GAO
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United States General Accounting Office
Washington, DC 20548

December 4, 2003

The Honorable Donald H. Rumsfeld
The Secretary of Defense

Subject: *Space Acquisitions: Committing Prematurely to the Transformational Satellite Program Elevates Risks for Poor Cost, Schedule, and Performance Outcomes*

Dear Mr. Secretary,

In a multibillion-dollar effort, the Department of Defense (DOD) plans to build a space-based communications system that leverages technologies never before used in space. Such a system would enable DOD to transform how information is collected on potential U.S. adversaries and how military forces are warned of hostile action. The backbone of this system will be the Transformational Satellite (TSAT),[1] which is expected to play a pivotal role in connecting communications networks on the ground, in the air, on ships, and in space. TSAT represents a potential leap forward in communications speed, security, and availability. The Air Force, which heads up DOD's space programs, intends for TSAT to be interoperable with similar systems being acquired for the National Aeronautics and Space Administration (NASA) and the intelligence agencies.

The initial TSAT program is expected to cost about $12 billion from 2003 to 2015 for development and production. Several billions more are to be spent acquiring and supporting the associated ground infrastructure, including thousands of user terminals. The Air Force intends to start the acquisition program in December 2003 and expects to launch the first TSAT in 2011.

To help pay for TSAT, the Air Force has scaled back its acquisition of the Advanced Extremely High Frequency (AEHF) satellites currently under development. However, because of senior military commanders' concerns about TSAT's risks and the potential delay in delivering improved space communications, the Air Force plans to reassess the need for future AEHF funding in November 2004. If TSAT is considered too high a risk to meet the warfighter's expectations, the contingency plan is to take TSAT's funding—thereby delaying TSAT's development—and use it to buy another AEHF satellite. The Air Force has targeted November 2004 as the latest date such a

[1] The TSAT program also includes development of another satellite, the Advanced Polar System (APS). Because development efforts for TSAT and APS are similar, we are referring to both programs as TSAT in this report. More information about APS is included in enclosure I.

decision could be made and still include funds for AEHF in the DOD budget submission for fiscal year 2006.

We conducted this assessment in response to the large investment planned and the importance of the communications capabilities promised by TSAT and AEHF. Specifically, we assessed the Air Force's readiness to (1) initiate a TSAT acquisition program in December 2003 and (2) make a decision in November 2004 about whether to take TSAT funding and use it to buy another AEHF satellite.

RESULTS IN BRIEF

Air Force officials have set two imminent deadlines: starting the TSAT program in December 2003, and deciding whether to shift funding from TSAT to AEHF in November 2004. The Air Force is currently not prepared to make an informed decision in either case.

Air Force officials are not ready to initiate the TSAT program in December 2003 because they do not have the knowledge to reliably establish cost, schedule, and performance goals. At program start, program managers are required by law to establish such goals.[2] Our past work on successful acquisition programs has found that these goals cannot be set reliably unless the critical technologies and design have been determined to meet minimum performance requirements. Programs that do not have this knowledge at program start have a much greater risk of resorting to costly design changes later in the development process, asking the warfighter to compromise on desired capabilities, or incurring schedule overruns to correct problems. Realizing that TSAT's schedule is ambitious, the Air Force added 2 years to the acquisition program. However, the extra time was mostly allocated to the latter part of the development process, not to the front end, when program managers typically need the time to become reasonably certain that technologies and early designs will work as envisioned.

We are concerned about the Air Force's readiness to make the planned decision in November 2004 to take TSAT funding to buy another AEHF satellite in case the TSAT program falters. Air Force officials have not defined what evaluation criteria they intend to use in making this decision. Senior military commanders want assurance that they will get at least the level of capabilities promised by AEHF early in the next decade. However, senior DOD and Air Force officials told us that if funds were shifted from TSAT back to AEHF, then TSAT—the linchpin of its plan to transform military communications—would be substantially delayed. To promote well-informed and objective investment decisions, our past work has found that decision makers establish and use measurable criteria for evaluating the costs, benefits, and risks of various alternatives.

[2] 10 U.S.C. sections 2220 and 2435.

We are recommending that you direct the Secretary of Air Force to develop critical technologies more fully and to conduct early design studies before starting the TSAT acquisition program. We are also recommending that you direct the Secretary to establish and use measurable evaluation criteria for the planned November 2004 funding decision. Although DOD agrees to adopt such criteria, it believes the acquisition program can be started because sufficient controls are in place to allow concurrent development of technology and product design.

BACKGROUND

DOD intends to develop a new generation of space communications systems, taking advantage of rapidly advancing technologies. This reflects an increasing demand and reliance on satellite communications systems to move larger volumes of information to more users. The Air Force reports that the demand for communications bandwidth increased 473 percent between Operation Desert Storm in 1991 and Operation Enduring Freedom in 2001. To help meet this demand, DOD has augmented its own satellite communications capability with commercial satellites. However, in each major conflict in the past decade, senior military commanders still reported shortfalls in communications capacity, particularly for rapid transmission of large digital files, such as those created by imagery sensors. DOD's communications studies indicate the shortfall will continue to grow, despite major improvements in communications satellites currently in development.

Investment Strategy for Satellite Communications Revised

In 1996, DOD developed and began to implement a space investment strategy that proposed a new mix of improved communication satellites for use in 2010 and beyond. Among the proposed systems were the AEHF satellite, the Wideband Gapfiller Satellite (WGS), Advanced Polar System (APS), and Advanced Wideband Satellite (AWS), a less capable and earlier version of TSAT. At that time, DOD believed that AWS, AEHF, and WGS would provide a significant increase in communications capacity and would meet the warfighters' needs in 2010 and beyond. (More information about these satellite systems and their associated acquisition programs is included in enc. I.)

In 2001, DOD developed a new Transformational Communications Architecture that uses emerging communications technologies. The architecture is expected to transform future combat and intelligence operations, with TSAT playing a critical role. The concept is to use laser-based and improved radio frequency transmission systems and high-speed, Internet-like networks that will link communications systems on the ground, in the air, on ships, and in space. Instead of circuit-based systems, such as those used today to link specific sending-and-receiving devices, future systems are expected to connect multiple sending-and-receiving devices at the same time. The ultimate goal is to remove the existing constraints to communication and enable transmissions regardless of location, size, or message.

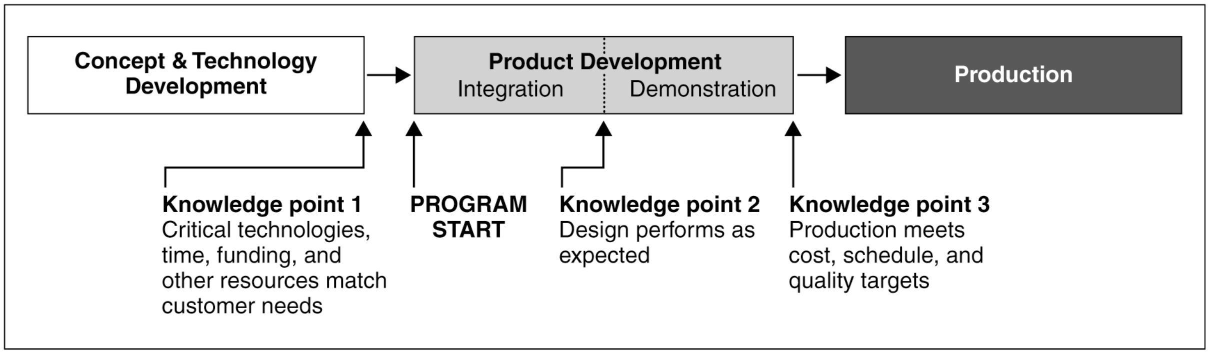
Knowledge-based Acquisition Strategy Results in Better Outcomes

Historically, DOD has had difficulty meeting the cost, schedule, and performance goals that were established at the start of its major defense acquisition programs such as TSAT. DOD's investments in money and time have far exceeded initial estimates for developing and acquiring communications satellites and other weapon systems. In addition, weapon systems have frequently been saddled with performance shortfalls.[3] To address some of these difficulties, DOD recently implemented a new space systems acquisition policy, which intends to provide decision makers in the Air Force with more consistent and robust information on costs, technologies, and requirements. The new acquisition policy also promotes rapid introduction of emerging technologies into space systems and allows technology, design, and system development to occur concurrently in an effort to speed the acquisition process. A recent GAO report identified some positive aspects of the policy; however, the report stated that any benefits will be limited because the policy permits major investments in new programs before managers know what resources are really required to deliver a promised capability.[4]

Our work on best practices in weapon system acquisitions has shown that program managers have a much higher probability of meeting cost, schedule, and performance objectives if the needed technologies are mature and the developing contractor has completed early design studies before starting the acquisition program. Having this knowledge in hand means managers can build a strong business case and ensure their products can be successfully developed. A business case provides the necessary structure for managers to identify the best product solution based on knowledge of performance, constraints and assumptions, and a risk-adjusted cost-benefit analysis. In the past several years, GAO has developed a knowledge-based acquisition model based on best practices by leading companies. The best practices model has three knowledge points. Each knowledge point builds on the preceding one. The acquired knowledge is used to identify and reduce any risks before moving a product to the next stage of development. Figure 1 shows when the three knowledge points occur on the best practices model.

[3] U.S. General Accounting Office, *Military Space Operations: Common Problems and Their Effects on Satellite and Related Acquisitions*, GAO-03-825R (Washington, D.C.: June 2, 2003).
[4] U.S. General Accounting Office, *Defense Acquisitions: Improvements Needed in Space Systems Acquisition Management Policy*, GAO-03-1073 (Washington, D.C.: Sept. 15, 2003).

Figure 1: Commercial Best Practices Model for the Acquisition Process



Source: GAO.

The first knowledge point sets the stage for the eventual outcome of an acquisition program—desirable or problematic. When the customer's needs match the developer's resources (which include technology, design knowledge, time, and money) before program start, successful outcomes are much more likely to occur. If a match occurs after program start, managers often make additional, unanticipated investments in money and time because gaps between requirements and resources are discovered later in the process.

AIR FORCE IS SETTING COST, SCHEDULE, AND PERFORMANCE GOALS AND STARTING TSAT BEFORE CRITICAL KNOWLEDGE IS ATTAINED

By December 2003, when the TSAT program is scheduled to start, Air Force officials are required by law to establish cost, schedule, and performance goals, but the knowledge they need to set reliable goals is still not available. Critical technologies are underdeveloped and early design studies have not been started. Without this essential knowledge, the Air Force is likely to have difficulty developing a sound business case for starting the TSAT program. If the Air Force proceeds without a sound business case, the program is at risk of higher costs, lower performance, and delays in providing capabilities to the warfighters. Our work has found that successful commercial and DOD development programs insist on having mature technologies and early design studies to support the business case.[5]

Critical Technologies Are Immature

Critical technologies are necessary building blocks for a system to meet its minimum performance requirements. If these technologies are not available when needed, the system cannot be completed as planned. And because technology development does

[5] U.S. General Accounting Office, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999); and U.S. General Accounting Office, *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001).

not happen on a planned or predictable schedule, it is difficult to predict when or if a critical technology will mature. This is why leading commercial companies demand that critical technologies are mature before the commitment to a new system is made. Within the federal government, NASA leveraged this best practice by developing an analytical tool to assess technology maturity. This tool—adopted by many DOD programs—establishes Technology Readiness Levels (TRL) for demonstrated performance, with a higher value indicating a greater maturity level. (The various levels are defined in enc. II.)

According to best commercial practices and DOD guidance, the minimum acceptable level for a technology to be included in an acquisition is TRL 6. At this level, the technology is considered sufficiently mature and has been engineered into a subsystem or prototype that closely resembles the final design. Also, the technology has been successfully demonstrated to work in a relevant environment. DOD policy[6] prefers the maturity to reach TRL 7—a prototype demonstration in an operational environment. A TRL 7 for a satellite would mean the technology prototype has achieved form, fit, and function and has been demonstrated in space. Commercial satellite companies frequently meet these criteria by including a new technology on an existing satellite design for demonstration purposes. Also, NASA usually requires all mission-critical technologies to be demonstrated in space before being placed on a new system. In some cases, demonstrating space technologies in an operational environment is important because operating a system in the harsh temperatures and radiation environment of space—where a satellite must last essentially maintenance-free for 10 to 15 years—is much more challenging than land-based operations. The new space acquisition policy does not require a minimum threshold for including new technology on a space acquisition program.

Critical technologies for TSAT include laser optics that can transport information over long distances in much larger quantities than radio waves; high-speed routers that enable multi-user networks, sophisticated data packaging; security algorithms and management utilities; multi-beam antennas; and software reprogrammable terminals. Table 1 shows that most of these technologies were at a TRL 3 or 4 in October 2003. When a technology is classified as a TRL 3, it means most of the work performed so far has been based on analytical studies and a few laboratory tests may have been conducted. A TRL 4 means some of the key components have been wired and integrated and have been demonstrated to work together in a laboratory environment. Significant effort is required to move from these TRL levels to a TRL 6, the minimum needed to effectively begin a new acquisition program. As shown below, the program office estimates that most of these technologies will have reached a TRL 6 threshold by fiscal year 2006.

[6] DOD Instruction 5000.2, Operation of the Defense Acquisition System, May 12, 2003.

Table 1: Current and Expected Technical Maturity Levels of TSAT Technologies

Critical technology	TRL as of October 2003	When TRL 6 is expected
Information protection	3-4	FY2006
Laser communication	4-5	FY2006
Information packet processing	6	FY2003
Antenna for communications on the move	4-5	FY2006
Information transmission management	3-4	FY2006
Protected bandwidth efficient modulation	3-4	FY2006

Source: MILSATCOM Joint Program Office.

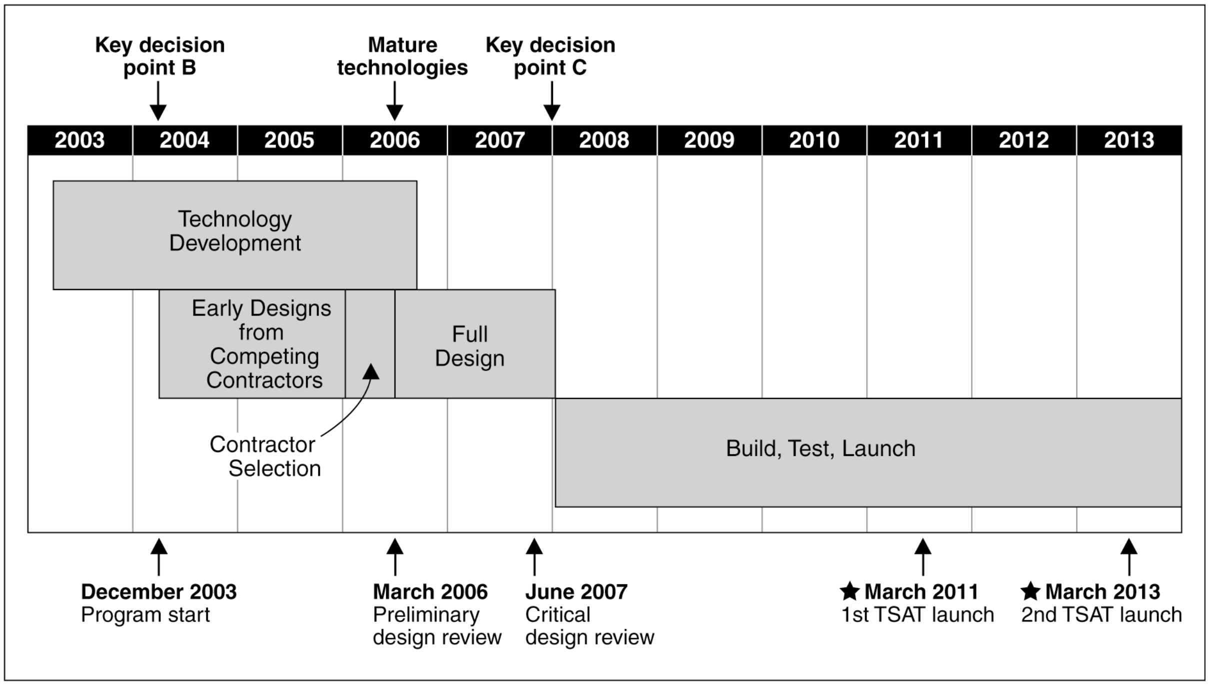
If one or more of TSAT's critical technologies encounters development problems, a backup technology should be available for insertion into the program. The laser communications technology does not have a backup provided by another satellite program. Typically, a backup technology does not meet all of the user's requirements and/or can negatively affect other design requirements of the new system, such as weight and power. For example, the alternative for TSAT's communications antenna is the current AEHF antenna, which does not provide the essential communications-on-the-move capability. Reverting to alternative technologies late in a development program results in a series of costly design changes and a need to go back to the warfighter to determine if the changes are acceptable.

Early Design Studies Have Not Been Started Yet

As of October 2003, 2 months before TSAT's scheduled start, the Air Force had not awarded contracts for early design studies. In the case of successful programs, we have found that the developing contractor evaluates the early designs according to system engineering principles to assure that designs are technically feasible, match the user's needs, and can be accomplished within the time frame and funds available. Without this disciplined engineering process, programs can learn too late that designs needed to achieve the warfighter's requirements are not feasible. Program managers then have little choice but to ask for more time and money to develop better designs, or they must compromise by asking the warfighter to accept a less capable backup design or technology. When discovered late in a development program, these changes can be costly. Our prior work has shown that the cost to change the design increases significantly as a program progresses through the key decision points of an acquisition program. For this reason, most commercial companies want greater assurance early in a program that the design is feasible and producible.

The Air Force plans to competitively award contracts for early design studies in December 2003, which is when the TSAT program is scheduled to start. These studies are to be completed in 2006, when contractors are expected to deliver a design specification in preparation for final design efforts. To prepare for the next step—critical design review—in 2007, the Air Force plans to assess the preliminary designs and select one or both contractors to continue with detailed design studies and development activities. Figure 2 shows key dates in TSAT's acquisition schedule.

Figure 2: TSAT's Acquisition Schedule (in fiscal years)



Source: Air Force.

After hearing senior warfighters express concerns about the ambitious schedule, the Air Force recently extended the launch date for the first TSAT from 2009 to 2011. However, the additional 2 years was mostly allocated to the build-and-test phase prior to launch. The front end of the acquisition schedule—technology development and design—remains much as it was before the extension. The technology development phase was not extended and the preliminary design and critical design review dates did not change. Based on our past reviews, the importance of technology development and design to the success of a program is critical and TSAT's current status shows significant immaturity to be overcome.

LACK OF EVALUATION CRITERIA RAISES CONCERNS ABOUT PENDING DECISION TO SHIFT FUNDS FROM TSAT TO AEHF

Despite intense interest across DOD in the November 2004 decision, Air Force officials have not defined what evaluation criteria they intend to use to assess alternatives if the TSAT program should falter. Senior military commanders have asked for assurances that promised communications capabilities will be delivered early in the next decade. If TSAT is likely to miss its promised launch date of 2011, they want funding to be allocated to complete the AEHF constellation of satellites. However, senior DOD and Air Force officials told us that if a fourth AEHF were acquired and a full AEHF constellation were delivered to the warfighter as originally planned, decision makers and funding organizations within DOD may want to wait until AEHF has reached the end of its useful life before replacing it with a next-generation satellite, such as TSAT. If the fourth AEHF is acquired, officials believe TSAT will be delayed by at least a decade. To these officials, this is not a tenable scenario because they see TSAT as the linchpin in DOD's plan to transform military communications and related combat systems.

To promote well-informed and objective investment decisions, our past work has found that decision makers establish and use measurable criteria for evaluating the costs, benefits, and risks of various alternatives. Although senior DOD and Air Force officials told us that they expect to have accomplished a number of tasks before making the November 2004 decision, they have not established measurable evaluation criteria for deciding whether to shift funds from TSAT back to AEHF.

CONCLUSIONS

DOD has embarked on a new transformational communications architecture to take advantage of emerging technologies and to remove communications constraints from combat. The department has told the warfighter and Congress that TSAT is a key system that is necessary to achieve this architecture. Responding quickly, the Air Force has set an imminent deadline of December 2003 to start the TSAT program. By starting the program so soon, the Air Force is moving ahead without mature technologies and early design studies—two pillars of knowledge that would help program officials to reliably establish cost, schedule, and performance goals. This knowledge is not expected to be available until 2006. Our work over the years has found that when programs have been started without the requisite knowledge, program managers and contractors are later burdened by unreasonable expectations about cost, schedule, and performance. Problems usually arise later that lead to cost increases, delays in delivering needed capability to the warfighters, and performance shortfalls.

For the planned November 2004 decision about whether to fund TSAT or AEHF, Air Force officials would be in a better position to make a well-informed, objective decision if they establish and use specific criteria for evaluating alternative investments. Reporting the Air Force's decision-making criteria and rationale to Congress would enhance transparency and provide Congress with better information for its oversight and funding responsibilities.

RECOMMENDATIONS FOR EXECUTIVE ACTION

To promote better cost, schedule, and performance outcomes, we recommend that you direct the Secretary of Air Force to delay the start of the TSAT acquisition program until technologies have been demonstrated to be at an acceptable level of maturity (at least TRL 6) and until the developing contractor has determined through systems engineering that the design is feasible and producible. We also recommend that you direct the Secretary to provide the appropriate level of funding necessary to gain this knowledge, which is critical for building a business case to start the TSAT program at a later time.

To promote a well-informed and objective decision—now scheduled for November 2004—about whether to fund another AEHF satellite, we further recommend that you direct the Secretary of Air Force to:

- establish measurable criteria for use when evaluating alternative investments in TSAT and AEHF and report this criteria in the Air Force's 2005 budget submission;
- consider the alternative investments in TSAT and AEHF against these measurable criteria; and
- provide the rationale for how these criteria were applied in the Air Force's 2006 budget submission.

AGENCY COMMENTS AND OUR EVALUATION

In commenting on a draft of this report, the Deputy Assistant Secretary of Defense for Networks and Information Integration disagreed with our primary recommendation to delay the start of the TSAT acquisition program until technologies are sufficiently matured and until the contractor determines through systems engineering principles that the design is feasible. DOD contends that the new Air Force National Security Space Acquisition Policy provides sufficient controls to allow concurrent development of technology and product design. DOD states that starting the TSAT program enables it to establish the funding and program controls—such as managing to the acquisition program baseline—provided by the new space acquisition policy. DOD did, however, concur or partially concur with the other recommendations to provide funding to mature TSAT's critical technologies and early designs, to establish criteria for making decisions, and to report these criteria and decisions to Congress.

We believe the new space acquisition policy does not have sufficient controls to reverse the higher costs and longer schedules that have plagued a number of satellite programs. The added risks of concurrent technology and product development have not helped improve the typical outcome for satellite programs. In a series of best practices reports issued over the years, we have identified problems resulting in substantially different cost and schedule outcomes when compared with initial expectations at the outset of a new acquisition program. We have offered improved approaches based on the best commercial and defense practices. DOD has endorsed the practices that call for a disciplined acquisition approach, one that separates technology from product development and bases decisions at key junctures on a set of critical product knowledge captured by the decision point. DOD incorporated this knowledge-based approach in its new acquisition system policy.[7]

[7] DOD Directive 5000.1 and Instruction 5000.2.

DOD's new space acquisition policy, on the other hand, is a step backward and is similar to an older acquisition policy that contributed to many unsuccessful acquisition programs of the past. DOD's history is filled with examples of programs that concurrently developed technology and new products and made decisions based on risk mitigation plans instead of knowledge about the new products. Our June 2003 report[8] on common problems in satellite programs identified Milstar, SBIRS-Low, SBIRS-High, AEHF, and others as suffering the consequences of this earlier acquisition strategy. Additionally, we have found that setting an acquisition program baseline that is not rooted in key product knowledge is unreliable and not useful as a management tool. In fact, starting the program before technologies are mature and a feasible design study is completed reduces accountability and straps the program manager and the contractor with unreasonable expectations in the baseline. Therefore, we believe that because DOD's new space acquisition policy does not require a knowledge-based acquisition strategy, it is destined to repeat the problems of the past.

DOD stated that extensive studies done over the last two years provide sufficient information for the Milestone Decision Authority to determine if the TSAT program should be initiated. However, these studies do not provide product-specific knowledge for building a business case for TSAT. Instead, these studies were focused on developing the overarching communications architecture rather than detailed technology and design information needed to build and launch TSAT.

While it is key to complete early design efforts before starting the program, substantial investments in system design and development are at risk if the Air Force cannot demonstrate TSAT's technologies, a number of which were still in the early paper study phase without hardware demonstrations to support that they would work. In its fiscal year 2004 budget submission, the Air Force had budgeted over $800 million in fiscal years 2004 and 2005 for system design and development.

To support its case for starting the TSAT program in December 2003, DOD states backup technologies exist and are ready to fill any technology void that might occur. They believe this will reduce the risk. However, there are no backup technologies that will satisfy the two most critical warfighter requirements—laser communications (critical to transporting intelligence, surveillance, and reconnaissance data) and communications on the move (critical to the Future Combat System). These capabilities were the primary basis for persuading the warfighter to favor the uncertain future of TSAT rather than to acquire the full constellation of four AEHF satellites, which would have provided a 500 percent increase over the communications capability used in Operation Iraqi Freedom.

If TSAT's investments were based on knowledge captured from mature technologies and feasible design, then these informed decisions would reduce the potential for major and costly changes as the program enters the build-and-demonstration phase,

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[8] U.S. General Accounting Office, *Military Space Operations: Common Problems and Their Effects on Satellite and Related Acquisitions*, GAO-03-825R (Washington, D.C.: June 2, 2003).

when it is too late to consider other options. We believe it is better to keep options open now, such as AEHF, and decide at a later time when enough knowledge has been gained to ensure TSAT is the right solution for the 2010 time frame. Our past work shows the negative outcomes of the concurrent and risk mitigation approach to acquisition. We also have shown the potential for more successful outcomes if a knowledge-based approach is applied. Therefore, we stand by our recommendation that TSAT's program start should be delayed until technologies are mature and the developing contractor has completed studies to demonstrate a feasible design.

To ensure that the warfighter is delivered an improved capability no later than 2011, DOD intends to decide in November 2004, based on an assessment of TSAT's progress, whether funding should be diverted back to the AEHF program. In its comments, the Air Force suggests criteria for this decision point that can only result in continuing the TSAT program. For example, criteria for laser communications or communications on the move do not apply to AEHF. These are capabilities promised by TSAT, not AEHF. We believe that the criteria should be based on the maturity of critical technologies and early design of TSAT. To ensure the transparency and objectivity of the decision process in November 2004, these criteria should be provided to Congress in the fiscal year 2005 budget for TSAT, not—as DOD suggests—in the 2006 budget, when the decision will already have been made.

In response to DOD's detailed comments, we made changes to the report where appropriate to correct technical inaccuracies. DOD's comments are provided in enclosure III.

SCOPE AND METHODOLOGY

In conducting our review, we analyzed the extent to which the TSAT and APS programs have acquired the knowledge needed to set specific cost, schedule, and performance goals. To do this, we compared the acquisition strategy with GAO's knowledge-based acquisition model and analyzed the differences between them. We specifically focused on the portion of knowledge-based acquisition dealing with the necessity of matching user's needs with developer's resources prior to making a development commitment. We collected and analyzed information from the Office of the Assistant Secretary of Defense for Command, Control, Communication and Intelligence (ASDC3I), Defense Information Services Agency (DISA), the National Security Agency (NSA), Air Force Space Command (AFSPC), U.S. Strategic Command (USSTRATCOM), Military Satellite Communication Joint Program Office (MJPO), Joint Forces Command (JFCOM), Aerospace Corporation and RAND Corporation. We conducted our review from February 2003 through November 2003 in accordance with generally accepted government auditing standards.

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As you know, 31 U.S.C. 720 requires the head of a federal agency to submit a written statement of actions taken on our recommendations to the Senate Committee on Governmental Affairs and the House Committee on Government Reform not later than 60 days after the date of the report and to the Senate and House Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of this report.

We are sending copies of this report to interested congressional committees. We will also make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff has any questions concerning this report, please contact me at (202) 512-4841. Key contributors to this report were Lily Chin, Mike Hazard, Dave Hubbell, Travis Masters, and Matt Mongin.

Sincerely yours,

R E Levin

Robert E. Levin
Director, Acquisition and Sourcing Management

Enclosure I: Descriptions of Communication Satellites

The Air Force is developing the following communication satellites.

Wideband Gapfiller Satellite

The Wideband Gapfiller Satellite (WGS) system is a joint Air Force and Army program intended to provide communications to U.S. warfighters, allies, and coalition partners during all levels of conflict, short of nuclear war. WGS will provide essential communications services for the commanders in chief to command and control their tactical forces. Tactical forces will rely on WGS to provide high-capacity links to the terrestrial portion of the Defense Information Services Network. WGS is the next generation wide-band component in the Department of Defense's (DOD) future Military Satellite Communications architecture. WGS is composed of three principal segments: Space Segment (satellites), Terminal Segment (users), and Control Segment (operators). The WGS program is leveraging commercial methods and technological advances in the satellite industry to rapidly design, build, launch, and support a constellation of highly capable military communications satellites.

The WGS program is being conducted as a DOD commercial acquisition and as such is not subject to the same milestone and/or review processes required in other space acquisition programs. The Air Force reports that 95 percent of satellite content will be commercial off-the-shelf products. The total budget for purchasing five WGSs is $1.5 billion. The contract is firm fixed price over 10 years and was awarded to Boeing Satellite Systems in January 2001. The Air Force purchased the first two satellites in fiscal year 2002 and the third satellite in fiscal year 2003. It plans to purchase satellites four and five in fiscal years 2007 and 2008, respectively. The first two WGS satellites are scheduled for launch in fiscal year 2005, with the third satellite planned for launch in fiscal year 2006.

Upon first launch into geosynchronous orbit in 2005, WGS will be the DOD's most capable and powerful communications satellite. Ultimately, five WGSs will be in orbit, providing service in both the X- and Ka band-radio frequencies. Each satellite is expected to have a capacity of at least 2,100 megabits per second. WGS will augment X-band communications now provided by the Defense Satellite Communications System (DSCS) and one-way Ka-band service provided by the Global Broadcast Service (GBS). Additionally, WGS will provide new two-way Ka-band services. These satellites are not interconnected. They will, however, provide communications capacity, connectivity, and flexibility for U.S. military forces while maintaining full interoperability with existing and programmed DSCS and GBS terminals.

Advanced Extremely High Frequency Satellite

The Advanced Extremely High Frequency (AEHF) satellite system is to be DOD's next generation of high-speed, secure communication satellites. This satellite system is intended to replace the existing communications satellites with improved, survivable, jam-resistant, worldwide, secure communication capabilities at lower launch costs. AEHF is to support the entire range of data rates to provide assured communications across the entire spectrum of conflict, including nuclear war. AEHF is also designed to be "backward compatible" with existing satellites, that is, it will support both low and medium data rates as necessary until an AEHF constellation with higher data rates becomes available at initial operating capability (two satellites on orbit). The first satellite is currently planned to launch in 2006 and the second is scheduled to launch in 2007.

The Air Force is responsible for funding, developing, and producing the AEHF satellites and the associated ground control systems. The Air Force's budget for developing and acquiring the first three AEHF satellites is $4.8 billion. Each service—Army, Navy, and Air Force—is separately responsible for funding, developing, and producing its own terminals to communicate with AEHF.

The AEHF program began in August 1998, and the final constellation will be composed of satellites in geosynchronous orbit that can transmit data to each other via radio frequency cross links, and communicate with ground stations and communication terminals carried by air, sea, and ground forces. Each satellite will have a capacity of about 250 megabits per second. Users communicate with the satellites through their terminals. The mission control segment provides command and control that directs the movements and other operations of satellites.

Transformational Satellite Communications

The Transformational Satellite (TSAT) communications system is designed to provide improved, survivable, jam-resistant, worldwide, secure and general purpose communications as part of an independent but interoperable set of space-based systems that will support the National Aeronautics and Space Administration, DOD, and the intelligence community. TSAT will replace the current satellite system and supplement AEHF.

The TSAT architecture, requirements, and cost baselines are to be approved in December 2003. Initial design contracts are to be awarded in December 2003; therefore, the final configuration of the TSAT system remains to be determined. Air Force budget documentation for TSAT (funded under the Advanced Wideband Satellite budget line) shows a total cost of $10.9 billion for purchasing the first five satellites plus a spare.

The TSAT system will be the key transport mechanism of DOD's space-based network communications system, which has individual satellites operating as routers in space. The TSAT constellation of five satellites will provide continuous communication coverage from 65 degrees south latitude to 65 degrees north. The satellites will support communications in the EHF and Ka band radio frequency bands, in addition to passing communications via lasers. The capacity of each satellite is expected to be at least 10 times greater than the AEHF satellites. The Air Force is currently conducting development activities necessary in order to make a decision to start the program in December 2003. The Air Force plans to launch the first TSAT in fiscal year 2011. The first two satellites will have radio frequency satellite cross links to engage the AEHF satellites as well as having the laser cross links; the third through the fifth satellites will have laser cross links only.

Advanced Polar Satellite

The Advance Polar System (APS) is a part of the Air Force's transformational communication architecture and is being developed and acquired as part of the TSAT/APS acquisition program. APS will provide the next generation protected EHF band, Ka band, and laser satellite communications capability in the north polar region starting in fiscal year 2012. APS will support strategic as well as tactical users who require anti-jam and low probability of detection EHF satellite communications. The results of the transformational communications architecture definition will affect the APS program content. Requirements are based on the July 1995 Polar Operational Requirements Document. According to Air Force program officials, APS is to be a "lighter" (i.e., lower capacity) version of the TSAT. The current APS plan is to acquire three satellites (two funded with development funds and one funded with procurement dollars) and associated ground infrastructure for $1.2 billion. The three APS satellites will be placed in highly inclined orbits and are expected to provide continuous communication services to forces deployed from 65 degrees north to the North Pole (90 degrees north).

Enclosure II: Descriptions of Technology Readiness Levels

The Interim Defense Acquisition Guidebook (formerly DOD 5000.2-R) directs that technology readiness assessments, using Technology Readiness Levels (TRL) or some equivalent assessment methodology, for critical technologies shall occur sufficiently before key decision points B and C to provide useful technology maturity information to the acquisition review process. TRLs, originally developed by the National Aeronautics and Space Administration (NASA), are measured along a scale of 1 to 9, starting with paper studies of the basic concept and ending with a technology that has proven itself in actual usage on the intended product. As the TRL scale increases, the risks associated with uncertain technology decrease, because more is known about their capabilities and performance. Unexpected problems can arise at every level, and effort must be expended to overcome them. This effort takes time and can delay the progress to the next readiness level. According to our previous reviews of best commercial practices and DOD guidance, a minimum level of TRL 6 should be reached before committing to a space acquisition program. Table 1 provides a detailed explanation of each TRL.

Table 2: TRL Scale for Assessing Critical Technologies

Technology Readiness Levels	Technology Readiness Level Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for level 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from level 6, requiring the demonstration of an actual system prototype in an operational environment. Examples include testing the prototype in a test bed aircraft.
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this level represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Source: GAO based on NASA and DOD guidance.

Enclosure III: Comments From the Department of Defense

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

NOV 21 2003

NETWORKS AND INFORMATION INTEGRATION

Mr. Robert E. Levin
Director, Acquisition and Sourcing Management
U. S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Levin,

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "Space Acquisitions: Committing Prematurely to the Transformational Satellite Program Elevates Risks for Poor Cost, Schedule, and Performance Outcomes," GAO-04-71R (GAO Code 120225) dated October 29, 2003.

The report includes five recommendations to the SECDEF. The Department of Defense non-concurs with the first recommendation, and partially concurs or concurs with the remaining four. Specific DoD comments on each of the recommendations are enclosed as Attachment 1.

The DoD does not agree with the key finding of the GAO report that the Air Force is not currently prepared to make informed decisions regarding either the starting of the TSAT program in the December 2003 timeframe or to shift funding from TSAT to AEHF in November 2004. The DoD has conducted extensive studies at the architecture and systems level over the past two years, by the government and by three contractor teams. The government developed a reference architecture which validated a point solution that satisfies a set of cost / schedule / performance criteria. The users at a Senior Warfighter Forum (SWarF) and JROC approved this architecture. The DoD believes that contractor, government, and FFRDC studies are providing sufficient information to the TSAT Milestone Decision Authority to determine if the program is sufficiently mature to warrant transition into a formal acquisition program at Phase B of the NSS Acquisition Policy 03-01.

The GAO report expresses concern that moving the TSAT program past KDP-B before the relevant technologies are at Technology Readiness Level (TRL)-6 could induce substantial cost, schedule, and performance risk. The DoD has mitigated these risks by developing an evolutionary acquisition strategy and technology investment plan structured to have all relevant technologies reach TRL 6 prior to system PDR. This technology investment plan will allow us to manage progress and, among other things, plan in advance if we need to use already identified fallback technologies to mitigate risk. We will manage this technology investment to detailed milestones in order to be able to make decisions as to if and when a fallback technology must be used if the primary technology does not mature as planned. These fallback technologies are all already at, or above, TRL-6. Even if the initial increment one TSATs have to use all of the fallback technologies, which is not likely, they would still be much more capable than AEHF. Additionally, even a reduced capability increment one TSAT puts DoD on the path to transformation and net-centric capability, so critical to our future operations.

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While we agree with the GAO that it would be inappropriate to commit to a detailed design with immature technology, we note that NSS Acquisition Policy 03-01 states that Space Programs are to be baselined at the beginning of the Risk Reduction and Technology Development phase, which is KDP-B. The increase in reporting requirements, and the program reviews associated with a baselined Phase B program facilitates increased DoD oversight/insight. The Transformational Communications MILSATCOM (TCM) program acquisition strategy has been developed in accordance with this precept, which, again, is the reason our technology investment plan is structured to have all relevant technologies reach TRL 6 prior to system PDR. This approach allows development of these maturation plans in synchronization with development of the program requirements. This, in turn, allows the products based on the technologies to be tailored to best meet and refine user needs within cost, schedule and risk constraints. Program management and DoD insight are aided by maintenance of an APB (Acquisition Program Baseline), through periodic acquisition reports, and through the program reviews associated with Phase B (e.g. SDR and PDR). User needs are tracked through the transition of the Capabilities Development Document (CDD) into the Capabilities Production Document (CPD). To expend the funds that the GAO and the Air Force agree are required without the reporting and review associated with a baselined program may, in fact, limit the effectiveness of the technology maturation.

It is also important to realize that the TSAT system will be procured using a capabilities based approach. In order to maintain schedule and cost, capabilities will be traded in a joint warfighter/ acquisition forum. This "cost as an independent variable" (CAIV) approach allows the DoD to develop affordable increments of militarily useful capability. We believe that the best way to provide the most transformational capability to the warfighter at the earliest possible date is to pursue this approach, and proceed to a KDP-B.

The GAO report itself contains a number of technical and other inaccuracies. Detailed comments are provided in Attachment 2.

The DoD appreciates the opportunity to respond to the GAO draft report.

Sincerely,

Michael Frankel

Michael S. Frankel
Deputy Assistant Secretary of Defense
Networks and Information Integration
(C3, Space, and IT Programs)

Enclosures:
DoD Comments to GAO Recommendations
Detailed Technical Comments on GAO Report

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Attachment 1

GAO DRAFT REPORT DATED OCTOBER 29, 2003
GAO-04-71R (GAO CODE 120225)

"Space Acquisitions: Committing Prematurely to the Transformational Satellite Program Elevates Risks for Poor Cost, Schedule and Performance Outcomes"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to delay the start of the TSAT acquisition program until technologies have been demonstrated to be at an acceptable level of maturity (at least TRL 6) and until the developing contractor has determined through systems engineering that the design is feasible and producible. (p. 9/GAO Draft Report)

DOD RESPONSE: **Non-Concur**. Technologies selected for incorporation on TSAT will be at or above Technology Readiness Level 6 by Preliminary Design Review in FY06. The DoD has further mitigated technology risk by developing an evolutionary acquisition strategy. This strategy allows us to select from identified fallback technologies if required to mitigate program risk. These fallback technologies are all already at, or above, TRL-6. Even if the initial increment one TSATs had to use all of the fallback technologies, which is not likely, they would still be much more capable than AEHF. Additionally, even a reduced capability increment one TSAT puts DoD on the path to transformation and net-centric capability, so critical to our future operations. Program initiation, governed by National Security Space (NSS) Acquisition Policy 03-01, begins before PDR.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense provide the appropriate level of funding necessary to gain this knowledge, which is critical for building a business case to start the TSAT program at a later time.
(p. 9/GAO Draft Report)

DOD RESPONSE: **Partially Concur**. The DoD is currently reviewing TSAT RDT&E funding to ensure that it is adequate to do the technology and non-recurring engineering work necessary to acquire the program with reasonable risk. The DoD will re-visit funding each year to ensure adequate funding is maintained to achieve TSAT program objectives. The DoD position is that the Dec 03 – Jan 04 timeframe is the proper time to start the TSAT program and establish a program baseline so that these investments can be properly tracked and managed. Our evolutionary strategy, fallback technologies, and CAIV approach will allow us to manage risk while developing an affordable increment of militarily useful capability.

RECOMMENDATION 3: The GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to establish measurable criteria for use when evaluating alternative

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investments in TSAT and AEHF and report these criteria in the Air Force's 2005 budget submission. (p. 10/GAO Draft Report)

DOD RESPONSE: **Partially Concur**. The decision will be based on known risks balanced against warfighter requirements. Measurable criteria are being developed and will be used to make this decision in November 2004. For example, one of the criteria we are considering is the ability to support communications on the move (COTM) at data rates above 250 kbps to a one-foot antenna mounted on a vehicle traveling at speeds above 25 mph. Another is the ability to support multiple high date rate Airborne ISR missions with interoperable laser communications links. The DoD will provide these criteria and resulting decision as part of the FY06 President's Budget process.

RECOMMENDATION 4: The GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to consider the alternative investments in TSAT and AEHF against these measurable criteria. (p. 10/GAO Draft Report)

DOD RESPONSE: **Concur**. The investment strategy for TSAT will support an evolutionary approach potentially using fallback technologies, this approach will allow us to manage risk while developing an affordable increment of militarily useful capability much more advanced than AEHF. This approach will also start us on the transformational path to net-centric operations that can be integrated with the DoD's other investments in transformational capabilities. These TSAT results will be compared to progress on the AEHF program, and against measurable criteria to form the basis of our decision. The DoD will use all appropriate criteria and consider alternative investments strategies that satisfy the needs of the warfighters.

RECOMMENDATION 5: The GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to provide the rationale for how these criteria were applied in the Air Force's 2006 budget submission. (p. 10/GAO Draft Report)

DOD RESPONSE: **Concur.** We will use the results of our evolutionary acquisition strategy as the basis of our FY06 budget submission to Congress. When the 2006 DoD budget is submitted in February 2005, the investment strategy will support the November 2004 decision to either buy a fourth AEHF and potentially slow the TSAT program, or proceed with TSAT as planned. The rationale and supporting data will be shared with Congress.

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