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AN ANALYSIS OF MILITARY USE OF COMMERCIAL SATELLITE COMMUNICATIONS

by

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September 2008

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13. ABSTRACT (maximum 200 words)

Since the Gulf War of 1991, United States military satellite communication (SATCOM) bandwidth demand has increased dramatically, as evidenced by recent usage rates in Operation Enduring Freedom and Operation Iraqi Freedom. The Department of Defense (DoD) has increasingly relied on commercial vendors to meet this demand. With an open-ended Global War on Terror and heavy reliance on bandwidth-intensive operations (such as unmanned aerial vehicle feeds), the demand is projected to continue increasing at huge levels. It is unlikely that reliance on commercial SATCOM will decrease, despite numerous planned military SATCOM assets launching over the next ten years. While commercial SATCOM is essential to most military operations and provides many advantages, its pervasive use also raises concerns related to security, cost, and survivability.

This thesis analyzes the balance between DoD use of commercial SATCOM versus military SATCOM. It surveys historical and current military usage of DoD and commercial SATCOM, evaluates current predictions for military use of commercial SATCOM, and describes measures of effectiveness that can be used to evaluate the various SATCOM options. In culmination, this thesis defines what constitutes an appropriate balance of military and commercial SATCOM usage using cost, technical, and policy compliance measures of effectiveness. The measures of effectiveness lead to a recommendation of a more deliberate, less ad hoc use of commercial SATCOM for the vast majority of military SATCOM needs.

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AN ANALYSIS OF MILITARY USE OF COMMERCIAL SATELLITE COMMUNICATIONS

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ABSTRACT

Since the Gulf War of 1991, United States military satellite communication (SATCOM) bandwidth demand has increased dramatically, as evidenced by recent usage rates in Operation Enduring Freedom and Operation Iraqi Freedom. The Department of Defense (DoD) has increasingly relied on commercial vendors to meet this demand. With an open-ended Global War on Terror and heavy reliance on bandwidth-intensive operations (such as unmanned aerial vehicle feeds), the demand is projected to continue increasing at huge levels. It is unlikely that reliance on commercial SATCOM will decrease, despite numerous planned military SATCOM assets launching over the next ten years. While commercial SATCOM is essential to most military operations and provides many advantages, its pervasive use also raises concerns related to security, cost, and survivability.

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LIST OF ABBREVIATIONS/SYMBOLS

AEHF	Advanced Extremely High Frequency
AFSATCOM	Air Force Satellite Communications System
AFSPACECOM	Air Force Space Command
ANS	American National Standard
ATO	Air Tasking Order
CENTCOM	Central Command
CINC	Commander in Chief
CJCS	Chairman Joint Chief of Staff
COO	Chief Operating Officer
COTM	Communication on the Move
CRAF	Civil Reserve Air Fleet
CRSF	Civil Reserve SATCOM Fleet
CSCI	Commercial Satellite Communications Initiative
CSS	Commercial Satellite Team (CST) Service Survey
CST	Commercial Satellite Team
DISA	Defense Information Systems Agency
DISN	Defense Information Systems Network
DITCO	Defense Information Technology Contracting Organization
DoD	Department of Defense
DSCS	Defense Satellite Communications System
DSTS-G	Defense Information System Network (DISN) Satellite Transmission Service-Global
EELV	Evolved Expendable Launch Vehicle
EHF	Extremely High Frequency
FLTSATCOM	Fleet Satellite Communications System
FOC	Full Operational Capability
FSS	Fixed Satellite Service
GAO	Government Accountability Office
Gbps	Gigabits per second
GBS	Global Broadcast System
GIG	Global Information Grid
GPS	Global Positioning System
ICD	Initial Capabilities Document
Kbps	Kilobits per second
KPP	Key Performance Parameter
L&EO	Launch and Early Orbit
LEO	Low Earth Orbit
Mhz	Megahertz
MOE	Measure of Effectiveness
MSS	Mobile Satellite Service
MUOS	Mobile User Objective System

RF	Radio Frequency
RFP	Request for Proposal
RFS	Request for Service
RSSC	Regional SATCOM Support Center
SAA	Satellite Access Authorization
SATCOM	Satellite Communications
TCA	Transformation Communications Architecture
TP	Transmission Plan
TR	Telecommunications Request
TSAT	Transformational SATCOM
TSO	Telecommunications Service Order
TSR	Telecommunications Service Request
U.S.C.	United States Code
UAV	Unmanned Aerial Vehicle
USCENTAF	United States Central Command Air Force
USSTRATCOM	United States Strategic Command
VHF	Very High Frequency
WGS	Wideband Global SATCOM *(previously Wideband Gapfiller Satellite)*

EXECUTIVE SUMMARY

Since the Gulf War of 1991, satellite communication (SATCOM) bandwidth demands by the United States military services have increased over 500% by some measures and the Department of Defense (DoD) has increasingly relied on commercial vendors to meet this demand. Approximately 80% of military satellite communications in the first two years of Operation Iraqi Freedom were provided by commercial satellites. With an open-ended Global War on Terror and heavy reliance on bandwidth intensive operations (such as unmanned aerial vehicle feeds), the demand is projected to continue increasing at significant levels. It is unlikely that reliance on commercial SATCOM will decrease dramatically, despite launching numerous planned military SATCOM assets over the next ten years. While commercial SATCOM is essential to most military operations and provides many advantages, its pervasive use also raises technical, financial, and policy concerns.

This thesis analyzes the balance between DoD use of commercial versus military satellite communications. It surveys military usage of DoD and commercial SATCOM, explores current predictions of future military use of commercial SATCOM, and presents measures of effectiveness used to evaluate the various SATCOM options. In culmination, this thesis attempts to define what constitutes an appropriate balance of military and commercial SATCOM usage through exploration of the various options available compared against defined measures of effectiveness.

The concluding recommendations of this study are that a MILSATCOM/commercial SATCOM mix with an emphasis on commercial SATCOM in all feasible cases provides the optimal balance based on technical, cost, and policy-compliance measures of effectiveness. This approach requires a long-term financial and strategic commitment as well as substantial cooperation between government and industry. Failure to make this shift risks non-compliance with current U.S. National Space Policy and continuation of a non-optimal solution. Several areas for further study are also recommended, including analyzing bandwidth reduction measures, and exploring more cost-effective alternatives to SATCOM.

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I dedicate this thesis to Sophie Forest. During my coursework, her frequent visits to my office (complete with hugs, throwing of stuffed animals, and random strumming of my guitar) helped to ensure the maintenance of my sanity and perspective.

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I. INTRODUCTION

A. BACKGROUND

1. Context

In 1991, Operation Desert Storm ushered in a new era of warfare, which became commonly referred to as "the first space war." It was the first major military operation to make heavy use of the Global Positioning System (GPS), high resolution satellite imagery, and satellite communications (SATCOM). Since then, while the Department of Defense (DoD) has remained relatively self-sufficient in the areas of navigation and imagery, the demand for SATCOM bandwidth has exploded far beyond the military's ability to satisfy it with DoD-owned satellites. According to a Joint Chiefs of Staff document, the need for bandwidth in a theater of war will grow to 14 Gbps by 2010, compared to 0.7 Gbps during the Operation Enduring Freedom (2001/2002) (Chisholm, 2003).

The military is struggling to develop and launch satellites to meet this growing need, but has experienced numerous schedule slips for a myriad of reasons ranging from technical difficulties, subcontractor quality issues, unstable funding, and launch vehicle integration troubles. The Wideband Gapfiller Satellite (WGS) program, now renamed Wideband Global SATCOM since it has grown beyond its original "temporary" intention, was originally scheduled for launch in 2004, but slipped over three years despite a firm-fixed price contract vehicle that heavily incentivized early launch. WGS's "protected" (i.e., hardened, nuclear-survivable) counterpart, Advanced Extremely High Frequency (AEHF) recently announced its own latest round of launch slips. Transformational SATCOM (TSAT) was originally projected to "remove comm as a constraint to the warfighter" starting in 2012; the current first launch estimate is 2018. At this time, the very future of TSAT is precarious; at a minimum, the program is likely to be financially gutted and delayed.

The launch delays of organic military communication satellites, combined with burgeoning operational needs, have caused the military to increasingly rely on commercial SATCOM. Commercial sources accounted for approximately 60 percent of SATCOM provided in Operation Enduring Freedom and 80 percent during Operation Iraqi Freedom (Chisholm, 2003). WGS and AEHF may mitigate this trend, but will hardly reverse it.

Operational need is not the only factor driving the DoD toward commercial SATCOM; the current U.S. National Space Policy essentially directs it. On August 31, 2006, President George W. Bush authorized a new national space policy that "establishes overarching national policy that governs the conduct of U.S. space activities." Most relevant to military SATCOM concerns was paragraph 7 (Commercial Space Guidelines), which stated, "It is in the interest of the United States to foster the use of U.S. commercial space capabilities around the globe and to enable a dynamic, domestic commercial space sector. To this end, *departments and agencies shall: Use U.S. commercial space capabilities and services to the maximum practical extent*; purchase commercial capabilities and services when they are available in the commercial marketplace and meet United States Government requirements; and *modify commercially available capabilities and services to meet those United States Government requirements when the modification is cost effective*." Coupled with the operational need, this policy buttresses the DoD's strong need to rely on commercial SATCOM for the foreseeable future. This policy links back to the overarching principles in the same document: "The United States is committed to encouraging and facilitating a growing and entrepreneurial U.S. commercial space sector." The message is clear: unless there is a national security or compelling practical reason, use U.S. commercial sources for military SATCOM.

2. Definitions

To understand the issues presented and analyzed in this thesis, it is helpful to define certain terms explicitly. Per American National Standard (ANS) T1.523-2001, Telecom Glossary 2000, *satellite communications* (SATCOM), is defined as the telecommunication service provided by one or more satellite relays and their associated uplinks and downlinks. SATCOM can be provided from satellites in different orbit types (geostationary; Molniya and other elliptical orbits; and low Earth orbits, both polar and non polar), each of which provides unique advantages and disadvantages. The military generally categorizes SATCOM assets as *wideband*, *narrowband* (also tactical or mobile), or *protected* (also nuclear-protected); these terms are defined below and generalized further in Table 1.

- Wideband: "Users of the wideband segment primarily have fixed and transportable land-based terminals; a few have terminals on large ships or aircraft. Their data rates vary from moderate to high, and their connectivity may be point-to-point or networked at distances ranging from in-theater to intercontinental" (Martin, 2001).
- Narrowband: "Users in the mobile-and-tactical segment of the architecture are characterized by small terminals with relatively low-gain antennas; they are located on ships, aircraft, and land vehicles. Data rates are low to moderate, and connectivity is typically in networks at distances ranging from in-theater to transoceanic" (Martin, 2001).
- Protected: "Mobility characterizes users of the protected segment of the MILSATCOM architecture, whether they are on ships, aircraft, or land vehicles. They accept very low to moderate data rates in exchange for considerable protection of their links against physical, nuclear, and electronic threats" (Martin, 2001).

	Wideband	Narrowband	Protected
General Functions	High data rate communication for fixed sites	Voice; low-rate data; Communication on the Move (COTM)	Highly secure, nuclear-survivable communication
Data Rates	High	Low	Varies (Low to Moderate)
Power Requirements	High	Low	Varies
Mobile	No	Yes	Varies
Antenna Size	Large	Small	Varies
Protection	Low to Moderate	Low to Moderate	High
Frequencies	SHF/EHF	VHF/UHF	Varies

Table 1. Characteristics of Wideband, Narrowband, and Protected Satellites

Commercial SATCOM, sometimes termed *C-SATCOM* to contrast it with organic *MILSATCOM*, can be either wideband or narrowband, but there is no "protected" commercial SATCOM at this time or in the foreseeable future. Figure 1 below depicts the frequency spectrum from Very High Frequency (VHF) to Extremely High Frequency (EHF) with corresponding commercial and military satellites on the top and bottom, respectively (Goeller, 2004). As seen, commercial SATCOM exists in proximity to military frequencies, although not *in* military frequencies, across the entire spectrum.

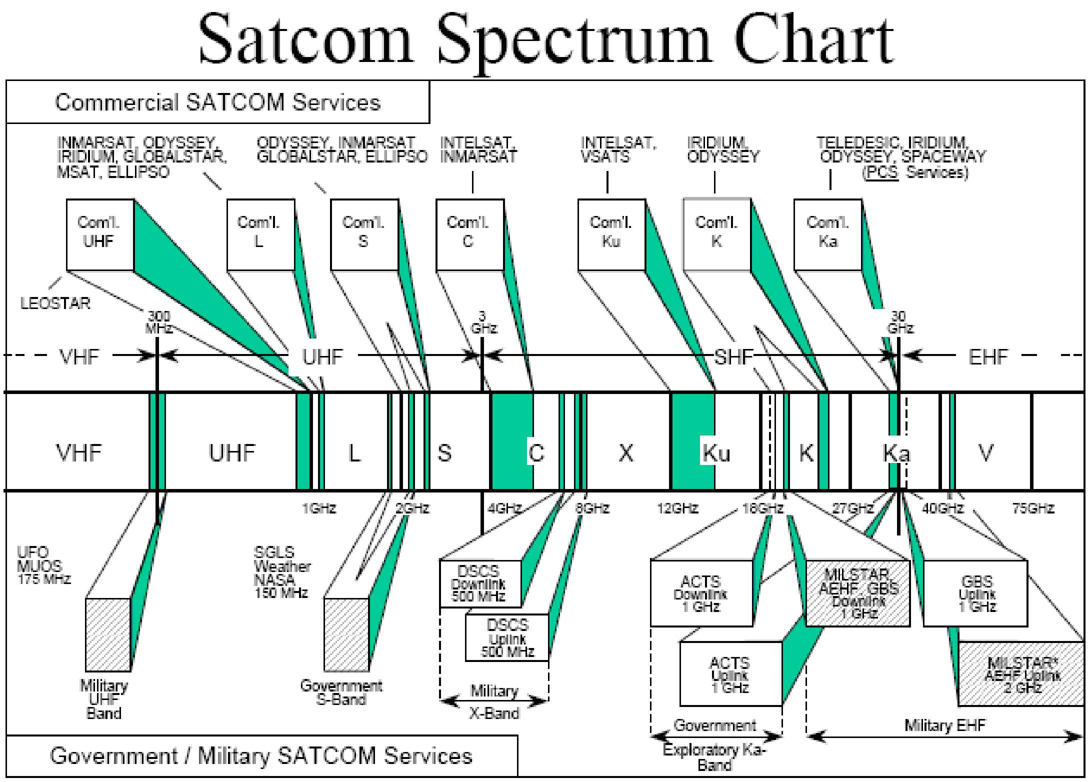

Figure 1. SATCOM Spectrum Chart

B. PURPOSE

The purpose of this thesis is to analyze the balance between DoD use of commercial versus military SATCOM. It surveys military usage of DoD and commercial SATCOM, explores current predictions of future military use of commercial SATCOM, and presents measures of effectiveness used to evaluate the various SATCOM options. In culmination, this thesis attempts to define what constitutes an appropriate balance of military and commercial SATCOM usage through exploration of the various options available compared against defined measures of effectiveness.

C. RESEARCH QUESTIONS

Following are the research questions that will be addressed in this thesis.

1. How has the DoD balanced use of commercial and military SATCOM since Operation Desert Storm?

2. What trends will affect future military use of commercial and military SATCOM?

3. What options exist to strike the appropriate balance between military SATCOM and commercial SATCOM?

4. Which of these options are recommended based on the measures of effectiveness as defined in the thesis?

D. BENEFITS OF THE STUDY

This thesis captures the history of military commercial SATCOM usage, provides a basis of knowledge for future SATCOM requirements analysis, and may aid in planning for future systems.

E. METHODOLOGY

This thesis uses the following methodology:

1. Conduct literature review of military use of SATCOM, to include historical, current, and predicted use; existing analysis of advantages/disadvantages of commercial SATCOM; and past research regarding the optimization of balancing military and commercial SATCOM.

2. Review the current DOD and service policies and guidance for SATCOM.

3. Solicit current and projected future usage data primarily from DISA, among other sources.

4. Interview subject matter experts for their perspectives on the research questions of this thesis.

5. Develop measures of effectiveness based on the most significant overall factors.

6. Correlate information gathered to develop options and recommendations for the appropriate balance between military and commercial SATCOM usage based on measures of effectiveness.

F. THESIS ORGANIZATION

The remainder of this thesis is organized as follows. Chapter II briefly looks at the history of military SATCOM use, focusing specifically on the dramatic contrast between Operation Desert Storm in 1991 and Operation Iraqi Freedom in 2003. Chapter III moves past the historical examples to look at present and future SATCOM use. It begins with an exploration of the current policies and organizations associated with SATCOM. The remainder of the chapter describes the present supply and demand issues. Chapter IV explores technical, cost, and policy measures of effectiveness. Chapter V weighs the measures of effectiveness against the various SATCOM options available to the government. The culmination of the previous sections, Chapter VI presents the recommendation for striking the appropriate balance between military SATCOM and commercial SATCOM and includes several suggestions for further study.

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II. COMMERCIAL SATCOM USE - PAST AND PRESENT

A. INTRODUCTION

The origins of military satellite communication reach back to the late 1940s, when the U.S. Army made radar contact with the moon. In the decade following, the Navy conducted communications experiments using the moon as a reflector and used this technology in 1959 to establish a communication link between Hawaii and Washington, D.C. (Martin, 2001). However, the real birth of military satellite communication, beyond experimental purposes, occurred in the mid-sixties with the launch and operational use of what became know as the Initial and Advanced Defense Communication Satellite Program. In the 1970s, the DoD began the trinity of wideband/narrowband/protected communications: (1) the enduring Defense Satellite Communications System (DSCS) began supporting wideband requirements, (2) Fleet Satellite Communications System (FLTSATCOM) was launched to provide operational narrowband communications, and (3) the protected constellation Air Force Satellite Communications System (AFSATCOM) became operational in 1979 (Martin, 2007).

The balance between "military SATCOM versus commercial SATCOM" is an old debate. The early 1960s saw policy debates on whether there should be separate military communication satellites or if military requirements could be met with commercial systems. Even then, the answer was a hybrid: yes; the military would establish and maintain a distinct communication satellite network to satisfy its unique needs, but decision makers also provided direction for the military to use commercial links if the requirements could be satisfied in a timely manner at a reasonable cost. Later, in 1976 and 1977, Congress directed the military to increase its use of leased commercial satellite services. This direction was specifically applied to the narrowband follow-on to FLTSATCOM, resulting in the Leasat program, which primarily served the Navy but also some mobile users of the other services. As Leasat approached end-of-life, the pendulum swung back towards organic military SATCOM; the narrowband sequel to Leasat was the

Navy-managed Ultra High Frequency Follow-On (UFO) (Martin, 2001). The next pendulum swing would come immediately after Operation Desert Storm.

B. HISTORICAL SNAPSHOTS

1. SATCOM in 1991 – Operation Desert Storm

Prior to Desert Storm, the utility of space capabilities in warfare was largely theoretical for the DoD, there having been no major U.S. military conflict since Viet Nam, which ended just as modern SATCOM was entering maturity. Desert Storm changed everything; in the words of General Kutyna, Commander in Chief for Space during the operation, it was “the first space applications war” (Day, 1996). Intertheater narrowband SATCOM was provided by FLTSATCOM and a Leasat while intratheater wideband was provided by two DSCS satellites on station over the Indian Ocean (Kiernan, 1991). “Reachback” SATCOM (from theater to the U.S.) was accomplished via FLTSATCOM satellites over the Atlantic and DSCS satellites over the Eastern Atlantic, providing a vital link between CENTCOM and CONUS (Military Space, 1990). Meanwhile commercial sources provided approximately 20% of Desert Storm SATCOM (Snodgrass, 2007). In the HQ AFSPACECOM Desert Storm “Hot Wash” report written immediately following the conflict, one of the lessons learned was titled *SATCOM Indispensable*. The write-up described SATCOM providing 80% of theater communications (both inter and intra) and emphasized that SATCOM requirements, as required at the strategic, operational, and tactical levels, had been significantly underestimated (Air Force Space Command, 1991).

Desert Storm set the benchmark for SATCOM use. Nearly twenty years later, the question is still asked, “How does that compare to Desert Storm?” Desert Storm SATCOM usage was a mere 1 Mbps per 5000 troops. As described in detail in the next section, modern usage seems enormous by contrast, spurred on in large part by the emergence of network-centric warfare.

2. Reforms Following Operation Desert Storm

Immediately following Desert Storm, Congress directed the DoD to explore increased use of commercial SATCOM. The fiscal year 1992 Defense appropriation provided $15 million for the DoD “to study ways of using commercial communication satellite capabilities” and “begin moving aggressively toward maximum utilization of commercial satellite communications systems” (GAO, 1994). This mandate to make greater military use of commercial SATCOM was the first of its kind since 1977.

The outgrowth of this congressional direction was the Commercial Satellite Communications Initiative (CSCI). Providing the framework for the department’s effort to integrate commercial SATCOM capabilities, CSCI policy stated that the DoD will “augment” its military SATCOM capability with both domestic and international commercial services to the extent operationally and fiscally practical (U.S. Army Information Systems Engineering Command, 1998). Primary responsibility for implementing this policy fell on the Defense Information Systems Agency (DISA), whose role will be elaborated on later in this section.

3. SATCOM in 2003 – Operation Iraqi Freedom

The next major turning point for military SATCOM use came in Operation Enduring Freedom in Afghanistan in 2001/2002, quickly followed by the even larger Operation Iraqi Freedom in 2003. As seen in Table 2, the total SATCOM used in Operation Iraqi Freedom, at the time the data was captured in 2003, was well over twenty times what it had been in Operation Desert Storm, a war in the same region just over ten years earlier. This increase is even more dramatic when one considers that the force size in Operation Iraqi Freedom was less than half what it was in Operation Desert Storm. If one analyzes the data on a “per 5000 military member” basis, the SATCOM bandwidth increase was fifty-fold (Rayermann, 2003). The causes of this growth are described in Chapter III of this thesis.

	Operation Desert Storm	Operation Iraqi Freedom
Total SATCOM Used (Mbps)	100	2,400
Total Force Engaged	500,000	235,000
Number of 5,000 Military Member Force Increments [i.e. brigades]	100	47
SATCOM Used per 5,000 Military Members (Mbps)	1	51.1

Table 2. Increasing Demand for SATCOM since 1990 (Rayermann, 2003)

Given this enormous increase in theater bandwidth requirements for the operation, it is no surprise that MILSATCOM alone could not meet the full need and that commercial SATCOM was heavily relied upon. Before Operation Iraqi Freedom, there were five commercial SATCOM terminals in theater for tactical purposes; during the early months of the operation, there were 34. This constitutes a 560% increase. For this same period, military SATCOM terminals increased from 20 to 44, a 120% increase (USCENTAF, 2003). This contrast underscores the military's practical reliance on commercial SATCOM as a surge capability. Another telling statistic is the frequently repeated fact that roughly 80 percent of the SATCOM capacity needed for Operation Iraqi Freedom was provided by commercial space assets (Helfgott, 2005). This is a complete reversal of the SATCOM balance in Operation Desert Storm.

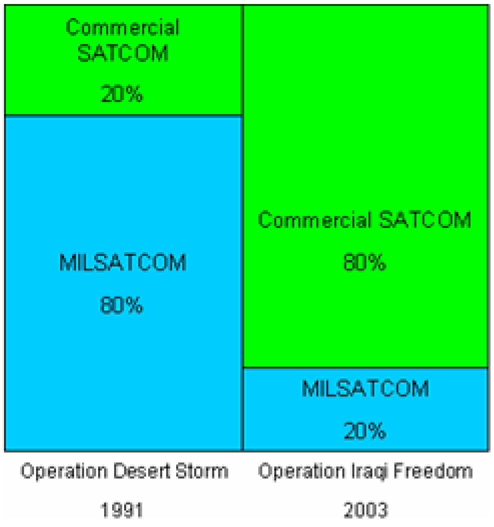


Figure 2. Comparison of SATCOM Balance (1991/2003)

4. Reforms Following Operation Iraqi Freedom

Just as Operation Desert Storm served as a wake-up call to legislators regarding DoD dependence on SATCOM and the need to rely on commercial SATCOM, Operation Iraqi Freedom experiences sent the message to legislators that DoD use of commercial SATCOM was inefficient. In December 2003, less than nine months after the war began, the U.S. Government Accountability Office (GAO) issued a key report calling for the DoD to improve the planning and procurement of commercial SATCOM used by the military (Helfgott, 2005). The GAO report, titled “Satellite Communications: Strategic Approach Needed for DoD's Procurement of Commercial Satellite Bandwidth” made the following points:

- DoD was the largest consumer of commercial fixed satellite services.
- DoD was buying its satellite services on an as-needed basis, thereby missing significant opportunities to leverage its buying power and to achieve considerable savings as a result.
- Some users viewed the process for acquiring commercial fixed satellite services as being too lengthy, particularly for time-critical military operations, and they believed that the cost was too high.
- DoD did not know exactly how much it was spending on commercial satellite services, nor did it know much about its service providers or whether customer needs were really being satisfied.
- Neither DoD nor DISA were collecting aggregated forecasts of users’ needs for commercial fixed satellite services, which is an important step toward optimizing DoD’s spending.
- GAO’s recommendations to DoD focused on the need to develop and implement a strategic approach to acquire commercial satellite services, along with correcting specific oversight and management weaknesses.

While the GAO report provided ammunition for those who said that commercial SATCOM costs “too much”, the report also paved the way for significant cost savings through reforms and would ultimately make commercial SATCOM a more cost-effective solution for meeting operational and policy requirements. As a result of these findings, Congress directed the DoD to submit a report on military guidance for this subject and an explanation of how the guidance addresses GAO’s recommendations. Like CSCI in the 1990s, the GAO report was a major turning point for SATCOM and, combined with the U.S. National Space Policy of 2006, may well have significant implications for MILSATCOM in the decades to come.

C. PRESENT STATE

1. Progress since 2003 GAO Report

Subsequent to the December 2003 GAO Report, significant DoD process improvements were made. In response to the report, the DoD issued in December 2004 a policy memorandum for the planning, acquisition, and management of commercial satellite communications fixed satellite services, published an action plan for implementing new policy, defined baseline requirements for commercial satellite communication services, and completed cost-benefit analysis. DoD submitted a response report to Congress on 29 July 2005. In the report to Congress, the DoD defined how it was planning to implement a more strategic approach for the planning, acquisition, and management of commercial fixed satellite services. The report also discussed the findings of the GAO report and described four elements for DoD’s new strategic approach for commercial fixed satellite services:

1. Integrated planning;
2. Cost-effective acquisition and effective provisioning;
3. Integrated management of commercial and military operations; and
4. Alignment of commercial and military satellites and earth equipment.

The 2003 GAO report provided seven specific options that could improve the DoD's practices in leveraging its buying power. A follow-up GAO report in 2005 provided status on each of these seven areas, as detailed in Table 3. As can be observed, two of the recommendations were fully addressed and five were at least partially addressed.

RECOMMENDATION	Extent Addressed
1. Inventory current and potential users of commercial bandwidth to determine existing and long term requirements	Fully addressed
2. Identify and exploit consolidation opportunities for bandwidth requirements of combatant commanders, military services, and defense agencies	Partially addressed
3. Adopt, when appropriate, commonly used commercial practices, such as conducting spending analyses and negotiating pricing discounts based on overall DoD volume, to strengthen DoD's position in acquiring bandwidth	Partially addressed
4. Improve the current funding structure by considering new funding approaches, such as centralized funding of commercial bandwidth and seeking legislative authority for multiyear procurements.	Fully addressed
5. Develop performance metrics to assess user satisfaction with the timeliness, flexibility, quality, and cost in acquiring commercial satellite services.	Partially addressed
6. Strengthen DoD's capacity to provide accurate and complete analyses of commercial bandwidth requirements, spending, and the capabilities of commercial satellite providers by enhancing core internal technical expertise and information systems.	Partially addressed
7. Assess, and implement as needed, changes to the key elements of the existing acquisition process—including requirements generation, solution development and evaluation, and contract vehicles—to facilitate a more strategic approach.	Partially addressed

Table 3. Status of Recommendations from 2003 GAO Report

Commercial SATCOM services provided through DISA were tangibly more timely and cost-effective for the warfighter. For example, DISA now leverages competition and DoD's buying power via their DSTS-G contract to acquire commercial SATCOM at approximately 25% below market average for the same service. In certain cases, DISA's Defense Information Systems Network (DISN) Satellite Transmissions Services-Global (DSTS-G) pricing is nearly 50% cheaper than available GSA pricing. Part of this reduction was caused by DISA reducing their fees from eight percent to 3.83

percent. Also, through their Six Sigma and Lean process improvements, DISA reports that requirement identification-to-award cycle time has been reduced by 73%--see Figure 3 (Mansir, 2005).

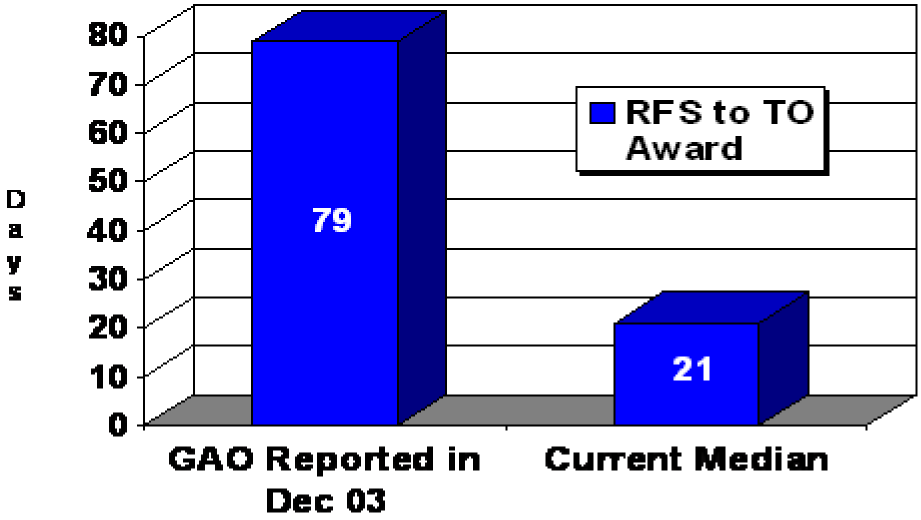


Figure 3. DISA RFS-to-Award Time Reduction (Mansir, 2005)

2. Commercial SATCOM Procurement Organizations

To better convey current and future commercial SATCOM procurement processes, this section will describe the various organizations involved in Fixed Satellite Service (FSS) and Mobile Satellite Service (MSS) procurement. At the highest DoD level below the Chairman Joint Chief of Staff (CJCS) Joint Staff J6, United States Strategic Command (USSTRATCOM) is designated at the SATCOM Operations Manager (SOM). As seen in Figure 4, in this capacity USSTRATCOM interfaces with various organizations, from combatant commanders to the commercial satellite industrial base. One critical relationship depicted is that with DISA, whom the Commander, USSTRATCOM, has designated as the Commercial Satellite System Expert (SSE) for fixed and mobile satellite services. A significant part of USSTRATCOM's role in commercial SATCOM is providing guideline, publicity, and operational prioritization to DISA, the day-to-day executer of commercial SATCOM procurement efforts.

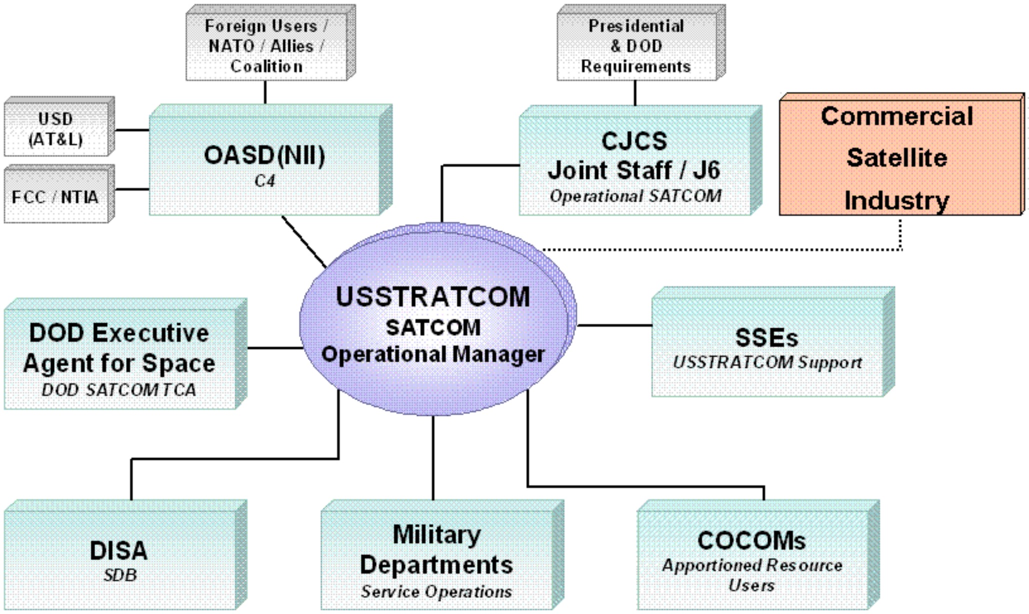


Figure 4. SOM Relationships (Snodgrass, 2007)

DISA is the DoD's *only* authorized service provider for commercial fixed and mobile satellite services. A significant part of the reason for having a sole DoD provider is to capitalize on the collective buying power of the DoD. In the past, even when the DoD was the largest SATCOM customer, it bought like 300 small customers instead of pooling together its significant purchasing power (Snodgrass, 2007). Purchasing discounted leases as a single entity with "most favored customer" status drives down cost and improves operationally prioritized responsiveness from the vendor.

To procure commercial SATCOM, the front line DISA organization is the Commercial Satellite Team (CST) within the Center for Network Services. The CST is "the principal facilitator for the planning, acquisition, engineering, and management of commercial wideband and mobile SATCOM goods and services. CST provides the interface between the customer, the contracting agencies, and the commercial vendors. The principal mechanisms for acquiring wideband goods and services are the DSTS-G contract and various Defense Information Technology Contracting Organization (DITCO) contracts through the DITCO on-line ordering process for mobile SATCOM goods and services" (DISA, 2008).

3. Commercial SATCOM Service Request Process

Using wideband as an example, the current process for procuring commercial SATCOM begins with the user identifying the need. From there, he or she contacts the Regional SATCOM Support Center (RSSC) and asks to speak with a CST representative; if no RSSC is identified, then the user contacts the CST directly. The CST representative can provide technical guidance, cost estimates, and advice on filling out the required documentation. The formal process, however, begins with the Request for Service (RFS); complicated requests may require more elaborate documentation. From there, the customer's work is largely done from the procurement perspective, though as seen in Figure 5, DISA has multiple steps to accomplish before service can be provided. Currently, DISA estimates between 21 and 45 days to complete the process, depending on the complexity of the request. While this may sound lengthy to the requester, the process is restrained by necessary legal steps yet remains a substantial improvement of the 79-day median RFP-to-award time prior to the reforms made since 2004.

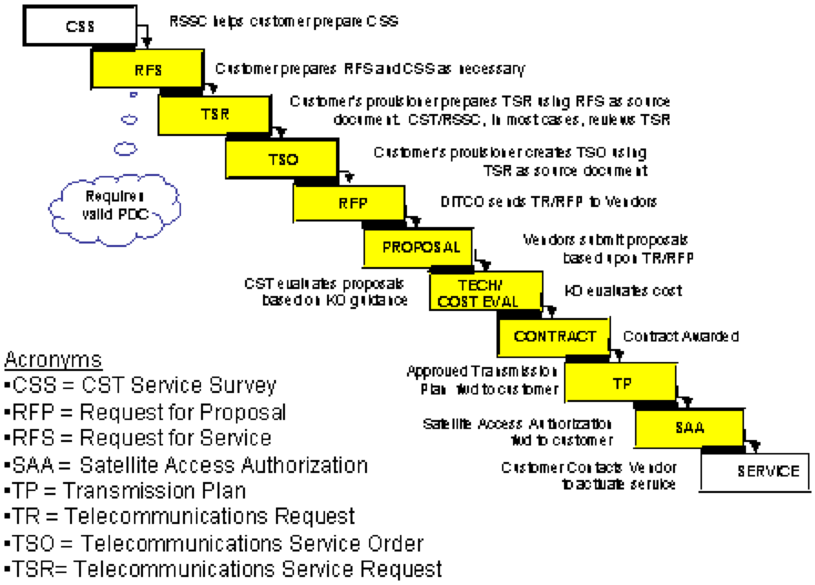


Figure 5. Commercial Satellite Team Acquisition Process (Mansir, 2005)

4. Commercial SATCOM Procurement Policies and Guidance

Commercial SATCOM procurement is guided by various policies at various levels. Current key policies and guidance pertaining to commercial SATCOM include:

- Assistant Secretary of Defense (Networks and Information Integration): DoD Policy for Procuring Mobile Satellite Services, dated 29 August 2001
    - Provides high-level guidance for narrowband / mobile commercial SATCOM
- Assistant Secretary of Defense (Networks and Information Integration): Policy for Planning, Acquisition, and Management of Commercial Satellite communications Fixed Satellite Services, dated 14 Dec 2004
    - Provides High-level guidance for wideband / fixed commercial SATCOM
- Chairman Joint Chiefs of Staff Instruction 6250.01B, Satellite Communications, 28 May 2004
    - Provides policy on the requesting and procurement of commercial SATCOM
- SATCOM Initial Capabilities Document (ICD), 14 August 2004
    - Describe the overarching required capabilities and desired effects for a SATCOM family of systems
- DISA CIRCULAR 310-130-5, 30 July 2002
    - At a more detailed level than the above documents, this circular provides instructions for the preparation and submission of requests for telecommunications in support of the departments, agencies, and offices of the DoD and other U.S. Government agencies authorized by the Secretary of Defense to contract for service through DISA
- DISA Acquisition Regulation Supplement (DARS), September 2003
    - Supplements the Federal Acquisition Regulations, providing rules and guidance for procurement of commercial SATCOM.

More recently, and at a higher level than any of the above documents, President George W. Bush authorized on August 31, 2006 a new U.S. National Space Policy (White House, 2006). A sweeping document affecting all U.S. space endeavors, one of the many fundamental goals of the policy was to “Enable a dynamic, globally competitive domestic commercial space sector” (White House, 2006). In paragraph seven, the policy elaborated on this principle: “It is in the interest of the United States to foster the use of U.S. commercial space capabilities around the globe and to enable a dynamic, domestic commercial space sector. To this end, departments and agencies shall use U.S. commercial space capabilities and services to the maximum practical extent; purchase commercial capabilities and services when they are available in the commercial marketplace and meet United States Government requirements; and modify commercially available capabilities and services to meet those United States Government requirements when the modification is cost effective” (White House, 2006).

The National Space Policy’s “to the maximum extent possible” direction is a much higher standard than the “augmentation” language of the SATCOM ICD and other preceding documents of policy and guidance. It remains to be seen how USSTRATCOM policy will adjust to fit the new National Space Policy tone. One important nuance of the language is “use U.S. commercial space capabilities and services to the maximum practical extent.” As shown in section III of this thesis, very few SATCOM providers are purely U.S., thus strict adherence to the new policy may have little practical effect—there are not enough exclusively U.S. companies to fill the need.

D. SUMMARY

Having surveyed the past and present of the military commercial SATCOM use, the dynamic and challenging nature of meeting SATCOM demand should be apparent. This chapter described the tremendous growth in SATCOM requirements between Operation Desert Storm and Operations Iraqi Freedom. It described the processes and policies during this critical period of growth. Of significant interest was the SATCOM procurement improvements spurred on by the 2003 GAO report. This thesis turns now to the future, exploring projected military SATCOM demand and the corresponding supply from both military and commercial sources.

III. SATCOM'S FUTURE - DEMAND AND SUPPLY

A. INTRODUCTION

The DoD's fundamental SATCOM challenge for the coming decades is essentially one of supply and demand, although both are ever-fluctuating by regions based on world events. This section will first describe the demand projections through 2020 from multiple sources. Second, this section will detail the various supply sources available to meet that demand, including both military and commercial SATCOM assets.

B. SATCOM DEMAND

Starting with Desert Storm, military bandwidth requirements during conflicts appear to be following the exponential growth that is often seen in depictions of Moore's law. SATCOM requirements are not merely increasing; they are increasing exponentially. The convergence of network-centric warfare, data-driven systems, and user demands has created an insatiable demand for SATCOM. The below figure depicts the bandwidth used per 5,000 military members in past, present, and future conflicts.

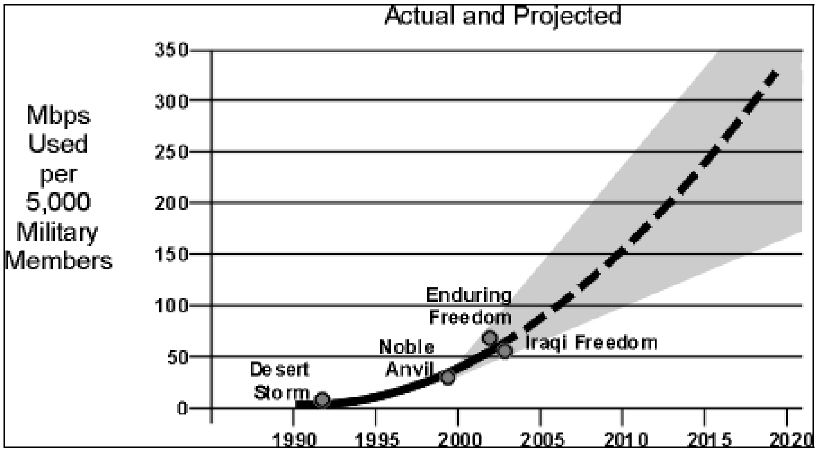


Figure 6. Growth in SATCOM Requirements (Rayermann, 2004)

Figure 7 shows an estimate from an August 2004 draft of the SATCOM ICD indicates a similar trend, independent of the "per 5000 military members" benchmark, contrasted with projected shortfalls in required capacity.

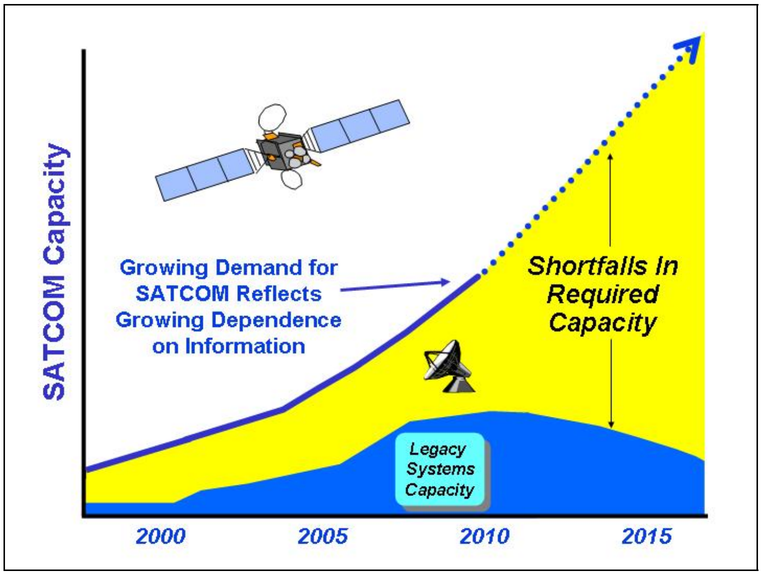


Figure 7. Notional Growing SATCOM Needs of DoD, IC, and NASA (Cartwright, 2004)

Figure 8 depicts the bandwidth requirement now along with the military and commercial supply sources. As seen, there remains a significant gap of unmet requirements, which could further be exacerbated by additional uncertain growth.

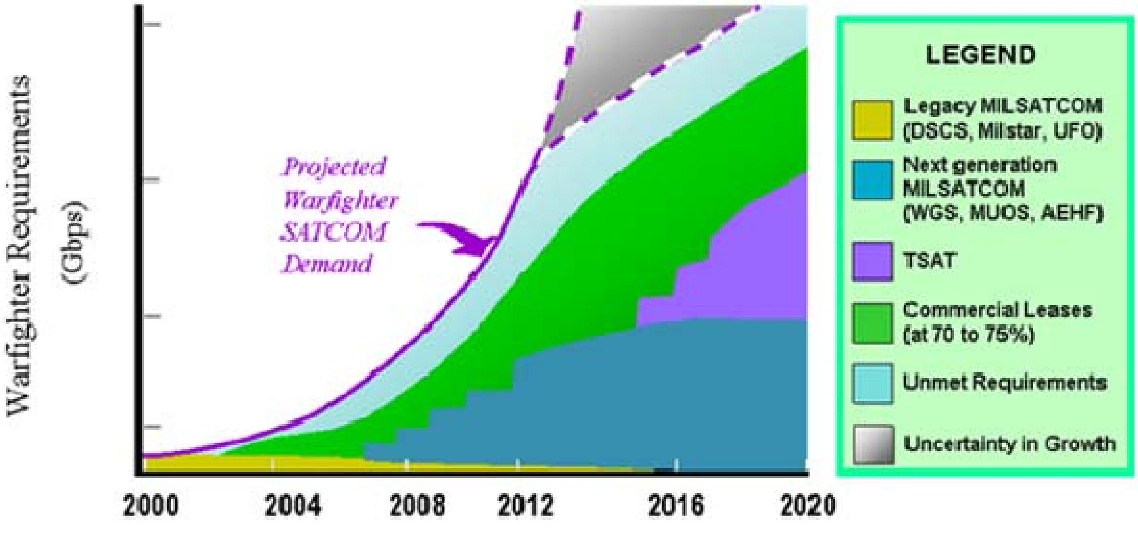


Figure 8. Military Demand for SATCOM (Snodgrass, 2007)

It is possible these figures above overestimate the need. For example, if Global War on Terror operations cease in the next few years and no other major operations occur through 2020, then yes—this model would likely result in an overestimation. However, the role of the DoD is to prepare for war, not peace; a best-case scenario model would undermine responsiveness to real-world situations. Furthermore, as U.S. Army Lieutenant Colonel Roy Snodgrass of USSTRATCOM/J663 pointed out at a recent LandWarNet conference, bandwidth requirements have been dramatically underestimated in *every* modern conflict (Snodgrass, 2007).

Given the projected increased reliance on Unmanned Aerial Vehicles (UAVs), streaming video, and high-resolution imagery in warfare, there is presently no reason to think that such bandwidth requirement growth will slow down anytime in the next several decades. The DoD has little choice but to plan for the current predictions, however daunting they may now appear.

1. Causes

Having examined the current predictions for future SATCOM requirements, it is worthwhile to explore to the causes of such dramatic growth. In his *Commercial SATCOM Support Current/Future* presentation, U.S. Army Lieutenant Colonel Roy Snodgrass of USSTRATCOM pinpoints the specific drivers for bandwidth growth. The first cause of increased demand for SATCOM is "SATCOM to lower echelons," meaning SATCOM need is not relegated to command centers but dispersed to nearly every solider and platform; in other words, almost no warfighter or system is untouched by network-centric warfare (Snodgrass, 2007). The second factor increasing demand is "SATCOM on the move," the increased need for mobile communication in adverse conditions and with low-power terminals (Snodgrass, 2007). A third driver is "Internet Protocol (IP) give and take," meaning the technical implications of IP can limit the efficient use of the SATCOM bandwidth available (Snodgrass, 2007). The fourth and final factor is arguably the most significant—high bandwidth applications: UAV uplinks and downlinks, streaming video, high-definition imagery, and weapon systems increasingly dependent on significant quantities of data (Snodgrass, 2007).

While the projections in Figure 6 are based on number of military personnel, “number of human beings” is hardly the most accurate barometer when discussing large bandwidth use. One of the biggest reasons for the bandwidth surge is UAV. In each successive operation depicted, UAV usage dramatically increased. According to David Helfgott, president and chief executive officer of Americom Government Services, some UAVs need to transmit high-definition data at speeds that can exceed 45 megabits per second (Frederick, 2006). This is for a *single* UAV—contrast that with the need for 500 military members depicted in Figure 9 and then imagine the bandwidth demands of a *fleet* of UAVs.

Predicting military bandwidth requirements is an art, not a science. By the very nature of world events and politics, one cannot accurately predict contingencies and thus corresponding needs. For example, U.S. Central Command required a mere 100 Mps in of commercial SATCOM in August 2001 (the month prior to 9/11) and then two billion bits per second (2 Gbps) in the winter of 2003 (Rayermann, 2004). This twenty-fold increase in about two years was unprecedented and dramatic, but certainly illustrates the problematic nature of attempting to predict wartime bandwidth requirements in a peacetime environment.

C. SATCOM SUPPLY

Given these bandwidth projections, the DoD is left with a fundamental supply and demand challenge. As the RAND report on the subject succinctly points out, there are three basic options (Bonds et al., 2000):

A. Limit demand so that it matches available bandwidth

B. Increase supply using DoD satellites

C. Increase supply using commercial satellites

There is also a fourth option not discussed in the RAND report: attempting to fulfill bandwidth requirements using non-satellite resources. Traditional means of fulfilling these requirements include exploiting temporary or permanent fiber solutions when viable. More innovative solutions include the use of high-altitude “near-space” balloons or extended flight communication UAVs.

Option A (“limit demand so that it matches available bandwidth”) is barely discussed in existing literature, perhaps partly for fear of implying that the warfighter is somehow using up precious bandwidth unnecessarily. Given the dire gap between projected supply and demand, however, there is merit in exploring the (1) design and modification of ground and air systems reduce bandwidth usage and/or (2) institute policies restricting use based on mission priority. However, such exploration is beyond the scope of this thesis and thus deferred to the “areas for further study” section. This leaves options B and C which will be explored further in the remainder of this section. The roadmap for military SATCOM is relatively clear.

	Deactivated	On-Orbit	Near-Term	Long-Term
Protected	AFSATCOM	Milsar	AEHF	TSAT
Wideband	DSCS II	DSCS III, GBS	WGS	TSAT
Narrowband	FLTSATCOM	UFO	MUOS	MUOS

Table 4. Roadmap for Military SATCOM

The roadmap for commercial SATCOM remains less certain, as the DoD does not possess specific insight into market-driven commercial satellite development the way it does with the organic military assets. However, for the foreseeable future, the three broad areas of SATCOM can be covered commercially as depicted in Table 5.

	Commercial
Protected	*None*
Wideband (aka Fixed Satellite Service – FSS)	• Intelsat • SES Global • Eutelsat • Loral Skynet
Narrowband (a.k.a. Mobile Satellite Service – MSS)	• Immarsat • Thuraya • Iridium • Globalstar

Table 5. Current Commercial SATCOM Constellations

D. MILITARY SATCOM ON-ORBIT

1. Milstar

According to the official U.S. Air Force fact sheet, “Milstar is a joint service satellite communications system that provides secure, jam resistant, worldwide communications to meet essential wartime requirements for high priority military users.” The Milstar constellation consists of five operational satellites in geosynchronous orbits. The first Milstar launched in February 1994 and the last in April 2003. Based on the 10-year design life, global coverage from Milstar should begin degrading in the 2010 time frame (Air Force Space Command, 2007).

In the wideband/protected SATCOM dichotomy, Milstar is the only U.S. on-orbit “protected” communications satellite. Among other characteristics, protected implies the ability to continue operations during and after a nuclear conflict. In additional to the hardened architecture of the satellite itself, Milstar also achieves its protected status through use of geographically dispersed mobile and fixed ground control stations.

Figure 9. Milstar Image (Air Force Space Command, 2007)

Milstar General Characteristics	
Primary Function	Protected global military communications
Primary Contractor	Lockheed Martin
Weight	10,000 pounds
Orbit altitude	22,250 nautical miles
Launch vehicle	Titan IVB/Centaur upper stage
Inventory	5 operational
Unit Cost	$800 million

Table 6. Milstar Characteristics (Air Force Space Command, 2007)

2. Defense Satellite Communications System (DSCS) III

Since first launching in 1982, DSCS III became and remains the wideband "workhorse" of military SATCOM, providing nuclear-hardened, anti-jam, high data rate, long haul communications to users worldwide. Due to recent end-of-life supersyncing, the DSCS constellation has shrunk to nine satellites, each providing super high frequency transponder channels capable of providing secure voice and high rate data communications. Due to the DSCS history of dramatically outliving its design life, the constellation has the capability continue providing operational SATCOM even after the launch of all six projected WGS satellites, though it may not be cost-feasible.

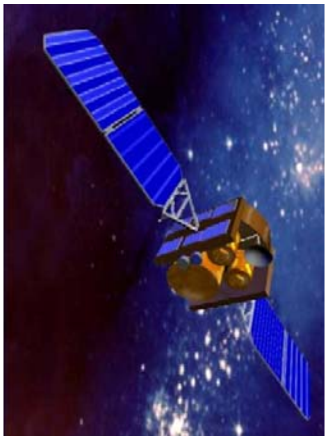


Figure 10. DSCS Image (Air Force Space Command, 2007)

DSCS General Characteristics	
Primary Function	Worldwide, long-haul communications
Primary Contractor	Lockheed Martin
Weight	2,716 pounds
Orbit altitude	19251 nautical miles
Launch vehicle	Atlas II and Evolved Expendable Launch Vehicle
Inventory	9
Unit Cost	$200 million

Table 7. DSCS Characteristics (Air Force Fact Sheet, 2007)

3. Ultra High Frequency Follow-On (UFO)

As the narrowband MILSATCOM component, the UFO mission is to provide communications for airborne, ship, submarine, and ground forces. While most MILSATCOM assets are procured by the U.S. Air Force's Space and Missile Systems Center (SMC), UFO is acquired and managed by the U.S. Navy as a replacement to their Fleet Satellite Communications System (FLTSATCOM) constellation. UFO provides nearly twice as many channels as FLTSATCOM and boasts about 10 percent more power per channel. The first UFO launch occurred in March 1993 and the constellation will ultimately consist of 11 satellites.

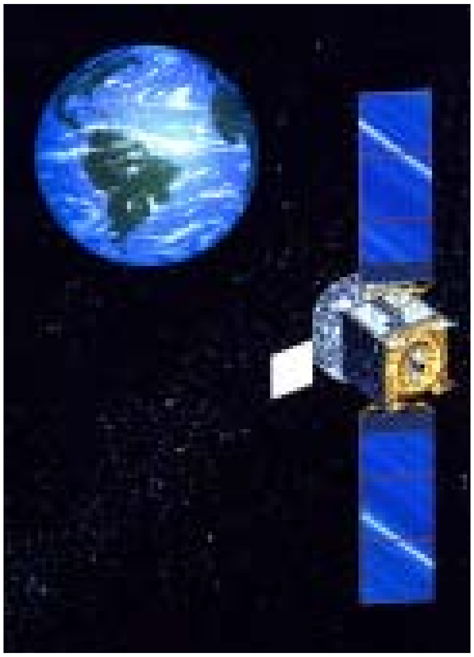


Figure 11. UFO Image (Navy Communications Satellite Programs, 1999)

UFO General Characteristics	
Primary Function	Narrowband communications for airborne, ship, submarine, and ground forces
Primary Contractor	Boeing
Weight	2,610 – 3,371 pounds
Orbit altitude	Geosynchronous orbit - 17716 nautical miles
Launch vehicle	Atlas-Centaur space booster
Inventory	11

Table 8. UFO Characteristics (Navy Communications Satellite Programs, 1999)

4. Global Broadcast System (GBS)

What could be termed “DirectTV for the warfighter,” DoD wideband asset GBS provides both classified and unclassified high data rate direct broadcast to military members worldwide. Provided since 1996, GBS is not a satellite itself but rather a payload installed on host satellites such as UFO and Telestar.

GBS General Characteristics	
Primary Function	High-capacity broadcast (audio, video, files, web, common operating picture)
Primary Contractor	Raytheon
Payload	Transponded Ka/Ku-band communications suite
Capability	96 Mbps per Ka satellite; 1.9 Terabytes to CENTCOM daily
Host vehicle	UFO satellites 8/9/10, Galaxy 10XR (CONUS) (Ku), Telestar 12 (EUCOM AOR) (Ku)
Inventory	3 Primary Injection Points, over 600 Receive Suites, 5 Theater Injection Points

Table 9. GBS Characteristics (Air Force Space Command, 2007)

E. MILITARY SATCOM FOR THE FUTURE

1. Wideband Global SATCOM (WGS)

Managed by the U.S. Air Force and developed by Boeing, WGS is a geosynchronous wideband communications satellite based on a widely used the commercial 702 bus. A successor to DSCS and GBS, it provides a huge leap in bandwidth capacity. A single WGS satellite provides roughly the same bandwidth as an entire 12-satellite DSCS constellation. While only three WGS satellites are required for “near-global” coverage (excluding the poles), an additional three have been contracted to provide additional capacity and extend total system life. The first launch occurred successfully in October 2007, while the remaining five will launch periodically between 2008 and 2013 (Air Force Space Command, 2007).

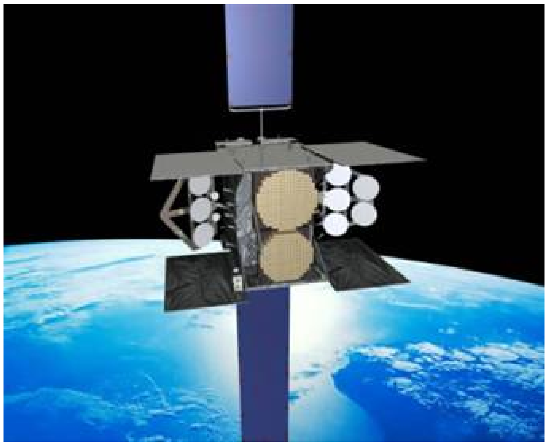


Figure 12. WGS Image (Air Force Space Command, 2007)

WGS General Characteristics	
Primary Function	High-capacity military communications satellite
Primary Contractor	Boeing Satellite Systems
Weight	Approximately 13,000 pounds at launch, 7,600 pounds on-orbit
Orbit altitude	19317 nautical miles
Payload	Transponded, cross-banded-X and Ka-band communications suite
Antennas	8 beam, transmit and receive X-band Phased arrays and 10 Ka-band Gimbaled Dish Antennas, 1 X-band Earth coverage
Capability	39 125-MHz Channels via digital channelizer/router
Launch vehicle	Delta IV and Atlas V EELVs
Inventory	5 on contract, 1 more planned
Unit Cost	Approximately $300 million per satellite

Table 10. WGS Characteristics (Air Force Space Command, 2007)

2. Advanced Extremely High Frequency (AEHF)

The future of protected military SATCOM for the near future, AEHF "provides global, secure, protected, and jam resistant communications for high-priority military ground, sea, and air assets" (Air Force Space Command, 2007). A replacement for Milstar, AEHF will provide over ten times the capability per satellite of its predecessor and incorporate more current survivable communications capability. Though like most military space programs it has been plagued by launch slips, the first AEHF satellite is currently schedule for launch in late 2008, with a second and third to follow. Recent discussions have also indicated the possibility of a fourth, fifth, and sixth AEHF satellite (Air Force Space Command, 2007).

Figure 13. AEHF Image (Air Force Space Command, 2007)

AEHF General Characteristics	
Primary Function	Global, secure, survivable satellite communications
Primary Contractor	Lockheed Martin
Weight	Approximately 14,500 pounds at launch, 9,000 pounds on-orbit
Orbit altitude	19317 nautical miles (geosynchronous)
Capability	Data rates from 75 bps to approximately 8 Mbps
Launch vehicle	Delta IV and Atlas V EELVs
Inventory	3 satellites ordered
Unit Cost	Approximately $580 million per satellite

Table 11. AEHF Characteristics (Air Force Space Command, 2007)

3. Mobile User Objective System (MUOS)

The Navy's replacement for the UFO constellation, MUOS provide global SATCOM narrowband (64 Kbps and below) connectivity for voice, video and data for the warfighter. Still under development, Lockheed Martin was awarded a $2.1 billion contract to build the first two MUOS satellites and associated ground control segment. However, the constellation will ultimately consist of four operational satellites, plus one on-orbit spare. The first MUOS satellite is scheduled for launch in late 2009, with Initial Operational Capability (IOC) declared in 2010.

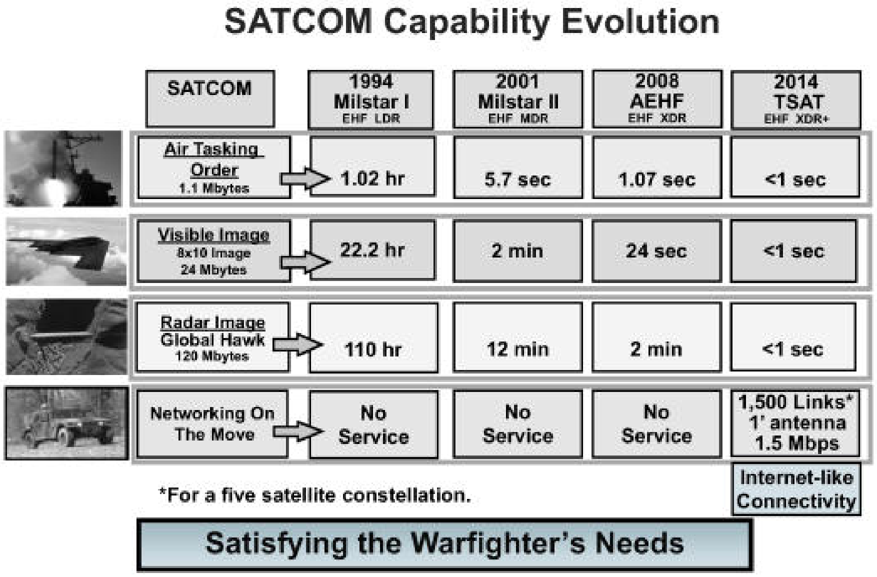
Figure 14. MUOS Image (Lockheed Martin, 2008)

MUOS General Characteristics	
Primary Function	Narrowband (64 Kbps and below) connectivity for mobile and deployed users
Primary Contractor	Lockheed Martin
Weight	6800 pounds
Orbit altitude	19323 nautical miles

Table 12. MUOS Characteristics (Lockheed Martin, 2008)

4. Transformational SATCOM (TSAT)

TSAT will “provide unprecedented satellite communications with Internet-like capability which will extend the DoD Global Information Grid (GIG) to deployed users worldwide and deliver an order of magnitude increase in capacity.” Figure 15 below shows just how dramatic the improvement will be, highlighting dramatic improvements in the speedy delivery of Air Tasking Orders (ATOs) and imagery. Characterized by high data rates and Internet-like routing protocols, TSAT is envisioned as a giant leap forward for MILSATCOM. Another transformational ambition of TSAT is to be the single follow-on to both its wideband (WGS) and protected (AEHF) predecessors. When this thesis began, the first TSAT launch was scheduled for late 2015, with Full Operational Capability (FOC) in 2019 (Air Force Space Command, 2007).



SATCOM Capability Evolution

SATCOM	1994 Milstar I EHF LDR	2001 Milstar II EHF MDR	2008 AEHF EHF XDR	2014 TSAT EHF XDR+
Air Tasking Order 1.1 Mbytes	1.02 hr	5.7 sec	1.07 sec	<1 sec
Visible Image 8x10 Image 24 Mbytes	22.2 hr	2 min	24 sec	<1 sec
Radar Image Global Hawk 120 Mbytes	110 hr	12 min	2 min	<1 sec
Networking On The Move	No Service	No Service	No Service	1,500 Links* 1’ antenna 1.5 Mbps

*For a five satellite constellation.

Internet-like Connectivity

Satisfying the Warfighter’s Needs

Figure 15. TSAT – SATCOM Capability Evolution (McKinney, 2007)

TSAT should not be confused with the Transformation Communications Architecture (TCA), which is the overarching vision for next-generation military communications, emphasizing Internet Protocol (IP) driven interoperability as the enabler for new communication solutions. TCA seeks to assure information dominance through improved, shared battlefield awareness; robustly networked GIG elements; time-critical targeting; and enhanced regulatory and spectrum coordination. As Figure 16 depicts, TSAT is merely part of the TCA, albeit a significant one (Air Force Space Command, 2007).

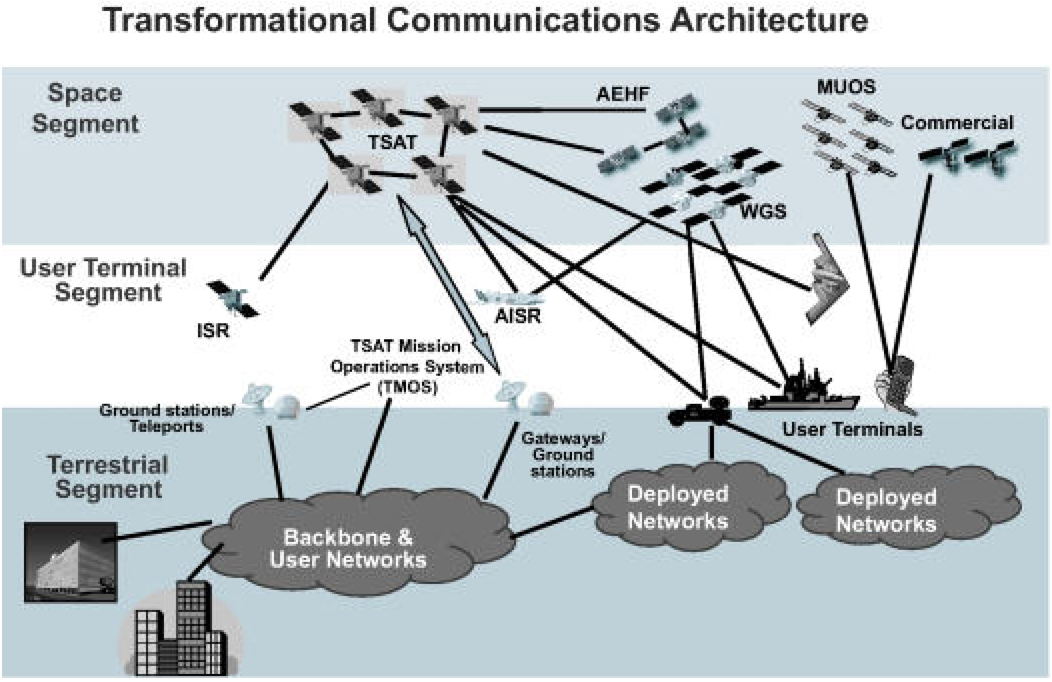


Figure 16. TCA Image (McKinney, 2007)

TSAT General Characteristics	
Primary Function	Space-based component of the GIG, extending its reach to deployed users
Primary Contractor	TBD
Orbit	Geosynchronous
Payload	Protected high data rate EHF, K-band (receive only) RF and Laser payloads
Launch vehicle	Delta IV and Atlas V EELVs
Inventory	5

Table 13. TSAT Characteristics (Air Force Space Command, 2007)

Despite the bold goals of TSAT, its challenges are numerous. In addition to the usual space acquisition challenges of funding cuts and fluctuating political support, TSAT also has increased technical maturity challenges when compared to less ambitious programs such as WGS and AEHF. Major Maurice McKinney argues in his thesis, *Transformational Satellite (TSAT) Communications Systems Falling Short on Delivering Advanced Capabilities and Bandwidth to Ground-Based Users*, that "advanced capabilities provided by TSAT are limited and will not be sufficient to serve the ground-based portion of the communications network supporting network-centric warfare" (McKinney, 2007). Lieutenant General William Shelton, commander of the 14th Air Force, agrees. "I don't think we'll ever have enough bandwidth," said Shelton in a 2007 Air Force Magazine article. "There are some who said that TSAT is going to take away bandwidth as a constraint—I don't think that will ever be true" (Hebert, 2007).

F. COMMERCIAL SATCOM ASSETS

This section describes a representative sample of the major commercial constellations commonly used to provide military SATCOM in various regions of the world. A comprehensive list and detailed descriptions can be found in *Communication Satellites* (Fifth Edition), authored by Donald Martin, Paul Anderson, and Lucy Bartamian. Since no protected SATCOM assets are available in the commercial market, the constellations have been generally categorized as either Fixed Satellite Service (comparable to wideband) or Mobile Satellite Service (comparable to narrowband).

1. Fixed Satellite Service

a. Intelsat

Intelsat is the world's largest commercial satellite communications services provider, owning and operating a fleet of 51 communications satellites at the time of the writing. Its premier status was solidified in 2006 when it acquired long-time rival PamAmSat for $4.3 billion. Intelsat has a strong international presence, with a headquarters in Bermuda and the majority of its revenue from non-U.S. customers (Martin, 2007).

Figure 17. Intelsat Image (Space Flight Now, 2008)

b. Loral Skynet (Telestar)

Not to be confused with the U.K. military satellite Skynet, Loral Skynet is the fourth-largest fixed satellite services provider in the world. It provides full-service global communications to a wide variety of customers, including HBO, Disney, Cable & Wireless, Singapore Telecom, Connexion by Boeing, Global Crossing, BT North America, Globecomm Systems, UPC and China Central Television. While previously a New Jersey based company, the company’s recent merger with Canadian firm Telesat undermined the previously domestic nature of the company. In mid-2007, Loral attempted, unsuccessfully, to acquire Intelsat (Martin, 2007).

Figure 18. Loral Skynet /Telestar Image (Space Mart, 2006)

c. SES Global

The result of various mergers, SES Global was formed in 2001 and immediately became one of the largest satellite service companies in the world. Its subsidiaries include SES Global Latin America, AsiaSat, and SES Sirius. Though General Electric is one of the largest shareholders (at 20%), the company is international and based in based in Betzdorf, Luxembourg (Martin, 2007).

Figure 19. SES Global Image (Cains' News, 2006)

d. Eutelsat

One the three largest satellite operators in the world in terms of revenue, Eutelsat provides coverage of the entire European continent, plus the Middle East, Africa, India and significant parts of Asia and the Americas. The company has approximately 20 satellites on orbit, with immediate plans for several more. While used primarily for television broadcast, it also provides corporate networks, mobile positioning and communications, Internet backbone connectivity and broadband access for terrestrial, maritime and in-flight applications. The company is based in France, with no major U.S. ownership (Martin, 2007).

Figure 20. Eutelsat Image (Space Flight Now, 1999)

2. Mobile Satellite Service

a. Iridium

A massive Low Earth Orbit (LEO) constellation, Iridium is comprised of 66 operational satellites plus on-orbit and grounded spares. The satellites are relatively light, at 1500 pounds, allowing multiple satellites to be launched at the same time (from two to seven depending on the launch vehicle). Initially a colossal economic failure, Iridium began providing services in November 1998 and declared bankruptcy less than a year later. The failure was due in part to mismanagement but primarily due to insufficient demand. The high cost of calls from Iridium phones, ranging from $3 to $14 per minute, no doubt discouraged many potential customers. This U.S.-based company survived, in large part due to extensive use by the DoD. Currently, the company is showing increases in subscribers and revenue (Martin, 2007).

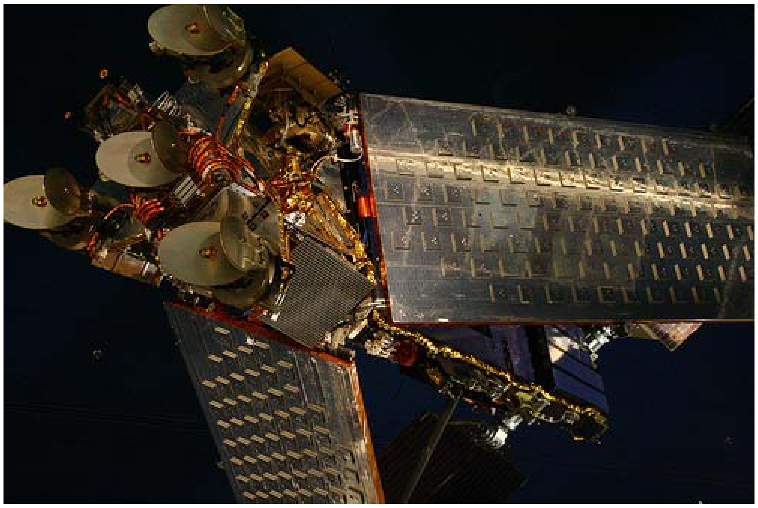


Figure 21. Iridium Image (Visual Satellite Observer, 2008)

b. Inmarsat

Growing out of an intergovernmental organization and now an international corporation, Inmarsat was founded in 1979 and today operates a constellation of approximately a dozen geosynchronous communications satellites. Its worldwide coverage (excluding poles) provides traditional voice calls, low-level data tracking systems, high-speed data services, and distress/safety services (Martin, 2007).

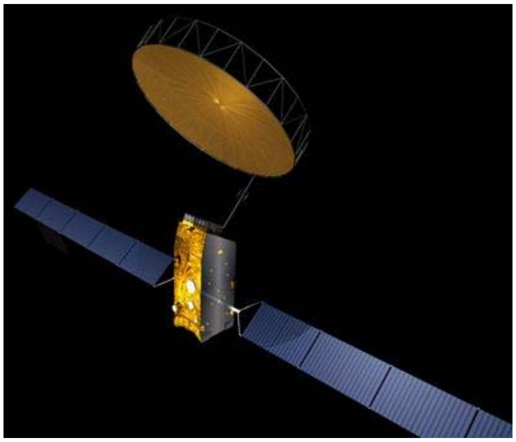


Figure 22. Inmarsat Image (British National Space Centre, 2001)

c. Globalstar

A LEO constellation similar to Iridium, Globalstar provides voice and low-speed data communications. Also, like Iridium, Globalstar is a U.S.-based company which was only able to survive through filing bankruptcy, albeit several years later in 2002. More recently, the satellites have experienced technical problems resulting in numerous dropped calls, possibly due to satellite radiation exposure (Martin, 2007).

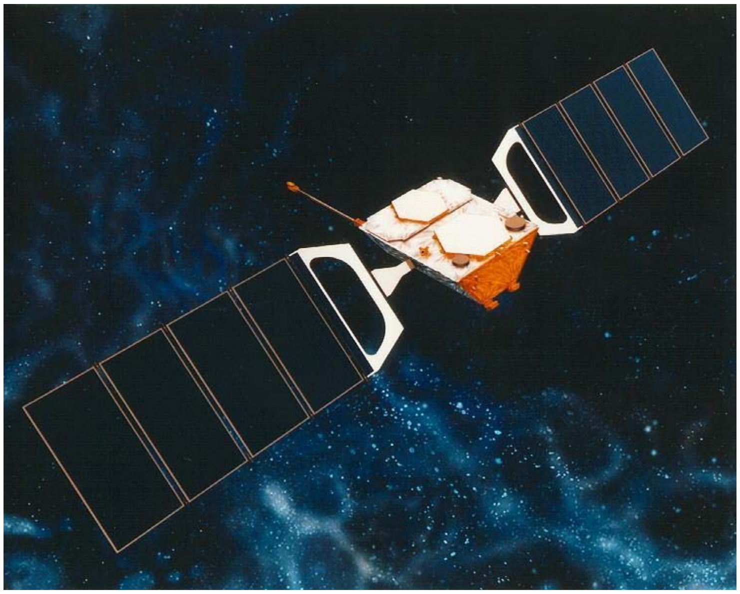


Figure 23. Globalstar Image (Sat News Daily, 2007)

d. Thuraya

Based in the United Arab Emirates, Thuraya is a smaller but geographically relevant constellation that provides mobile voice and low-rate data communications to Europe, Middle East, and Africa. In the future, Thuraya tentatively plans to expand to East Asia, Australia and possibly South America. The company has about a quarter million subscribers and has proved profitable in recent years. The Middle Eastern nature of the service makes it both appealing and suspect for DoD use. Currently there are two Thuraya satellites operational; the third is experiencing launch delays at the time of this writing (Martin, 2007).

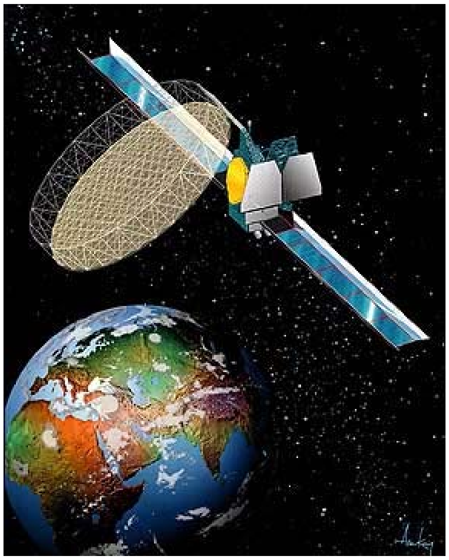


Figure 24. Thuraya Image (Boeing, 2008)

G. SUMMARY

Having surveyed the military's SATCOM supply and demand issues, it is apparent that a serious challenge is facing the DoD. Present and future organic MILSATCOM clearly cannot meet the projected military demand. Even adding commercial SATCOM to the equation, a supply and demand shortfall still appears to exist for the foreseeable future as depicted in Figure 8. The next section will explore the advantages, disadvantages, and cost factors associated with commercial SATCOM. With this foundation, the thesis will present and evaluate the options for striking the optimal balance between military and commercial SATCOM.

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IV. MEASURES OF EFFECTIVENESS

A. INTRODUCTION

To reach the objective in the next section of defining the appropriate balance between military SATCOM and commercial SATCOM, it is critical to have clear and objective measures of effectiveness (MOE). The MOE used in this thesis are: (1) technical, (2) cost, and (3) compliance with policy. Each of these MOEs is described and explored in this section.

B. TECHNICAL

SATCOM technical MOEs are formally defined in the MILSATCOM ICD (Cartwright, 2004). The following table details all five SATCOM Key Performance Parameters (KPPs): connectivity, information assurance, operations management, interoperability, and operational suitability.

KPP	*Threshold*	*Objective*
CONNECT-IVITY	Coverage of users operating anywhere in the worldwide and North Polar areas is required.	Coverage of users operating anywhere in the global coverage area is required.
	The SATCOM family of systems must provide satellite communications and data relay capacity to support the full range of projected DoD operations.	Threshold plus each individual SATCOM system or service within the SATCOM family of systems should have the reserve capacity to accommodate surge loading and support multiple operations.
	Provide protected capacity[1] to users and networks deemed most at risk to disruption of their SATCOM links with the protective features sufficient for them to operate as intended in their postulated threat environments.	Provide protected capacity to all users and networks with the protective features sufficient for them to operate as intended in their postulated threat environments.
INFORMATION ASSURANCE	SATCOM systems and services must have the ability to avoid, prevent, negate, or mitigate the degradation, disruption, denial, unauthorized access or monitoring, and/or exploitation of sensitive and classified information that originates in, is conveyed by, or provided to them.	SATCOM systems and services must have the ability to avoid, prevent, and/or negate the degradation, disruption, denial, unauthorized access or monitoring, and/or exploitation of sensitive and classified information that originates in, is conveyed by, or provided to them.
OPERATIONAL MANAGEMENT	The Operational Management systems supporting the overall SATCOM family of systems and its constituent parts must provide platform, payload, and network management, monitoring, control,	Objective equals threshold.

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[1] Capacity varies by satellite. Exact values were not included in ICD reference document and some values may be classified.

	and configuration capabilities to plan and perform spacecraft launch and early orbit (L&EO) activities, on-orbit operations, network support, and satellite disposal.	
INTER-OPERABILITY	The SATCOM FoS and its constituent systems must satisfy all of the top-level information exchange requirements designated critical in Appendix F of the ICD.	The SATCOM family of systems and its constituent systems should satisfy all of the top-level information exchange requirements identified in Appendix F of the ICD.
	Interoperability must exist between and among the SATCOM networks of all operational elements (ground, air, special operations, maritime, intelligence, and support forces, to include Allies and coalition partners) with which they will form military or inter-agency mission task forces or otherwise be conducting operations.	Objective equals threshold.
OPERATIONAL SUITABILITY	The various systems and services of the SATCOM family of systems must comply with the minimum performance standards of their intended user communities' information systems.	The various systems and services of the SATCOM family of systems must comply with objective performance standards of their intended user communities' information systems.

Table 14. SATCOM Key Performance Parameters (Cartwright, 2004)

Clearly, commercial SATCOM cannot meet all of these threshold and objectives presently or in the foreseeable future. For example, the corporate world is unlikely to independently develop narrowband satellites capable of penetrating dense foliage (which requires non-commercial UHF allocation). Nor is it likely companies would take the initiative to develop a nuclear-hardened communication satellite for any non-governmental customer.

However, there is no technical reason the military-unique requirements of the SATCOM ICD cannot be met by the private sector. For example, a frequent objection to commercial SATCOM is that it limits users to commercial frequencies. However, this need not be the case, as evidenced by XTAR's recent development. In *Satellite Evolution Global*, XTAR Chief Operating Officer (COO) Dr. Denis Curtin described his company's flagship satellite constellation, which is "the world's first commercial provider of X-band satellite services designed exclusively for government users." Could a private company build and operate satellites catering to both military and commercial frequencies? Absolutely—Dr. Curtin states that "the multi-frequency government/commercial hybrid model is a very efficient and cost-effective way of building a satellite system" (Satellite Evolution Global, 2006).

While it is unlikely that commercial SATCOM will autonomously build to the ICD parameters in the way that XTAR targeted government frequencies, there is no inherent reason why commercial companies could not build, launch, and operate satellites to meet these requirements provided long-term partnering and the proper incentives are provided. This would require a dramatic paradigm shift in government dealings with commercial SATCOM providers. Instead of waiting for the capabilities to be available, the government would need to actively partner with and financially commit to satellites prior to their development and launch. Though put off by "partnering" in a shared management sense, commercial sources have responded very positively to early involvement in "anchor tenancy" arrangements in which the government would commitment to commercial satellite development in order to make it viable. This is a very important principle to corporations which do not ordinarily commit to launching a new satellite until 75% of the capacity is pre-sold (Lacy, 2001). In other words, the military would need to begin behaving more like a corporation in its SATCOM procurements—committing in advance of launch to long-term leases. As seen in the next section, this is also an approach that could dramatically reduce cost.

C. COST

Though not specifically called out in the MILSATCOM ICD as a KPP, cost is clearly a major factor and one that merits independent discussion. While one might expect cost to be the most quantifiable of the three MOEs, the variability and complexity actually makes objective cost comparison extremely difficult. It cannot be simply stated that MILSATCOM is more expensive that commercial SATCOM (or vice versa). The reality is… it depends. Although attempts at cost comparisons have been made, Lieutenant Colonel Roy Snodgrass of USSTRATCOM/J663 poignantly observes that there are very few "pure" analyses to rely on and that commercial SATCOM lease costs have historically been high due to inefficient leasing practices (Snodgrass, 2007). Thus technical compliance and policy compliance become simpler, almost binary, MOEs while cost as a MOE remains an unfortunate question mark.

1. Military SATCOM Costs

Pricing the total lifecycle cost of a MILSATCOM satellite is nearly rocket science in itself. Beyond the epidemic cost growth described later in this section, it is important to consider that the price touted by contractors and journalists is often the mere tip of the iceberg. For example, AEHF satellites are generally mentioned in the press as having a under $600 million per unit price tag. However, recent estimates of AEHF 4 are over double this amount, due largely to inefficiencies in the procurement schedule. However, these "per satellite" estimates usually do not account for all development, sustainment, government overhead, and launch costs. None of these additional amounts are trivial and combined they can eventually exceed even the cost of the satellite itself.

For a current look at a relatively "simple" satellite (i.e., one with no low technology readiness level components and based on a proven COTS platform), Wideband Global SATCOM is an interesting example. In mid-2007, the government had already contracted three WGS Block I satellites and was debating the size of the WGS Block II satellites. In response, the WGS contractor Boeing provided an analysis comparing the cost of acquiring additional Wideband Global SATCOM satellites against the cost of leasing commercial transponders. In this study, Boeing estimated that one additional WGS satellite would cost $640M over a 14-year lifecycle and that equivalent transponder leases would cost $2.7B. In other words, commercial fixed satellite service transponder leasing is 400% more expensive that buying an additional WGS satellite! Beyond that, the document also cites numerous advantages such as superior security, steerable beams, and greater responsiveness (Boeing, 2007). Based on such compelling arguments, the government has now not only funded three additional WGS satellites, but is also weighing the purchase of Block III satellites. What was once a "gapfiller" now appears to be the future of wideband SATCOM for the next 25 years.

However, WGS is almost entirely unique in being a firm-fixed price contract. In the far more commonplace cost-plus satellite procurement contracts, the government bears the risk of escalating development costs and launch delays. This is a huge risk and cost that cannot be trivialized. As Captain Jeremiah Stahr points out in his 2006 thesis, *A*

Study On Improving United States Air Force Space Systems Engineering And Acquisition, the U.S. military "space systems acquisition process has increasingly become synonymous with exorbitant cost overruns, substantial schedule delays, and sometimes outright program failure" (Stahr, 2006). In the 2005 Lexington Institute report titled *Can The Space Sector Meet Military Goals For Space*?, Loren B. Thompson places unplanned cost growth as the first of three factors that constitute "the biggest problems facing the national-security space sector" (Thompson, 2005).

While the WGS versus lease SATCOM cost comparison presented above is relatively apples-to-apples, the same cannot be said of the protected SATCOM category. Narrowband and wideband are readily available in commercial equivalents, but there is no commercial parallel to systems such as Milstar and AEHF. Even the most ardent advocates of military use of commercial SATCOM, such as Richard DalBello of Intelsat, takes "the relatively small amount of satellite traffic that demands the highest levels of protection" off the table in his 2007 editorial advocating greater military use of commercial SATCOM (DalBello, 2007).

Finally, in reviewing estimates of MILSATCOM, it is also important to maintain a realistic degree of skepticism in light of historical cost growth. One of the key findings of the Defense Science Board task force on acquisition of national-security space programs in 2003 was "the space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the acquisition process" (Thompson, 2005). Thus the typical cost-plus MILSATCOM contract is likely to grow in cost, whereas a contractual commercial SATCOM lease arrangement is generally a set cost not subject to the typical satellite acquisition cost growth. Though not communication satellites, Space Based Infrared System High grew from $4 billion to over $10 billion and National Polar-orbiting Operational Satellite System grew from $6 billion at inception to current estimates of over $11 billion (GAO, 2006). For a SATCOM-specific example, consider that early estimates of AEHF were approximately $2.5 billion, a figure that grew to $5.3 billion and is expected to grow further. In the military satellite acquisition business, the doubling of costs appears to be more of the rule than the exception.

2. Commercial SATCOM Costs

What is the cost of procuring commercial SATCOM? The unfortunate answer is: it depends. Like MILSATCOM, commercial SATCOM has also been the frequent target of "high cost" accusations. Richard DalBello points out that "some senior military officials have stated publically that an investment in military broadband satellite is necessary to reduce reliance on 'costly commercial satellite systems.' Given what DoD has spent on its military satellites, however, this is a bit like hearing the owner of a garage full of Ferraris commenting on the high price of public transportation" (DalBello, 2007). Despite this colorful defense, high commercial SATCOM costs have been a serious and legitimate concern of Congress, the GAO, and the DoD, particularly since Operations Enduring Freedom and Iraqi Freedom.

The cost among commercial SATCOM service providers varies wildly. For example, a report by the Federation of American Scientists detailed the costs and specifications of four major mobile SATCOM service providers. The terminal costs ranged from $750 to $2500—over a threefold cost differential. The "per minute" usage costs ranged from $0.60 to $3.00—a fivefold increase from lowest to highest (Federation of American Scientists, 2008).

One of the single largest factors in determining the cost of procuring commercial SATCOM lies in the manner in which the government acquires the services. As described in recent GAO reports and other documents, part of the reason commercial SATCOM services tend to be expensive is because the DoD has historically procured it in an inefficient manner. For example, one vendor cites that a transponder lease costs $200,000 per month on a five-year lease and $330,000 per month on a one-year lease. With its historical tendency towards shorter term leases, the military is paying 65% more per month (Lacy, 2001). DISA and GAO report significant progress in procurement efficiencies, as reported in section II of this thesis, but room for progress remains.

As discussed in the technical measures of effectiveness section, pre-launch commitments to commercial satellite could yield not only superior technical solutions, but also cost savings through long-term, pre-negotiated rates. This has appeal not only from the government perspective, but was also a concept widely embraced by industry during a study in the year 2000 which the Global Information Grid Commercial SATCOM Working Group (GIG CSWG) solicited industry opinions on potential military procurement strategies for commercial SATCOM. In fact, the "anchor tenancy" approach was "liked" by 66% of vendors (the highest of any option) and deemed "best strategy" by 33% (again, the highest of any option). One member remarked that this paradigm would have the greatest potential to give the government the "best deal possible" (Lacy, 2001).

Seeing the results of the WGS cost estimate in which commercial SATCOM leases were 400% more expensive, one might wonder why commercial SATCOM should even be considered. It is important to remember that the WGS cost/benefit analysis was conducted and presented by Boeing (a <u>builder</u> of SATCOM satellites), at a time when the government was considering procuring additional satellites nonetheless. Similarly, Intelsat (a <u>leaser</u> of SATCOM) performed a similar cost/benefit analysis—taking into account satellite costs, launch costs, operations, fill rates, commercial pricing, and risk—and came to the opposite conclusion: that commercial SATCOM leasing is the cheaper solution (DalBello, 2007). If the government looks to industry to provide an answer to the "which is cheaper" question, industry will invariably use or exclude numbers to reach the conclusion that is good for their business. The government needs a truly independent cost/benefit analysis of the situation and based on the literature review conducted for this thesis, no such analysis exists.

D. POLICY COMPLIANCE

While SATCOM policy exists at DoD and lower levels, the overarching policy is contained at the federal level in the U.S. National Space Policy. The MILSATCOM ICD has yet to adapt to the most current version of the U.S. National Space Policy compliance. The U.S. National Space Policy as authorized by President George W. Bush on August 31, 2006, provides direction that is clearly applicable to the SATCOM. In paragraph 7 (*Commercial Space Guidelines*), it states, "departments and agencies shall use U.S. commercial space capabilities and services to the maximum practical extent;

purchase commercial capabilities and services when they are available in the commercial marketplace and meet United States Government requirements; and modify commercially available capabilities and services to meet those United States Government requirements when the modification is cost effective."

The above guidance, logically extrapolated to DoD SATCOM needs, implies that nearly all military wideband and narrowband requirements should be met under these provisions. However, valid counterarguments can certainly be posed. For example, the policy advocated use of "U.S. commercial space capabilities" and, as seen in section III of this thesis, many of the current SATCOM providers are international in their ownership and management. Targeting strictly U.S. corporations for SATCOM service is at least initially limiting. Additionally, it could be argued that the "meet United States Government requirements" clause support greater MILSATCOM development since commercial companies do not at present fulfill military security and technical requirements.

E. SUMMARY

Having analyzed the technical, costs, and policy measures, the complexity of the issue should be clear. Neither commercial nor military SATCOM possesses a monopoly on technical, cost, or policy superiority. Arriving at an optimal balance is as much an art as a science. In the next section, this thesis will attempt to apply this art by evaluating the measures of this section against the various options for meeting military SATCOM requirements.

V. GETTING THE BALANCE RIGHT

A. INTRODUCTION

In a 2002 issue of *The Edge*, the editor writes, "The conundrum faced by the DoD SATCOM community at large can be summed up as whether to lease or whether to buy SATCOM capability" (MITRE, 2002). This assessment is flawed in its assumption that the DoD must do one *or* the other; the options are not mutually exclusive. The real conundrum faced by the DoD SATCOM community is what is the appropriate *balance*. This challenge is recognized by both government and industry leaders. As Rebecca Cowen-Hirsch, director for DISA's SATCOM, Teleport & Services Program Executive Office, stated, "…with the launching of the Wideband Global Satellites we will begin to see a greater balance between MILSATCOM and commercial SATCOM, but we will still have a continued dependence and reliance on commercial SATCOM for the future" (Via Satellite, 2007). The vice-president of government affairs at Intelsat writes that both government and industry need to "tackle the truly hard job of creating a communications satellite procurement approach that most cost effectively meets the needs of our military commanders and troops in the field" (DalBello, 2007). Both sides of the fence are clearly struggling with the issue of optimal balance.

What then is the current policy on balancing commercial SATCOM and MILSATCOM? There does not appear to be one. The MILSATCOM ICD states "commercial systems augment USG-owned SATCOM in many areas and are an important constituent of worldwide capacity that supports the GIG infrastructure's users," yet there is no attempt to define the degree of augmentation. Presumably, commercial augmentation in this context could be defined as *fulfilling the delta between MILSATCOM supply and military SATCOM demand*. (However, one could argue that in the current 80/20 commercial/military SATCOM balance, it is actually the MILSATCOM that is augmenting the commercial SATCOM!) No definition beyond this inferred one was found during the literature review conducted for this thesis. As one observer writes, "How should the U.S. Department of Defense determine what traffic goes on the nation's military satellites and what goes on the commercial? Is it something that should be planned? Or should it remain, as it is today, a more or less fluid process involving the hopeful convergence of military demands, commercial supply, and the availability of operation and maintenance dollars for leasing?" (DalBello, 2007).

Thus the objective of this thesis is to attempt to define what has never been officially defined: the appropriate balance between military SATCOM and commercial SATCOM. The remainder of this section described the options available and compares them against the measures of effectiveness (technical, cost, and policy-compliance) from the previous section.

B. SATCOM OPTIONS

1. 100% Military SATCOM Policy

One possibility to meeting DoD SATCOM requirements is to cease relying on commercial SATCOM altogether and leverage a 100% MILSATCOM solution. An extreme solution, this would require an enormous acquisition investment. It would be theoretically feasible if one imagines littering the skies with AEHF, MUOS, and especially WGS satellites. However, such a policy would allow little or no ability to "surge" beyond what is immediately available through MILSATCOM; any ability to surge would have to be built into the constellation.

While such a policy could meet the technical MOE, it would likely fail the cost MOE and would surely flunk the policy MOE. Such an approach is a clear violation of the 2006 U.S. National Space Policy and would furthermore severely limit DoD ability to surge with commercial space assets during contingencies.

100% MILSATCOM		Comments
Technical	G	With sufficient funding and lead time, all technical requirements likely to be met.
Cost	Y	Capability to surge is very limited and would need to be "built in" to MILSATCOM. This option is likely to be costly.
Policy	R	Does not comply with U.S. National Space Policy

Table 15. 100% MILSATCOM Assessment

2. 100% Commercial SATCOM Policy

A similarly extreme policy would be 100% reliance on commercial SATCOM services. With long-term planning and well-crafted partnering, such a policy could work well for the vast majority of wideband and narrowband requirements. However, turning over protected SATCOM requirements to commercial vendors would likely violate information assurance KPP of the technical MOE. The cost of addressing advanced technical and protected requirements through such a mechanism is also a significant risk. While this paradigm fully embraces the “use commercial” thrust of the U.S. National Space Policy, it does not comply full with security policies.

100% Commercial		Comments
Technical	R	With sufficient funding, partnering, and lead time, most technical requirements likely to be met. Information assurance KPP likely violated.
Cost	Y	Cost is highly uncertain for advanced and protected capabilities.
Policy	Y	Supports leveraging commercial capabilities as described in U.S. National Space Policy.

Table 16. 100% Commercial SATCOM Assessment

3. Civil Reserve Air Fleet (CRAF) Paradigm

The Civil Reserve Air Fleet (CRAF) is an arrangement by which U.S. airline companies voluntarily contract to allow their civil aircraft to be used to support DoD mobility needs in time of emergency. Although the program has existed since 1952, it was only been used once (in support of Desert Shield/Storm requirements). The paradigm is widely known in the defense environment and subsequently it is frequently suggested that commercial satellite companies could enter into a similar arrange—a sort of Civil Reserve SATCOM Fleet (CRSF). In the paper *Commercial Communications Analogy to Civil Reserve Air Fleet*, the authors propose almost precisely this (Dobbs, 1999).

While CRAF has proved relatively successful, perhaps more as an insurance policy than in actual practice given its one-time use, applying the same principle to SATCOM is more challenging. In the 2001 Aerospace Corporation report prepared by Dr. Robert Lacy, there are strong indications that industry is unsupportive of this approach due to the long-term nature of SATCOM contracts and the type of customers using SATCOM. As the author points out, airline customers are accustomed to being bumped off flights; however, businesses relying on their long-term SATCOM contracts for their livelihood are unlikely to be as forgiving or accommodating (Lacy, 2001). It would likely take a tremendous financial incentive to convince SATCOM providers to participate in such a CRAF-like program.

CRAF Paradigm		Comments
Technical	Y	Would partially address technical requirements.
Cost	Y	Cost to incentivize contractors to participate could be prohibitive.
Policy	G	Supports leveraging commercial capabilities as described in U.S. National Space Policy.

Table 17. CRAF Paradigm Assessment

4. Depot 50/50 Paradigm

Though not suggested anywhere outside this thesis to the author's knowledge, another paradigm that could be applied to the question of SATCOM commercial/military balance is the "50/50 rule" levied upon depot maintenance. Under 10 United States Code (U.S.C.) 2466, the military departments and defense agencies can use no more than 50% of annual depot maintenance funding for work performed by private sector contractors. The point of this law is to ensure that the military is not overly dependant upon the private sector in the maintenance of their weapon systems. A similar policy could state no more than 50% of SATCOM used by the military should come from commercial sources. As a general target, this policy provides guidance to increase MILSATCOM capacity and could "ease the minds" of those who believe the military is overly dependant what is often perceived to be unsecure, precarious, and costly commercial SATCOM. On the other hand, the number is arbitrary and could limit ability to meet SATCOM requirements during operations if strictly enforced.

Depot 50/50 Paradigm		**Comments**
Technical	**G**	Addresses technical requirements provided MILSATCOM is appropriately expanded to ensure compliance with 50/50 rule.
Cost	**G**	Increases cost of MILSATCOM, reduces cost of commercial SATCOM during periods of heightened operations.
Policy	**Y**	Does not fully support maximum leveraging of commercial sources as described in U.S. National Space Policy.

Table 18. Depot 50/50 Paradigm Assessment

5. Optimized Hybrid

From assessments of the first two options described in this section, it is clear that neither 100% MILSATCOM nor 100% commercial SATCOM is optimal. A hybrid is needed to "go green" in all three measures of effectiveness. This proposed option seeks to do the following:

- Maximize technical compliance by (1) allocating protected and advanced technology requirements to MILSATCOM and (2) allocating proven wideband and narrowband requirements to commercial SATCOM via long-term anchor tenancy arrangements.
- Maximize cost-effectiveness on commercial SATCOM through anchor tenancy, "most favored buyer" arrangements, and long-term leases.
- Maximize policy compliance by favoring U.S.-owned companies for the vast of majority commercial wideband and narrowband SATCOM leases. While U.S.-based SATCOM companies are presently limited, this policy would foster greater U.S. corporate investment.

Optimized Hybrid		**Comments**
Technical	**G**	With sufficient funding and lead time, all technical requirements likely to be met. Methodical, vice ad hoc, partnering with industry improves likelihood of achieving technical requirements.
Cost	**G**	Reduces cost of commercial SATCOM through increasing buying power and enabling long-term leases. The more methodical and long-term approach in this arrangement puts the U.S. government in an improved buying position.
Policy	**G**	Fully supports maximum leveraging of commercial sources as described in U.S. National Space Policy.

Table 19. Optimized Hybrid Assessment

One could argue that this hybrid with commercial SATCOM emphasis is, in reality, not wildly different than what exists today in that it resembles the current 80/20 commercial/military SATCOM mix. However, there are two important differences from the status quo. One, this policy would effectively negate future military wideband and narrowband SATCOM programs (i.e., no next generation WGS or MUOS). Second, the deliberate nature of this policy has dramatic implications for government partnering with industry. Instead of being short term post-launch customers who purchase what is available as needed, the military would become long-term customers/investors with a voice in the technical requirements. If executed wisely, this relationship could yield both cost savings and technical advantages, such as improved terminal interoperability and desired frequency availability.

Another objection to this paradigm is that hosting such a large proportion of military traffic on commercial SATCOM is the security vulnerability. However, the risk is no greater than the status quo in which 80% of Operation Iraqi Freedom SATCOM traffic is commercial. This hybrid paradigm, in which the DoD injects itself into the commercial SATCOM design process, actually could substantially reduce this risk by planning, designing, and funding more robust anti-jam capabilities.

C. SUMMARY

This section surveyed five options for obtaining the proper balance between MILSATCOM and commercial SATCOM. From the analysis, it is seen that there are viable options that satisfy most MOEs (*Depot 50/50 Paradigm*) and that one option that satisfies all MOEs (*Optimized Hybrid*). The optimized hybrid brings optimizes technical requirements compliance by allocating inherently military SATCOM (protected and advanced technology) to MILSATCOM while designating commercial sources for proven, broad SATCOM requirements. It provides cost optimization through a more strategic, less ad hoc partnership with industry. Finally, it satisfies U.S. Space Policy through use of the commercial satellite industry to the maximum extent possible. The next section provides a conclusion to the thesis and recommends areas for further study.

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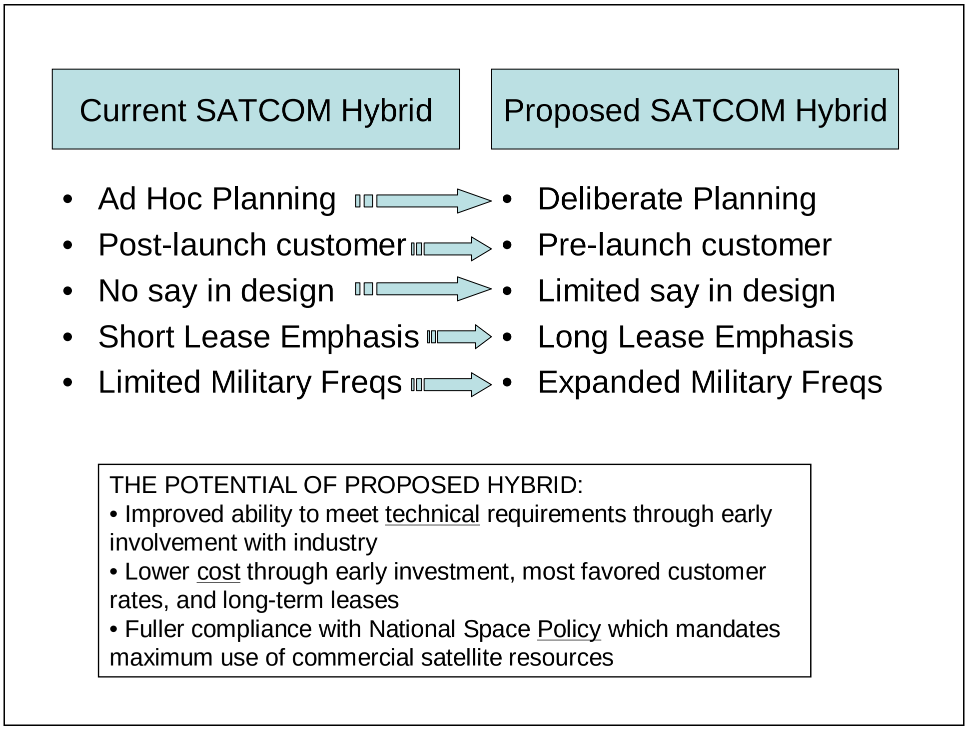
VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

As seen in the previous section, only the *Optimized Hybrid* military/commercial SATCOM paradigm is rated as green in all three measures (technical, cost, and policy). This option is the primary recommendation of this thesis, although the *Depot 50/50 Paradigm* also scored relatively high. The following figure depicts how commercial SATCOM is better leveraged under the new paradigm versus the current hybrid.



Current SATCOM Hybrid	Proposed SATCOM Hybrid
Ad Hoc Planning	Deliberate Planning
Post-launch customer	Pre-launch customer
No say in design	Limited say in design
Short Lease Emphasis	Long Lease Emphasis
Limited Military Freqs	Expanded Military Freqs

THE POTENTIAL OF PROPOSED HYBRID:

- Improved ability to meet technical requirements through early involvement with industry
- Lower cost through early investment, most favored customer rates, and long-term leases
- Fuller compliance with National Space Policy which mandates maximum use of commercial satellite resources

Figure 25. Commercial SATCOM Under Proposed SATCOM Hybrid

The most significant commercial SATCOM shift is from ad hoc planning to deliberate planning. The move from hopeful convergence and vague policy to strategic partnering and defined policy is the key enabler for remaining shifts and benefits listed above. It allows the government to be a pre-launch customer with a say in planning that allows requirements to be better met. It builds on recent DISA cost and responsiveness improvements by making the military a larger customer with discounted leases and a greater long-term stake in commercial satellite ventures.

To make this option a viable and successful reality, several “sub-recommendations” are required.

B. FURTHER RECOMMENDATIONS

1. Conduct Independent Cost/Benefit Analysis

As described in Chapter IV of this thesis, very few “pure” and comprehensive analyses have been done comparing military and commercial SATCOM. Specifically, estimates have come from biased sources, key cost factors have been excluded, and commercial leasing costs have been based on inefficient procurement practices. A thorough and definitive cost/benefit analysis from an independent source should be conducted so that decision-makers can make a more informed long-term policy decision.

2. Explore Anchor Tenancy

While the Optimized Hybrid policy could be pursued without anchor tenancy, this author contends that implementing this concept is the cornerstone to successful partnerships with industry in better meeting DoD requirements. Anchor tenancy is essentially a financial commitment during the development phase of a product that enables the viability of the project. In other words, it is a way for the government to financially and contractually say, “If you build it, we will come.” Without such arrangements, industry will be wary of taking risks to meet theoretical government needs. Investors require some degree of guarantee of return on their investment, especially in the space business where many risk-takers of the last ten years have not been rewarded. As discussed in section V of this thesis, there is significant industry enthusiasm for this concept (Lacy, 2001). In addition to being a win for industry, this concept can enable better prices, greater design influence to improve security and protection, and limited financial risk for the government.

There is likely to be some resistance to anchor tenancy due to perceived violation of acquisition policies and federal statutes. However, there are provisions for such arrangements in Title 15, Chapter 84 of the U.S.C., which described "an arrangement in which the United States Government agrees to procure sufficient quantities of a commercial space product or service needed to meet government mission requirement so that a commercial venture is made viable." There is also precedent for the concept via the two-year contract between the DoD and Iridium as signed in December 2000 (Lacy, 2001).

3. Establish Explicit DoD Policy

It is the recommendation of this thesis that the Optimized Hybrid paradigm, with its emphasis on strategic partnering with industry for the majority of requirements, be incorporated into DoD policy. Not only does it provide advantages in technical and financial areas, but it also moves the DoD into alignment with the current U.S. National Space Policy. In addition to the risk of non-compliance with national policy, the current ad hoc nature of the military/commercial SATCOM balance is optimal for none of the measures of effectiveness. Without a defined policy to march toward, effective planning is extremely difficult for the government and industry.

4. Modify Acquisition Strategy to Fit Policy

Clearly, such a policy cannot be *immediately* implemented into DoD acquisition and procurement activities. It will take time to develop corresponding contractual arrangements with industry and naturally time to develop then launch the appropriate satellites. Also, the next generation of wideband, narrowband, and protected MILSATCOM (WGS, MUOS, and AEHF) is well underway and it would not be prudent in any way to "pull the plug" on such programs in light of their current progress. This policy is necessarily long-term—applicable to the next "next generation" in 2025 and beyond.

C. SUGGESTED AREAS FOR FURTHER STUDY

In addition to exploring the further recommendations described above, the author recommends the following areas for further study:

1. Analyze Bandwidth Reduction

Military bandwidth requirements are increasing at a near exponential rate, akin to Moore’s Law as seen in section II of this thesis. While there is ample literature and discussion regarding how to increase the supply, there is virtually no literature or discussion on how to reduce the demand. A comprehensive “bandwidth reduction initiative” could be instituted across the DoD and dramatically reduce SATCOM usage. This initiative could address both *system* bandwidth use (i.e., designing UAVs that require less bandwidth) and *personnel* bandwidth use (i.e., limiting non-essential network use).

2. Explore SATCOM Alternatives

While SATCOM is often considered to be economical long-distance communications, it is not in many situations the most economical nor the most optimal. For example, fiber surpasses SATCOM in terms of cost and is clearly favored for communications in developed areas. Also, for undeveloped areas where the military does not already have SATCOM presence, leveraging near-space communication balloons or a communication-enabled UAV could be far more responsive and cost-effective. The bottom-line is that SATCOM is only one of many supply options available for operational communications and other viable options exist for meeting the demand.

D. SUMMARY

From its experimental beginning in the later 1950s to its operational coming-of-age in Desert Storm to its recent explosion of use in Operation Iraqi Freedom, SATCOM has grown to become an indispensible force enabler for the warfighter. As the need for SATCOM has grown, reliance on commercial SATCOM has grown along with it at an often alarming rate. However, in this growth, the maturity of policy and planning wisdom has often been lacking. Recent attention from Congress and the GAO has improved commercial SATCOM procurement, but these improvements were reactionary and tactical in nature. What is needed now are improvements that are proactive and strategic.

Military use of commercial SATCOM will continue to be critical to operations and this criticality demands that certain questions be answered. For example, will commercial SATCOM be procured in long-term, methodical manner or will it be purchased on as as-needed, just-in-time basis? Will the DoD fully embrace the commercial emphasis of the U.S. National Space Policy? If commercial SATCOM usage is out of balance, what is the right balance? Whatever the answers to these questions, they should be answered in a clear and transparent manner for all government and industry stakeholders to see. At this time, these questions remain unanswered.

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