NAVAL WAR COLLEGE
Newport, R.I.

THE COMMERCIAL SPACE SEGMENT AND THE NEED FOR CONTROL

By

E. S. HOFFMAN
Lieutenant Colonel, USMC

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature:____________________________

13 May 2002

REPORT DOCUMENTATION PAGE

1. Report Security Classification: UNCLASSIFIED			
2. Security Classification Authority:			
3. Declassification/Downgrading Schedule:			
4. Distribution/Availability of Report: DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.			
5. Name of Performing Organization: JOINT MILITARY OPERATIONS DEPARTMENT			
6. Office Symbol: C		**7. Address**: NAVAL WAR COLLEGE 686 CUSHING ROAD NEWPORT, RI 02841-1207	
8. Title (Include Security Classification): The Commercial Space Segment and the Need for Control (UNCLASSIFIED)			
9. Personal Authors: Lieutenant Colonel Everett Scott Hoffman USMC			
10.Type of Report: FINAL		**11. Date of Report**: 13 May 2002	
12.Page Count: 22 **12A Paper Advisor (if any):n/a**			
13.Supplementary Notation: A paper submitted to the Faculty of the NWC in partial satisfaction of the requirements of the JMO Department. The contents of this paper reflect my own personal views and are not necessarily endorsed by the NWC or the Department of the Navy.			
14. Ten key words that relate to your paper:			
15.Abstract: attached			
16.Distribution / Availability of Abstract:	**Unclassified** **X**	**Same As Rpt**	**DTIC Users**
17.Abstract Security Classification: UNCLASSIFIED			
18.Name of Responsible Individual: CHAIRMAN, JOINT MILITARY OPERATIONS DEPARTMENT			
19.Telephone: 841-6461		**20.Office Symbol:** **C**	

Security Classification of This Page Unclassified

Abstract of

THE COMMERCIAL SPACE SEGMENT AND THE NEED FOR CONTROL

With the current and projected continuance of the military's dependence upon the commercial space segment, it is imperative that the United States develops a strategy that regains the initiative and enables the attainment of an information superiority capability.

It is critical to the United States that it maintains a position of information superiority across the spectrum of military operations. The access to commercial satellite systems will be a critical but challenging element of that advantage. Success will depend upon the practice of disciplined investment in space technologies as well as alternatives to reduce the dependence upon their limited capacity. It will also require the eventual development of force applications to counter known and probable threats to all space-based systems. Change is required now. Without guaranteed access to the required capacity for bandwidth, the U.S. technological advantage will be mitigated.

Introduction

Joint Force Commanders of the late twentieth and early twenty-first centuries experience an advantage as a result of technology development and adaptation for force applications. The ability of the United States to exploit that technological advantage has been largely dependent on the military's access to the space dimension. The duration of any operational advantage will depend on the ability of the United States to deny the access of processed information through the space dimension to its adversaries while it protects its own access. This quest for information superiority in Joint Operations will also depend upon the government's ability to recognize the functional relationship of technology transfer over time and the need for disciplined investment. In the commercial space segment, the United States has rarely been able to exercise control. With the current and projected continuance of the military's dependence upon the commercial space segment, it is imperative that the United States develops a strategy that regains the initiative and enables the attainment of an information superiority capability.

Analogy of Space to Air, Land and Sea

Consider the challenges that military commanders have historically faced in order to control the dimensions of land, sea, and air. Land operations have traditionally been bound by rate of movement, employment of terrain to an advantage for both offense and defense, and access. Access to land can be constrained by weather, topography, obstacles, and approach (by sea, land, air and space). Maneuver became the primary principle of war that dictated movement to gain advantage over an adversary at the time, place and force level of a commander's choosing. Certain technologies have enabled a military force or capability to maneuver but history illustrates that it was not until the twentieth century that maneuver became a doctrinal element of the operational art. One only needs to study the First World War to realize that mankind wasted multiple generations of its populace ignoring obvious opportunities and alternatives to attritional warfare.

Sea power is another dimension that nations attempted to understand and control for centuries. Those that were successful prospered economically, diplomatically and culturally. The factors have always been access, control and employment of the sea dimension. Many nations and cultures have been able to exploit the sea for regional advantage since the Peloponnesian War but it was not until the European nations explored the sea dimension for global access to resources and trade routes that international commerce truly evolved. Colonization of lands on separate continents provided great reward to those nations that invested in capital ships and their employment as instruments of area access and denial.

Control of the sea is perhaps the most attributable reason for the rise of the United States as a global power in the twentieth century. It is an advantage the United States still maintains but it could easily be lost if the investment and re-capitalization initiatives are diminished. Regional navies of adversaries would logically gain operational advantage if the United States failed to maintain its investment in a global capability. Access to the dimension of the sea and the ability to deny the same dimension to its adversary is vital to the United States.

The evolution of airpower and its employment (again access and denial) have been even more crucial to maneuver and the empowerment of the land and sea forces. The tremendous relative advantage that the United States enjoys today is yet another slow lesson learned. Development of air doctrine in the early twentieth century was significant to the success the United States achieved in World War II but it fatally ignored opportunities to achieve a more relative advantage. The failure to fully develop the integration of strategic and operational air with the amphibious and land based operations resulted in lessons learned similar to historical failures of nations to integrate land and sea forces. The United States learned that air could enhance sea power and that "sea and land based airpower were necessary adjuncts to each other." It was stated in 1945 that the best employment of air power was through "a joint air command and control system under the authority of a single naval or air force officer." [i] Why then did this proposal from 1945 take until the 1990s to become the doctrine for a Joint Force Air Component Commander?

A common theme that emerges in the three previous dimensional comparisons are the choices a nation makes which determine when and how much to invest on force applications. These technological changes are not merely important because they reshape the opportunities for relative advantage. Investment in the development and control of technology is what is relative. Land forces were originally enabled by foot, then wheeled cart or horses, and then by motorized, amphibious or airborne platforms. Ships were originally propelled by manpower and wind, then coal and diesel, and eventually nuclear energy. Surface capabilities were eventually expanded to include subsurface and aerial capabilities. Air power has been guided in the visual mode, then by instruments and digital navigational assets, all aboard propeller driven and then jet aircraft.

Nations that invest, train and incorporate capabilities to exploit technological change will gain a relative advantage. That advantage can only be maintained through mature decisions to recognize the need to continue or discontinue investment, and the mature discipline to control the information that exploits that technology to an advantage. Some technologies can be controlled and some cannot but, generally, technology transfer is relative to time. Artillery, tanks, aircraft, radar, cryptography, and nuclear technology all bear evidence to the reality of technology transfer over time. Navigation, imagery, sensory, and communication technologies are no different and all of these are present in the dimension of space (both atmospheric and exo-atmospheric). What is common to all applications is that technology can not be exploited without access to the required operating space.

Early Space Access

Exploration of the space dimension began as a competitive search for strategic advantage between the United States and the former Soviet Union. The launch of Sputnik 1 in 1957 sparked the race for development of launch, delivery and orbital systems. The original advantage in space belonged to the nations that invested in technology development and protected that technology. History demonstrated again that technology transfer over time resulted in a lost advantage. There are far too many nations that now possess space programs with the capabilities to launch vehicles, re-enter the atmosphere and deliver regional and intercontinental weapons. Any advantage the United States maintains in space today is not due to technology but rather investment discipline.

That discipline to invest has been evident with weapons technology, missile systems and initially with reconnaissance assets. The development of the National Reconnaissance Office and government investment in the Corona program produced a tremendous advantage to the United States in information superiority for almost 40 years (1960s through 1990s). [ii] Global technology transfer and investment in delivery systems eventually rendered many of those same capabilities accessible to open market access today. With satellite communications (SATCOM), the United States invested much less and, as a result, never really experienced a relative period of advantage.

INTELSAT launched its "Early Bird" in 1965 and marked the beginning of global satellite communications. The initiative for information exchange (voice and data) in space has arguably been maintained by the commercial sector since that date. INTELSAT's initial launch enabled communications between seven countries (U.S., U.K., Germany, France, Japan, Italy, and Brazil) and by 1969 when the APOLLO 11 mission landed on the moon, the network had expanded globally (to include the Indian Ocean area) and provided global distribution which allowed television viewing to over one-half billion people. [iii] The U.S. government investment in SATCOM at that time was limited to the Defense Satellite Communication System (DSCS) program and there were only three of eight programmed satellites in orbit. DSCS would be the legacy wideband SATCOM program and the investment would never surpass nine functioning satellites. DSCS III began in 1982 with a projected life cycle of ten years. [iv] The projected worldwide global satellite program to replace DSCS III has not yet launched any satellites.

Current Situation in Space

The growth of the commercial and industrial programs in space by all countries of the world has been phenomenal over the past twelve years. There are two unique differences about the commercial assets that are currently in orbit. First is the fact that the platforms provide dual use technologies. Unlike commercial shipping or aircraft that are limited to dual-purpose functionality for transport only, satellites enable real time information access that can be employed for either civilian or military applications. Space capabilities include voice, facsimile, messaging, paging and data transfer communications as well as imagery with resolution to one-half meter. Space capabilities also include continuous tracking, navigation, meteorology, and remote sensing.

The second unique difference is that the majority of the assets are financed, owned and controlled by multinational corporations, international consortiums and private enterprise. The supply and demand function of open market economies is the governing factor and diplomatic relationships between nation states may not impact consumer relations or product limitations. The following data in Table 1 [v] illustrates the growth of the commercial space market since Operation Desert Storm.

Number of geosynchronous commercial satellites	18 Intelsat & 4 Leasat (1990)	236 commercial (2002)
# DSCS satellites	5 satellites (1990)	9 satellites (2002)
Nation states with assets on orbit	10 (1990)	33 (1999)
$ Value of space market (government) $ Value of space market (commercial)	$40 billion (1990) $40 billion (1990)	$40 billion (2002) $140 billion (2002)
Inter-regional satellite **capacity** (commercial)	40 Gigabits (GBps) (1990)	155 GBps (2001)
# countries with cellular satellite service # worldwide cellular subscribers	59 (1990) 11 million (1990)	167 (1998) 318 million (1998)

Satellite retail and leasing revenues	$16 billion (1996)	$37 billion (2000)
Naval SATCOM **capacity** standard	9.6 KBps (1991)	3000 KBps (2000)
Military SATCOM requirements for single MTW	100 Megabits (MBps) (1990)	2 GBps (2000)
Military DSCS **capacity** for global conflict	500 MBps (1990)	900 MBps (2002)
USAF ISR capacity requirements for 2 MTW	900 MBps (1997)	5600 MBps (2000)

Table 1 (KBps=1000 bits per second MBps=1,000,000 GBps=1,000,000,000)

Note the growth in the commercial satellite capacity in comparison to military satellite capacity in Table 1. Appendix A further illustrates the specific location and designator of each of the 236 commercial satellites in geosynchronous orbit in comparison to the 21 military communication satellites (United States MILSATCOM) illustrated in Appendix B. Of all the commercial satellite vendors, only six companies provide fixed satellite service to the United States government and they only control 36 of the 236 commercial satellites. [vi] The available commercial capacity would not necessarily be available for U.S. government use. If the demand for communications and intelligence access to space was focused on Iraq (specifically between zero degrees and 90 degrees East), MILSATCOM provides only five platforms with capacity in comparison to 78 available commercial platforms (does not consider number of military reconnaissance platforms).

Challenges to Information Superiority in Space

"Information Superiority is essential to our capability to meet the challenges of the 21st Century. It is a key enabler of Joint Vision 2010 and its four fundamental operational concepts of dominant maneuver, precision engagement, full dimensional protection and focused logistics." [vii] The challenges to a United States advantage in space are diverse and expectedly unconventional. There are real threats to physical security from military capabilities and there are simple but effective access issues that enable dissemination of critical information to an adversary. These challenges also include programmatic competition and denial tactics being developed by adversary nations.

Assured Access. This can either be a function of insufficient capacity or an inability to access available capacity. Either approach must address the relationship of supply (capacity) and demand. There have been numerous projections of requirements for military SATCOM capacity since Desert Storm and they all have projected deficient capacity as a shortfall. They have also illustrated a common failure to underestimate the true demand. [viii] Most of the deficient forecasts were the result of exponential growth of software applications and networking within the Department of Defense (DOD). The commercial sector has been driving the military employment of technology since the advent of the internet and the proliferation of the commercial communications industry. Technology advances have been equally as hard to predict and the shortened production cycles made the technology affordable to DOD outside the traditional acquisition programs.

The growth in demand is a key factor in the issue of access to space. The USS Nassau (LHA) deployed to the Persian Gulf in August 1990 for Desert Storm with only one networked terminal requiring connectivity to DOD (World Wide Military Command and Control System–WWMCCS terminal). An ad-hoc installation of a satellite terminal was performed in transit to enable the WWMCCS terminal connection with DOD systems in the United States. Today that same ship has no less than 377 networked computer terminals that each have an appreciably greater capacity than the WWMCCS terminal (161 of the 377 are Secure Internet Protocol Routing Network–SIPR workstations that can access JOPES screens). [ix]

Demand has also grown exponentially as a result of emerging capabilities. General Franks commands the Central Command (CENTCOM) region and conducts all the current operations from MacDill Air Force Base in Tampa, Florida (nearly 8,000 miles from the theater). He stated that "the technology available to us here allows us to do things we have never been able to do and we wouldn't necessarily have that if we moved [the headquarters] forward." [x] "Franks can sit in his chair and call up live video" from UAVs over Afghanistan and "he can pull in radar images and video from J-STARS aircraft throughout the region." [xi] There is debate whether or not this capability is a requirement but merely a redundant drain upon the capacity reserved for operational commanders in theater. What is not arguable is the fact that the availability of the information enables an advantage to General Franks in his decision cycle.

The United States Air Force requirements for capacity are a good illustration of the exploitation of technology. The employment of unmanned aerial vehicles for targeting and surveillance applications has contributed to the increase in demand for capacity. As a result of similar applications for dissemination of intelligence, surveillance and reconnaissance access, the overall satellite requirement for the Air Force grew from 900 MBps in 1997 to 5600 MBps in 2000 (reference Table 1).

CENTCOM's current operations in Southwest Asia do not equate to the level of effort reached during Desert Storm (Major Theater of War-MTW) but they far exceed the SATCOM capacity used during Desert Storm and they far exceed the projections for capacity requirements of a regional contingency. During Desert Storm, the space segment throughput for information never exceeded 100 MBps and 70% of that was satisfied by DSCS (military system). [xii] Today in CENTCOM under Operation Enduring Freedom, CENTCOM has exceeded 430 MBps over SATCOM of which only 19% is DSCS (the same 70 MBps of military capacity used in Desert Storm). [xiii] The tremendous cost of commercial SATCOM capacity (360 MBps) is now at $54 million (annual renewal cost). [xiv] This money was not programmed and, if it is not fully funded next year (assuming continuity of operations in the region), access to space will have been partially denied solely upon financial constraints.

The requirement to lease commercial capacity has been well understood. In 1997, the General Accounting Office (GAO) report to the Secretary of Defense (SECDEF) on Defense Satellite Communications estimated the 1997 global requirement for SATCOM to be one (1) GBps and projected the 2006 requirement to be 3.6 GBps. It attributed the increase in demand to be a result of the shift in military strategy that required more units be stationed in and deployed from the United States. It also attributed the increase to be a result of the increased availability of advanced satellite communication technologies and services. It recognized the deficiency in DSCS and the high cost of commercial leases but concluded that the only viable alternative to meet the requirement was increased commercial lease.

Marginal increases were made to enhance commercial capacity but the large deficiency in capacity was never programmed for investment. Part of the problem was the failure to project a more accurate demand for SATCOM. The more accurate projection during 1997 was 20 GBps (more than five times the GAO projection). [xv] The bottom line is that these studies failed to spark substantial investments for SATCOM capacity. Even more alarming is that 60% of the total military bandwidth today comes from the commercial sector and that the dependence on the commercial sector will increase to 90% by the year 2010. [xvi]

Control. The Air Force Doctrine Document for Space Operations states that "space control is the means by which space superiority is gained and maintained to assure friendly forces can use the space environment while denying its use to the enemy." [xvii] It expands the doctrine and further states that "counter-space is the mission carried out to achieve space control objectives" and it "includes offensive and defensive operations." What is not addressed in the doctrine for counter-space operations is any mention of commercial space systems. In fact, the United States Air Force Doctrine Document 2-2 does not address commercial space systems at all. "Space planners have been operating without approved [commercial] space doctrine for over a decade." [xviii] The major cause for this doctrinal impasse is that the military is uniquely constrained by United Nations policy on space that ensures "open skies and open access." [xix]

Offensive counter-space operations are doctrinally the application of military power to destroy or neutralize the adversary's space systems or capabilities. Those targets are well understood when opposing a conventional military and strategic level infrastructure. But those scenarios are hard to find today with the global access to commercial space systems. The transnational corporations and consortiums that operate and control the majority of the commercial space segment do not reside in a single country or region. Any offensive targeting of terrestrial facilities that control commercial satellites would be diplomatically unacceptable and in most cases not feasible (many commercial networks utilize redundant control stations in multiple locations). Another overwhelming challenge is that much of the access to space is employed with small mobile terminals that do not require a hardened information network. [xx]

In Operation Enduring Freedom, the government did manage to deny the Al Qaeda access to commercial satellite products over Afghanistan but the method was very much indirect. The National Imagery and Mapping Agency contracted the entire imaging space capability over Afghanistan with a company called Space Imaging for what was reported to be a significant multi-million dollar contract. [xxi] A spokesman for the company stated that if there had been a commercial competitor with their similar capability (one meter resolution), the United States would not be able to afford what it would have cost to buy out multiple vendors. This perspective illustrates the fact that Afghanistan has not traditionally been a market in demand for commercial satellite products until now. The resources used to deny this access was not budgeted and may not be affordable with the next series of operations.

Consider the possibility of an Iraq invasion. The current international support for a United States invasion of Iraq is minimal and the current analysis is that it would practically be a unilateral operation. The diplomatic, informational and economic environments are completely dissimilar between what the United States faced in Afghanistan and what they will face in Iraq. Saddam Hussein has access to tremendous personal wealth that has been estimated in excess of seven billion dollars. [xxii] He has been investing in global business interests since the early 1980s and some of these multinational corporations even own subsidiaries in the United States.

There are multiple competitors in the commercial space segment with access and routine demand for voice and data communications, imagery, meteorology and remote sensing capabilities over the Arabian Peninsula (many corporate and official entities in France, China, Japan, Russia, India, and the ARABSAT consortium). Even governments are disseminating space information to satisfy commercial demand. The Russian Space Agency is "now selling the data from military space systems over the internet" because they are unable to fund their "space research and development efforts." [xxiii] Saddam Hussein's wealth and unrestrained fiscal environment enables his advantage to deny the United States access to commercial space greater than the capability of the United States to deny access to Iraq.

Conventional Threats. There are several nations that possess missile delivery systems with space reentry capabilities. The space dimension is vital to those regional and long-range targeting and delivery capabilities with nuclear or area denial weapons. The growing missile threat is a good example of technology transfer. The most obvious example of the impact of technology transfer and its effect upon the space dimension are the findings of the Cox Commission Report on the People's Republic of China (PRC) in 1999. [xxiv] The report disclosed many strategic issues of which the PRC space program was only one element. It illustrated the PRC intent to prevent the uncontested use of space by several means. First is the use of espionage and industry reform to expedite technology transfer. Second is the specific plan to exploit the technology against U.S. information systems (specifically satellites, computer systems and the infrastructure grid).

The PRC program has been very successful in the attainment and application of sensitive technologies. They have the design information on the most advanced U.S. ballistic missiles technologies, guidance systems and re-entry vehicles. They also have design information on developmental and research technology that can be used to attack satellites (details are classified by the Cox Commission report). The PRC has also proliferated these technologies to other countries hostile to the U.S. that include Iran, Libya, Syria, North Korea and Iraq. Those same technologies have specifically enhanced and modernized the PRC Long March rockets and they are now capable of delivering the full realm of commercial and military platforms into space (communications, reconnaissance, space based sensors, command and control, and intelligence).

Two likely offensive threats that the U.S. must plan to counter in the near term are the employment of anti-satellite systems and the probability of a low earth orbit nuclear detonation. PRC tested an anti-satellite system in late 1999 that is capable of interfering with any commercial or military space system in any type of orbit (to include entire constellations and the space station). [xxv] This system has the capability to launch nanometer sized parasitic satellites that track, attach to or destroy targeted satellites. The parasitic satellites can be employed offensively or programmed to remain dormant until remotely activated by ground controllers. The PRC did not conceptualize this capability. The "soft killing" approach to satellites was initially presented by Alvin and Heidi Toffler in 1993. [xxvi] Despite its origin, development of this application has now enabled the PRC capability to control the use of space.

It is probable that the employment of space-based weapons will eventually include the use of inertia weapons to include laser and photon technologies. Although it is estimated that constellations of space based lasers will not appear until 2020, there is a scenario which is plausible today. [xxvii] American space war games throughout the 1990s included the scenario in which a nation deploys and detonates an "exo-atmospheric nuclear weapon to create artificial radiation belts at low earth orbit altitudes." [xxviii] The possibility is only remote because it would also deny access to the commercial assets by any nation or commercial user. Despite the results of the war games, DOD has failed to develop policies or establish funding for hardening of commercial satellites.

Current Strategies

The satellite industry is not the first entity that illustrated that the commercial sector is no longer driven by the military industrial complex. The globalization phenomenon and acceleration of commercial technologies at affordable prices have affected a much broader area than the space acquisition program. The U.S. government has fully realized its dependence on commercial technologies and is attempting to convert processes to enable their exploitation. The strategic guidance is provided in Presidential Decision Directive 63. It calls for a partnership with the private [commercial] sector and the development of concepts to share information throughout the continuum of the Defense infrastructure. Its "goal is the establishment of an information-sharing model that allows for a continuous and credible information flow from the installation level to senior levels in government to include the National Information Protection Center (NPIC)." [xxix]

The specific dependence upon the commercial space segment has been repeatedly stated. In 2000, a contracted study to propose investment options for DOD reached the same conclusions the 1997 GAO report to the SECDEF presented about leasing. The 2000 study stated five basic conclusions about a required strategy to exploit commercial satellites. [xxx]

(1) A large gap exists between demand for and capacity of all present, planned and programmed systems. Commercial leases provide an alternative to increase capacity.

(2) Cost is not the only criterion. Access, control and protection are high priorities. (3) DOD must develop operational concepts that enable flexibility with commercial systems that mitigate vulnerability to enemy disruption, failures or market forces.

(4) It would be more economical to make long term commitments and waste capacity than to underestimate needs that can not be met on an ad-hoc basis.

(5) Long term savings of leasing should prohibit buying DOD unique satellites.

DOD should lease satellites based on the required operational requirements.

The leasing approach has been underway since DOD learned how expensive short term access cost was in Bosnia during 1996 (Defense Advanced Research Projects Agency-DARPA and Defense Information Systems Agency-DISA had to expeditiously contract commercial technologies that included satellite transponders to satisfy deficiencies both within the theater and to infrastructure in the United States and Europe). Two examples of significant long-term leases were executed by DISA and Special Operations Command (SOCOM). In 1999, DISA signed a contract with AT&T, MCI and Sprint for Defense Information System Network Transmission Services that totaled $600 million over a three-year period (also included seven one year options). [xxxi] In November 2001, SOCOM signed a contract for its network and transmission services that was worth $270 million over nine years. [xxxii]

Alternative Strategies

While it appears investments are being made to access the commercial space segment, little else it being done to reduce the demand upon commercial satellite or develop force applications in space to protect the segment. There has been a great deal of fiscal resource applied to the deficiency in military capacity since the terrorist attacks of 11 September 2001. The money would not have been allocated if there had not been such a glaring deficiency in capability to communicate on both a regional and global scale. There are two specific options briefed prior to 11 September that provide strategic alternatives. One is for the near term and the other requires a long term commitment and a change in the political environment.

One way to reduce the demand upon commercial and military satellite capacity is to lease global fiber access for regional and intercontinental transmission connectivity. DISA has conceptualized the leasing of undersea fiber cable with the Global Fiber Initiative (GFI) program but it has not been funded. The current available capacity of inter-regional submarine cable is staggering. Between the U.S. and Europe, Latin America, and Asia, there is over 10,000 GBps capacity (the global commercial satellite capacity is only 140 GBps). [xxxiii] There are several advantages to fiber over satellite. Fiber is one-tenth the cost and the costs are projected to decline significantly over the next several years as the customer base grows. Fiber also has almost twice the life expectancy. In 2000, 80% of the world's transoceanic telecommunications market was over fiber. The infrastructure requirements are almost similar at the strategic level whether the transmission path is over satellite or fiber. Operational commands would have to be supported by capabilities to distribute communication services to line of sight and local networked systems. Those capabilities are not presently available below the Army Corps or Marine Corps MEF level commands.

The other alternative is for the U.S. to develop capabilities for the application of force in space. The current national policy would have to be modified and the diplomatic environment would require change. Technology now supports the development of space based inertia weapons (lasers and optics). It is also possible to build airborne or earth-based weapons systems that can attack space systems (the Air Force has recently demonstrated the capability to destroy a satellite with a missile launched from an F-15). [xxxiv] The risk with employment of terrestrial or space-based weapons is usually the collateral damage the attack causes on other satellites in similar orbits. At a minimum, the government must deal with the reality that there exists a conventional threat from PRC in space.

The two previous alternative strategies are capability based approaches and do not address the intangible benefits of adapting a coherent space strategy. There was an advanced research project [xxxv] completed by two students at the Naval War College in 2001 that addressed the policies and directives that contribute to the availability and survivability of commercial space systems. Their summary conclusions specifically recommend that the U.S. needs to establish doctrine and develop a national space security strategy, invest to maintain a space technology industrial base, and establish a budget process that enables the employment of the commercial space sector. Its recommendation for the development of a national space security strategy will be paramount to the long term access and control of space by the United States.

Conclusion

The recurring theme that technology transfer over time renders an advantage lost is perhaps the most important lesson this paper has supported. Mankind's access to space for any purpose is no older than the average Lieutenant Colonel on active duty. To place the ripeness of space programs into perspective, Barry Watts of the Center for Strategic and Budgetary Assessments makes a telling comparison. He believes that space power will be comparable in the year 2025 with the level of force application the United States reached with air power in World War II. [xxxvi]

It is critical to the United States that it maintains a position of information superiority across the spectrum of military operations. The access to commercial satellite systems will be a critical but challenging element of that advantage. Success will depend upon the practice of disciplined investment in space technologies as well as alternatives to reduce the dependence upon their limited capacity. It will also require the eventual development of force applications to counter known and probable threats to all space-based systems. Change is required now. Without guaranteed access to the required capacity for bandwidth, the U.S. technological advantage will be mitigated.

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