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Transformational Satellite (TSAT) Communications Systems

Falling Short on Delivering Advanced Capabilities and Bandwidth to Ground-Based Users

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Disclaimer

Foreword

It is my great pleasure to present another of the *Wright Flyer Papers* series. In this series, Air Command and Staff College (ACSC) recognizes and publishes our best student research projects from the prior academic year. The ACSC research program encourages our students to move beyond the school's core curriculum in their own professional development and in "advancing air and space power." The series title reflects our desire to perpetuate the pioneering spirit embodied in earlier generations of Airmen. Projects selected for publication combine solid research, innovative thought, and lucid presentation in exploring war at the operational level. With this broad perspective, the *Wright Flyer Papers* engage an eclectic range of doctrinal, technological, organizational, and operational questions. Some of these studies provide new solutions to familiar problems. Others encourage us to leave the familiar behind in pursuing new possibilities. By making these research studies available in the *Wright Flyer Papers*, ACSC hopes to encourage critical examination of the findings and to stimulate further research in these areas.

JAY H. LINDELL
Brigadier General, USAF
Commandant

Abstract

The Transformational Communications Office's (TCO) 17 December 2003 report states, "The current SATCOM and data relay systems are unable to meet future bandwidth demands. They lack capacity, in both aggregate data rate and the number of users they can support. . . . Furthermore, the life expectancies of the existing space segments and much of their associated terminal and management segments do not extend beyond the 2010–2015 time frame."[1] These shortfalls and the military's insatiable demand for bandwidth led to the creation of the Department of Defense's (DOD) TSAT.

TSAT's five-satellite constellation will be capable of delivering advanced capabilities to the war fighter via 8,000 radio frequency (RF) links and between 20 and 50 laser communication (lasercom) links. These advanced capabilities will deliver significant communications bandwidth by incorporating advanced laser and RF technologies, software-configurable terminals, packet switching, network management, and interface standards. All of these technologies will rely on Internet protocol (IP) interoperability as the enabling technology for connecting the war fighter.

The thesis of this paper is that the 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 (NCW). To validate this proposition, this study will start by identifying space-based systems that will enable NCW, discuss the requirements for ground-based NCW, and finally determine the combination of spaced-based systems sufficient to deliver advanced capabilities to the war fighter.

Preface

I have enjoyed researching the transformational satellite (TSAT). This topic was particularly interesting because I was a communications officer for the 264th Combat Communications Squadron at Peoria Air National Guard Base, Illinois. Our mission was to deliver satellite communications (SATCOM)/wideband communications to austere locations anytime and anywhere. I felt that on my return to my Guard unit, I would be equally versed in current and future SATCOM and wideband technologies.

However, the selection of TSAT as a research topic and completion of this study was not possible without the help of Lt Col James Rothenflue. I would like to thank Colonel Rothenflue for the temporary duty assignment to Kirtland AFB, New Mexico. Prior to that I had not selected a research topic. In fact, I had no idea of what I wanted to research. It was during that trip that I selected TSAT as my research topic. I would also like to thank Colonel Rothenflue for the guiding comments in finishing this study. His comments kept me focused and on track to completion. I hope that it met his expectations.

I would also like to thank my wife, Lori, and our three children, Maurice II, Jacob, and Kaeleb, for their support and understanding. Thanks for putting up with my long days and short nights. Without your encouragement and support, I could not have completed Air Command and Staff College. God willing, we will have a safe and relaxing summer, and I look forward to our first family vacation in years.

Introduction

The vision of the Transformational Communications Architecture (TCA) is to enable new mission capabilities by removing communications as a constraint.

—TCA Baseline Version 1.0

The United States military relies heavily on the use of satellite bandwidth as a part its overall strategy in winning current and future battles. For example, during Desert Storm the US military forces numbered 542,000 and had 99 megabits per second (Mbps) of satellite bandwidth available.[2] In Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF) bandwidth rose to 3,200 Mbps while US forces were reduced to 350,000.[3] Now, DOD planners are projecting the need for approximately 16 gigabits per second (Gbps) of bandwidth to support a large, joint-service operation by 2010.[4]

This study's thesis is that the real-time intelligence, surveillance, and reconnaissance (ISR) capabilities provided by TSAT will not be sufficient to serve the ground-based portion of the communications network supporting NCW. To validate this proposition, this study will begin by identifying TSAT's and other space-based systems' advanced capabilities that will enable NCW. Then the minimum requirements for DOD ground-based NCW will be discussed and finally, alternatives sufficient to deliver advanced capabilities and bandwidth to the future war fighter will be recommended.

In 2002, the intelligence community (IC), the DOD, and the National Aeronautics and Space Administration (NASA) communities collaborated on the design, synchronized acquisition, and coordinated deployment of an interoperable, multisegment transformational communications architecture (TCA).[5] After 18 months of work focused on evolving the TCA, the team delivered the TCA Baseline Version 1.0 document.[6] The document provides a technical foundation for the development of US government communications capabilities for the next 20 years.

The TCA consists of eight categories. As shown in figure 1, each category has multiple communication-systems programs designed to enable advanced capabilities. The technologies in each category are designed with the same goal of removing communications as a constraint to the war fighter.

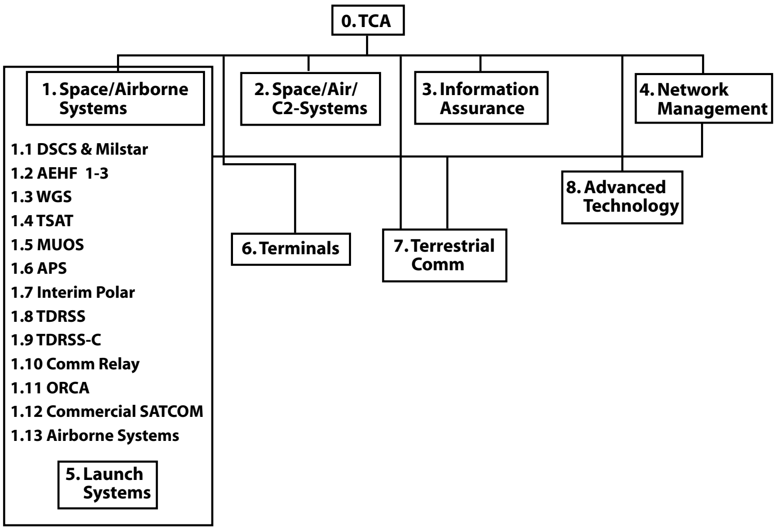

Figure 1. TCO Roadmap Tool Work Breakdown Structure (Reprinted from Transformational Communications Office, "Transformational Communications Architecture Version 1.0" [U], 17 December 2003, 2. [U/FOUO] This information is extracted and has been cleared for public release: distribution unlimited.)

As shown in figure 1, the Space/Airborne Systems category consists of 13 programs. Seven of the programs support existing space/airborne-communications systems, one program was terminated, and the five other programs will support next-generation satellites. The seven existing space/airborne programs are the Defense Satellite Communications System (DSCS), Milstar, communications relay, commercial SATCOM, airborne systems, and NASA's Tracking and Data Relay Satellite System (TDRSS) and TDRSS-continuation. In 2004, the National Reconnaissance Office's (NRO) optical relay communications architecture program was terminated. The NRO now plans to use TSAT for data relay purposes.[7]

The five next-generation secure-satellite systems that promise to deliver additional bandwidth and IP capabilities to the war fighter are TSAT, advanced extremely high frequency (AEHF), Wideband Gapfiller System (WGS), Mobile

User Objective Systems (MUOS), and advanced polar system (APS). This study will focus on the five next-generation satellite programs within the space/airborne-systems category.

The TSAT constellation will provide advanced lasercom and RF technologies connecting space- and ground-based communications to the Global Information Grid (GIG). The AEHF satellites will provide protected communications to support strategic assets with upgraded extremely high frequency (EHF) protected/survivable features. The WGS is a "follow-on" generation for wideband communications.[8] The MUOS is the next-generation narrowband solution providing critical connectivity for more than 80,000 ultrahigh frequency (UHF) devices, such as small antenna radios (as small as one foot) found in tactical ground vehicles, hand-held manpacks, and airborne systems.[9] The APS is the next-generation laser-satellite communications system supporting the North Polar Region.

The TCA end-to-end architecture will enable access to the terrestrial GIG via three segment domains, user terminals, terrestrial infrastructure and networks, and space.[10] The user terminal segment consists of space, airborne, and terrestrial user terminals and performs the RF or optical handling, waveform-communications processing, traffic shaping, dynamic bandwidth management, and network/security protocols.[11]

The terrestrial infrastructure and network segment interfaces the TCA with the GIG and other terrestrial networks. Specifically, it enables connectivity between the space-segment and continental-United States (CONUS) networks.[12] In essence, data would traverse DOD gateway terminals and connect to terrestrial fiber networks, allowing high-speed connectivity to ground-based networks.

Lastly, the space segment demonstrates an "independent and interoperable" philosophy.[13] Meaning, TCA uses ground connectivity and interoperable high-bandwidth TSAT crosslinks so NASA, DOD, and IC systems have block utility and can fully support their missions without depending on successful and timely deployment of other TCA programs.[14] Simply put, TCA is the architectural blueprint from which TSAT and other space-based platforms will be built.

Space-Based Bandwidth Capabilities

Basically, TSAT is the overall system. The satellites are part of that, the ground segment is part of that, and TMOS is part of the overall TSAT system. [TSAT missions operations system]

—Troy Meinke, Air Force TSAT Program Manager

So what is TSAT? Some people may confuse TSAT with TCA. To the war fighter, TSAT is just one node in a host of other TCA satellite programs. Simply put, TSAT is a secure, protected, wideband, five-satellite constellation capable of providing worldwide coverage to the war fighter. More importantly, it will be the only fully laser cross-linked satellite constellation providing EHF, X-band, and K_a-band frequencies supporting airborne intelligence, surveillance, and reconnaissance (AISR) and other next generation satellite constellations such as AEHF, MUOS, WGS, and APS.

The lasercom cross-link and RF hybrid terminals will also provide wideband connectivity between terrestrial data networks such as the GIG bandwidth expansion (GIG-BE) and battlefield networks such as the War Fighters Information Network-Tactical (WIN-T), Joint Tactical Radio Systems (JTRS), and existing satellites such as Milstar and DSCS.

Figure 2 shows TSAT's direct and indirect connectivity to AEHF, MUOS, WGS, and APS. The TSAT laser cross-links running at 10 to 40 Gbps will interconnect the five-satellite constellation. The EHF and K_a-band will connect to lower-bandwidth satellites such as WGS, APS, MUOS, AEHF, and satellite ground stations as fast as 300 Mbps, while the RF links will connect to forward-based ground terminals as fast as from 256 kilobits per second (Kbps) to 45 Mbps.

In addition to its laser and RF advances, TSAT will be the only next-generation, laser-based, secure, protected, wideband satellite communications capable of delivering medium-data-rate (MDR) communications-on-the-move (COTM) to as small as one-foot terminals.[15] This technology will allow mobile forces to communicate while moving swiftly, eliminating the vulnerability of troops otherwise forced to pause to communicate. Therefore, the TSAT program is a critical element of the DOD's vision for removing commu-

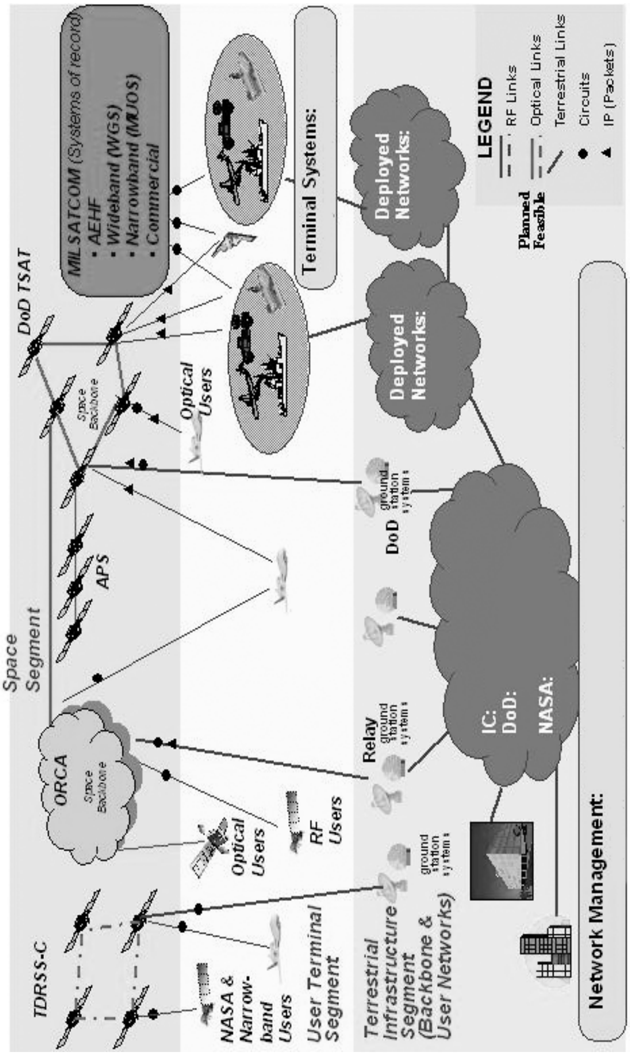

Figure 2. Top-Level View of TCA (Reprinted from TCO, "Transformational Communications Architecture Version 1.0" [U], 17 December 2003, 2. [U/FOUO] This information is extracted and has been cleared for public release: distribution unlimited.)

nications constraints and enabling IP connectivity to deployed forces on land, sea, and air.

Figure 3 shows the Air Force Space Command roadmap for TSAT and other space-based programs. The TSAT constellation is projected to have initial operational capability (IOC) between 2015 and 2016. The first launch is tentatively scheduled for 2013. However, as depicted in figure

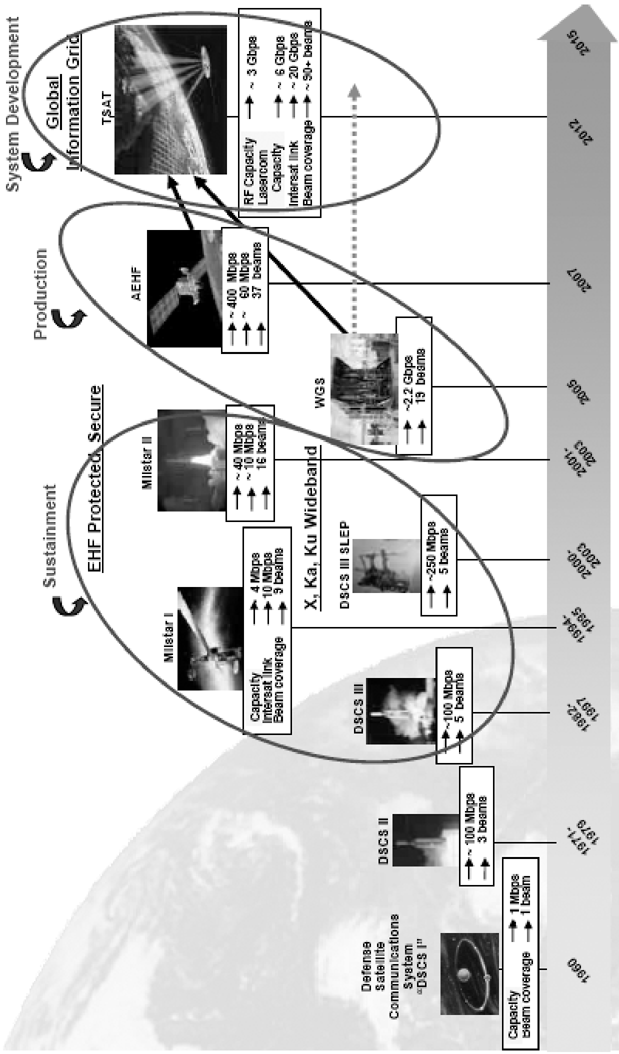

Figure 3. Military Satellite Communications, 1960–2020. (Reprinted from Christine Anderson, director, Military Satellite Communications [MILSATCOM] Joint Program Office, briefing, SMC/MC SCAPR [Space and Missile Center/MILSATCOM Southern California Aerospace Professionals], "Military Satellite Communications, Global Network, Global Power," 14 February 2005.)

3, there is a gradual migration from WGS in approximately 2005, to AEHF in approximately 2007, and then to TSAT in approximately 2013. Fortunately, for the war fighter, the other space-based satellites will stay in orbit and interoperate with TSAT via lasercom or RF.

Satellites are just one component of TSAT. The ground segment, also known as the TMOS segment, performs network management and gateways access. TMOS will give TCA the ability to act as a broadband, on-demand global Internet based on IP, incorporating key emerging network technologies like quality of service provisioning and bandwidth guarantees.[16] The IP communication is designed to allow users access to information from multiple platforms using a single terminal. More importantly, it will allow war fighters access to the terrestrial GIG anywhere, anytime.

The TMOS segment will require extensive software programming. The critical part of TMOS will be writing nearly five million lines of software code, which accounts for about 80 percent of TMOS program development.[17] As TMOS defense contractor Ray Kolibaba, vice president of space systems at Raytheon, succinctly stated, "We've done programs in the range of 2.5 to 3 million lines of code . . . but this is a challenge. This is a very aggressive program."[18]

In January 2006, the DOD awarded the TMOS contract to Lockheed Martin Integrated Systems and Solutions. The Pentagon says that "awarding the TMOS contract now decreases TSAT program risk by providing an integrating construct for network architecture and design, and allows the awarded contractor to begin work on formal network interface definitions and specifications."[19] Clearly, the Pentagon's goal is to have TMOS in place before the first TSAT launch in 2013.

Space-Based Alternatives

This discusses the four other next-generation space-based alternatives (WGS, AEHF, MUOS, and APS) that promise to deliver additional bandwidth and capabilities to the war fighter. These space-based systems are interoperable with TSAT's five-satellite constellation and will connect via lasercom and/or RF links to enable high-bandwidth data transfers.

Wideband Gapfiller System

The WGS is the next-generation wideband satellite-communication system. The WGS five-satellite constellation will provide communications capacity in the military X-band and the high-capacity two-way K_a-band to support mobile and tactical personnel. It will provide worldwide weather resistant communications in X-band and support dispersed MDR users in K_a-band.

The name *gapfiller* is somewhat misleading because preliminary estimates indicate that a wideband gapfiller satellite will provide transmission capacity up to 2.4 Gbps.[20] In fact, WGS transmission capacity exceeds the entire existing DSCS and Global Broadcast Service (GBS) constellations.

Advanced Extremely High Frequencies

The AEHF, will be applied in Milstar III, a three-satellite constellation that will provide mid-latitude and equatorial tactical, protected, and survivable strategic communications. Each satellite will have a capacity of about 250 Mbps, and each military service will communicate with the satellites through their own procured terminals.

The AEHF system will have up to 12 times the total throughput of Milstar II. In some scenarios, single-user data rates will increase from a maximum of 1.544 Mbps (MDR) to 8 Mbps (high data rate [HDR]).[21] The protected AEHF will be interoperable with the other Milstar series satellites.

Mobile User Objective Systems

The MUOS is the next-generation narrowband satellite communications system. The MUOS is the successor to the Navy's UHF follow-on system and is the key transport element in the Advanced Narrowband System (ANS). It will provide narrowband global satellite communications (UHF 64 Kbps and below) connectivity for voice, data, and handheld combat-survivor-evader locator units.[22] The MUOS will provide narrowband beyond-line-of-sight (BLOS) communication to support mission objectives across all branches of the military.

Advanced Polar Systems

The APS is next-generation laser satellite communications systems supporting the North Polar Region (from 65 degrees north latitude to the North Pole at 90 degrees north).[23] Starting in 2012, the APS satellites will provide next-generation protected EHF band, K_a-band, and laser satellite communications capability in the North Polar Region.[24] The current APS plan is to acquire three satellites and associated ground infrastructure for $1.2 billion.[25] The goal of APS is to provide tactical and strategic users who require anti-jam and low probability of detection of EHF satellite communications. The protected polar-satellite communications will support submarines, aircraft, and other platforms and forces operating in that region. In addition to TSAT, these four supporting space-based systems, WGS, AEHF, MUOS, and APS, are critical for increasing additional bandwidth to the war fighter and removing communications as a constraint to real-time information.

Network-Centric Warfare Bandwidth Requirements

The ability to link closely and share intelligence and reconnaissance through an effective command and control structure gave U.S. forces [during OIF] the ability to operate with enormous speed and with unprecedented flexibility.

—Gen Richard Meyers,
former chairman of the Joint Chiefs of Staff

The military's insatiable demand for battlefield bandwidth has no apparent end. All services are planning to deploy some form of tactical terminals to "foot soldiers," which will result in increased communications traffic. This means communications-on-the-move technologies will require higher bandwidth. It also means embedded satellite terminals with connections to line-of-sight (LOS), BLOS, and IP (voice, video, and data) and Web services will increase bandwidth and user requirements.

The military services are continuing to plan new space-based, ground-based, and forward-deployed wireless tactical networks to bring information-retrieval systems to war fighters who all seek the same goal—shared battlefield knowledge. From a ground-based perspective, shared battlefield knowledge starts with the Joint Tactical Radio Systems, software-programmable tactical radios that transmit and receive voice, data, and video communications. More importantly, the JTRS provides interoperable communications among the military services.

The US military forces are developing and buying the JTRS as a *family* of radios called a *cluster*.[26] The Army-led cluster 1, JTRS, is for Army and Marine ground-based vehicles and Army helicopters, as well as for Air Force ground-based tactical air controllers. Cluster 2 is for special operations forces and handheld radios and manpacks. Cluster 3 is for ships and fixed sites. Cluster 4 is for aircraft radios, and cluster 5 is for handhelds, manpacks, and small radio sets such as the Army's Future Combat Systems platforms. By 2010, about 2,358 JTRS terminals are expected to be operational in the protected communications inventory for the Air Force, Navy, Army, and Marines.[27] Beginning in 2010, the Army currently plans to purchase about 10,000 JTRS radios per year.[28]

Army

> *First, at all levels of command within the Army, the current demand for bandwidth is larger than the supply—shortfalls of as much as an order of magnitude (or up to 10 times the amount of supply) can exist. Second, shortfalls in the supply of bandwidth will persist at some command levels through and after 2010, when the capabilities associated with the Army's transformation begin to be put into the field.*
>
> —Congressional Budget Office,
> "The Army's Bandwidth Bottleneck,"
> August 2003

Three major programs are expected to increase the Army's bandwidth demand by 2010 and beyond. The Army plans to field the JTRS, WIN-T, and Multiband Integrated Satellite Terminal (MIST). The JTRS will boost bandwidth in what the Army calls the "lower tactical Internet," and WIN-T and MIST will boost bandwidth demand in the "upper tactical Internet."[29]

By 2020, the Army plans to buy a total of 106,000 JTRS radios, which would be sufficient to equip about one-half of its forces.[30] If each JTRS radio maximum throughput is about 2 Mbps, then total projected maximum throughput for 100,000 radios is 200 Gbps. This bandwidth demand exceeds any space-based TCA bandwidth supply.

The WIN-T and MIST are major components of the Army's plans to improve communications between the brigade, division, and corps command levels. To take advantage of the bandwidth provided by the WIN-T's high-capacity radios, the Army plans to upgrade the associated satellite terminals as well. The MIST program will provide improved satellite communications. Coupling WIN-T equipment and software to the new satellite terminals will deliver a maximum engineering throughput of about 24 Mbps and an effective bandwidth of about 2.5 Mbps.[31] While JTRS does not encompass all the Army bandwidth requirements, it does give a snap shot of the future bandwidth expectations.

Air Force

> *Austere infrastructure and the operational requirements of the operations plan for OIF necessitated secure SATCOM to provide superior situational awareness and vital command and control of combatant forces. The resulting impact was that enemy forces were literally reduced to ineffectiveness even before they had awareness of being targeted.*
>
> —Lt Gen Larry J. Dodgen, commanding general, US Army Space and Missile Defense Command

The Air Force bandwidth requirements will most likely come from unmanned, high-altitude, long-range aircraft for reconnaissance and persistent theater surveillance. Since TSAT will be placed in the geosynchronous Earth orbit (GEO), high-bandwidth communications to airborne assets such as the Airborne Warning and Control System (AWACS), Joint Surveillance Target Attack Radar System (JSTARS), and Global Hawk unmanned aerial vehicle will most likely have direct lasercom connectivity to TSAT. However, only 20 to 50 devices will have simultaneous connectivity to TSAT's laser links.

The Air Force will take full advantage of next-generation satellite communications systems. As depicted in figure 4, the speed in which data is transmitted to the user increases exponentially as space-based technologies evolve. For example, simply issuing an air tasking order in 1994 took about 1.02 hours through the Milstar I satellite system. However, that improved tremendously over the past decade, as DOD moved to Milstar II, which cut the time for an air tasking order down to about 5.7 seconds. Introduc-

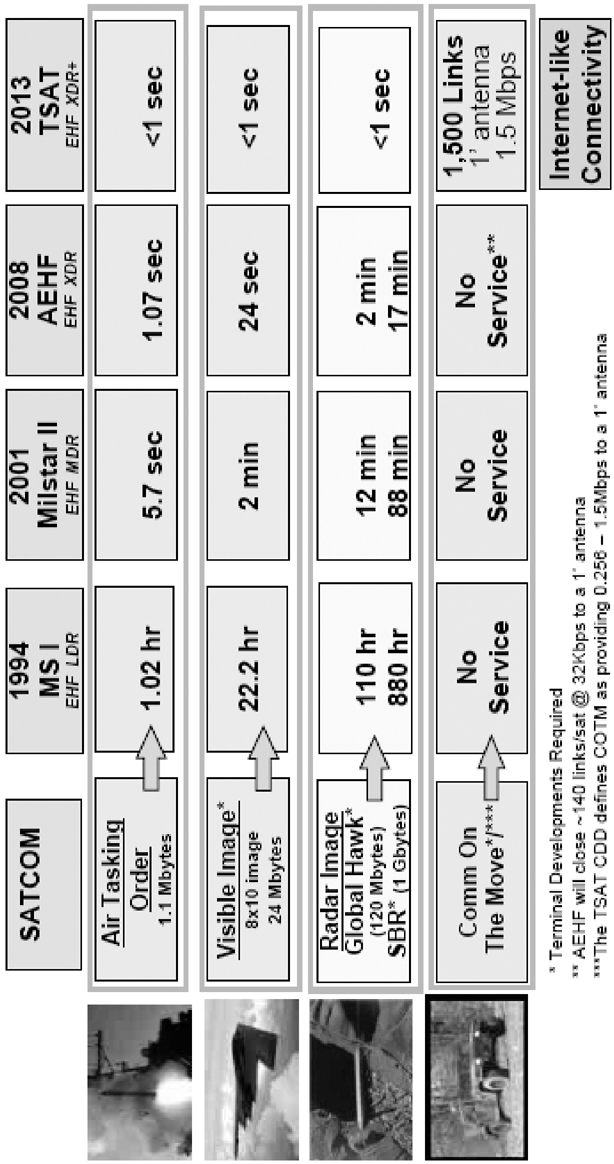

Figure 4. Evolution in SATCOM (Reprinted from Christine Anderson, director, MILSATCOM Joint Program Office, briefing, SMC/MC SCAPR, "Military Satellite Communications, Global Network, Global Power," 14 February 2005.)

tion of the AEHF satellite constellation in 2008 will drive that time down to an estimated 1.07 seconds, while TSAT satellites will transmit the data in less than 1 second.

Navy/Marines

The software communications architecture (SCA) being developed by the Raytheon Company will allow US Navy ships and ground facilities to communicate with high-bandwidth next-generation satellites. The software-based approach underlies the Navy Multiband Terminal (NMT) program. According to the Michelle Bailey, manager, Communications Program Office, "The terminals will allow Navy ships and ground facilities to communicate with future communications satellites, such as the WGS and AEHF satellites."[32]

The Navy's NMT terminals will communicate on the EHF and X-bands, but will have the flexibility to operate on the new satellites K_a- and X-bands.[33] The terminal is designed to remain locked on a satellite in heavy seas with 35 degree rolls.[34] The Navy also projects that NMT will serve as a bridge between legacy systems and future satellites such as TSAT.

Mitigating Bandwidth Shortfalls

> *If you know your enemy and know your self, you need not fear the result of a hundred battles.*
>
> —Sun Tzu, Chinese general

The Pentagon is spending billions to "know" the enemy. In fiscal year 2006, the DOD expects to spend more than $23 billion to develop, acquire, and operate satellites and other space-related systems.[35] The DOD believes the rationale for spending billions on space-related systems is justified because the next-generation satellites and space-related systems are intended to provide war fighters with real-time information that will allow forces to precisely locate and attack targets.

Current Status

Currently, the TSAT program is projected to cost between $12 billion and $18 billion for the entire constellation.[36] In 2003, to help pay for TSAT, the Air Force scaled back its acquisition of the AEHF satellites under development.[37] In the fiscal year (FY) 2006 defense budget, Congress gave the Pentagon about half of the $836 million it wanted for TSAT.[38] Congress also directed the Air Force to focus on maturing the needed technology for the TSAT program and allocated 120 million of the 436 million dollars for TSAT to analyze whether more satellites like the WGS or the AEHF, would be needed prior to the first TSAT launch. If so, that $120 million could go to fund the WGS or the AEHF system instead. In November 2001, the AEHF system contract was awarded to the Lockheed Martin Space Systems and TRW Space and Electronics team for the system development and demonstration phase of the new program. As of 2003, the Air Force had budgeted $4.8 billion for developing and acquiring the first three satellites.[39]

The WGS contract was awarded to Boeing Satellite Systems in January 2001. At an estimated cost of $1.5 billion, the implementation plan calls for a minimum of three geosynchronous spacecraft and associated ground-control software.[40] This program is being managed as a DOD commercial acquisition and is not subject to the same milestones and review process required by AEHF, APS, MUOS, and TSAT.

The Navy's Space and Naval Warfare Systems Command (SPAWAR) has been charged with the acquisition responsibility for MUOS. On 24 September 2004, Boeing was awarded a $2.1 billion contract to build the first two satellites and associated ground-control elements for the MUOS system. The contract also provides for options on three additional spacecraft. With all options exercised, the contract for up to five satellites has a total potential value of $3.26 billion.[41]

Under the Army's current plans, the likely total investment in the WIN-T, JTRS, and new SATCOM terminal will range from 19 to 24 billion dollars through 2020. In the defense program covering fiscal years 2003–2007, overall spending for the Army's digitization programs is projected to average 4.1 billion dollars annually. The WIN-T, JTRS, and new SATCOM terminal account for about one-third of the 28 percent of total digitization funding allocated to communications between 2003 and 2007. The remaining two-thirds of that funding is designated for upgrades to the Army's large fixed-base satellite communications terminals; for command-and-control programs associated with the fire-support and intelligence nets; and for other, less expensive, less complex radio systems.[42]

The Navy plans to invest $1.4 billion in its Navy Multiband Terminal and Software Communications Architecture. The SCA will allow the NMT will to operate in "low, medium, and extended data rate (LDR, MDR and XDR) waveforms." The Navy anticipates initially communicating with WGS and AEHF and then migrating to TSAT. They believe their NMT investment is justified because it will allow them to take advantage of TSAT's future gigabyte up-and-down-links capability.[43]

Expectation Management

As *Military Information Technology* explains, TSAT users fall into two broad categories: high-data-rate access users and low-data-rate access users. The HDR access provides a data rate of 2.5 gigabits to 10 gigabits per second through lasercom. However, only 20 to 50 or so of these links would be available, and they will most likely be dedicated to major intelligence, surveillance, and reconnaissance assets in space and in the air.[44] As depicted in figure 5, others on the LDR end can still use about 8,000 simultaneous RF data links, which will provide connectivity to strategic assets and tactical users as well as the AISR platforms.[45]

The way TSAT is currently being promoted to the Army, Navy, Air Force, Marines, and Special Forces is wrong. Specifically, TSAT is being promoted as the next-generation satellite that will provide high-bandwidth and advanced capabilities to the war fighter, thereby removing "communications as constraint" on the battlefield. What the promotional material should say is: TSAT is the next-generation satellite that will provide high-bandwidth and advanced capabilities to approximately 8,000 RF users and 20 to 50 near-space lasercom war fighters, thereby removing communications as constraint to users who will have the proper system capabilities and authorization to access TSAT.

Recommendations

For TSAT to be truly successful, this paper has three recommendations. First, the TSAT Program Office (TSAT PO) must manage customer expectations. Currently, the Navy, Army, Air Force, Marines, and Special Forces all believe that their next-

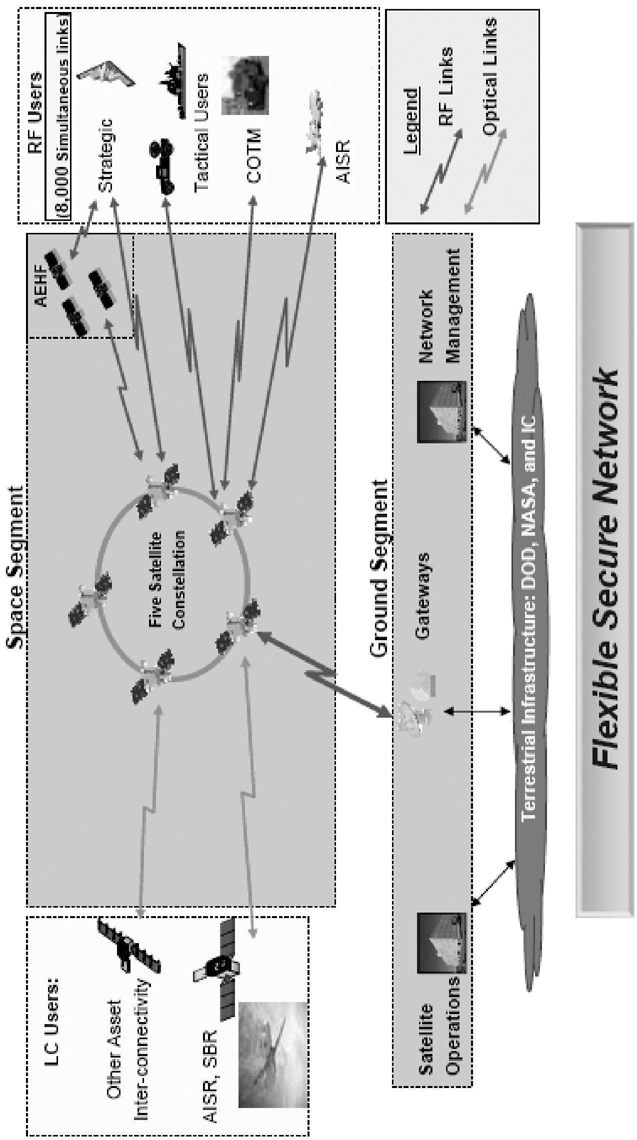

Figure 5. TSAT's Space and Ground Segments (Reprinted from Christine Anderson, director, MILSATCOM Joint Program Office, briefing, SMC/MC SCAPR, "Military Satellite Communications, Global Network, Global Power," 14 February 2005).

generation high-capacity bandwidth systems will directly connect to TSAT's high-capacity lasercom and/or RF links.

As discussed in chapter 3, by 2020, the Army plans to have nearly 106,000 JTRS terminals in use. According to the Army, the JTRS are being designed for use in “wide-band network waveform (WNW) to provide high-capacity bandwidth.”[46] One could argue that it is unlikely that the Army will simultaneously attempt to connect 100,000 terminals to TSAT during peacetime. But it’s safe to say, that during war, at least 8,000 or more simultaneous connections are likely.

The Air Force probably believes its Global Hawk, Predator, AWACS, JSTARS, and other manned and unmanned, high-altitude, long-range AISR aircraft will have a monopoly on TSAT’s lasercom links. While this may or may not be true, if the Air Force continues to procure about five Global Hawks per year (13 procured between FY 2004 and FY 2006) the Global Hawk fleet could be nearly 60 aircraft by the time TSAT reaches IOC in 2015. TSAT is planned to provide 20 to 50 lasercom links.[47]

The Navy Multiband Terminal is designed to provide “the Navy with a flexible framework to add new systems, the service will be able to integrate future systems such as the Transformational Communications Satellite . . . quickly.”[48] The Navy plans on fielding NMT terminals on ships, submarines, and shore-based antennas. Simply put, the TSAT PO needs to manage customer expectations while researching for alternatives to increase TSAT’s simultaneous lasercom and RF user base.

The second recommendation is to clearly identify which space-based and ground-based systems will access TSAT’s lasercom and RF links. During the research for this paper, it was discovered that COTM means different things to different people and organizations. While both space-based systems will provide COTM, TSAT will support only MDR speeds, and MUOS will support only LDR. This means that if the Army plans to procure 10,000 JTRS radios per year starting in 2010, they should decide early which users will access MUOS and which will access TSAT. In essence, the wrong JTRS procurement decision in 2010 and beyond could lead the Army to waste precious American tax dollars.

The final recommendation is to begin research on laser and RF engineering solutions that could possibly increase the number of TSAT’s lasercom and RF links without procuring another $18-billion TSAT system. For example, the creation of dense wave division multiplexing (DWDM) exponentially increased terrestrial fiber capacity and bandwidth. DWDM works by combining and transmitting multiple signals simultaneously at different wavelengths on the same fiber. In effect, one fiber is transformed into multiple virtual fibers, thereby increasing bandwidth and number of users/systems supported. More importantly, DWDM networks can transmit data in IP, asynchronous transfer mode, synchronous optical networking, and Ethernet and handle bit rates between 100 Mbps and 2.5 Gbps. Therefore, DWDM-based networks can carry different types of traffic at different speeds over an optical channel.[49] Maybe some of the $120 million Congress directed the Air Force to use on "maturing the needed technology for the TSAT program" could be used to research "DWDM-like" technologies for TSAT lasercom and RF waveforms.

Conclusion

In conclusion, this study has discussed TSAT's capabilities. It also discussed other space-based satellite systems such as MUOS, APS, WGS, and AEHF. It demonstrated that TSAT is only capable of providing approximately 8,000 RF links and 20 to 50 lasercom links. This means a large shortfall in supporting future service requirements.

This study concluded with three recommendations for the TSAT PO. The first recommendation is for the TSAT PO to manage customer expectations. The second recommendation is that the TSAT PO identifies the organizations which space-based and ground-based systems will access TSAT's lasercom and RF links. The final recommendation is to invest funds in researching advanced laser and RF techniques that could potentially increase lasercom and RF link capacity. Fortunately, even with TSAT's shortfalls, the next generation satellite communication systems vision of enabling advanced capabilities and "removing communications as a constraint" to the war fighter is still valid, but the scope of TSAT's vision is limited by TSAT's user capacity.

Notes

(All notes appear in shortened form. For full details, see the appropriate entry in the bibliography.)

1. Transformational Communications Office (TCO), "Transformational Communications Architecture."
2. "Satellite Bandwidth."

3. Ibid.
4. Ibid.
5. TCO, “Transformational Communications Architecture,” i.
6. Ibid.
7. “NRO Stops Plans.”
8. “Transformational Communications Study.”
9. Ibid.
10. TCO, “Transformational Communications Architecture,” 5.
11. Ibid., 6.
12. Ibid.
13. Ibid., 7.
14. Ibid.
15. Anderson, briefing. The MILSATCOM Joint Program Office is the DOD’s primary acquirer of satellite communications systems to satisfy war fighter requirements.
16. “Lockheed’s Team Wins.”
17. Bates, “T-Sat Ground Network.”
18. Ibid.
19. “Lockheed’s Team Wins.”
20. Elfers and Miller, “Future U.S. Military Satellite.”
21. Ibid.
22. Ibid.
23. Ibid.
24. Frankel, “Space Acquisitions.”
25. Ibid.
26. Keller, “Transformational Communications.”
27. Congressional Budget Office (CBO), “Army’s Bandwidth Bottleneck,” appendix A, 2.
28. Ibid., 3.
29. Ibid., Summary.
30. Ibid., 3.
31. Ibid.
32. Brown, “Warfighting and Ground Terminals.”
33. Ibid.
34. Ibid.
35. Levin, “Defense Acquisitions,” abstract.
36. Ibid.
37. “Transformational SATCOM (TSAT).”
38. Frankel, “Space Acquisitions.”
39. Ibid.
40. Ibid.
41. Ibid.
42. CBO, “The Army’s Bandwidth Bottleneck,” appendix A, 1.
43. Kenyon, “Telecommunications Standard Key.”
44. “Special Report: USA’s Transformational Communications.”
45. Anderson, briefing.
46. CBO, “The Army’s Bandwidth Bottleneck,” chap. 2, 1.
47. Lorenz, briefing. As shown on the Global Hawk funding profile.
48. Kenyon, “Telecommunications Standard Key.”
49. As defined in http://www.webopedia.com/TERM/D/DWDM.html.

Acronyms

ACSC	Air Command and Staff College
AEHF	advanced extremely high frequency
AISR	airborne intelligence, surveillance, and reconnaissance
ANS	Advanced Narrowband System
APS	Advanced Polar System
AWACS	Airborne Warning and Control System
BLOS	beyond line of sight
CONUS	continental United States
COTM	communications on the move
DOD	Department of Defense
DSCS	Defense Satellite Communications System
DWDM	dense wave division multiplexing
EDR	extended-data rate
EHF	extremely high frequency
FY	fiscal year
Gbps	gigabits per second
GBS	Global Broadcast Service
GEO	geosynchronous Earth orbit
GIG	Global Information Grid
GIG-BE	GIG bandwidth expansion
HDR	high-data rate
IC	intelligence community
IOC	initial operational capability
IP	Internet protocol
ISR	intelligence, surveillance, and reconnaissance
JSTARS	Joint Surveillance Target Attack Radar System
JTRS	Joint Tactical Radio Systems
lasercom	laser communications
LDR	low-data rate
LOS	line of sight
Mbps	megabits per second
MDR	medium-data rate
MIST	Multiband Integrated Satellite Terminal
MUOS	Mobile User Objective Systems
NASA	National Aeronautics and Space Administration
NCW	network-centric warfare
NMT	Navy Multiband Terminal
NRO	National Reconnaissance Office

OEF/OIF	Operation Enduring Freedom/Operation Iraqi Freedom
RF	radio frequency
SATCOM	satellite communications
SCA	software communications architecture
SPAWAR	Space and Naval Warfare Systems Command
TCA	Transformational Communications Architecture
TCO	Transformational Communications Office
TDRSS	Tracking and Data Relay Satellite System
TMOS	TSAT Missions Operations System
TSAT	transformational satellite
TSAT PO	TSAT Program Office
UFO	UHF follow on
UHF	ultra high frequency
US	United States
WGS	Wideband Gapfiller System
WIN-T	War Fighters Information Network-Tactical
WNW	wide-band network waveform
XDR	extended-data rate

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