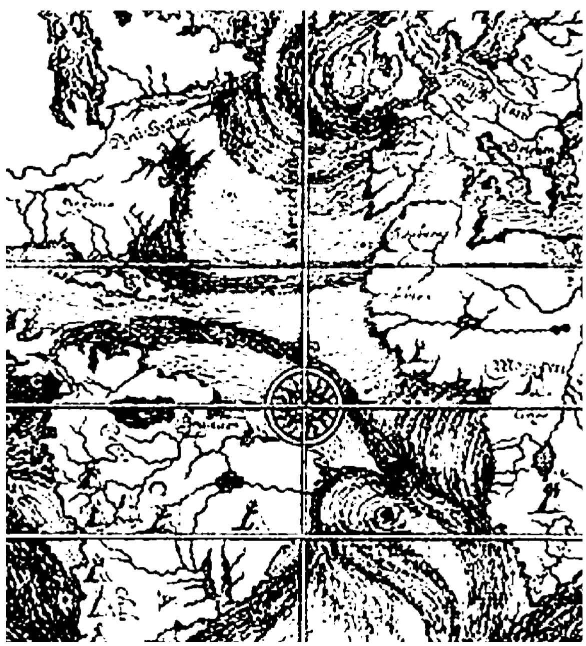
MINI STUDY ON:

COMMERCIAL SPACE & MILITARY INFORMATION DOMINANCE:

ASSESSING SECURITY ON THE NEW FRONTIER



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Comments or questions should be directed to:
David R. Tanks, Principal Study Investigator

The Institute for Foreign Policy Analysis, Inc.

Washington, DC Office:
1725 DeSales Street, NW, Suite 402
Washington, DC 20036
Tel: 202•463•7942
Fax: 202•785•2785

Cambridge, MA Office:
Central Plaza Building, Tenth Floor
675 Massachusetts Avenue
Cambridge, MA 02139
Tel: 617•492•2116
Fax: 617•492•8242

Graphics and Layout by: ***Christine Redding***

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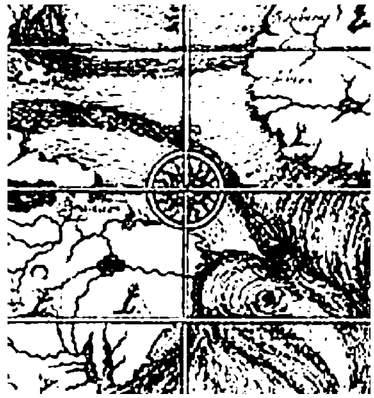

Introduction

At the conclusion of a recent workshop on commercial space and military information dominance, a senior military officer interjected that the situation, "...sounds almost like a speeding train without an engineer. Nobody knows where the heck it is going, but there sure is a lot of movement." Unfortunately, that comment fairly accurately describes the situation. The commercialization of space and the speed with which it is occurring are outpacing the intellectual understanding of the implications of this "movement" on future U.S. military operations.

Undoubtedly, it will require time for the ramifications of commercial domination of space to be understood by the U.S. policymaking community and for the subsequent consensus to develop as to how to respond to this new reality. In an effort to facilitate "movement" toward developing a better understanding of the issue and a consensus on needed action, this report will: review commercial space trends, examine the implications of those trends with regard to the U.S. military's intent to dominate information during future crisis situations, and identify areas requiring U.S. policy or technological action.

It should be noted that this report is the second in a series of mini-studies that are aimed at systematically examining military space issues. The first report, entitled *Future Challenges to U.S. Space Systems*, June 1998, focused on the vulnerabilities of space assets and the various methods that are expected to be employed to deny the United States or other space powers access to space assets or to destroy space capabilities.[1] This second report shifts the focus to the benefits and vulnerabilities that will accompany commercial space activity–in short, the good news and the bad news of commercial space development.

Assumptions

Obviously, when projecting the future, some assumptions must be used. It was assumed that:

- **The economic factors used to project the development of space are generally correct.** This means that the ongoing plans to commercialize space continue and that the current economic slow down in Asia reverses itself during the next couple of years and does not trigger some unforeseen catastrophe, such as a global economic depression. Obviously, the commercialization of space will require a substantial investment. A significant proportion of this capital is tied to Asia.

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1 Institute for Foreign Policy Analysis, Future Challenges to U.S. Space Systems, June 1998.

- **The United States continues movement toward military exploitation of space with its accompanying increase in dependency on space products for terrestrial combat operations.** Space provides tremendous advantages in terms of command, control, and communications (C^3); navigation; weather; signal intelligence; and imagery. These advantages are of such significance that space development will continue despite the vulnerabilities that such dependency will create.

- **In the future, new actors will attempt to create their own space-based networks or exploit commercial space assets as they become available.** There are reports of space programs in other states that are working to create their own versions of space navigation and intelligence collection constellations. They will also undoubtedly attempt to gain the advantages available to the major powers by exploiting commercial space applications.

Background

During the Cold War, space was a strategic asset which supported the national command authority. It provided strategic communications, strategic missile warning, nuclear targeting information, indicators of size of military force structures and equipment development activities, and a means of verifying arms control agreement compliance. Military tactical commanders did not expect nor plan to receive support from space-based assets. Space was not seen as being available or responsive to tactical military needs.[2] As a result, the military was organized and equipped to conduct its own tactical reconnaissance to "see the battlefield." Unfortunately, tactical assets had range limitations which restricted the ability of operational commanders to gain a high degree of transparency regarding enemy activity.

Desert Storm was the first time space assets were used to support tactical operations. Many of the space products supplied were provided on an ad hoc basis. Commercial global positioning system (GPS) receivers were provided to troops, often by family members who purchased them from local stores or mail-order houses. Space imagery was, for the first time, provided to maneuver control headquarters where commanders had to learn under field conditions how to handle the product. As Iraq began its *Scud* missile attacks, space assets provided warning of missile launches.

As the military absorbed the lessons of *Desert Storm* and the benefits of space, military planners wholeheartedly embraced the goal of integrating space capabilities into future

2 Institute for Foreign Policy Analysis, *Experts Workshop on Commercial Space & Military Information Dominance,* Russell Senate Office Building, April 29, 1998. The information was contributed by a senior military official on a nonattribution basis.

force development and employment concepts and plans. Today, the use of space products has become routine in tactical military operations. The roadmap to the future envisions an even greater dependency on space-based assets.

Joint Vision 2010, the military's roadmap to the future, is based on the fundamental premise that the operational commander will continue to enjoy information superiority which will enable U.S. military forces to control the course and outcome of any military engagement.[3] Moreover, most military planners do not envision that future adversaries will ever again allow the United States the luxury of building up force structure and developing plans for six months prior to implementing ground combat operations, as was the case in *Desert Storm*. It is anticipated that future military operations often will be planned and coordinated while en route to the theater of operations. This coordination will require maps, intelligence data and pictures, and communication hookups (on the fly), which can only be provided if the U.S. military commands have direct access to space assets.

Commercial space assets will be part of the solution. Even today, over one half of the military's communications are carried by commercial assets. Commercial assets also provided significant portions of the military requirements for *Operation Desert Storm*.[4] What is worrisome to many planners is the likely effect that the commercialization of space will have on other national capabilities to pursue informational dominance of the battlefield. Forty-six countries have national space programs,[5] several of which also support major military space efforts. For example, the United States, Russia, France, Japan, China, India, and Israel have all established protected military command and control facilities to track international space activity. These facilities are all similar to the U.S. facility in Cheyenne Mountain, Colorado Springs, CO (See Figure 1).[6] It seems likely that the number of nations with military space efforts will increase as commercial space development makes it easier to exploit space.

Commercial Space Trends

With the end of the Cold War, military budgets dropped and much aerospace capacity became excess to the needs of the defense-industrial complex. This surplus capacity created political pressures to change U.S. policy toward

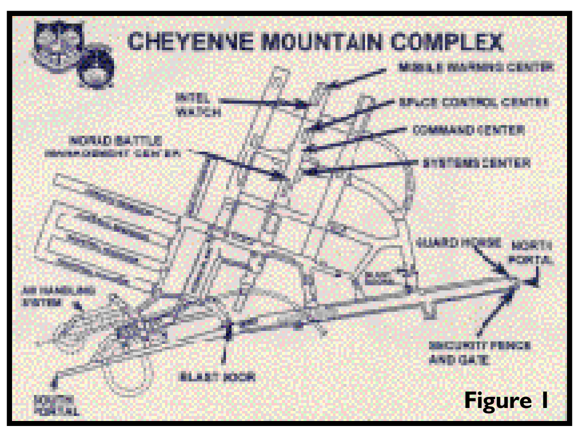

Figure 1

3 Conversation with Thomas Behling, National Reconnaissance Office, October 1997.
4 Institute for Foreign Policy Analysis, *Experts Workshop on Commercial Space & Military Information Dominance*, Russell Senate Office Building, April 29, 1998. The information was contributed by a senior military official on a nonattribution basis.
5 General Howell M. Estes III, *Testimony, U.S. Senate Strategic Forces Subcommittee*, SASC, March 11, 1997.
6 John Joss, "Space Command and Control in the Coming Millennium," *Launchspace*, April 1998, p. 27.

space so as to better utilize the idle infrastructure and expertise. Consequently, a strong argument was made that the United States no longer had a requirement to control space as closely as it had in the past. The aerospace companies agitated for a change in U.S. policy, and President Clinton issued PDD-23 on March 10, 1994. PDD-23 opened the way for the commercialization of space. In essence, the commercialization of space is part of the post-Cold War peace dividend.

In the intervening four years, commercial space activity has blossomed at an astounding rate. Many new companies have been formed, thousands of jobs have been created, billions of dollars of private investment funding have been generated, and the space sector has been growing at a compounded rate of 15-20 percent per year, a rate that is expected to continue for some time to come.[7] In 1996, global space revenue amounted to $77 billion; the sector employed 835,900 people worldwide. This was also the first year in which commercial revenue exceeded government revenue by a 53 to 47 percent margin.[8] Space revenue is growing rapidly; $85 billion is being generated in 1998.[9] It is projected to reach $121 billion by the year 2000. Between 1996 and 2000, the world will spend a half-trillion dollars on space.[10]

In the ten-year period between 1998-2007, a projected 1700 satellites will be launched into space. Of that number, 1200-1300 of the systems will be commercial assets.[11] This activity represents a huge investment, especially when one considers the cost of satellites and satellite launch services and realizes that 1700 satellites, over a ten-year period, averages 170 satellites per year–over 14 per month. Although most of the commercial satellite projects are telecommunication systems, at least 37 commercial imaging satellites are expected to be in orbit by 2008.[12]

Over the next 10 years, *1700 satellites will be launched; 1200-1300 will be commercial, to include 37 imaging systems*

On the other side of the ledger, commercial satellites usually provide a huge return on an investment. For example, a telecommunication satellite that Loral put into orbit in 1980 generated 16 times its cost in revenue *during each year of operation*. It is anticipated that the planned international investment of $76 billion in new commercial satellites will generate $77 billion in revenue *each year* (satellites can operate 5-15 years, but many die young).[13] The new focus on commercial earnings is creating a cultural shift within the space industry.

7 At the 1998 National Space Symposium in Colorado Springs, CO, April 8-10, 1998, speaker after speaker expressed their amazement at the rate of growth in commercial space development. The pace has surprised even those who were most optimistic in the past over the prospects for commercial space development.

8 Larry W. Janski, "The Global Relevance Of Space: Civil, Commercial, and Military," *1998 National Space Symposium*, Colorado Springs, CO, April 8, 1998.

9 Janski, *op cit.*; and "Lieberman Calls On Military To Review Treaties, Develop Space Policy," *Inside Washington*, March 2, 1998.

10 Institute for Foreign Policy Analysis, *Select Workshop on Future U.S. Military Space Requirements: Exploring the Policy and Technological Ramifications*, Dirksen Senate Office Building, October 22, 1997. Information was provided by a senior military officer under conditions of nonattribution.

11 Robert Berry and Donald L. Croner, "The Global Relevance Of Space: Civil, Commercial, and Military," *1998 National Space Symposium*, Colorado Springs, CO, April 8-9, 1998.

12 Col. James G. Clark, "The Global Relevance Of Space: Civil, Commercial, and Military," *1998 National Space Symposium*, Colorado Springs, CO, April 8, 1998.

13 Berry, *op cit*. Other sources claim private investment in space will amount to $80 billion during the next few years. See Sandra I. Erwin, "Pentagon Investments in Space Guided by Commercial Options," *National Defense*, April 1998, p. 22.

Previously, the industrial focus was on national security under conditions of great uncertainty with regard to cost and risk. With the shift to a commercial focus, the emphasis is now on predicting time of development, understanding and controlling costs, and being able to calculate the return on investment.[14] This focus places a premium on minimizing risks (as is evidenced by U.S. corporate assistance to the Chinese launch industry).

One of the more interesting aspects of the commercialization of space is the realization that most of the revenue created is generated by the production and sale of ground-based equipment that uses space products. Although the estimates vary, 50-80 percent of the economic benefit that will be created by commercial space activity will come as a result of the development of services and equipment that apply space assets to human endeavor.[15]

For example, locator beacons that when activated by coded transmissions broadcast their GPS-determined location are being embedded in expensive cars to help police find the vehicle if stolen. Similar applications are being made to freight shipments to facilitate tracking. Mobile communication handsets provide another example. In essence, commercial space firms believe that space development will very rapidly become a key economic factor in American life. The amount of employment and earnings that will be created by space-related activity will be enormous. Space is the new *El Dorado*.

One of the primary obstacles to mining the gold of space is the very high cost of getting payloads into space. Consequently, one of the major space-related efforts now ongoing is the search for more efficient ways of getting beyond the earth's atmosphere. As space commercializes, this effort is becoming more intense. Research organizations and industrial firms from around the globe are examining new concepts and new technologies which when perfected will result in a dramatic decrease in the cost of space access. As a side note, success in this endeavor has significant implications for U.S. missile defense requirements.

Xenon Ion Propulsion

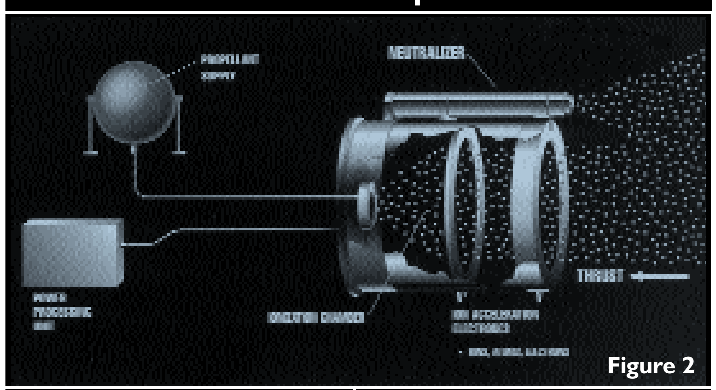

Figure 2

HS 601HP Thruster:
13 centimeters in diameter
2568 seconds I_{sp}
18 mN of thrust

HS 702 Thruster:
25 centimeters in diameter
3800 seconds I_{sp}
165 mN of thrust

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14 Ibid.

15 The 50-80 percent figure cited was the range discussed by the various presenters at the 1998 National Space Symposium in Colorado Springs, CO, April 8-10, 1998.

A related problem is reducing the launch weight of satellite systems and increasing their life on station. One of the technological breakthroughs that is expected to contribute to these objectives is the development of ion propulsion systems which are ten times more efficient than are the current thruster systems used to maintain satellite orbits (See Figure 2). Technological developments of this type, along with the development of new fabrication materials, will reduce the launch weight of space payloads since satellites will require less on board fuel, thus reducing weight while still increasing satellite longevity.

Communication satellites. The vast majority of commercial satellites are communication systems. In an information era, communication networks provide the economic heart and arteries of the international system. Although the developed world is creating networks of fiber-optic cable supplemented by mobile communications, the developing world is still largely unwired. As factories and technology spread around the globe, satellite capabilities provide the connectivity needed to function in an international economy. Even within developed countries, terrestrial cellular telephones will not be accessible in many parts of their territory. For example, as much as one half of Japan and 60 percent of U.S. territory will not have access to terrestrial cellular services.[16] At the same time, demand for telephone services is expanding rapidly. Studies show worldwide telephone use in 1996 totaled five-trillion minutes, three percent of which were wireless. By 2001, telephone use is projected to climb to eight-trillion minutes, ten percent of which will be wireless.[17]

Most communication satellites operate in geostationary orbits at altitudes above 22,000 miles. Many of these satellites provide long-haul relay capabilities that connect local and national terrestrial networks. Other services, such as broadcast capabilities for television and radio networks, are also provided by these assets. As of May 1997, about 172 satellites were in this orbit. This number is projected to increase to 250 by the year 2000.[18] These systems operate at such great distances from earth that special antennas are required to communicate with these networks (See Figure 3).

NOAA Satellite Tracking Antennas
at Gilmore Creek, AK

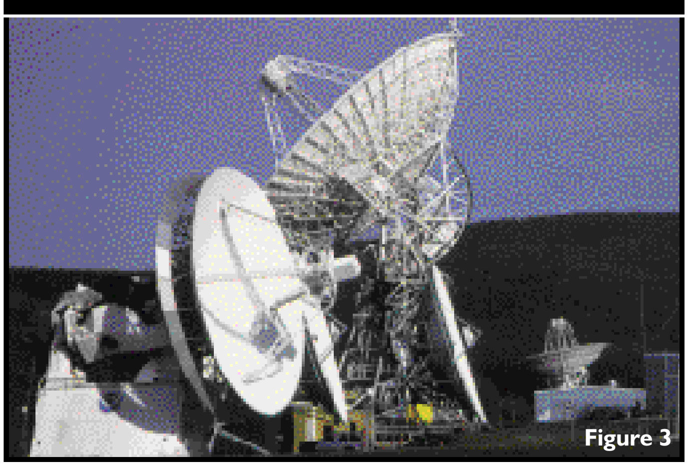


Figure 3

16 Milan Ruzicka, "The Race To LEO," *Launch Space Magazine*, August/September 1997, p. 32.
17 Ibid.
18 Cynthia Boeke and Robustiano Fernandez, "Via Satellite's Global Satellite Survey, 1997," *Via Satellite*, July 1997, p. 32.

In a move to make cellular communications available on a global basis, a number of satellite ventures have been launched to establish communication satellite constellations in low earth orbit (LEO). By operating within roughly 1000 kilometers of earth, less power is required to establish a connection with these satellites, thus making them well suited for low power transmissions, such as those produced by cellular phones. The LEO satellite communication projects include:

- *Iridium*, with representation from 17 nations, has established a constellation of 66 satellites (See Figure 4)
- *Odyssey*, a TRW and Canadian Teleglobe partnership, is working on a constellation of 12 satellites.
- *Globalstar*, a 48-satellite constellation.
- *Orbcomm*, an Orbital Sciences project, is planning a 36-satellite grouping.
- *Starsys*, a GE Americom project, will add a 24-satellite system.
- The British are building the 12-satellite *ICO* system.
- The Russians are putting up a 12-satellite constellation called *Gonets*.

Iridium
A Constellation of 66 Satellites

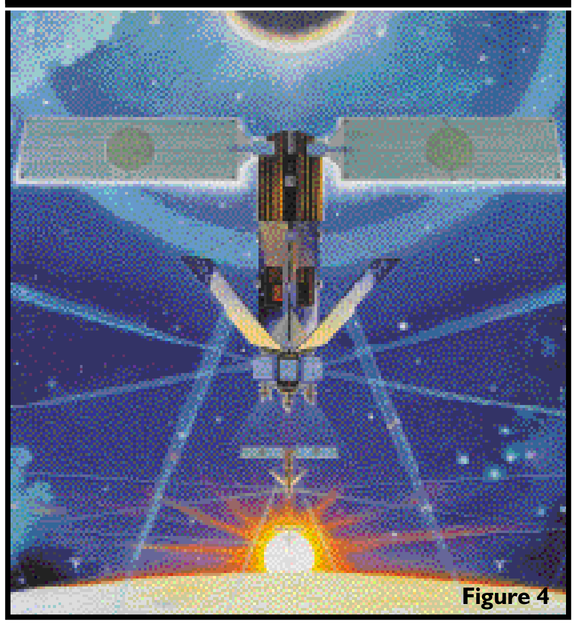


Figure 4

Other networks are also being established to offer high-speed data and video transmissions which will operate at speeds thousands of times faster than today's modems. It is projected that there will be a $600 billion market for this type of capability by 2010. The two largest constellations planned are:

- *Teledesic*, 288 satellites in LEO, is being developed by Bill Gates and Craig McCaw. Motorola became the prime contractor as a result of a merger in which the former *Celestic* project was absorbed by *Teledesic*.
- *Alcatel*, which will network 64 French satellites in LEO with Loral's three geosynchronous *CyberStar* satellites[19]

[19] All information on plans for LEO systems was extracted from Ruzicka, *op cit*.

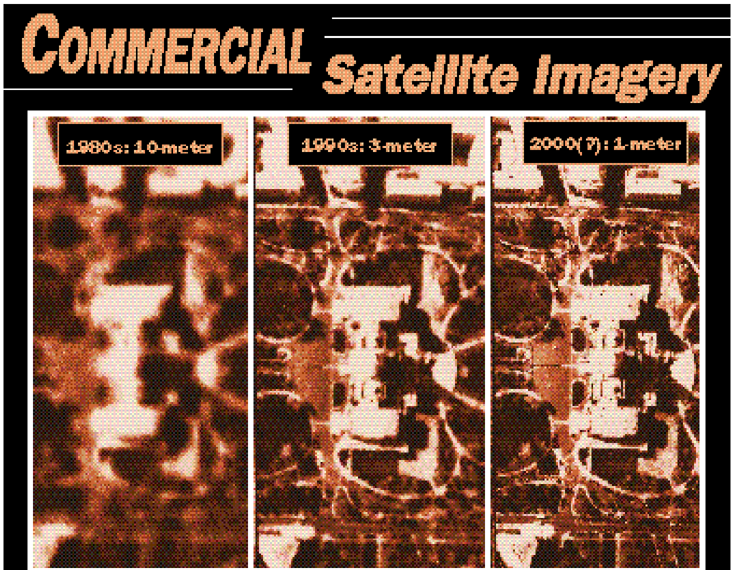


Figure 5

Some analysts predict that many of these constellations will eventually become accessible through common access standards, providing a service which will be transparent to the user. In essence, it will work similar to today's long-distance carrier service in the United States, in which the phone is dialed, and various carriers such as AT&T, MCI, Sprint, and others handle the long-distance transaction, regardless of what network the called party uses, and somehow everyone gets paid.[20] With the amount of assets that are projected to be in space, how will the United States go about insuring that adversarial militaries are unable to use these communication systems during periods of hostility? It will be like looking for a needle in the Internet haystack.

Imaging issues. High-resolution imagery has long been one of the principle tools of the major powers to collect intelligence information. Consequently, the pending launches of commercial satellites capable of producing imagery with a resolution of .8 meters (the so-called one-meter resolution) generates concern in the national security community. As can be seen in Figure 5, one-meter resolution provides sufficient detail to permit tactical targeting, based on the space imagery provided. Once the commercial imagery industry matures, of even greater concern is the speed with which its products are likely to be distributed to the user.

Although imaging satellites are often thought of as being optical systems, there is a second class of remote sensing satellites which rely on radar to view objects of interest. Radar satellites have less resolution than optical systems but have an advantage in being able to "see" through cloud cover and darkness, environments that severely limit the capability of optical systems. Currently, there are a few commercial radar satellites in operation. For example, Canada operates a 10-meter resolution radar satellite; (See Figure 6) it is planning to orbit higher resolution radar satellites in the future. Although the United States wants to limit commercial radar satellites to a resolution of about 4 or 5 meters, Canada plans to orbit a 3-meter system in 2001.[21]

20 Institute for Foreign Policy Analysis, *Experts Workshop on Commercial Space & Military Information Dominance*, Russell Senate Office Building, April 29, 1998. The information was contributed by a senior participant on a nonattribution basis.
21 Conversation with David G. Weincek, April 1998.

Altogether, about a dozen companies are developing commercial imaging satellites (See Figure 7 on next page). Although many in the U.S. policy community are calling for export controls and limits on one-meter satellite imagery, the fact is that the United States does not have a monopoly on this technology. For example, Germany has developed a one-meter capability which India wants to buy.[22] Germany is not interested in foregoing the export potential of this technology, especially when U.S. firms soon will be selling one-meter imagery. It should be noted that even without the German imagery system, India will be orbiting indigenous 2.5-meter imaging satellites around the year 2000.[23] In short, the U.S. may be able to delay proliferation of high-resolution imagery for a year or two (if it chooses to do so), but the roadmap is clear–high-resolution commercial imagery will become common within the next few years.

Even today, high-resolution imagery of an historical nature is being made available on the web. On June 24, 1998, Microsoft initiated its Terra Server database which contains the world's largest on-line imagery atlas at resolutions of one- and two-meters. The imagery was taken by Russian spy satellites between 1989-1994. It will be available for less than $10 dollars per image.[24] Within the next 12-18 months, at least three providers of current one-meter imagery should be in operation.

The United States is in the process of developing licensing regulations for imagery satellites.[25] Although the proposed regulations have not been finalized, it is clear that the United States is seeking the ability to shut off imagery flow to potential adversaries during crisis situations. During hostilities, if foreign satellite operators fail to cooperate with United States request to control imagery data, then the United States reportedly is prepared to act to end the capability of their satellites to operate.[26] The U.S. government's proposed licensing regulations are also structured to prevent sensitive U.S. technologies from falling into foreign hands. Many analysts suspect that, even with safeguards, some imagery and

Canadian Radarsat
10 Meter Resolution

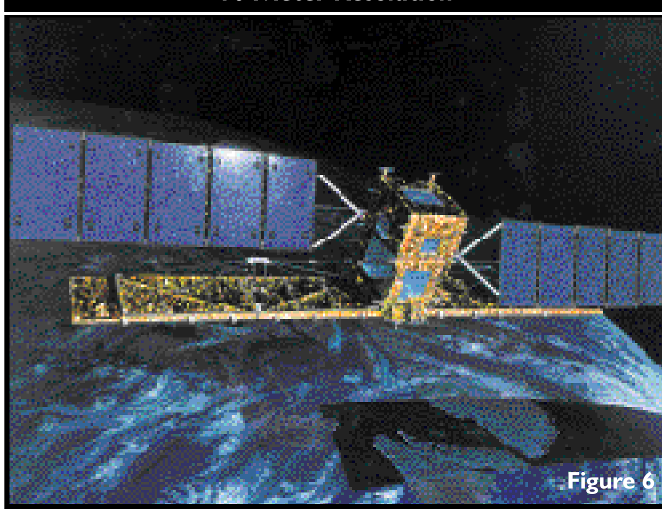


Figure 6

22 Institute for Foreign Policy Analysis, Experts Workshop on Commercial Space & Military Information Dominance, Russell Senate Office Building, April 29, 1998. The information was contributed by a senior participant on a nonattribution basis.
23 "In Orbit," Aviation Week & Space Technology, October 13, 1997, p. 17.
24 The system will allow downloading of data files or will process request for photos by sending the data files to Kodak which will produce prints within 48 hours. Details at www.TerraServer.com
25 Kim Alvarez, "Workshop On Assessing The Security Implications Of Commercial Observation Satellites," Space Policy Institute, George Washington University, May 8, 1998.
26 Ibid.

Figure 7

EXISTING OR PLANNED SATELLITE SYSTEMS OF 10M OR BETTER RESOLUTION

SYSTEM	STATUS	RESOLUTION	SWATH WIDTH	DATA SOURCES	OPERATOR	SPECTRAL BANDS	SENSOR(S)	WWW	REVISIT TIME
EarlyBird	Lost 12/97	Pan=3m MS=15m	Pan=36km MS=925km	EarthWatch	EarthWatch	Pan, G, R, NIR	Pan, MS	www.digital globe.com	2 to 5 days depending on latitude
QuickBird	Expected 1999	Pan=1m MS=4m	Pan=22km MS=22km	EarthWatch	EarthWatch	Pan, MS, NIR	Pan, MS	www.digital globe.com	1 to 4 days depending on latitude
IKONOS-1 & IKONOS-2	Expected mid- to late 1998	Pan=1m MS=4m	11km	Space Imaging	Space Imaging	Pan, VNIR	Pan, MS	www.space imaging.com	Every 3-5 days from a different angle; 140 days for the same path in the same orbit
IRIS-1C/1D	Operational	Pan=5.8m MS 3=23.5m, 70.5m, 188m	LISS=141km Pan=70km WiFS=774km	Space Imaging (in U.S.)	Indian Remote Sensing Agency	LISS 3, WiFS, Pan	LISS 3, (Linear Imaging Self Scanner) & Pan & WiFS (Wide Field Sensor)	www.space imaging.com	24 days
OrbView-3	Expected 1999	Pan=1 & 2m MS=4m HS=8m	Pan=8km MS=8km HS=5km	OrbImage	OrbImage, Inc	Pan, MS,	Pan, MS, HS	www. orbimage.com	Less than 3 days
RADARSAT	Operational	Microwave: 8-100m	50-500km	Space Imaging (in U.S.)	Canadian Space Agency (CSA)	C Band	Synthetic Aperture Radar (SAR)	www.space imaging.com	24 days
Resource 21	Expected 1999	10-20m cirrus 100+m	205km x 4000km	Boeing Resource 21	Resource 21	MS	MS	www. boeing.com	Twice in 25min per day at equator; twice weekly with nadir view
Resurs	Operational	MS=2m, 10m	180km, 200km	U.S. Spin-2	Sovinform-sputnik	Pan, digitized photographs	KVR-1000 Camera	www.spin-2.com	16--17 days
SPOT 4	Operational	Pan=10m MS=20m Veg=1km	60km, 2250km	SPOT Image	CNES & SPOT Image	MS, VNIR, Pan, side-looking	2 HRVs (Haute Resolution Visible)	www.spot.com	26 days

Pan = panchromatic; MS = multispectral; NIR = near infrared; VNIR = visible near infrared; HS = hyperspectral; Veg = Vegetation

Source: Space Policy Institute, George Washington University imagery technology will covertly circumvent the control regimes. The new capabilities that are emerging or projected to emerge are generating much uncertainty as to what new vulnerabilities will be created for U.S. military operations based on the availability of commercial imagery.

Understanding the workings of satellite imagery. Circling the globe about once every 90 minutes, imagery satellites fly the polar orbits. Since the world is turning as these platforms circle from north to south and back to the north, the tracks over the globe curve as the world spins under each orbit (See Figure 8). Satellites normally revisit the same spot, looking straight down, every 18-26 days. By using side views, a satellite can revisit the same spot in 1-2 days. The width of the swath that is imaged depends on the ground tasking to the satellite. Satellites can image broad areas at relatively low resolutions or sharpen the focus to examine a narrow swath in great detail. This relationship is similar to road atlas maps: one page shows the interstate network for the entire U.S.; another page may show the streets of a major city. However, if a satellite is to acquire a high-resolution image of a particular area of interest, it needs precise instructions prior to orbiting that spot. Metaphorically, if there is a demand for a street map of Detroit, the satellite must be instructed in advance to focus on that city or else the product produced will be a map of Michigan.

Radarsat One-Day Coverage

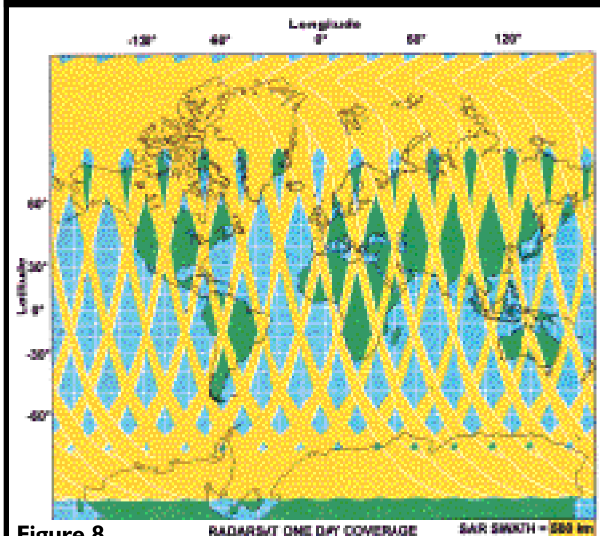
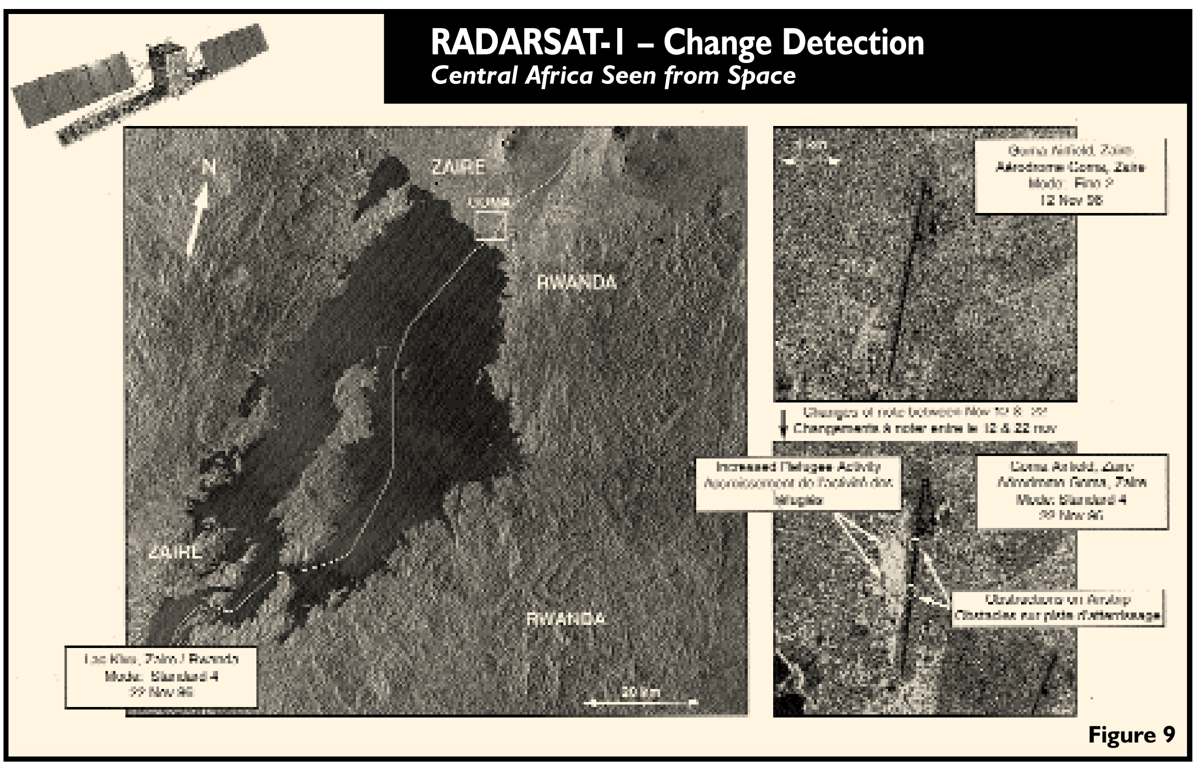


Figure 8

With prior planning, some extremely high-resolution imagery can be developed using computer enhancement techniques, which may include stereoscopic images of the target area. Stereoscopic imagery requires that at least two views of the target area be acquired. These images will be computer processed into a single composite image that has a 3-D appearance. By viewing the target area from two positions, the image will reflect depth much as human eyes, working as a pair, can distinguish depth. A satellite can swivel its optics and take two frames of the same site along its flight path; or, alternatively, it can swivel sideways, make a frame, and on the next orbit, make a second frame of the same site looking straight down. Obviously, processing stereoscopic imagery is not an operation for amateurs.

In the commercial world, there are a number of anticipated uses for commercial space imagery. Some of the envisioned uses will undoubtedly cut into the aerial photography market, which is currently estimated to be a $3 billion-a-year enterprise,[27] but commercial space imagery ventures also expect to encourage the development of some totally new markets. For example, multispectral imagery is expected to provide geologists with a new analytical tool which can be employed to help discover new natural resource deposits of such commodities as oil, gold, and coal.[28] Radar imaging satellites will map areas of the world that are usually covered by clouds. This capability should prove particularly useful in the 20 degree equatorial belt, from 10 degrees North to 10 degrees South, an area which is called the cloud belt. There are border disputes around the world in this zone, the intensity of which is often compounded because of inaccurate mapping. For instance, a major contributing factor to the ongoing dispute between Ecuador and Peru stems from the lack of detailed maps of their border regions, an area continually covered by clouds.[29]

Non-governmental organizations (NGO) are also likely customers for satellite imaging products. Monitoring rain forest deforestation rates, unusual fires in places like Indonesia, endangered species' habitats, and cases of mass migration of refugees are all examples of issues in which commercial space products can



RADARSAT-1 – Change Detection
Central Africa Seen from Space

Figure 9

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27 Kevin O'Connell, "Workshop On Assessing The Security Implications Of Commercial Observation Satellites," *Space Policy Institute*, George Washington University, May 8, 1998.
28 Gilbert Rye, "The Global Relevance Of Space: Civil, Commercial, and Military," *1998 National Space Symposium*, Colorado Springs, CO, April 8, 1998.
29 Bill Stein; and John Weikel, "Workshop On Assessing The Security Implications Of Commercial Observation Satellites," *Space Policy Institute, George Washington University*, May 8, 1998.

provide powerful tools to improve the effectiveness of intervention efforts. Other potential customers include United Nation operations or coalition operations in which the participants elect to share situation information through the use of commercial products rather than revealing the capabilities of their respective national imaging systems. Figure 9 shows refugee activity in Zaire in 1996.

It is anticipated that many of these organizations initially will have difficulties interpreting the imagery products they procure. It requires a considerable level of expertise to analyze aerial or space imagery. As a result, a number of analysts expect the market for space imagery to develop more slowly than is being projected by the corporations that are developing commercial imaging satellites. Consequently, it is feared that of the dozen or so space imaging projects on the drawing boards, some will survive, but many may fail.

Navigation satellites. The United States' global positioning system (GPS) satellites have been extremely successful in spawning terrestrial economic activities as new ways have been invented to apply GPS capabilities. As a security measure, the new GPS IIF system will be equipped with a capability to block the unencumbered signal (the signal not encoded) on a regional basis if hostilities should occur. It will also be resistant to hostile jamming operations (See Figure 10). This means that future U.S. forces could have access to the encrypted GPS signal, while adversaries would not. Unfortunately, a number of countries have developed or have announced plans to develop their own versions of GPS. Russia developed GLONASS, a 24-satellite constellation that mirrors GPS. Economic difficulties, however, have taken a toll on the Russian system–not all of its satellites are now working. China is planning to develop its own navigational satellite system, although it will not be as robust as the GPS system. France has publicly discussed plans to field its own version of a satellite navigation system to insure that the U.S. system does not establish a monopoly on satellite navigation.

New GPS System: GPS IIF

(Allows selective denial of signal to regions)

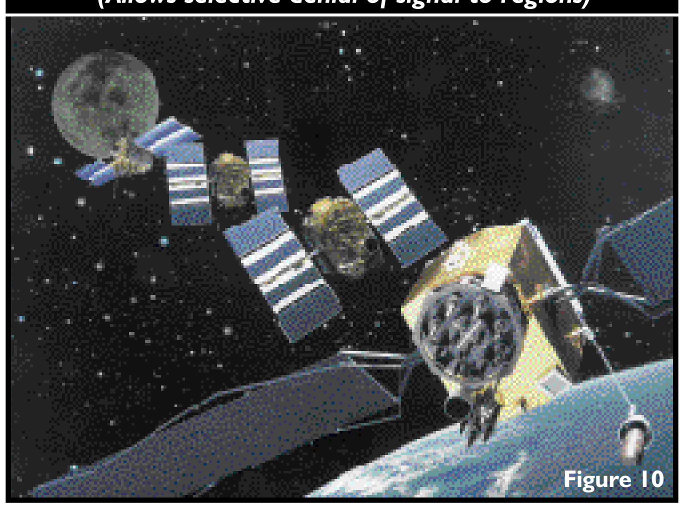

Figure 10

Moreover, because so many commercial companies are dependent on GPS systems, it would not be easy for the United States to restrict the unencumbered signal except in case of dire national emergency. Aircraft and ship navigation, tracking of shipments of parts and components (which might be required by the military), timing mechanisms for cellular phone network operations, fiber-optic cable transmission systems, etc. are all examples of functions that are increasingly dependent on GPS availability. Furthermore, if the announced plans of other nations come to fruition, the United States may no longer have a monopoly on satellite navigational systems.

Military Implications

For the U.S. military, the evolution of commercial space in conjunction with the rapid advances being made in processing technology and information warfare creates a great deal of uncertainty. The uncertainties created include:

- **What priority will the military have on access to commercial space systems? In short, will the capability be there when it is needed?** Commercial systems are being financed and built based on projected commercial revenue. In many cases, the financing is being provided by international groups that do not have any allegiance to the United States. The international corporations establishing the projects are contracting for the delivery of specific blocks of capability to users, such as CNN. These contracts represent legal liabilities. Failure to deliver the specified service leaves the provider subject to lawsuit. Some fear that during an evolving crisis which has not yet resulted in conflict, the military may not be able to gain access to commercial systems in a timely manner.

- **Will the data downloaded from commercial imaging satellites be accurate?** In the entertainment industry, computer simulation capabilities have been developing rapidly. One routinely sees people surfing in wheat fields, Forest Gump meeting the President, and prehistoric animals in Jurassic Park. It is projected that the capability will exist in the not too distant future to tamper with satellite imagery on a near-real-time basis. How can the military be certain that the commercial satellite data provided is "not a setup" that could mislead military commanders with regard to the enemy and friendly situation?

- **Which of the commercial firms in competition will provide the best service to the military?** Not all of the firms currently in the race are expected to survive. A premature commitment to one system over another could result in the military committing a lot of resources to a losing system. In short, no one in the military wants to choose the Beta video recording system and then find that the VHS system is the only one that survives.

- **When should the military make a commitment to a commercial system?** The military attitude has been, "First you build it, then we will come." The commercial attitude has been, "If you're not there in the beginning, don't come." The commercial firms are working for a stable and predictable source of income. If the military does not make its requirements known when the system is being designed then the commercial firms are not building the capability into the system to accommodate the military.[30]

- **If the military fails to use and support the commercial systems, could it find itself facing an adversary in the future who is using a superior commercial information service?** Government systems traditionally have been slower to develop and are kept in service longer than commercial systems. If the military remains exclusively tied to government-owned systems, will it be able to maintain informational dominance on the battlefield?

- **With hundreds of satellites carrying commercial communications, can the military realistically expect to deny such assets to an adversary?** Control of space is a key objective of stated U.S. policy; however, there are serious questions regarding an implementation strategy. Until the implementation question can be answered satisfactorily, the United States military cannot be assured of information dominance.

In assessing these questions, some extenuating factors must be taken into consideration. Commercial satellites are not particularly hardened against the effects of radiation or high energy microwaves. A 50-kiloton nuclear explosion in low earth orbit will not only destroy the satellites in the vicinity of the burst but will also increase the natural levels of radiation to the point where all unhardened satellites in LEO will cease to function within one to two months of the explosion.[31]

Space Radiation Hardened
DC-DC Converter Series 6200

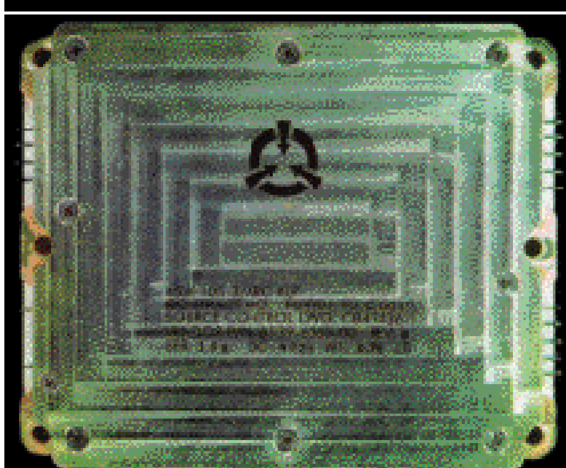

Figure 11

Although most key U.S. government satellites are composed of components that are hardened against radiation effects, hardening can add millions of dollars to a satellite's cost (even though it is only 1-5 percent of production cost).[32] Consequently, commercial satellite makers have made costs versus

30 Erwin, *op cit*.
31 R.C. Webb, "The Effects of A Nuclear Detonation in Space," Defense Special Weapons Agency Briefing, May 13, 1998.
32 For additional insight into hardening issues, see Mark Walsh, "DoD Tries to Boost Nuke-Resistant Chip Industry," Defense News, May 26-June 1, 1997, pp. 1, 29.

Advanced Focal Plane Technology
On-chip spectral filtering

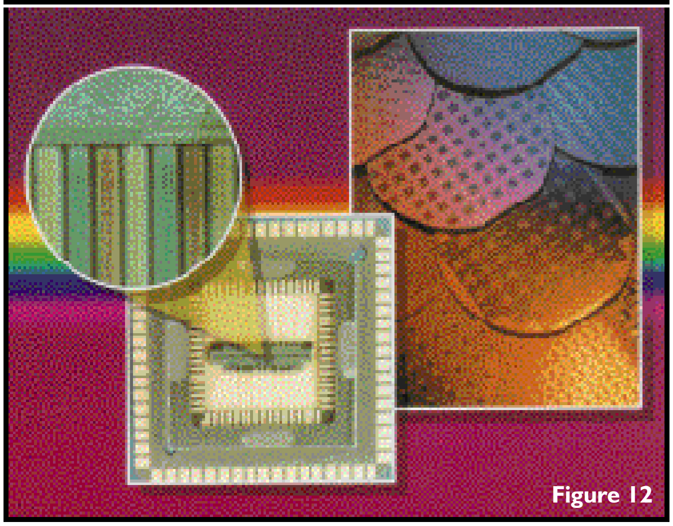

Figure 12

risk assessments and made decisions to forego radiation effects hardening (See Figure 11).

Considering the fragility of commercial space assets, how dependent on commercial systems should the United States military become? Yet, without the availability of augmenting commercial space assets, can the U.S. military realistically expect to develop a sufficiently large array of space assets to permit continuous communication and imagery support of the battlefield? Information dominance is dependent on access to vast quantities of communication, and battlefield information assets possessing sufficient artificial intelligence so that the user is not overwhelmed with raw information. When this requirement is juxtaposed against the earlier explanations of satellite orbits and revisit limitations, it becomes obvious that the information dominance objective envisioned in *Joint Vision 2010* will require more space assets than are likely to be owned by the U.S. government, especially in light of recent budget trends.

At the same time, some of the commercial imaging assets will provide some very advanced and helpful capabilities. The past focus of U.S. government imaging efforts has been black and white products. A number of commercial imaging systems will be equipped with cutting-edge multispectral imaging technology. Multispectral has the potential to provide the military with much more insight into battlefield situations than has been the case in the past. However, multispectral imaging will present a new challenge that will have to be mastered by military image interpreters (See Figure 12).

Clearly, information dominance will require U.S. military access to a combination of dedicated government assets and dependable commercial assets. Since space assets are difficult to master, then information dominance will require that the U.S. military develop the control mechanisms needed to increase the agility of ground-space interaction. This means control systems capable of quickly tasking satellites for specific imagery, to include stereoscopic, and delivering those products with such speed that an adversary cannot react in time to counter the advantage gained.

To insure that selected commercial satellite assets are available and survivable, the military must begin to make some judgments regarding which commercial assets can best support U.S. military operations and also have a high likelihood of being commercially successful (i.e., survivable as a business endeavor). Arrangements need to be initiated early to insure that these commercial assets will be able to handle the military's requirements during future conflict situations. Some of these assets must also be hardened against radiation effects.

The irony of the United States space control policy is that if it is successful, an adversary will have nothing to lose by destroying all commercial assets in LEO. In such a case, doing so would negatively affect the United States more than it would hinder any other nation. Although regional states could probably interdict a limited number of space assets using direct-ascent or co-orbital antisatellite weapon systems, jamming, laser attack and/or destruction of some ground stations, the overall effect of such actions on U.S. military capability would probably be somewhat limited considering the large number of satellites that will be in operation. This would be the classic "safety in numbers" situation.

Conversely, if an adversary anticipates that the United States will be able to control space and deny its opponents access to the advantages of space, then it would be in that country's interest to detonate a nuclear weapon in LEO prior to an anticipated conflict situation. In presentation after presentation in recent space workshops and symposia, there has been unanimity among U.S. space planners on the issue of how the United States would likely respond to such a detonation. No one believed that the United States would risk a war on earth to retaliate against the destruction of satellites in space, particularly when no loss of life was involved.

The issue of protection of space assets is likely to become increasingly important as the twenty-first century unfolds. American history shows that when commerce is severely disrupted, the commercial community applies to Congress for redress. When the Barbary pirates demanded tribute to permit commerce on the high seas to proceed unimpeded, businessmen pressed Congress for action. Likewise, most defense specialists seem to believe that space interests will eventually pressure the U.S. government for protection of space assets. The real question is how will this protection be provided.

In many ways, the current situation in space resembles the situation on the high seas in the 17th century. During that era, ships would leave port (none, of course, had radios), and many of the ships would never be heard from again. It usually was impossible to determine if they had sunk in a storm, shipwrecked on a foreign shore and been killed by hostile natives, or had been boarded and scuttled by pirates. Likewise, space assets are not equipped to report when they are under attack. Today, space assets sometimes fall silent abruptly and no one knows why. Is space debris a bigger problem than is currently understood? Are the systems malfunctioning? Or have some of them been destroyed by hostile action? If protection of space assets is a military mission, a means must be developed to report hostile actions.

Recommendations

The following recommendations are offered:

- **U.S. policy community should determine what space support it requires from commercial venders and insure that any special military requirements are designed into the commercial satellite systems prior to their construction.** The commercial space companies are not going to spend money to provide military required features without some assurance that the military will use their assets. Although the military does not necessarily need to choose space service providers in the first round of commercial space competition, it will certainly need to do so prior to the production of second generation systems.

- **Selected commercial satellite assets must be hardened against radiation effects. Since hardening will increase the cost of satellite construction by about 1-5 percent, a system for remunerating the commercial operators needs to be established.** There are two obstacles to gaining commercial cooperation in hardening satellite components. The first, as mentioned, is the extra cost of construction. Hardening can add millions of dollars to a satellite's cost. Commercial operators are not going to pay for this feature. Most analysts believe that a program such as was used to establish the civil reserve air fleet (CRAF) will be required if satellites are to be hardened. The CRAF program made commercial aircraft available to the U.S. military in times of declared national emergencies. The aircraft owners were provided some government subsidies in return for the pre-commitment of their assets. The second obstacle is a reluctance to submit satellite components to testing for radiation hardness. Radiation hardened satellite components are listed on the U.S. munitions list which means their export is controlled. Many satellite components, if tested, could end up on the U.S. munitions list thus making it more difficult for satellite manufacturers to export their product. To the producers, this is a case of "what you don't know can't hurt you." Obviously, this issue would also have to be addressed.

- **The United States needs to focus research effort on the development of extremely capable ground-to-space asset control mechanisms that will maximize the responsiveness and agility of the information dominance technologies.** Foreign nations may well circumvent U.S. space control efforts. As a result, the United States' command and control over space assets must be more efficiently organized than are those of potential adversaries.

- **The United States needs to determine how it will protect space assets. As a first step, technology needs to be developed that will provide U.S. Space Command with the space equivalent of the black box found on aircraft that records vital events and helps determine what caused a crash.** The United States has a policy of protecting its space assets. Currently, it has no means of determining if a satellite has been damaged as a result of hostile action. The United States needs to determine how space assets can realistically be protected.