United States Government Accountability Office

GAO

Report to the Chairman, Subcommittee on Strategic Forces, Committee on Armed Services, House of Representatives

March 2006

SPACE ACQUISITIONS

DOD Needs a Departmentwide Strategy for Pursuing Low-Cost, Responsive Tactical Space Capabilities

GAO-06-449

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GAO Accountability · Integrity · Reliability

Highlights

Highlights of GAO-06-449, a report to the Subcommittee on Strategic Forces, Committee on Armed Services, House of Representatives

Why GAO Did This Study

For more than two decades, the Department of Defense (DOD) has invested heavily in space assets to provide the warfighter with mission-critical information. Despite these investments, DOD commanders have reported shortfalls in space capabilities.

To provide tactical capabilities to the warfighter sooner, DOD recently began developing TacSats—a series of small satellites intended to be built within a limited time frame and budget—and pursuing options for small, low-cost vehicles for launching small satellites.

GAO was asked to (1) examine the outcomes to date of DOD's TacSat and small, low-cost launch vehicle efforts, (2) identify the challenges in pursuing these efforts, and (3) determine whether experiences with these efforts could inform DOD's major space system acquisitions.

What GAO Recommends

GAO is recommending that DOD assign accountability for developing and implementing a departmentwide strategy for pursuing low-cost tactical capabilities—both satellite and launch vehicles—and identify corresponding funding. In commenting on the report, DOD agreed with the recommendation.

www.gao.gov/cgi-bin/getrpt?GAO-06-449.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Michael J. Sullivan at (202) 512-4841 or sullivanmj@gao.gov.

What GAO Found

Through effective management of requirements and technologies and strong leadership, DOD was able to deliver the first TacSat satellite in 12 months and for less than $10 million. The Office of Force Transformation, TacSat 1's sponsor, set requirements early in the satellite's development process and kept them stable. DOD modified existing technologies for use in space, significantly reducing the likelihood of encountering unforeseen problems that could result in costly design changes. The satellite was also built within DOD's science and technology environment, which enabled service laboratory scientists to address problems quickly, inexpensively, and innovatively. The vision and support provided by leadership were also key to achieving the successful delivery of TacSat 1. DOD has also made progress in developing three additional TacSats and is working toward developing a low-cost launch vehicle available on demand.

Despite this achievement, DOD faces several challenges in providing tactical capabilities to the warfighter sooner. First, DOD has yet to develop a low-cost, small launch vehicle available to quickly put tactical satellites, including TacSat 1, into orbit. Second, limited collaboration between the science and technology and the acquisition communities—as well as the acquisition community's tendency to expand requirements after program start—could impede efforts to quickly procure tactical capabilities. Securing funding for future TacSat experiments may also prove difficult because they are not part of an acquisition program. Finally, DOD lacks a departmentwide strategy for implementing these efforts, and because key advocates of the experiments have left DOD, it is unclear how well they will be supported in the future.

Regardless of these challenges, DOD's experiences with the TacSat experiments thus far could inform its major space system acquisitions. DOD's approach to developing the TacSats—matching requirements to available resources, using proven technologies, and separating technology development from product development—reflects best commercial practices that lead to quicker delivery with less risk. According to some DOD officials, the TacSats and small, low-cost launch vehicles—once they are developed—could also provide an avenue for large space system acquisitions to prove out technologies in the space environment, something DOD has avoided because of the high cost of launching such experiments. These officials also believe that giving space professionals the opportunity to manage small-scale projects like TacSats may better prepare them for managing larger, more complex space system acquisitions. Finally, these officials noted that building small-scale satellite systems and launch vehicles could create opportunities for small, innovative companies to compete for DOD contracts and thereby broaden the space industrial base.

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Abbreviations

ARES	Affordable Responsive Spacelift
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
OFT	Office of Force Transformation
ORS	Operationally Responsive Space

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United States Government Accountability Office
Washington, DC 20548

March 14, 2006

The Honorable Terry Everett
Chairman
Subcommittee on Strategic Forces
Committee on Armed Services
House of Representatives

Dear Mr. Chairman:

Department of Defense (DOD) satellites and other space-related assets provide intelligence, surveillance, reconnaissance, missile warning, navigation, and other information critical to conducting military operations. DOD's space network is expected to play an increasingly important role in military operations. According to DOD, approximately 70 percent of weapons used in Operation Iraqi Freedom were precision-guided—mostly through global positioning satellites. Yet in each major conflict over the past decade, senior military commanders reported shortfalls in space capabilities, such as those intended to provide imagery data.

To address such shortfalls and provide tactical capabilities to the warfighter sooner, DOD recently began building a series of small satellites, referred to as TacSats, within the science and technology environment—an environment that lends itself to demonstrating technologies within a relatively short time frame and small budget. Although small satellites offer less performance than large satellites in areas like resolution, operational control, and power, the TacSats are expected to quickly provide the warfighter with the information needed to conduct operations in theater. DOD is also developing a small, low-cost launch vehicle that could be used to launch small satellites like the TacSats.

Given the potential these efforts may offer in changing the way DOD does business, you asked us to (1) examine the outcomes to date from the TacSat experiments as well as from efforts to develop small, low-cost launch vehicles, (2) identify the challenges in pursuing TacSats and the launch vehicles, and (3) determine whether DOD's experiences with TacSats and small, low-cost launch vehicles could inform major space system acquisitions.

To conduct our work, we interviewed DOD officials in the Office of Force Transformation, Air Force Space Command, Space and Missile Systems Center, the Air Force and Navy research labs, and in other cognizant offices, and analyzed documents obtained from these officials. We also interviewed industry representatives involved in developing large space systems and small commercial launch vehicles. We analyzed a number of GAO and DOD studies that discuss acquisition problems and associated challenges, including our work on best practices in weapon system development that we have conducted over the past decade. We conducted our review from June 2005 to March 2006 in accordance with generally accepted government auditing standards. For more on our scope and methodology, see appendix I.

Results in Brief

DOD delivered the first TacSat satellite in 12 months and for less than $10 million.[1] A number of elements enabled this achievement. First, the Office of Force Transformation, as TacSat 1's sponsor, effectively managed the satellite's requirements by reaching consensus on requirements early in the development process and keeping them stable. Second, DOD incorporated existing technologies and adapted them for new uses in space, significantly reducing the likelihood of encountering unforeseen problems that could result in costly design changes. Third, DOD built the satellite within the science and technology environment, enabling scientists at DOD's service labs to address problems quickly, inexpensively, and innovatively. Finally, DOD leadership provided a motivating vision, prompt funding, and high-level support throughout the experiment—a key factor in positioning new development efforts for success. DOD has made progress toward developing three additional TacSats—expected to be launched in May 2007, summer 2007, and April 2008—and is working toward developing a low-cost launch vehicle.

While DOD delivered the first TacSat on time and within its overall budget, the department faces several challenges in providing tactical capabilities to the warfighter sooner. First, while DOD is working to demonstrate a low-cost small launch vehicle to quickly put the tactical satellites into orbit, it has yet to deliver such a vehicle. As a result, TacSat 1 has not been launched. Second, the procurement of tactical capabilities in the future could be hindered if collaboration between the science and technology and acquisition communities is limited and the acquisition community

[1]In addition to the $10 million, available surplus hardware valued at $5 million was used to build the satellite.

expands requirements after program start—as has been the case in the past. Third, it may be difficult to secure continued science and technology funding for future TacSat experiments since they currently are not part of an acquisition program. Finally, DOD lacks a departmentwide strategy and leadership for implementing efforts in this area. Because key advocates of the experiments have left DOD, it is unclear how well the experiments will be supported in the future.

DOD's experiences with TacSats thus far may inform major space system acquisitions, and some DOD officials and industry representatives believe there are potential long-term benefits. The approach to developing TacSats reflects best practices—managing requirements to match available resources, using relatively mature technologies, and keeping additional technology development separate from product development—that larger space system programs could emulate to achieve quicker delivery of more robust systems that meet program objectives with less risk. In addition, according to some DOD officials, the TacSats could provide an avenue for incremental capabilities as well as a venue for large space system acquisitions to prove out technologies in the space environment—something DOD has avoided because of the high cost of conducting such experiments. These officials also believe that giving space professionals the opportunity to manage small-scale projects like TacSats may better prepare them for managing larger, more complex space system acquisitions in the future. Finally, these officials noted that building small-scale satellite systems and launch vehicles could create opportunities for small, innovative companies to compete for DOD contracts and thereby broaden the space industrial base.

To help ensure low-cost tactical capabilities continue to be developed and delivered to the warfighter quickly, we are recommending that DOD assign accountability for developing and implementing a departmentwide strategy for pursuing low-cost, responsive tactical capabilities—both satellite and launch—for the warfighter, and identify corresponding funding. In written comments on a draft of this report, DOD concurred with our findings and recommendation (DOD's letter is reprinted in app. II).

Background

The TacSat experiments and efforts to develop small, low-cost launch vehicles are part of a larger DOD initiative: Operationally Responsive Space (ORS). In general, ORS was created by DOD's Office of Force Transformation (OFT) in response to the Secretary of Defense's instruction to create a new business model for developing and employing

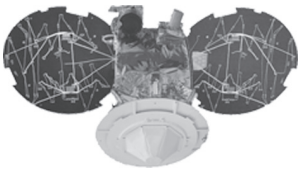
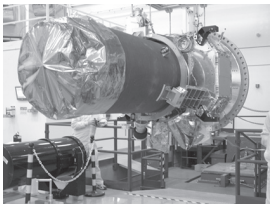
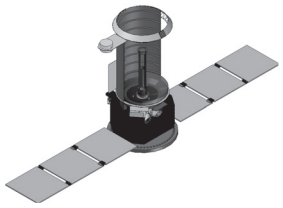
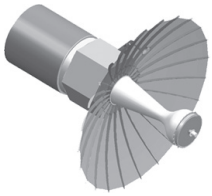
space systems. Under ORS, DOD aims to rapidly deliver to the warfighter low-cost, short-term joint tactical capabilities defined by field commanders—capabilities that would complement and augment national space capabilities, not replace them.[2] ORS would also serve as a test bed for the larger space program by providing a clear path for science and technology investments, enhancing institutional and individual knowledge, and providing increased access to space for testing critical research and development payloads. ORS is a considerable departure from the approach DOD has used over the past two decades to acquire the larger space systems that currently dominate its space portfolio. These global multipurpose systems, which have been designed for longer life and increased reliability, require years to develop and a significant investment of resources.[3] The slow generational turnover—currently 15 to 25 years—does not allow for a planned rate of replacement for information technology hardware and software. In addition, the data captured through DOD's larger space systems generally go through many levels of analysis before being relayed to the warfighter in theater.

The TacSat experiments aim to quickly provide the warfighter with a capability that meets an identified need within available resources—time, funding, and technology. Limiting the TacSats' scope allows DOD to trade off reliability and performance for speed, responsiveness, convenience, and customization. Once each TacSat satellite is launched, DOD plans to test its level of utility to the warfighter in theater. If military utility is established, according to a DOD official, DOD will assess the acquisition plan required to procure and launch numerous TacSats—forming constellations—to provide wider coverage over a specific theater. As a result, each satellite's capability does not need to be as complex as that of DOD's larger satellites and does not carry with it the heightened consequence of failure as if each satellite alone were providing total coverage. DOD currently has four TacSat experiments in different stages of development (see figure 1).

[2]Smaller satellites would become a node within a tiered network of sensors that would include larger space systems, unmanned aircraft, and air and surface assets.

[3]In fiscal year 2006, DOD plans to spend almost $20 billion to develop and procure major satellites and other space-related systems.

Figure 1: Overview of TacSat Experiments

TacSat 1	TacSat 2	TacSat 3	TacSat 4
			
Tactical mission capabilities/requirements			
• Tactical radio frequency payloads and ultra-high-frequency cross-platform link • Low-resolution visible and infrared cameras • Payload scheduling and data access via the Secret Internet Protocol Routing Network	• Common Data Link X-band radio to send data directly to theater • Tactical imaging and radio frequency • Science payloads • Payload scheduling and data access via the Secret Internet Protocol Routing Network	• Hyperspectral imaging sensor for tactical targeting of camouflaged and hard-to-detect targets • Secondary space communications payload for data exfiltration/infiltration to warfighter	• Mobile Data Communication services • Data relay from terrestrial sensors • Friendly forces tracking • Payload scheduling and data access via the Secret Internet Protocol Routing Network
Mission selection process			
Mission selected based on knowledge of specific combatant command's need	Mission selected based on existing Air Force Research Laboratory demonstration satellite	Mission selected through Air Force Space Command formalized process	Mission selected through Air Force Space Command formalized process
Primary developer and intended user			
Office of Force Transformation/Naval Research Laboratory for U.S. Pacific Command	Air Force Research Laboratory for U. S. Strategic Command (sponsors include Air Force Research Laboratory, Director of Defense Research and Engineering, and a joint Advanced Concept Technology Demonstration)	Air Force Research Laboratory for U.S. Army Space and Missile Defense Command, U.S. Special Operations Command, and other combatant commands (sponsors include Air Force Research Laboratory, Office of Force Transformation, Army and Office of Naval Research)	Naval Research Laboratory for U. S. Strategic Command (Office of Force Transformation/Office of Naval Research satellite sponsors; Air Force launch sponsor)

Source: Naval Research Laboratory and Air Force Research Laboratory.

According to Naval Research Laboratory officials, TacSat 2's delay is primarily the result of overestimating the maturity of its main payload—an off-the-shelf imager that was being refurbished for space use. Officials also noted that the contracting process, which took longer than expected, used multiple and varied contracts awarded under standard federal and defense acquisition regulations.

DOD is also using the TacSat experiments as a means for developing "bus" standards—the platform that provides power, attitude, temperature control, and other support to the satellite in space. Currently, DOD's satellite buses are custom-made for each space system. According to DOD

officials, establishing bus standards with modular or common components would facilitate building satellites—both small and large—more quickly and at a lower cost.

To achieve one of the TacSat experiments' goals—getting new capabilities to the warfighter sooner—DOD must secure a small, low-cost launch vehicle that is available on demand. Instead of waiting months or years to carry out a launch, DOD is looking to small launch vehicles that could be launched in days, if not hours, and whose cost would better match the small budgets of experiments. A 2003 Air Force study determined that DOD's current class of launchers—the Evolved Expendable Launch Vehicle—would not be able to satisfy these requirements.

DOD Successfully Delivered First TacSat through Managing Requirements and Is Moving Forward with Additional Efforts

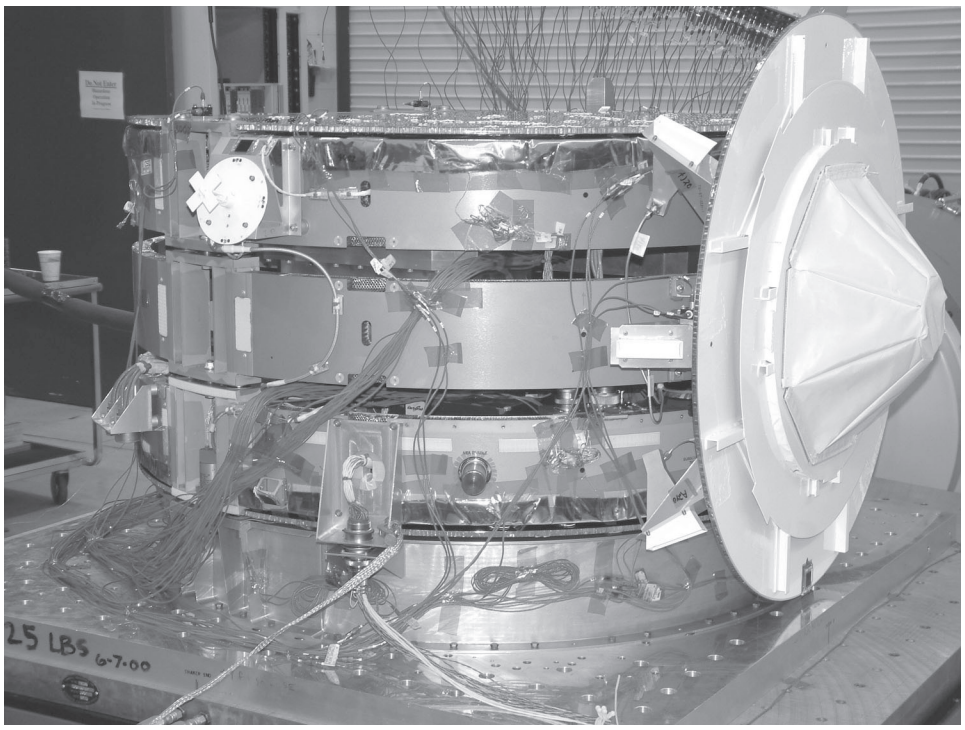
DOD delivered the TacSat 1 satellite within cost and schedule targets. To develop the first TacSat, DOD effectively managed requirements, employed mature technologies, and built the satellite in the science and technology environment, all under the guidance of a leader who provided a clear vision and prompt funding for the project. DOD is also moving forward with developing additional TacSats; bus standards; and a small, low-cost launch vehicle available on demand.

TacSat 1's Development Approach Enabled Successful Delivery

In May 2004, 12 months after TacSat 1 development began, the Naval Research Laboratory delivered the satellite to OFT at a cost of about $9.3 million, thereby meeting its targets to develop the satellite within 1 year and an estimated budget of $8.5 million to $10 million.[4] Once TacSat 1 is placed into orbit, it is expected to provide capabilities that will allow a tactical commander to directly task the satellite and receive data over DOD's Secure Internet Protocol Router—a need identified by the warfighter.

[4]In addition to the $10 million, available surplus hardware valued at $5 million was used to build the satellite.

Figure 2: TacSat 1 Ready for Vibration Testing at Naval Research Laboratory



Source: DOD.

Before TacSat 1's development began, OFT and the Naval Research Laboratory worked together to reach consensus on known warfighter requirements that would match the cost, schedule, and performance objectives for the satellite. Our past work has found that when requirements are matched with resources, goals can be met within estimated schedule and budget. To inform the requirements selection process, the Naval Research Laboratory used an informal systems engineering approach to assess relevant technologies and determine which could meet TacSat 1 mission objectives within budget and schedule. Once TacSat 1's requirements were set, OFT did not change them. To meet its mission objectives, OFT sought a capability that would be "good enough" for the warfighter, given available resources—rather than attempting to provide a significant leap in capability. OFT and the Naval Research Laboratory agreed to limit TacSat 1's operational life span to 1 year, which allowed the laboratory to build the satellite with lower radiation protection levels, less fuel capacity, and fewer backups than would have been necessary for a satellite designed to last 6 years or longer.

The use of existing technologies for the satellite and the bus also helped to keep TacSat 1 on schedule and within cost. For example, hardware from unmanned aerial vehicles and other aircraft were modified for space flight to protect them in the space environment, and bus components were purchased from a satellite communications company. Using items on hand at the Naval Research Laboratory—such as the space ground link system transponder and select bus electronics—resulted in a savings of about $5 million. Using and modifying existing technologies provided the laboratory better knowledge about the systems than if it had tried to develop the technologies from scratch. According to a laboratory official, the TacSat 1 experiment also achieved efficiencies by using the same software to test the satellite in the laboratory and fly the satellite.

Developing the TacSat within the science and technology environment also helped the experiment meet its goals. As we have stressed in our reports on systems development, the science and technology environment is more forgiving and less costly than the acquisition environment. For example, when engineers encountered a blown electronics part during TacSat 1's full system testing, they were able to dismantle the satellite, identify the source of the problem, replace the damaged part, and rebuild the satellite—all within 2 weeks of the initial failure. According to the laboratory official, this problem would have taken months to repair in a major space acquisition program simply because there would have been stricter quality control measures, more people involved, and thus more sign-offs required at each step. Moreover, the contracting mechanism in place at the Naval Research Laboratory allows the laboratory to respond quickly to DOD requests. Specifically, the center used several existing engineering and technical support contracts that are competed, generally, at 5-year intervals, rather than competing a specific contract for TacSat 1.

According to a number of DOD officials, the ultimate success of the TacSat 1 procurement was largely the result of the former OFT director, who

- provided the original impetus and obtained support for the experiment from high levels within DOD and the Congress;
- negotiated a customized mission assurance agreement with Air Force leaders to launch TacSat 1 from Vandenberg Air Force Base at a cost that was affordable given the experiment's budget;

- empowered TacSat 1's project manager at the Naval Research Laboratory to make appropriate trade-off decisions to deliver the satellite on time and within cost; and

- helped OFT staff develop an efficient work relationship with the Naval Research Laboratory team and provided the laboratory with prompt decisions.

DOD Is Working on Developing Future TacSats and Low-Cost Launch Vehicles

DOD is currently working on developing three additional TacSat experiments—along with bus standards—and a low-cost, on-demand launch vehicle. These efforts are generally in the early stages. DOD expects to launch TacSat 2—which began as an Air Force science and technology experiment and was altered to improve upon TacSat 1's capability—in May 2007. TacSat 3, which will experiment with imaging sensors, is in the development phase. TacSat 4, which will experiment with friendly forces tracking and data communication services, is in the design phase. Table 1 shows the development cost and schedule estimates and the target launch date for each satellite.

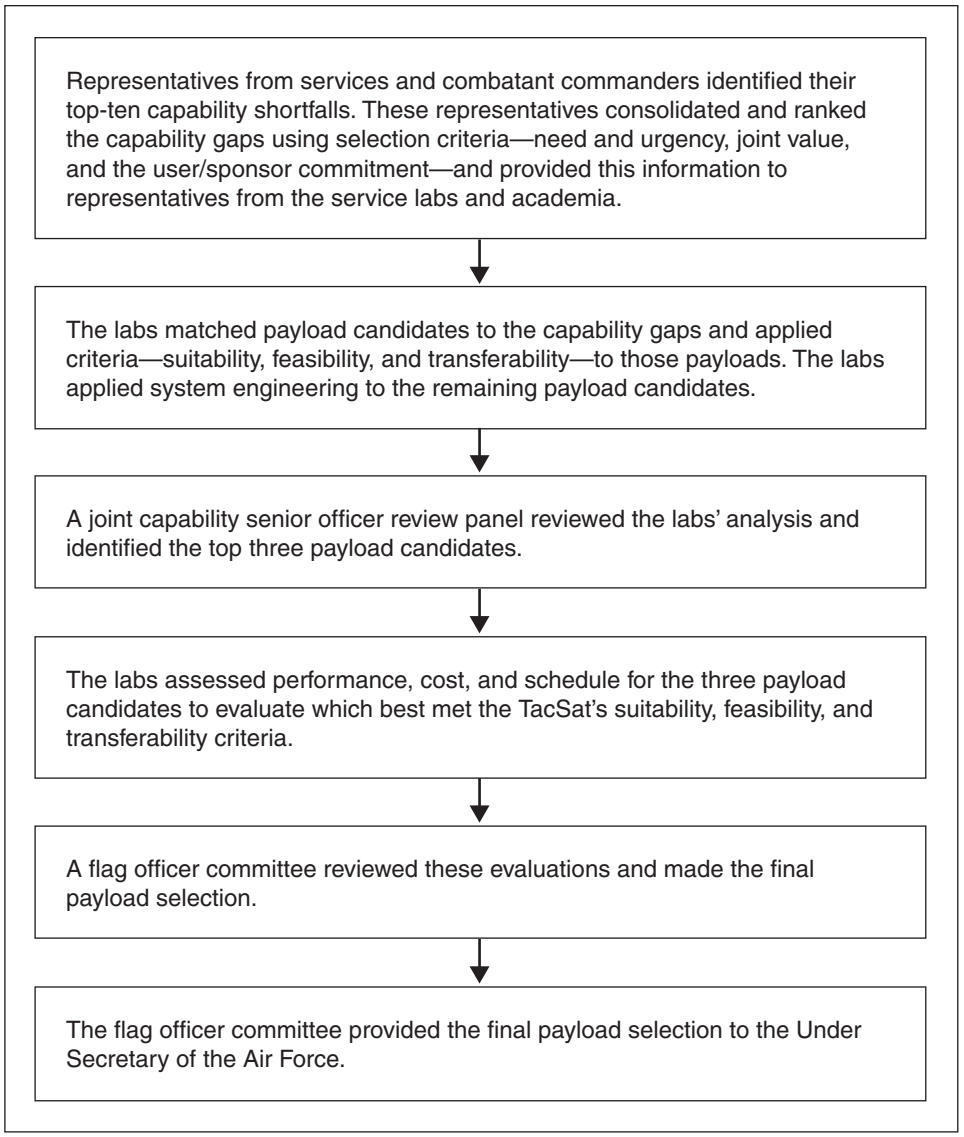
Table 1: Development Cost and Schedule Estimates and Target Launch Dates for TacSats 2, 3, and 4, as of March 2006

	Development cost estimate	Development completion	Target launch
TacSat 2	$39 million	29 months	May 2007
TacSat 3	$40 million	18 months	Summer 2007
TacSat 4	$41 million	24 months	April 2008

Source: Naval Research Laboratory and Air Force Research Laboratory.

With TacSat 3, the Air Force began to formalize the process for evaluating and selecting potential capabilities for the TacSats, leveraging the experiences from the first two TacSats. The selection process, which currently takes 3 to 4 months, includes a presentation of capability gaps and shortfalls from the combatant commands and each branch of the military, and analyses of the suitability, feasibility, and transferability of the capabilities deemed the highest priority. According to DOD officials, this process allows the science and technology community to obtain early buy-in from the warfighter, thereby increasing the likelihood that requirements will remain stable and the satellite will have military utility. Obtaining warfighter involvement in this way represents a new approach for the TacSat series. See figure 3 for a more complete description of this evolving process.

Figure 3: Capability Selection Process for TacSats 3 and 4



Source: DOD.

The Air Force has also begun to create plans for procuring TacSats for the warfighter should they prove to have military utility. The Air Force has developed a vision of creating TacSat reserves that could be deployed on demand, plans to establish a program office within its Space and Missile Systems Center, and plans to begin acquiring operational versions of successful TacSat concepts in 2010.

DOD is also working to develop bus standards. Establishing bus standards would allow DOD to create a "plug and play" approach to building satellites—similar to the way personal computers are built. The service research labs, under the sponsorship of OFT, and the Space and Missile Systems Center are in the process of developing small bus standards, each using a different approach. The service labs expect to test some standardized components on the TacSat 3 bus, and system standards by prototyping a TacSat 4 bus. The Space and Missile Systems Center is also proposing to develop three standardized bus models for different-weight satellites, one of which may be suitable for a TacSat. The service labs expect to transition bus standards to the Space and Missile Systems Center in fiscal year 2008, at which time the center will select a final version for procurement for future TacSats.

Both DOD and private industry are working to develop small, low-cost, on-demand launch vehicles. DOD's Defense Advanced Research Projects Agency (DARPA), along with the Air Force, established FALCON, a joint technology development program to accelerate efforts to develop a launch vehicle that meets these objectives. Through FALCON, DARPA expects to develop a vehicle that can send 1,000 pounds to low-earth orbit for less than $5 million with an operational cost basis of 20 flights per year for 10 years. FALCON is expected to flight-test hypersonic technologies and be capable of launching small satellites such as TacSats. DARPA is currently pursuing two candidates for its FALCON launch vehicle—AirLaunch, a company that expects to launch rockets that have been ejected from the back of a C-17 cargo airplane, and SpaceX, whose two-stage launch vehicle will include the second U.S.-made rocket booster engine to be developed and flown in more than 25 years, according to the company's founder.[5] DARPA could transition the AirLaunch concept to the Air Force after its demonstration launch in 2008. TacSat 1 is contracted to launch for about $7 million on SpaceX's vehicle. In addition, in 2005, the Air Force began pursuing a hybrid launch vehicle to support tactically and conventionally deployed satellites. The project is known as Affordable Responsive Spacelift, or ARES, and the Air Force has obtained internal approval to build a small-scale demonstrator that would carry satellites about two to five times larger than TacSats.

[5]Space Exploration Technologies (SpaceX).

DOD Faces Several Challenges in Pursuing Responsive Tactical Capabilities for Warfighters

DOD has several challenges to overcome in pursuing a responsive tactical capability for the warfighter. Although DOD and others are working to develop small, low-cost launch vehicles for placing satellites like the TacSats into space, such a vehicle has yet to be developed, and TacSat 1 has waited nearly 2 years since its completion to be launched. Transferring knowledge from the science and technology community to the acquisition community is also a concern, given that these two communities have not collaborated well in the past. Further, it may be difficult to secure funding for future TacSat science and technology projects since DOD allocates the majority of its research and development money to acquisition programs. Finally, there is no departmentwide vision or strategy for implementing this new capability, and the recent loss of leadership makes it uncertain to what extent efforts to develop low-cost, responsive tactical capabilities such as TacSats will continue to be pursued.

DOD Has Yet to Provide a Low-Cost, Small Launch Vehicle

While DOD has delivered TacSat 1 on time and within budget, the satellite is not yet operational because it lacks a reliable low-cost—under $10 million—small launch vehicle to place it in orbit. TacSat 1's original launch date was in 2004 on the SpaceX's first flight of its low-cost small launch vehicle. However, because of technical difficulties with the launch vehicle and launch facility scheduling conflicts, the TacSat 1 launch has been delayed 2 years and more than $2 million has been added to the total mission costs.[6] SpaceX now plans to use a different small satellite for its first launch.

Placing satellites in orbit at a low cost has been a formidable task for DOD for more than two decades because of elusive economies of scale. There is a strong causal relationship between satellite capabilities and launch lift. As capabilities and operational life are added, satellites tend to become heavier, requiring a launch vehicle that can carry a heavier payload. With longer-lived satellites, fewer launches are needed, making per unit launch costs high. In addition, the high cost of a large launch vehicle can only be justified with an expensive, long-living multimission satellite. Ultimately, the high cost of producing a complex satellite has created a low tolerance for risk in launching the satellite and a "one shot to get it right" mentality.

Over the past 10 years, DOD and industry have attempted to develop a low-cost launch vehicle. Three launch vehicles in DOD's inventory—the Pegasus, Taurus, and, to some extent, the Minotaur—were designed to

[6]Mission costs include spacecraft, launch, equipment, ground station preparation, and 1 year of flight operations.

provide space users with a low-cost means of quickly launching small payloads into low-earth orbit.[7] DOD expected that relatively high launch rates, from both commercial and government use, would keep costs down, but the market for these launch vehicles did not materialize. For example, since its introduction in 1990, Pegasus has launched only 36 times, an average of 3 launches per year; Taurus has been launched only 7 times since it was introduced in 1994. The average cost of these launch vehicles is $16 million to $33 million. To provide another avenue for launching small satellites, the Air Force has proposed refurbishing part of its fleet of decommissioned intercontinental ballistic missiles—450 of which have been dismantled. The cost of retrofitting the missiles and preparing them for launch is about $18 million to $23 million. However, one Air Force official questioned whether these vehicles are too large for current TacSats.

Some new developers in the space industry are cautiously optimistic about the small satellite market. For example, SpaceX signed seven contracts to launch various small satellites, including TacSat 1. Despite this optimism, SpaceX's first launch of its new vehicle has yet to occur—in part because it lacks a suitable launch facility. The launch facilities located in the United States cannot readily accommodate quick-response vehicles. Vandenberg Air Force Base—one of two major launch sites in the United States—has lengthy and detailed scheduling processes and strict safety measures for preparing for and executing a launch, making it difficult to launch a small satellite within a tight time frame and at a low cost.[8] SpaceX's launch of TacSat 1 at Vandenberg was put on hold because of the potential risks it posed to a billion-dollar satellite that was waiting to be launched from a nearby pad. In addition, the Air Force licensed the use of another nearby pad at Vandenberg to a contractor for larger-scale launches. Given the proximity of the launch pads, SpaceX's insurance premium increased 10-fold, from about $50,000 to as much as $500,000, which added $2.3 million to TacSat 1's total mission costs. Because of these delays, SpaceX decided to carry a different experimental satellite on its first launch and to use a launch facility on Kwajalein Atoll, in the Pacific Ocean.[9] The potential effect of changes—such as increased

[7]Pegasus, Taurus, and Minotaur launch vehicles are built by Orbital Sciences Corporation.

[8]The other launch facility, Cape Canaveral Air Force Station, is currently not expected to be used for TacSats launches.

[9]The tentative launch window for the first flight of SpaceX's launch vehicle is March 20 through 25, 2006.

premiums or the need to transport satellites to distant locations—on efforts to keep costs low and deliver capabilities to the warfighter sooner is unknown.

The Air Force is beginning to examine ways to better accommodate a new generation of quick-response vehicles. For example, Air Force officials are examining the feasibility of establishing a location on Vandenberg specifically for these vehicles that is separate from the larger launch vehicle pads. Officials are also assessing the suitability of other locations, such as Kodiak Island, for quickly launching small satellites.

Procurement of TacSats by DOD's Acquisition Community May Be Hindered by Limited Transfer of Knowledge and Requirements Instability

To achieve a low-cost, on-demand tactical capability for the warfighter, the TacSat experiments will need to be transitioned into the acquisition community. We have previously reported that DOD's acquisition community has been challenged to maximize the amount of knowledge transferred from the science and technology community, and that DOD's science and technology and acquisition organizations need to work more effectively together to achieve desired outcomes. Many of the space programs we reviewed over the past several decades have incurred unanticipated cost and schedule increases because they began without knowing whether technologies could work as intended and invariably found themselves addressing technical problems in a more costly environment.[10] Although DOD recently developed a space science and technology strategy to better ensure that labs' space technology efforts transition to the acquisition community, the acquisition community continues to question whether labs adequately understand acquisition needs in terms of capabilities and time frames. As a result, the acquisition community would rather use its own contractors to maintain control over technology development.

According to DOD officials, action has been taken to improve the level of collaboration and coordination on the TacSat experiments. Officials from DOD laboratories involved in TacSats and acquisition communities agree that they are working better together on the experiments than they have on past space efforts. However, in pursuing a low-cost, on-demand tactical capability, the science and technology and acquisition communities have moved forward on somewhat separate tracks, and it is unclear to what

[10]GAO, *Technology Development: New DOD Space Science and Technology Strategy Provides Basis for Optimizing Investments, but Future Versions Need to Be More Robust*, GAO-05-155 (Washington D.C.: Jan. 28, 2005).

extent the work and knowledge gained by the labs will be leveraged when the TacSat experiments are transferred to the acquisition community. For example, the Air Force and Navy labs are working to develop bus standards for the TacSat experiments that are scheduled to be transitioned to the Space and Missile Systems Center, the Air Force's acquisition arm, in fiscal year 2008. Yet, the Space and Missile Systems Center, working with the Aerospace Corporation, has proposed three different options for standardizing the bus. While two of the options are generally larger—and are intended for larger space assets—one of the proposed designs may be suitable for TacSats, although it will likely be costlier than a lab-generated counterpart.

In addition, our past work has shown that DOD's space programs—as well as other large DOD programs—have been unable to adequately define requirements and keep them stable, and seldom achieve a match between resources and requirements at the start of the acquisition. One factor that contributes to poorly defined and unstable requirements is that space acquisition programs have historically attempted to achieve full capability in a single step and serve a broad base of users, regardless of the design challenge or the maturity of technologies. Given this track record, some DOD officials expressed concern over Space and Missile Systems Center's ability to adopt the TacSat approach of delivering capabilities that are good enough to meet a warfighter need within cost and schedule constraints. Air Force officials identified the center's organizational culture of risk avoidance and the acquisition process as two of the most significant barriers to developing and deploying space systems quickly.

Short-Term Funding for Upcoming TacSats Uncertain

TacSats 1 and 2 have been fully funded within DOD, and TacSats 3 and 4 were recently funded. However, funding is uncertain for TacSats beyond 3 and 4. While the Congress added funding to DOD's 2006 budget to support TacSat efforts, such as developing bus standards, DOD did not request such funding. According to a DOD official, there would not be an effort to develop bus standards if funding had not come from the Congress.

Historically, DOD's research and development budget has been heavily weighted to system acquisitions—80 percent of this funding goes to weapon system programs, compared with 20 percent going to science and technology. In addition, science and technology funding is spread over thousands of projects, while funding for weapon system programs is spread over considerably fewer, larger programs. This funding distribution can encourage financing technology development in an acquisition

program. However, as we have previously reported, developing technologies within an acquisition program typically leads to cost and schedule increases—further robbing the science and technology community and other acquisition programs of investment dollars.

Lack of DOD-wide Strategy and Loss of Leadership

DOD currently has no departmentwide strategy for providing a responsive tactical capability for the warfighter. Without such a strategy, it is unknown whether and to what degree there may be gaps or overlaps in efforts. DOD efforts to develop low-cost satellite and launch capabilities are moving forward under multiple offices at different levels (see table 2).

Table 2: DOD Current Planning Efforts

DOD organization	Planning action
National Security Space Office (primarily aligned with the Secretary of the Air Force as Executive Agent for Space)	• Developing a responsive space investment architecture and road map
U.S. Strategic Command (primarily aligned with the Secretary of Defense via the Joint Chiefs of Staff)	• Developing a joint capabilities document
Air Force Space Command (primarily aligned with U.S. Strategic Command)	• Developing four initial capabilities documents • Planning for establishment of an acquisition office • Developing Enabling Concept Document
Space and Missile Systems Center (primarily aligned with Air Force Space Command)	• Planning for establishment of an acquisition office • Planning for establishment of an office that coordinates the transition of experiments to acquisition programs

Source: DOD.

Since these efforts are occurring simultaneously, it is unclear how and if they will be used to inform one another. Moreover, there are different visions for the roles of low-cost, responsive satellites and launch vehicles in DOD's overall space portfolio. For example, one Air Force official stated his office is looking for direction from the Congress on how to move forward rather than from somewhere within DOD. Further, when interviewed, other Air Force officials were not in agreement over how the Air Force's vision for using TacSats fits in with OFT's proposed use of this capability for DOD.

In addition to the lack of a DOD-wide strategy, the recent departure of key personnel may have created a gap in leadership, making it uncertain to what extent efforts to develop tactical capabilities such as TacSats will be pursued. As we reported in November 2005, program success hinges on whether leaders can make strategic investment decisions and provide programs with the direction or vision for realizing goals and alternative ways of meeting those goals.[11]

One official involved in developing the overall architecture described the pursuit of these capabilities as a "grassroots effort," underscoring the importance of having enthusiastic individuals involved in moving it forward. According to a number of DOD officials, the former OFT director was widely respected within and outside the agency and served as a catalyst for transformation across DOD, and was credited with championing and pursuing innovative concepts that could sustain and broaden military advantage. With the departure of the OFT director and other key advocates of the TacSat concept, service lab officials told us they are concerned about the fate of the TacSat experiments. DOD officials we spoke with acknowledged that there is no agreement on who should ultimately be responsible for deciding the direction of the TacSat experiments and other efforts to develop low-cost responsive tactical capabilities for the warfighter.

Experiences with TacSats May Inform Major Space System Acquisitions and Lead to Long-Term Benefits

DOD's experiences developing a tactical capability for the warfighter through TacSats may be used to inform the way major space systems are acquired. Specifically, DOD's process for developing TacSat 1 reflects best practices that larger space system programs could employ to achieve better acquisition outcomes. In addition, some DOD officials believe that these efforts—focusing on delivering capabilities to the warfighter through TacSats and small, low-cost launch vehicles—could lead to long-term benefits, including providing opportunities for major space systems to test new technologies, enhancing the skills of DOD's space workforce, and broadening the space industrial base.

[11]GAO, *Best Practices: Better Support of Weapon System Program Managers Needed to Improve Outcomes*, GAO-06-110 (Washington, D.C.: Nov. 30, 2005).

Our past work has shown that commercial best practices—such as managing requirements, using mature technologies, and developing technology within the science and technology community—contribute to successful development outcomes. TacSat 1 confirms that applying these practices can enable projects to meet cost and schedule targets. While TacSat 1, as a small experimental satellite with only a few requirements, is much less complex than a major space system, we have reported that commercial best practices are applicable to major space system acquisitions and recommended that DOD implement them for such acquisitions. Despite our recommendation, DOD's major space system acquisitions have yet to consistently apply these best practices.

- *Manage requirements.* DOD's major space acquisition programs have typically not achieved a match between requirements and resources (technology, time, and money) at program start. Historically, these programs have attempted to satisfy all requirements in a single step, regardless of the design challenge or the maturity of technologies needed to achieve the full capability. As a result, these programs' requirements have tended to be unstable—that is, requirements were changed, added, or both—which has led to the programs not meeting their performance, cost, and schedule objectives. We have found that when resources and requirements are matched before individual programs are started, programs are more likely to meet their objectives. One way to achieve this is through an evolutionary development approach, that is, pursue incremental increases in capability versus significant leaps.

- *Use mature technologies*. DOD's major space acquisition programs typically begin product development before critical technologies are sufficiently matured, forcing the program to mature technologies after product development has begun. Our reviews of DOD and commercial technology development cases indicate that demonstrating a high level of maturity before new technologies are incorporated into product development puts those programs in a better position to succeed.

- *Develop technology within the science and technology environment.* DOD's space acquisition programs tend to take on technology development concurrently with product development, increasing the risk that significant problems will be discovered late in development and that more time, money, and effort will be needed to fix these problems. Our reviews have shown that developing technologies separate from product development greatly minimizes this risk.

DOD officials and industry representatives we spoke with also noted that some long-term benefits could result from focusing on delivering capabilities to the warfighter quickly.

- First, small, low-cost, responsive satellites like the TacSats could augment major space systems—provided there is a means to launch the satellites. Because TacSats do not require significant investment and are not critical to multiple missions, the consequence of failure of a TacSat is low. In contrast, major space systems typically are large, complex, and multimission, and take many years to build and deliver. If a major space satellite fails, there are significant cost and schedule consequences. Ultimately, the already long wait time for the warfighter to receive improved capabilities is extended.

- Second, developing small, low-cost launch vehicles could provide an avenue for testing new technologies in space. According to DOD officials, less than 20 percent of DOD's space research and development payloads make it into space, even while relying heavily on the National Aeronautics and Space Administration's Space Shuttle, which was most recently grounded for 2 ½ years. We recently reported that DOD's Space Test Program, which is designed to help the science and technology community find opportunities to test in space relatively cost-effectively, has only been able to launch an average of seven experiments annually in the past 4 years.[12] According to industry representatives and DOD officials, efforts to develop a small, low-cost launch vehicle could improve the acquisition process because testing technologies in an operational environment could lower the risk for program managers by providing mature technologies that could be integrated into their acquisition programs.

- Third, giving space professionals the opportunity to manage small-scale projects like TacSats from start to finish may better prepare them for managing larger, more complex space system acquisitions in the future. According to Navy and Air Force lab officials, managing the TacSat experiments has provided hands-on experience with the experiment from start to finish, unlike the experience provided to program managers of large systems at the Air Force Space and Missile Systems Center.

[12] GAO-05-155.

- Finally, building low-cost, responsive satellites and launch vehicles could create opportunities for small, innovative companies to compete for DOD contracts and thereby increase competition and broaden the space industrial base. In April 2005, over 50 small companies sent representatives to the Third Responsive Space Conference, an effort hosted by a small private launch company. An industry representative stated that a number of small companies are excited about developing TacSats and small, low-cost launch vehicles and the potential to garner future DOD contracts, but he cautioned that it would be important to maintain a steady flow of work in order to keep staff employed and preserve in-house knowledge. Other industry representatives told Air Force officials that they are receiving mixed signals from the government regarding its commitment to these efforts—there has been a lot of talk about them, but relatively little funding. In addition, another industry representative stated that requirements must be contained; otherwise, costs will increase and eventually squeeze small companies back out of the business.

Conclusions

For more than two decades, DOD has invested heavily in space assets to provide the warfighter with critical information needed to successfully conduct military operations. Despite this investment, DOD has been challenged to deliver its major space acquisitions quickly and within estimated costs. TacSat 1—an experimental satellite—has shown that by matching user requirements with available resources, using mature technologies, and developing technologies separate from product development, new tactical capabilities can be delivered quickly and at a low cost. By establishing a capabilities selection process, the TacSat initiative has also helped to ensure that future TacSats will address high-priority warfighter needs. At the same time, the TacSats may demonstrate an alternative approach to delivering capabilities sooner—that is, using an incremental approach to providing capabilities, rather than attempting to achieve the quantum leap in capability often pursued by large space systems, which leads to late deliveries, cost increases, and a high consequence of failure. By not optimizing its investment in TacSat and small launch efforts, DOD may fail to capitalize on a valuable opportunity to improve its delivery of space capabilities. As long as disparate entities within DOD continue moving forward without a coherent vision and sustained leadership for delivering tactical capabilities, DOD will be challenged to integrate these efforts into its broader national security strategy.

Recommendation for Executive Action

To help ensure that low-cost tactical capabilities continue to be developed and are delivered to the warfighter quickly, we recommend that the Secretary of Defense assign accountability for developing and implementing a departmentwide strategy for pursuing low-cost, responsive tactical capabilities—both satellite and launch—for the warfighter, and identify corresponding funding.

Agency Comments

We provided a draft of this report to DOD for review and comment. DOD concurred with our recommendation and provided technical comments, which we incorporated where appropriate. DOD's letter is reprinted as appendix II.

We plan to provide copies of this report to the Secretary of Defense, the Secretary of the Air Force, and interested congressional committees. We will make copies available to others upon request. In addition, the report will be available on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions concerning this report, please contact me at (202) 512-4841. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to the report are Arthur Gallegos, Maricela Cherveny, Jean Harker, Leslie Kaas Pollock, Noah B. Bleicher, and Karen Sloan.

Sincerely yours,

Michael J. Sullivan
Director, Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To assess the outcomes to date from the TacSat experiments and efforts to develop small, low-cost launch vehicles, we interviewed Department of Defense (DOD) officials in the Office of Force Transformation, Washington, D.C.; Air Force Space Command, Peterson Air Force Base, Colorado; Space and Missile Systems Center, Los Angeles Air Force Base, California; Air Force Research Laboratory, Kirtland Air Force Base, New Mexico, and Wright-Patterson Air Force Base, Ohio; U.S. Naval Research Laboratory, Washington, D.C.; and the Defense Advanced Research Projects Agency, Virginia, via written questions and responses. We also analyzed documents obtained from these officials. In addition, we interviewed industry representatives involved in developing large space systems and small commercial launch vehicles.

To understand the challenges to DOD's efforts and to determine whether DOD's experiences with TacSats and small, low-cost launch vehicles could inform major space system acquisitions, we analyzed a wide body of GAO and DOD studies that discuss acquisition problems and associated challenges, including our work on best practices in weapon system development that we have conducted over the past decade. In addition to having discussions with officials at the Office of Force Transformation, the Air Force Space Command, the Space and Missile Systems Center, and the Air Force and Navy research labs, we spoke with officials from the National Security Space Office, Virginia, and the Force Structure, Resources, and Assessment Directorate of the Joint Chiefs of Staff, Washington, D.C. We conducted our review from June 2005 to March 2006 in accordance with generally accepted government auditing standards.

Appendix II: Comments from the Department of Defense

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

NETWORKS AND INFORMATION INTEGRATION

MAR 02 2006

Mr. Michael J. Sullivan
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Mr. Sullivan,

This is the Department of Defense (DoD) response to the General Accountability Office (GAO) draft report, 'DEFNSE ACQUISITIONS: DOD Needs a Department-Wide Strategy for Pursuing Low-Cost Tactical Space Capabilities,' dated February 10, 2006 (GAO Code 120457/GAO-06-449).

We concur with the report recommendation for the Secretary of Defense to designate an office to develop and implement department-wide strategy to develop and implement low-cost tactical space capabilities (see enclosure). The department is in fact already acting to develop and assign this responsibility. Thank you for the opportunity to comment on the subject draft report.

Sincerely,

Steven Huybrechts
Director, Space Programs
OASD (C3 Policies & Programs &
Space Programs)

Enclosure:
As stated

GAO DRAFT REPORT - DATED FEBRUARY 10, 2006
GAO CODE 120457/GAO-06-449

"DEFENSE ACQUISITIONS: DOD NEEDS A DEPARTMENT-WIDE STRATEGY FOR PURSUING LOW-COST TACTICAL SPACE CAPABILITIES"

DEPARTMENT OF DEFENSE COMMENTS TO THE RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense assign accountability for developing and implementing a department-wide strategy for pursuing low-cost tactical capabilities--both satellite and launch--for the warfighter, and identify corresponding funding. (p. 21/GAO Draft Report)

DOD RESPONSE: Concur.

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