time of crisis or conflict. The U.S. could be subjected to serious difficulties if the functions of U.S. satellites were significantly disrupted or degraded as the President was working to ease a crisis between nuclear-armed adversaries or to end a conflict before an adversary used weapons of mass destruction against the U.S. or its allies.

The U.S. is an attractive candidate for a "Space Pearl Harbor."

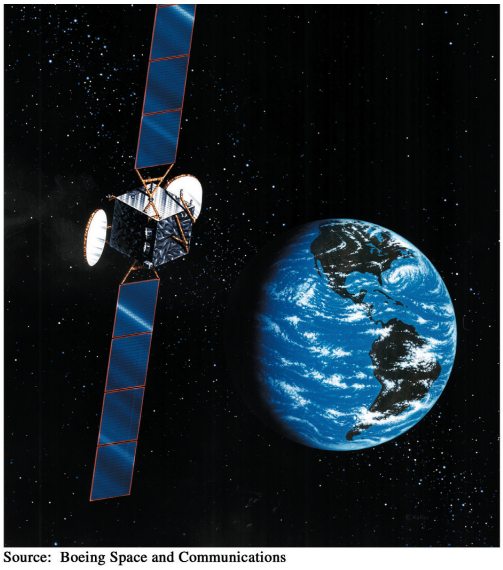
As history has shown—whether at Pearl Harbor, the killing of 241 U.S. Marines in their barracks in Lebanon or the attack on the USS Cole in Yemen—if the U.S. offers an inviting target, it may well pay the price of attack. With the growing commercial and national security use of space, U.S. assets in space and on the ground offer just such targets. The U.S. is an attractive candidate for a "Space Pearl Harbor." The warning signs of U.S. vulnerability include:

- In 1998, the Galaxy IV satellite malfunctioned, shutting down 80 percent of U.S. pagers, as well as video feeds for cable and broadcast transmission, credit card authorization networks and corporate communications systems (Figure 14). To restore satellite service, satellites had to be moved and thousands of ground antennas had to be manually repositioned, which took weeks in some cases.

- In early 2000, the U.S. lost all information from a number of its satellites for three hours when computers in ground stations malfunctioned.

- In July 2000, the Xinhau news agency reported that China's military is developing methods and strategies for defeating the U.S. military in a high-tech and space-based future war. It noted, "for countries

that could never win a war by using the method of tanks and planes, attacking the U.S. space system may be an irresistible and most tempting choice. . .” These reports illustrate a troubling but little-noticed view of the future.



Source: Boeing Space and Communications
Figure 14: Malfunction of the Galaxy IV satellite shut down 80% of the nation's pagers

- Hackers are routinely probing DoD networks and computers. The U.S. Space Command’s Joint Task Force for Computer Network Defense reported that detected probes and scans are increasing, access to hacking tools is becoming easier and hacking techniques are becoming more sophisticated. In 1999 the number of detected probes and scans against DoD systems was just over 22,000; in the first eleven months of 2000, the number had grown to 26,500.

- If the GPS system were to experience widespread failure or disruption, the impact could be serious. Loss of GPS timing could disable police, fire and ambulance communications around the world; disrupt the global banking and financial system, which depends on GPS timing to keep worldwide financial centers connected; and interrupt the operation of electric power distribution systems.

The signs of vulnerability are not always so clear as those described above and therefore are not always recognized. Hostile actions against space systems can reasonably be confused with natural phenomena. Space debris or solar activity can “explain” the loss of a space system and mask unfriendly actions or the potential thereof. They can be explained as computer hardware or software failure, even though either might be the result of malicious acts. Thus far, the indicators have been neither sufficiently persuasive nor gripping to energize the U.S. to take appropriate defensive steps. For this reason, the Commission believes that the U.S. is not as yet well prepared to handle the range of potential threats to its space systems.

Threats to U.S. space systems might arise under a variety of conditions:

- In peacetime, as a terrorist act.
- In time of crisis, as an act of coercion or escalation.
- In wartime, as an effort to degrade U.S. intelligence or military performance.

Threatening or attacking the space capabilities of the U.S. would have domestic, economic and political consequences and could provoke international disputes about the origin and intent of an attack. Such ambiguity and uncertainty could be fatal to the successful management of a crisis or resolution of a conflict. They could lead to forbearance when action is needed or to hasty action when more or better information would have given rise to a broader and more effective set of response options.

There are a number of possible crises or conflicts in which the potential vulnerability of national security space systems would be worrisome. For example:

- Efforts to identify and strike terrorist strongholds and facilities in advance of or in retaliation for terrorist attacks on U.S. forces or citizens abroad, or on the U.S. homeland or that of its allies.
- Conflict in the Taiwan Straits, in which the U.S. attempts to deter escalation through the conduct of military operations while seeking to bring it to a favorable end through diplomatic measures.
- War in the Middle East, posing a threat to U.S. friends and allies in the region and calling for a rapid political and military response to threats by an aggressor to launch ballistic missiles armed with weapons of mass destruction.
- The disabling of a remote sensing satellite being used by a regional power to monitor Southwest Asia, followed shortly thereafter by another state in the region launching a long range ballistic missile armed with a weapon of mass destruction.
- Cyber attacks on nuclear command and control systems that precipitate a crisis in South Asia involving India and Pakistan and their respective allies.

In each of these contingencies and others like them, the President, his senior advisors and military commanders would be dependent on U.S. satellite systems to help manage the crisis, conduct military operations or bring about a resolution to the conflict. If the performance of U.S. systems were affected, the diplomatic and military leverage of the U.S. could be reduced, that of an adversary improved, and the cost and risks associated with achieving U.S. objectives commensurately increased.

That U.S. space systems might be threatened or attacked in such contingencies may seem improbable, even reckless. However, as political economist Thomas Schelling has pointed out, "There is a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered looks strange; what looks strange is thought improbable; what is improbable need not be considered seriously." Surprise is most often not a lack of warning, but the result of a tendency to dismiss as reckless what we consider improbable.

We are on notice, but we have not noticed.

History is replete with instances in which warning signs were ignored and change resisted until an external, "improbable" event forced resistant bureaucracies to take action. The question is whether the U.S. will be wise enough to act responsibly and soon enough to reduce U.S. space vulnerability. Or whether, as in the past, a disabling attack against the country and its people—a "Space Pearl Harbor"—will be the only event able to galvanize the nation and cause the U.S. Government to act.

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