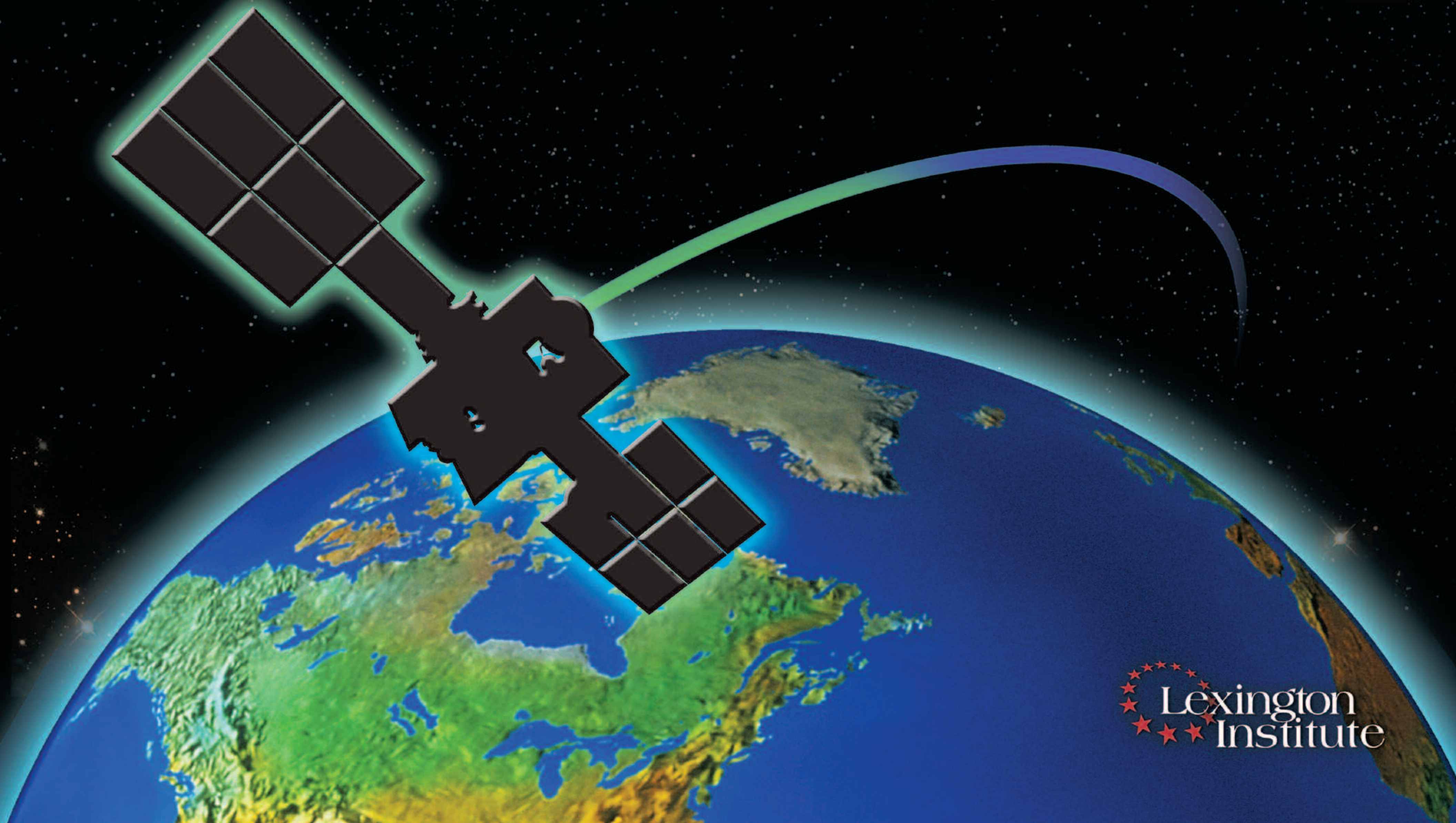
TSAT

Essential to Security



Lexington Institute

FINDINGS IN BRIEF

The Transformational Satellite Communications program, or TSAT, is a planned constellation of five communications satellites in geosynchronous orbit linked to thousands of portable terminals distributed across the joint force. It will use internet-style technology to connect war-fighters all over the world in a global communications network with unprecedented carrying capacity, accessibility and reliability. TSAT is the only orbital communications option presently available to the military that can reconcile rapidly growing demand for bandwidth with the need to protect sensitive information from jamming, eavesdropping and nuclear effects.

TSAT was conceived as part of a "transformational communications architecture" to bring war-fighters and other members of the national security community flexible, unfettered communications — even when they are on the move or under fire. It will be the first satellite constellation built for the military that fully exploits "internet protocol" technology, a set of technical standards that enables information to traverse diverse networks as if they were a single unified web. When combined with high-capacity laser links and dynamic allocation of bandwidth, the internet-style communications system supported by TSAT will deliver major benefits to war-fighters:

- Greatly increased carrying capacity
- Interoperability across diverse networks
- Expanded access for local users
- Enhanced quality of service
- Advanced information protection
- Improved situational awareness

Because it can deliver these benefits even to mobile, isolated users, TSAT is arguably the single most important technology initiative the military is currently funding. It will save money and lives across the joint force, enabling strategies that would not have been feasible employing legacy communications systems. However, although most of the technologies necessary to bring TSAT to fruition have already matured in the commercial world, the program has been repeatedly delayed by cutbacks in funding. Failure to fund the program adequately in the future could leave war-fighters ill-equipped for the fluid and diverse challenges of the information age.

This report was written by Dr. Loren Thompson of the Lexington Institute staff in consultation with a working group of public-sector and private-sector experts convened to provide the most current, authoritative assessment of future military communications needs.

TSAT:
ESSENTIAL TO NATIONAL SECURITY

Transformational Satellite Communications, or TSAT, is a constellation of five satellites conceived to provide war-fighters and intelligence operatives with the most flexible, resilient global information network ever devised. When linked to mobile terminals on the ground, in the air and at sea, TSAT will enable U.S. forces anywhere on earth to gain immediate access to the full resources of the Defense Department and the intelligence community — everything from satellite imagery to streaming video to electronic intercepts to technical databases. It would also assure continuous connectivity among all elements of the joint force, even where war-fighters are on the move or under fire. And it would deliver that connectivity in a form that prevents enemy eavesdropping, jamming or manipulation.

TSAT is sometimes referred to as an "internet in the sky" because of its versatility and reach. It is designed to operate in an era when war-fighters will require instant access, seamless interoperability and nearly limitless bandwidth from their communications networks. Nothing like it has ever existed in the military before, which is why it is called "transformational." However, like other initiatives bearing that designation, TSAT is complicated and expensive. There is no guarantee that it will survive the budget battles that determine how military priorities are translated into funded programs.

The purpose of this report is to explain why TSAT is the single most important technology initiative undertaken in pursuit of military transformation, and why failure to implement the communications principles it embodies could have devastating consequences for the United States. In order to make that case, the report addresses four topics:

- How internet-style communications are changing global commerce and culture, including the conduct of war.

- How TSAT and the global information architecture of which it is a part are designed to greatly surpass the performance of existing military networks.

- How TSAT would enhance the availability, versatility and security of communications links available to the joint force.

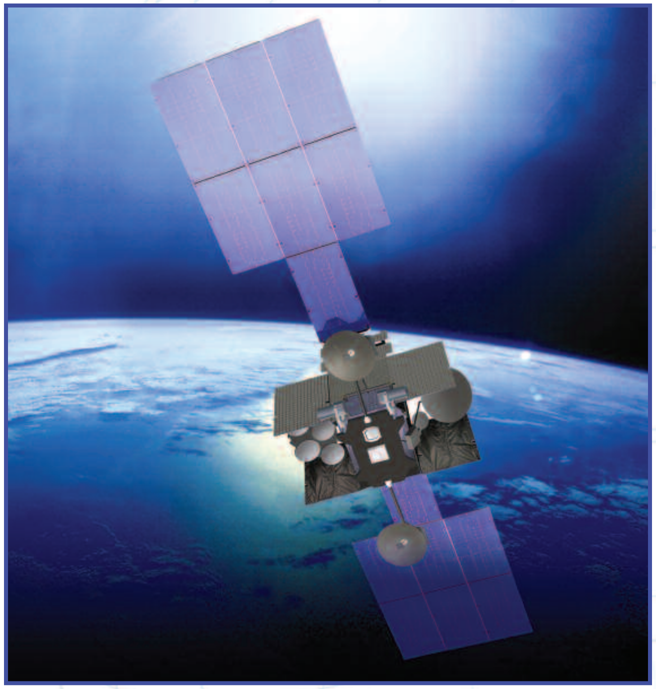
- How the program must be managed to deliver new communications capabilities as soon as possible that can save lives and money.

TSAT
AND THE INTERNET REVOLUTION

Transformational Satellite Communications was conceived to exploit the full potential of "internet protocol" communications. Internet protocol, or IP, is a set of technical standards that allows bursts of data to travel across diverse networks as if they are a single, unified web. Without this feature, the internet would be impossible. TSAT and other components of the future military communications network are based on internet protocol principles so that war-fighters can be freed from the constraints of older technology and enjoy the operational advantages of unlimited connectivity.

In order to grasp how this would save lives and money in the conduct of war, it is first necessary to understand why the internet is so different from previous methods of communication. Once the uniqueness of the internet is understood, it is easier to see why the principles underpinning it are transforming civilization — including the way in which nations approach military conflict.

The first true revolution in modern communications came with the invention of the telegraph in the 1840s. The telegraph harnessed electricity to enable transmission of information at the speed of light (about 300,000 kilometers per second). Later inventions such as the telephone and two-way radio exploited electricity in more sophisticated ways, but for over a hundred years all forms of electronic communication shared a common feature: a connection or "circuit" had to be created between the sender and the receiver before information could move.



Communications satellites in geosynchronous orbit are vital to the connectivity of the joint force, providing global reach even in places where ground lines do not exist.

Inventors recognized early on that the need for dedicated circuits would limit how much information could be transmitted. Within a few years after the first telegraph lines were strung, researchers were working on ways of getting more transmission capacity out of each wire. Alexander Graham Bell invented the telephone while conducting one such experiment. But the bottleneck presented by "circuit switched" networks persisted until the second half of the 20th century.

In the 1970s, an alternative called "packet switching" emerged. Defense Department researchers devised a method of splitting electronic messages into brief bursts or "packets" that could be transmitted over whatever networks were available, without first establishing a dedicated circuit to the intended destination. Software standards, or protocols, enabled the packets to transit many different networks and then be reassembled in their proper order for the recipient.

Designers called this "connectionless" approach to communications the internet, because it employed diverse networks as if they were one big web. The designers saw that such a decentralized system was more likely to survive the unpredictable damage inflicted in wartime, because when nodes were lost messages would automatically seek out other pathways with the assistance of computers called routers. In addition to being more resilient, packet switching freed up transmission capacity that no longer needed to be dedicated to maintaining point-to-point circuits.

The new approach was so appealing that in 1982 it became an official standard for all military networks. Private use of the internet and internet protocol communications began spreading rapidly after European researchers developed the Worldwide Web in 1990. The Worldwide Web simplified the task of accessing the internet and opened up a limitless array of potential applications. The explosive growth of the internet during the final decade of the 20th century convinced many observers an information revolution was at hand — one that would eventually transform every facet of human activity.

Military planners soon began exploring the war-fighting implications of this revolution, and crafted the concept of "network-centric warfare" to capture the myriad ways in which new information technology might influence future strategy. By the time network-centric warfare gained a following, though, the military had begun falling behind the private sector in exploiting the benefits of the new technology. Among the factors contributing to this lag were the steep cost of modernizing legacy networks, the unique communications demands of modern warfare, and the highly bureaucratized nature of the military acquisition system.

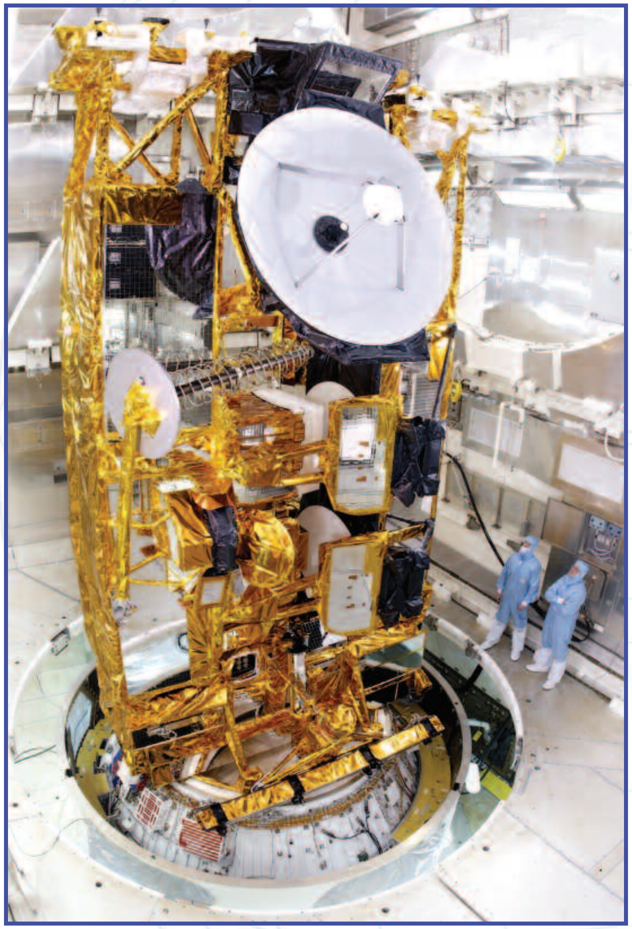
When the Bush Administration took office in 2001, it embraced military transformation as a way of overcoming such obstacles so that the agility, awareness and precision made possible by new technology could be delivered to war-fighters as soon as possible. One of the first technology initiatives the new administration pursued was a "transformational communications architecture." The architecture had many facets, but its centerpiece was a constellation of five communications satellites that would combine the power of internet protocol communications with the global reach of spacecraft in geosynchronous orbit.

TSAT
DESIGN FEATURES

The idea of using satellites in geosynchronous orbit as communications nodes was first proposed by the science-fiction writer Arthur C. Clarke in 1945. Satellites orbiting at an altitude of 35,800 kilometers (22,200 miles) match the rate at which the earth's surface is rotating, and so they seem to hover above one spot. That allows them to be used as if they are fixed points for relaying communications signals. By the time TSAT was conceived, the United States had been operating such satellites for 40 years, and a typical "satcom" could sustain thousands of connections simultaneously. But all of the existing satellites were based on circuit switching technology and thus could not take full advantage of internet protocol communications.

In 2001, a Pentagon study of future communications needs found that existing and planned satellite constellations would not satisfy projected military demand. Aside from the limited carrying capacity (or "bandwidth") of existing satellites, there were problems with interoperability across diverse networks, accessing satellites while on the move, and securing information flows from enemy jamming or interception. These problems constrained the ability of U.S. forces scattered around the globe to achieve the speed, awareness and precision demanded by new war-fighting concepts. Simply stated, the existing communications system was too fragmented and weak to allow full utilization of U.S. capabilities.

To overcome the problems, policymakers decided to develop a fundamentally different kind of communications architecture based on internet



Military communications satellites are typically more complex than their civilian counterparts because they must protect sensitive communications from electronic jamming, unauthorized interception and other hostile actions.

protocol technology — including an orbital "backbone" of high-capacity satellites linked by laser beams. Lasers, like radio signals, are a form of electromagnetic energy. But because their frequency (vibrations per second) is typically a hundred thousand times greater than that of the highest-frequency radio signals, they can pack many more of the binary pulses called "bits" into a brief transmission. It is for precisely that reason that terrestrial communications providers have shifted from copper wires carrying radio waves to fiber lines carrying light waves.

The basic idea behind the "transformational communications architecture" designed in 2002 was to create high-capacity optical networks both on the earth and in space that would operate according to internet protocol principles. Conditions in the lower atmosphere would still force troops to rely on radio frequency signals for communications over "the last tactical mile," but to the maximum degree feasible designers wanted a system with the carrying capacity of light beams and the flexibility of packet switching. It is common to refer to this system-of-systems as the Global Information Grid, and TSAT is the orbital backbone that will tie the system together when surface lines are not available.

TSAT and the broader architecture of which it is a part will be fully integrated, unifying military, intelligence and civil networks that were not previously connected. The new communications system thus will be able to serve the disparate needs of the Defense Department, intelligence agencies and NASA's civil space program. More importantly, it will enable information to flow freely among all of the participating organizations, so that managers, analysts and war-fighters with appropriate security clearances can tap into the full information resources of the national-security system. The TSAT architecture has four parts:

- A space segment consisting of the TSAT constellation with connectivity to other satellites such as the Wideband Global System and Advanced Extremely High Frequency (AEHF) satcom.

- A terminal segment consisting of tens of thousands of small transmitters/receivers on aircraft, ships, ground vehicles and even in backpacks for communicating with the satellites.

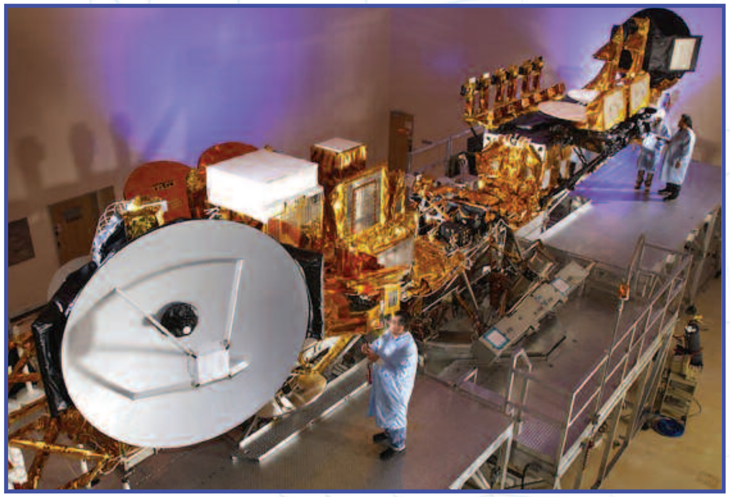
- A network operations and management segment that ties together the ground networks of the agencies utilizing the space and terminal segments.

- A terrestrial infrastructure segment that links the TSAT architecture to the rest of the Global Information Grid.

The National Security Space Office is developing specifications for the latest version of the transformational architecture, to be designated 3.0. Such refinements are necessary given the rapid evolution in military requirements and relevant technologies, but several core features of TSAT satellites are likely to persist throughout the lifetime of the program. First, each satellite must be able to support both packet switched and circuit switched networks in order to accommodate the full range of new and legacy equipment linked to the system. Second, each satellite must be able to receive, process and transmit billions of bits (gigabits) of data per second to efficiently utilize the carrying capacity of the laser cross-links connecting the constellation. Third, each satellite must be able to dynamically prioritize and allocate bandwidth to assure that war-fighters most in need get the quality of service they require.

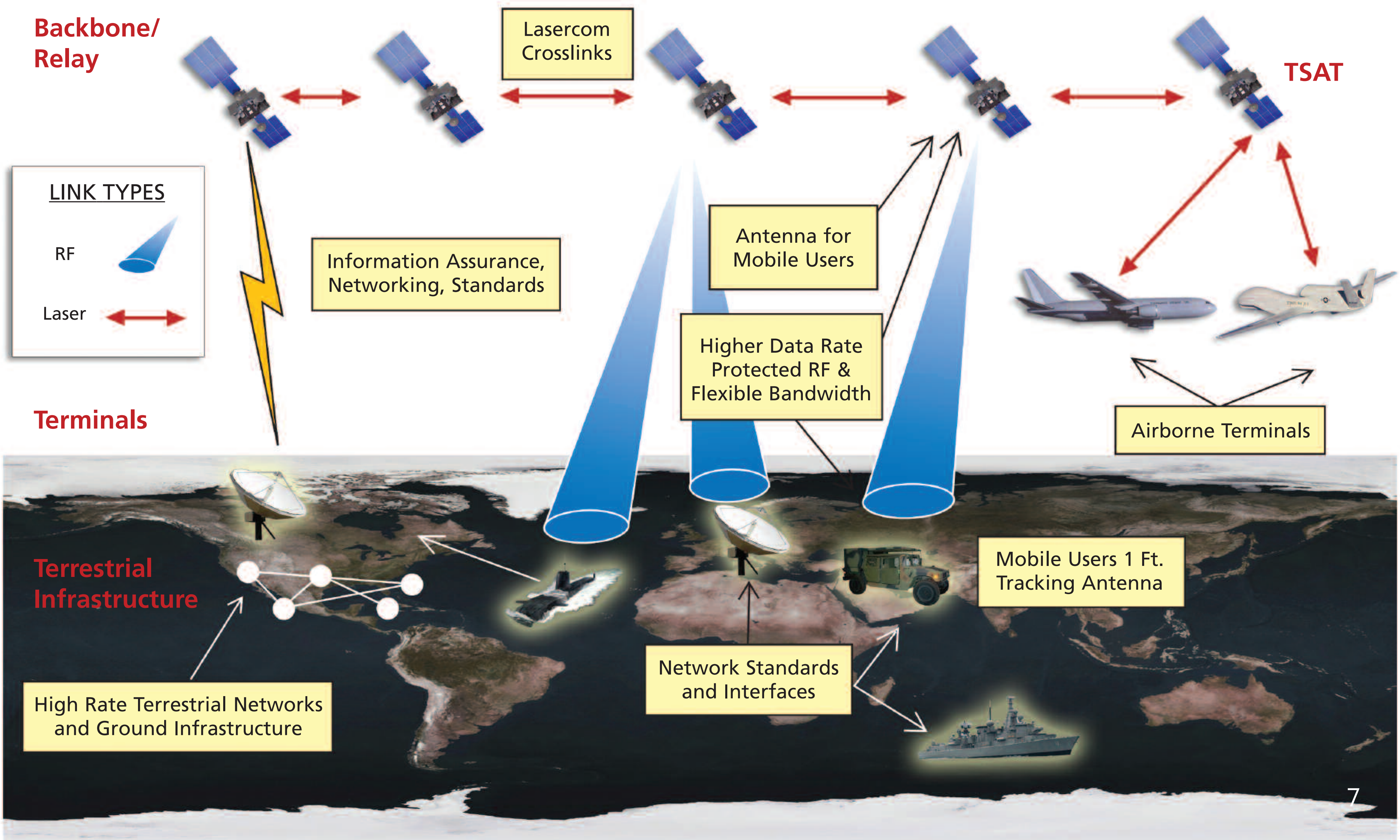
Beyond those defining features, there are several other characteristics each TSAT satellite must incorporate given the demands of military operations. These include countermeasures to overcome enemy jamming, bulk encryption of sensitive messages, antennas suitable for providing communications to surface users on the move, and a capacity to withstand nuclear effects. In addition, the airborne and surface terminals developed to communicate with the satellites must be sufficiently compact and easy to use so that tens of thousands can be distributed across the joint force and employed under virtually any circumstances. Not surprisingly, the need to host so many functions on the spacecraft while minimizing the size of terminals results in satellites of considerable complexity.

The Advanced EHF satellite combines improved carrying capacity and user access with sophisticated security measures, but it does not fully support internet-protocol communications.



The Milstar system the Advanced EHF satellite will replace was designed to free military communications of vulnerable ground gateways while protecting transmissions from enemy eavesdropping and degradation.

TSAT
Key Technologies



TSAT
BENEFITS TO THE WAR-FIGHTER

It makes sense to integrate national-security networks with an internet-style communications system that can make maximum use of available bandwidth. However, the real measure of TSAT's value will be whether it can bolster the ability of the joint force to fight and win wars while sustaining minimal casualties. All of the design features described in the previous section contribute to that goal by delivering a wireless network with operational advantages not currently available to war-fighters.

First, each TSAT satellite will offer a tenfold **increase in carrying capacity** for secure military communications compared with the planned AEHF constellation. Since AEHF itself offers a tenfold increase in secure transmission capacity beyond the existing Milstar constellation, TSAT will be one hundred times more capable than what the joint force is using today to carry its most sensitive information. This leap in carrying capacity is made possible mainly by the utilization of laser cross-links in space and laser up-links/down-links with aircraft flying above the clouds. In addition, packet switching greatly reduces the bandwidth required to send messages by using available capacity efficiently rather than tying it up in dedicated point-to-point circuits. Carrying capacity is further enhanced by dynamic allocation of bandwidth and techniques that maximize the capacity of radio frequency signals to and from terminals.

Second, TSAT will enable **interoperability across diverse networks** on a scale not previously seen in military communications. A common complaint about the current military communications system is that networks operated by various services and agencies are not compatible, limiting the exchange of information. TSAT will eliminate that constraint by introducing the same flexibility that made the internet possible, transforming previously disconnected networks into a single, unified web. Thus it will become possible for war-fighters to remain continuously linked to all the resources of the joint force and the intelligence community, receiving whatever information or support they need in the most timely and useful form possible.

Third, TSAT will permit **greatly expanded access** to the Global Information Grid through the proliferation of tens of thousands of portable terminals across the joint force. Virtually every warship, aircraft and ground vehicle in the force will eventually be equipped with these foot-wide transmitters/receivers. A typical Army division will have hundreds, so that even if it is deployed far from terrestrial telecommunications infrastructure, it will still enjoy robust, resilient connectivity down to the platoon level. Furthermore, the TSAT architecture will deliver high-capacity communications even when troops are on the move, ending the need to halt and set up fixed communications nodes as ground forces do today. This "comms-on-the-move" feature will adapt automatically to changing weather conditions, assuring less than one percent signal degradation to mobile users even in torrential downpours.

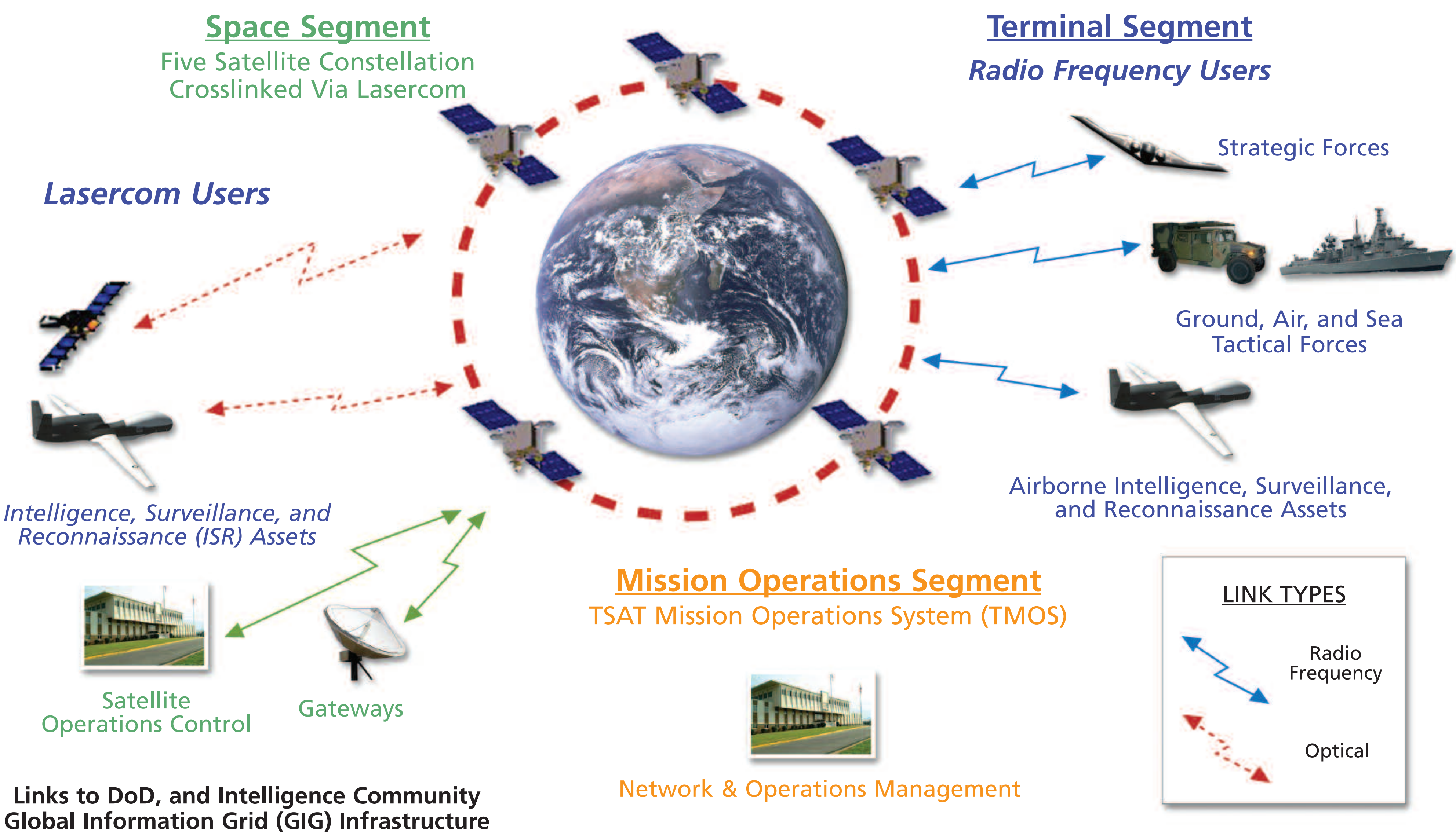
Fourth, TSAT will guarantee **quality of service** using dynamic allocation of bandwidth. Although the transformational communications architecture was conceived to remove bandwidth as a constraint on military operations, planners recognized that some demands on the system would be more important than others, so TSAT was designed to prioritize requests for service according to specific operational criteria. What this means in practice is that the most urgent needs are met first. Thus, desperate war-fighters will never be deprived of vital information simply because they accessed the grid later than routine users. Unlike other communications systems, TSAT automatically moves their requests for service to the head of the line.

Fifth, TSAT will provide **advanced information protection** against enemy efforts to disrupt, intercept or exploit messages moving over its network — without impeding the ability of legitimate users to get the information they need in a timely fashion. Although the openness of the internet facilitates access and innovation, it also allows hostile users to manipulate content for undesirable purposes. TSAT will combine the flexibility of packet switched networks with the multi-level security of more traditional military grids, so that participants do not need to worry about their information being misused. The anti-jam characteristics of the TSAT signal, software and hardware are so powerful that they can withstand almost any level of interference, and the location of satellites in geosynchronous orbit will place them far beyond the reach of most anti-satellite weapons.

Sixth, TSAT will deliver **enhanced situational awareness** by facilitating the global availability of intelligence, surveillance and reconnaissance from diverse sources. A key deficiency in the current military posture is the inability of forces to quickly obtain critical intelligence generated outside their chain of command. Sometimes this problem arises from lack of transmission capacity, other times from lack of interoperability across networks or burdensome security restrictions. By wiping away such limitations, TSAT enables the joint force to migrate from its traditional, "need-to-know" mindset to a "need-to-share" culture in which all raw and processed intelligence is available and users download what they require. In such an operating environment, war-fighters will possess far more timely, actionable information relevant to their circumstances than ever before.

What all of these operational features add up to is the most robust military communications system ever built, a system that will deliver more immediacy, versatility and security to war-fighters than any other option available — by a very wide margin. It will not "eliminate bandwidth as a constraint" as some proponents contend, because demand for carrying capacity is growing too fast for any system to do that. But TSAT will impose fewer constraints on war-fighters than any other wireless network, providing valuable, life-saving information in the most economical manner feasible.

TSAT
System Segments



TSAT
MANAGING TSAT FOR SUCCESS

Transformational Satellite Communications has the potential to revolutionize military communications, but whether that revolution ever comes to fruition will depend on how well the program is managed. There are already signs of trouble: initial operating capability, once planned for 2012, slipped to 2014, and then to 2016, because Congress did not fully fund budget requests. Further delays might compromise the whole effort as policymakers are forced to fund alternative schemes aimed at meeting near-term communications needs. With many of TSAT's original proponents now departed from public life, there is no guarantee that the program will survive budget battles in the years ahead.

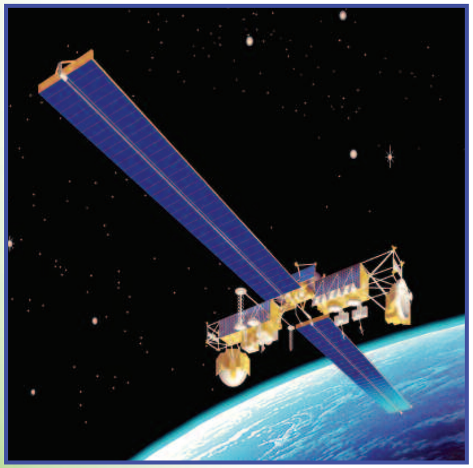
Setbacks in other military space programs during the present decade have taught planners important lessons about what ingredients are required to maximize the potential for success. Planners have learned that the requirements process must be controlled to discourage excessive performance demands; that technical risks must be reduced early in development rather than later when their resolution can be very costly; that program managers must be empowered with adequate training and authority to enforce decisions; and that funding profiles must be stable from year to year to avoid inefficiency and schedule slippage. These lessons appear to be even more compelling when a program has many moving parts as TSAT does, because the spacecraft, terminal, network and infrastructure segments of the project all must move forward in tandem to assure timely fielding.

Fortunately, TSAT is one of the first programs to be managed pursuant to a revitalized space acquisition policy reflecting the lessons of past mistakes. Although it represents a monumental challenge in integrating cutting-edge technologies and operational cultures, steps have been taken at the outset to reduce risk and assure competent oversight. Most of the key technologies defining the TSAT constellation have been matured in earlier programs, including packet switching, dynamic allocation of bandwidth, laser communications, multi-level security protocols and antenna design for mobile communications. Similarly, the technology for compact, portable terminals and flexible, resilient ground networks has emerged from other, earlier efforts that prove its feasibility. That does not mean that TSAT will be an easy undertaking, but it does suggest that with stable funding the program can avoid the pitfalls seen in other space programs.

That leaves funding as the greatest source of uncertainty for the TSAT effort. Congress repeatedly cut budget requests for the program during its early years, demanding evidence that the Defense Department had learned to manage military space programs more professionally. That evidence has now begun to accumulate as formerly troubled programs yield increasingly positive results. Changes in acquisition practices combined with the manifest inability of existing satellites to meet burgeoning military demand for secure, mobile communications give hope that Congress will see the wisdom of fully funding TSAT in the future. That will require some discipline on the part of the lawmakers, because TSAT requires more money than any other satellite constellation in current plans, and political cycles are much more compressed than the technology cycles that drive development of programs like TSAT.

In the final analysis, the fate of TSAT hinges on whether policymakers and legislators alike can grasp the advantages delivered to war-fighters by a space-based communications network incorporating internet protocol technology, laser cross-links, and dynamic allocation of bandwidth. Such items may sound arcane to the uninitiated, but they will make the difference between life and death for American soldiers, sailors and airmen in the battles that lie ahead. TSAT isn't just the cheapest way of delivering agility, awareness and precision to the joint force of the future — in many situations, it is the *only* way.

The legacy Milstar constellation was conceived in 1983 and completed twenty years later with the launch of a sixth spacecraft in 2003.



Successful development and integration of military communications satellites is a protracted, demanding process, but it confers operational advantages on U.S. forces that no adversary can match.

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