United States Government Accountability Office

GAO

Report to the Chairman, Committee on Appropriations House of Representatives

June 2005

DEFENSE ACQUISITIONS

Resolving Development Risks in the Army's Networked Communications Capabilities Is Key to Fielding Future Force

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Highlights

Highlights of GAO-05-669, a report to the Honorable Jerry Lewis, Chairman, House Committee on Appropriations

Why GAO Did This Study

The Army has embarked on a major transformation of its force. Central to this transformation is the Future Combat Systems (FCS), a $108 billion effort to provide warfighters with the vehicles, weapons, and communications needed to identify and respond to threats with speed, precision, and lethality.

Establishing reliable, robust communications and networking capabilities is key to FCS's success. Each of the systems integral to the FCS communications network—the Joint Tactical Radio System (JTRS), the Warfighter Information Network-Tactical (WIN-T), and the System of Systems Common Operating Environment (SOSCOE)—rely on significant advances in current technologies and must be fully integrated to realize FCS. Given the complexity and costs of this undertaking, GAO was asked to review each of these key development efforts to identify any risks that may jeopardize the successful fielding of FCS.

What GAO Recommends

GAO is making recommendations aimed at reducing development risks so that FCS is provided with enabling communications and networking capabilities. If FCS proceeds without these capabilities, critical aspects of the FCS network will remain undemonstrated. In commenting on this report, the Department of Defense indicated it has begun taking actions to address our recommendations.

www.gao.gov/cgi-bin/getrpt?GAO-05-669.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Paul L. Francis at (202) 512-4841 or francisp@gao.gov.

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What GAO Found

Each of the programs for developing FCS's communications network is struggling to meet ambitious sets of user requirements and steep technical challenges within highly compressed schedules. As currently structured, the programs are at risk of not delivering intended capabilities for the first spiral of FCS, slated to start in fiscal year 2008.

The JTRS Cluster 1 program—a program to develop radios for ground vehicles and helicopters—began development with an aggressive schedule, immature technologies, and a lack of clearly defined and stable requirements. As currently designed, the radio will only have a transmission range of only 3 kilometers—well short of the required 10 kilometers—and will not meet security requirements for operating in an open networked environment. The program's struggle to mature and integrate key technologies has contributed to significant cost and schedule growth. A recent review of the program concluded that the current program structure is not executable, and in April 2005, DOD directed the Army to stop work and notify the contractor that it was considering terminating the contract.

Meeting requirements for JTRS Cluster 5 radios—miniaturized radios, including those that soldiers carry—is even more technically challenging given their smaller size, weight, and power needs. The smallest of these radios weighs only about 1 pound, compared with 84 pounds for Cluster 1 radios. Several programmatic changes and a contract award bid protest have further slowed program progress. The Army is considering options for restructuring the program to meet the needs of FCS and address the technical issues encountered in the Cluster 1 program.

The Army does not expect to fully mature the technologies for WIN-T—communications equipment that supports an expanded area of battlefield operations and interfaces with JTRS radios—when production begins in March 2006. Moreover, the compressed schedule assumes nearly flawless execution and does not allow sufficient time for correcting problems. Significant interdependencies among the critical technologies further increase overall program risk. The program was directed to deliver networking and communications capabilities sooner to meet near-term warfighting needs and synchronize with the restructured FCS program. A plan for how to develop and field WIN-T capabilities sooner to address FCS needs remains undetermined.

According to Army network system integration officials, SOSCOE—the operating software to integrate the communications network—may not reach the necessary technical maturity level required to meet program milestones. In addition, top-level FCS requirements are still evolving and have not been translated into more detailed specifications necessary for writing SOSCOE software.

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Abbreviations

DOD	Department of Defense
FCS	Future Combat Systems
GHz	gigahertz
JNTC-S	Joint Network Transport Capability-Spiral
JTRS	Joint Tactical Radio System
MHz	megahertz
SOSCOE	System of Systems Common Operating Environment
WIN-T	Warfighter Information Network-Tactical

United States Government Accountability Office
Washington, DC 20548

June 15, 2005

The Honorable Jerry Lewis
Chairman
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

To counter the complex set of battlefield threats that have emerged since the Cold War, the Army has embarked on a major transformation of its force. Central to this transformation is the Future Combat Systems (FCS) program, a large and difficult effort to develop a suite of new manned and unmanned ground and air vehicles, sensors, and munitions linked by a new information network, with a total cost of at least $108 billion. FCS will depend on this network to provide Army warfighters and commanders with the high-quality data and real-time communications needed to identify and respond to threats with speed, precision, and lethality. Indeed, the network's performance is what makes the FCS concept work—superior information enables the FCS vehicles to be lethal and survivable despite weighing a fraction of what today's vehicles weigh. Continuously providing the quality and volume of information necessary for the force to operate seamlessly together places significant demands on the network components. The components must generate high power, work at long range, and be reliable while conforming to the tight physical constraints of the small FCS systems.

Four key systems are integral to the FCS communications network:

- Joint Tactical Radio System (JTRS) Cluster 1, which is developing radios for ground vehicles and helicopters;
- JTRS Cluster 5, which is developing small radios, including those that soldiers carry;
- Warfighter Information Network-Tactical (WIN-T), which is developing a high-capacity communications network for higher-level command units; and
- System of Systems Common Operating Environment (SOSCOE), which is being developed as part of the FCS program and is the operating software that integrates the communications network.

If JTRS, WIN-T, and SOSCOE do not work as intended, battlefield information will not be sufficient for FCS units to operate effectively. JTRS

Cluster 1 and Cluster 5 radios and new advanced networking waveforms[1] are expected to provide the warfighter with a high-capacity, high-speed information link to access maps and other visual data, communicate on-the-move via voice and video with other units and levels of command, and obtain data directly from battlefield sensors. WIN-T is expected to provide military commanders access to intelligence, logistics, and other data critical to making battlefield decisions and supporting battlefield operations. Collectively, JTRS and WIN-T are estimated to cost over $34 billion to develop and produce, above the $108 billion cost of FCS. SOSCOE is the interface that allows all the systems to communicate with one another. The Army plans to begin fielding the full set of FCS systems to brigade-size units in 2014. However, the Army also plans to field FCS capabilities to the current force incrementally through spirals. The first FCS spiral is scheduled for the 2008-2010 timeframe and emphasizes enhanced communications and network capabilities.

Because JTRS, WIN-T, and SOSCOE all rely on significant advances in current technologies and capabilities and must be fully integrated to realize FCS, there are substantial risks to this effort. Given the complexity of this undertaking and the size of the investment, you asked us to review each of these key development efforts to identify any risks that may jeopardize the successful fielding of FCS's communications and networking capabilities.

We conducted our review from January 2004 through May 2005 in accordance with generally accepted government auditing standards. To assess the development risks of each system, we obtained and reviewed relevant documents, including program acquisition reports, technology readiness assessments, test and evaluation plans, cost performance reports, and other information. We also met with various program and agency officials and obtained in-depth briefings on the system development efforts. More details about our scope and methodology are in appendix I.

[1] A waveform is the representation of a signal that includes the frequency, modulation type, message format, and/or transmission system. In general usage, the term *waveform* refers to a known set of characteristics, for example, frequency bands (VHF, HF, UHF), modulation techniques (FM, AM), message standards, and transmission systems. In JTRS usage, the term *waveform* is used to describe the entire set of radio functions that occur from the user input to the RF output and vice versa. A JTRS waveform is implemented as a reusable, portable, executable software application that is independent of the JTRS operating system, middleware, and hardware.

Results in Brief

The JTRS Cluster 1 program began development several years ago with an aggressive schedule, immature technologies, and a lack of clearly defined and stable requirements. Since then, the program has continued to struggle to mature and integrate key technologies and has been forced to make major design changes. For example, the Cluster 1 design does not generate sufficient power or meet size and weight constraints. Consequently, the radio's projected range is only 3 kilometers—well short of the 10 kilometer range required. In addition, the radio design is not sufficient to meet security requirements for operating in an open networked environment. These factors have contributed to significant cost and schedule problems that led the Army in December 2004 to propose restructuring the program by adding $458 million and 24 months to the development effort. However, recently the Department of Defense (DOD) directed that work on the Cluster 1 radios be stopped while an assessment is conducted to determine the future of the program. In addition, the Army is concerned about the contractor's ability to develop the radios and notified the contractor that it was considering a contract termination. At this point it is not clear what the outcome will be and what impact this will have on the future of the program. Consequently, it is unlikely the Cluster 1 radios will be available for the start of the first spiral of the FCS network, slated for fiscal year 2008. This is especially critical for FCS, as Cluster 1 is to provide what has been called the backbone of the FCS network—a Wideband Networking Waveform that will serve as the main conduit of information to and from Army tactical units.

The JTRS Cluster 5 program has also experienced technical challenges and program changes that have impeded progress. Meeting requirements for JTRS Cluster 5 radios is even more challenging than for Cluster 1, given Cluster 5 radios' smaller size, weight, and power needs. For example, the smallest of these radios, which weigh only about 1 pound each, compared with 84 pounds for Cluster 1, are not going to be able to provide the power and cooling needed for the Wideband Networking Waveform. In addition, the program will require a new networking waveform, the Soldier Radio Waveform. Several programmatic changes and a contract award bid protest have also slowed progress of the Cluster 5 program. Furthermore, in light of unresolved technical issues with the Cluster 1 program, DOD has initiated an assessment to restructure the Cluster 5 program. Consequently, Cluster 5 small form radios needed for the first spiral of FCS may not be available in time. The Army is seeking ways to accelerate program deliveries.

The WIN-T program also began with an aggressive schedule and immature technologies. None of the critical technologies will be fully mature at the time production begins in March 2006. The tightly compressed schedule assumes nearly flawless execution and may not allow sufficient time for correcting problems. In addition, significant interdependencies among critical technologies further increase overall program risk. Any delay in maturing an individual technology may hinder the program's ability to achieve its performance objectives—specifically, on-the-move communications. Other critical program issues, such as deciding on a suitable airborne platform to achieve on-the-move communications, remain unresolved. More recently, the program shifted its focus to deliver networking and communications capabilities sooner to meet near-term warfighting needs while continuing to support the restructured FCS program. A plan for how to develop and field WIN-T capabilities sooner to address FCS needs remains undetermined.

SOSCOE faces the dual challenge of a software development that is high-risk and evolving requirements. According to Army program officials, SOSCOE software may not reach the necessary technical maturity level required to meet program milestones. In addition, top-level FCS requirements are still evolving and have not been translated into more detailed specifications necessary for writing SOSCOE software. As a result, it is unclear whether SOSCOE will be sufficiently developed to support the first spiral of FCS beginning in fiscal year 2008.

Given the criticality of these four systems to the performance of the FCS network, this report makes recommendations to the Secretary of Defense aimed at reducing their development risks so that they provide the first spiral of FCS with enabling communications and networking capabilities. In commenting on a draft of our report, DOD generally concurred with our findings and recommendations. As part of its comments, DOD provided some information on actions it has begun to take to address each of our recommendations. While these actions should help strengthen the management of JTRS, WIN-T, and SOSCOE, we remain concerned that a demonstration of FCS's communications and networking capabilities will not be known for some time. Until these capabilities are demonstrated, investment in FCS platforms and systems carries substantial risk.

Background

Over the last decade, the Army has begun to transform its warfighting capabilities to more effectively counter a broad and complex set of potential threats. According to Army officials, the transformation is the most comprehensive change in the Army in over a century, and will affect all aspects of its organizations, training, doctrine, leadership, and strategic plans as well as its acquisitions. Through this transformation, the Army expects to establish a force that provides both the lethality and survivability of today's heavily armored units and the deployability and responsiveness of today's lighter combat units. As envisioned, the future force will operate very differently than forces have in the past. It will function in smaller, more agile and deployable modular brigade combat teams (composed of roughly 3,000 to 4,000 personnel) that can react quickly to changing missions and circumstances. To be effective, force components—soldiers, platforms, weapons, and sensors—must be "net-centric," that is, closely linked and able to operate seamlessly together.

The transformation involves two major, interrelated acquisitions: (1) development of new advanced communications and networking systems—computers, software, and a wireless tactical internet—to acquire, exchange, and employ timely information throughout the battlespace and (2) development of a new generation of battlefield vehicles, weapons, and sensors. The Army has taken initial steps toward transformation through its Digitization and Stryker programs. Under the Digitization program, the Army installed computers, software, and interfaces to communications systems on Abrams tanks, Bradley fighting vehicles, and other vehicles in selected units that enable both in-theater and higher commands to share battlefield data with lower-level units. The Stryker program introduced a new family of vehicles expected to make units more lethal, mobile, and survivable than today's light forces. In addition, the Army has initiated a major restructuring of its force into modular brigade combat teams—brigade-sized units that will have a common organizational design.

FCS is the culminating stage in the Army's ongoing transformation to a lighter, more agile and capable force. It is a large and complex development effort to provide a networked family of weapons and other systems for the future force. Establishing reliable, robust communications and networking capabilities is essential to FCS. Without these capabilities, the lighter, more decentralized units would be vulnerable to enemy attack.

Currently, the armed forces have limited communications and networking capabilities on the battlefield, making it necessary to patch together or reroute information through multiple radio, data terminal, and network systems to get critical information to the warfighter and commanders. Current "dial-up speed" data rates further delay forces' ability to identify, assess, and respond to time-critical targets. FCS's networked on-the-move communications for voice, data, video, and imagery are expected to be a revolutionary improvement over current communications capabilities (see table 1).

Table 1: Future Communications and Networking Capabilities Compared with Current Capabilities

Capability	Current	Future force
Interoperability	Numerous unique systems, noninteroperable	Small number of systems, interoperable
Mobility	Point-to-point, with limited mobility	Mobile and integrated network operations
Data rate	Low data rate—mostly voice	High data rate—voice, data, video, imagery that can communicate simultaneously
Range	Mostly line-of-sight, limiting performance in urban settings, mountainous terrain, and other complex environments	Expanded to include beyond line-of-sight
Links	Single network thread to fixed/relocatable operations centers	Network integrated warfighting platforms with mobile operations centers and seamless connectivity from foxhole to the Pentagon
Speed	Dial-up speed	Broadband speed
Security	Susceptible to interception and detection by adversaries	Multiple levels of security with reduced probability of interception and detection
Efficiency	Circuit-switched, spectrum inefficient	Packet-switched, spectrum efficient
Flexibility	Defense unique/proprietary technology—inflexible	Open-systems architecture—drawing on universal Internet-Protocol-based commercial technology, flexible, standards-based

Source: GAO analysis.

The FCS communications and networking capabilities are being designed around five components:

- *Platforms and sensors*: Under FCS, the Army is developing new warfighting systems, including manned and unmanned aerial and ground vehicles that will provide and use intelligence, surveillance, and reconnaissance information.

- *Applications*: Software applications will support battlefield command functions, including command and control, logistics support, training, and modeling and simulation.

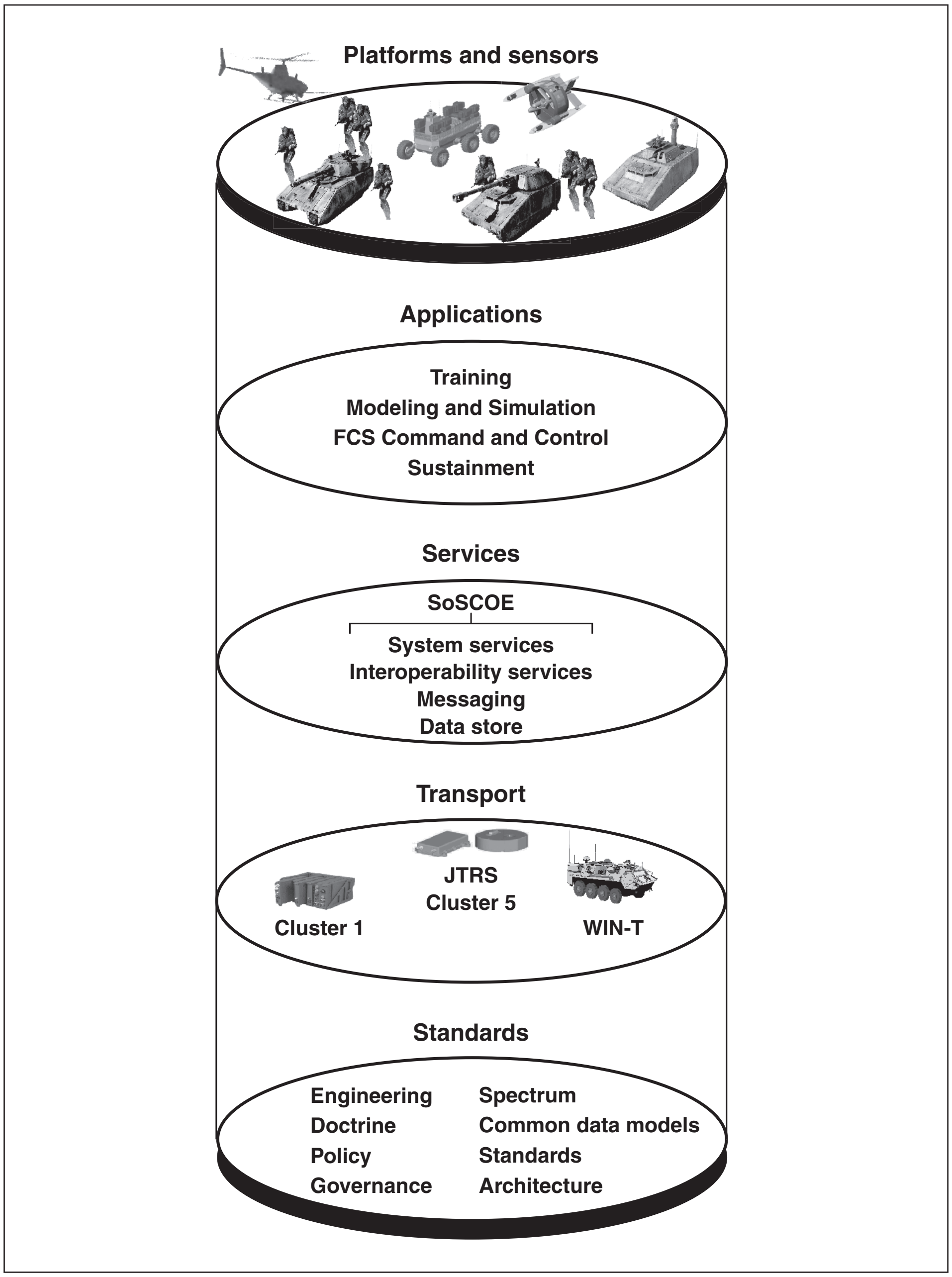
- *Network services*: SOSCOE will be the network-centric operating system, or middleware, that enables the integration of separate FCS communications software packages, independent of their location and the technology used to develop them. The Army likens the SOSCOE architecture to Microsoft Windows, but many times larger. SOSCOE represents about 10 percent of the more than 30 million lines of FCS software code.

- *Transport systems*: Transport systems—primarily JTRS and WIN-T—will provide wireless communication capabilities to transport information within the FCS network and the broader DOD-wide network.

- *Standards*: Standards implement DOD-wide policies and doctrine developed by offices such as the Office of the Secretary of Defense, Networks and Information Integration, and the Joint Chiefs of Staff. Two critical objectives of these standards are net-centric operations and inter-service interoperability.

Figure 1 shows a representation of the five FCS network components.

Figure 1: FCS Network Components



Source: U.S. Army.

JTRS is a software-reprogrammable radio that is intended to operate with many different legacy radio systems and provide the warfighter with additional communications and networking capabilities—including seamless interoperability and increased data throughput—to simultaneously access maps and other visual data, communicate via voice and video with other units and levels of command, and obtain information directly from battlefield sensors. A key component of JTRS is developing waveforms to operate with legacy radios as well as new waveforms to provide advanced networking capabilities, such as the Wideband Networking Waveform. The Wideband Networking Waveform represents a new, critical capability for DOD. The development of the Wideband Networking Waveform is intended to address many of the current limitations associated with DOD tactical wireless networking, including line-of-sight limitations that cause many network partitions, unique network monitoring systems, and predefined security enclaves that require hardware for each security level. The waveform is expected to provide data rates of 5 megabits per second or more--hundreds of times faster than existing communications systems--and facilitate the routing of large amounts of information among users anywhere in the battlespace.

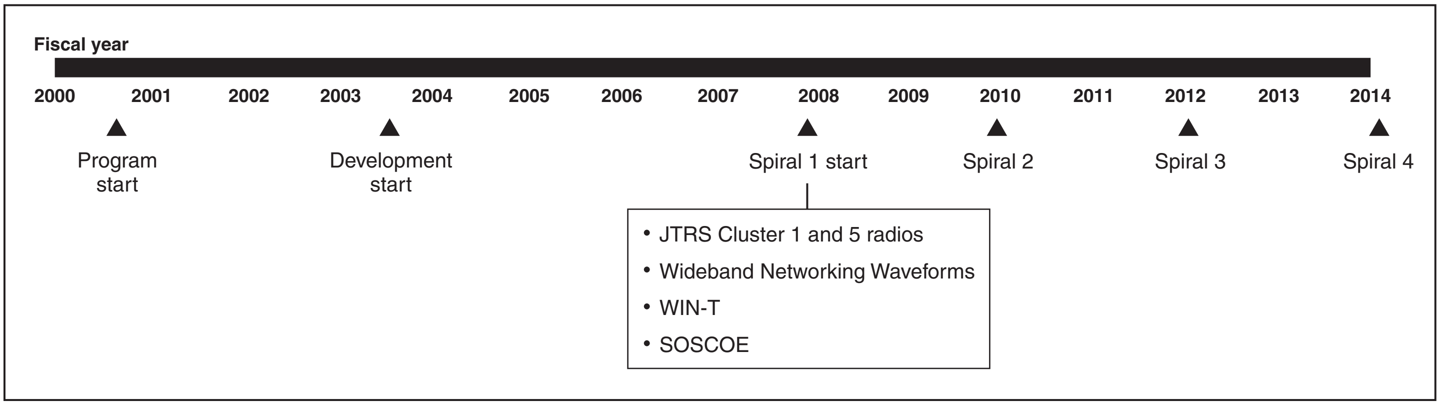
DOD has structured the JTRS development effort into several programs clustered by requirements. The JTRS Cluster 1 program is developing radios for ground vehicles and helicopters to equip the current force as well as FCS. The program is expected to cost $15.6 billion to develop and acquire over 100,000 Cluster 1 radios. The JTRS Cluster 5 program is developing handheld and manpack radios for soldiers as well as several smaller varieties of radios for use in weight- and power-constrained platforms—such as Unattended Ground Sensors and Intelligent Munitions Systems. The program is expected to cost $8.5 billion to develop and acquire over 300,000 Cluster 5 radios.

The WIN-T program is developing communications equipment that supports an expanded area of battlefield operations and interfaces with JTRS radios to connect warfighters and command centers, including joint, allied, and coalition forces, providing commanders with access to on-the-move communications—that is, continuously updated, real-time multimedia information from dispersed locations throughout the theater. It will replace existing communications networks that have limited capacity to support on-the-move communications. Leveraging advanced commercial technologies that enable mobile communications, the WIN-T system includes data routing and switching hardware, computers, video and teleconferencing equipment, high-capacity line-of-sight radios and satellite terminals—all of which make up a tactical operation center's communications element. WIN-T is being developed in three blocks, with each block adding capabilities. Based on current plans, Block 1 is projected to cost approximately $10 billion; Blocks 2 and 3 have yet to be funded.

The SOSCOE software will reside within each FCS platform's integrated computer system and provide a number of services for the users of the integrated computer system. These services include interoperability services, information assurance services, and communications services. SOSCOE will enable integrated management of the network and will allow systems within the network to access sources of information. The Army estimates that SOSCOE software development will be completed in 2011. The Army plans to field the SOSCOE software in increments to align with the overall FCS software builds and planned FCS spirals.

When FCS began system development in May 2003, the JTRS and WIN-T programs were under way with schedules that aligned with FCS planned fielding. However, the Army restructured the FCS program in July 2004 to address development risks. The restructuring added 4 years to develop the platform systems and established an evaluation unit to demonstrate FCS capabilities. Even though the restructuring provided additional time to the program, it also emphasized developing FCS capabilities in spirals and accelerating the development of the network into the current force. The Army now plans to test and field its FCS capabilities incrementally between 2008 and 2014 through four spirals. A 2-year period of testing will precede the actual fielding of capabilities in each spiral. The Army has defined the initial spiral of FCS around the capabilities needed by the current force, to include the main components of the communications network--JTRS Cluster 1 and 5 radios and the wideband waveforms, some form of WIN-T communications capability, and SOSCOE. The capabilities for the other FCS spirals will be defined over time. Figure 2 shows the FCS spirals' timeline.

Figure 2: FCS Spirals' Timeline



Source: Unit of Action Program Office.

JTRS Cluster 1 Began System Development without Requisite Knowledge, Resulting in Cost and Schedule Problems

The JTRS Cluster 1 program began system development and demonstration in 2002 with an aggressive schedule, immature technologies, and a lack of clearly defined and stable requirements. These factors have contributed to significant cost and schedule problems that the program has not recovered from. The program has not been able to mature the technologies needed to produce radios that generate sufficient power as well as meet platform size and weight constraints and has been forced to make design changes to accommodate evolving security requirements. Because of cost, schedule, and performance problems, in December 2004, the Army proposed restructuring the program by adding $458 million and 24 months to the development schedule. However, recently DOD directed that work on the Cluster 1 radios be stopped while an assessment is completed to determine the future of the program. In addition, because of increased concern about the contractor's ability to develop the radios, the Army notified the contractor that it was considering contract termination. At this point it is not clear what the outcome will be and what impact this will have on the future of the program. As a result, it is unlikely JTRS Cluster 1 radios will be available for the first FCS network spiral, slated to begin in fiscal year 2008. FCS and other users dependent on Cluster 1 radios, such as Army helicopters, will have to rely on legacy radios to fill the gap.

Accelerated Schedule Incompatible with System Immaturity

Prior to the start of system development in 2002, the JTRS Cluster 1 schedule was accelerated 27 months to meet the Army's plan to modernize its helicopters with various technological upgrades including advanced communications. Cluster 1 proceeded into the system development and demonstration phase with none of the program's 20 critical technologies sufficiently matured and with requirements not clearly defined—contrary to best practices and DOD guidance.[2] Although many of the technologies had been used in other radio applications, significant technical advances were nonetheless required for developing key components of the radio. The program's acquisition strategy, for example, highlighted technology risks associated with the following requirements:

- *Wideband Networking Waveform*: As the core of the JTRS networking capability, the Wideband Networking Waveform is to operate across a wide range of radio frequency spectrum, 2 megahertz (MHz) to 2 gigahertz (GHz), and provide increased routing and networking capabilities. The Wideband Networking Waveform must also be compliant with the Software Communications Architecture, which demands a modular approach to waveform design, imposing much greater processing and memory requirements. This is especially critical for FCS, as the waveform is to provide what has been called the backbone or main conduit of the FCS network.

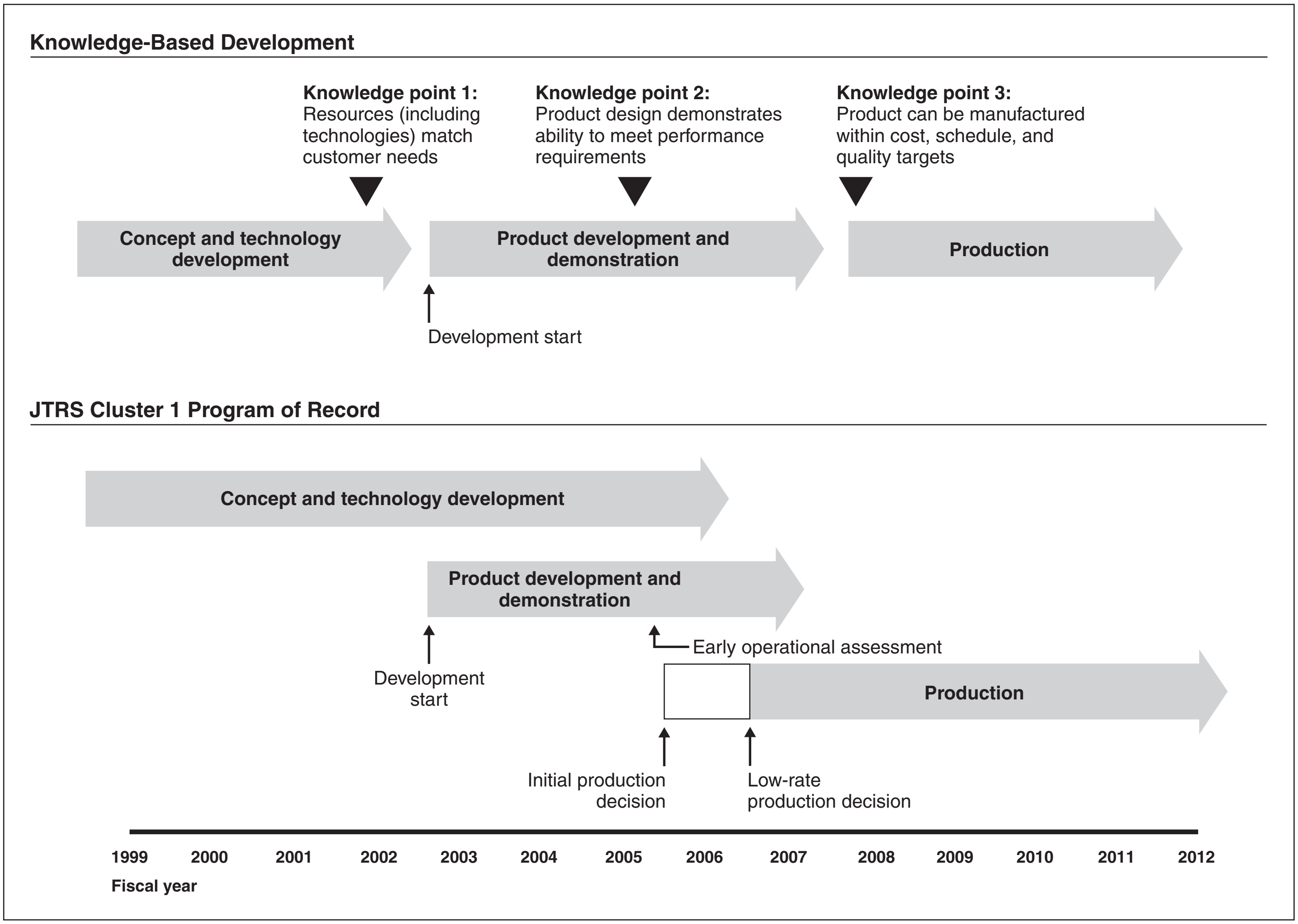
- *Security*: The JTRS radio set is intended to operate applications at multiple levels of security. For it to do so, developers not only have to be concerned with traditional radio security issues but also must be prepared to implement the features required for network and computer security. This will require development of new technologies, obtaining certification through a rigorous process by the National Security Agency, and accommodating an expected growth in security requirements.

- *Interference mitigation*: Prior to JTRS, tactical radios were largely designed for single channel and single band operations. Because JTRS radio sets will operate multiple channels—as many as eight channels—simultaneously within the same radio set, developers must ensure that communications over one channel do not interfere with communications over another, because such interference would degrade the quality of service and limit the radio's high data rate capability.

[2]To help avoid cost and schedule overruns, best practices and DOD guidance call for achieving a high level of technological maturity before allowing new technologies into product development.

The accelerated acquisition strategy compressed the development cycle and allowed little time for testing prior to key development decisions. For example, the schedule called for making the initial production decision for selected platforms immediately following an early operational assessment of a partially functioning prototype of the JTRS radio in surrogate vehicles (see fig. 3). This is in contrast to the knowledge-based approach captured in best practices, which advocates making production decisions based on an assessment of production-representative prototypes in a realistic environment. Historically, programs that must define requirements, develop technology, and design products concurrently have experienced cost increases and schedule delays. While the Army recognized the risk of moving forward with immature technologies, it expected that emerging technologies in radio software technology would enable it to develop the critical technologies and integrate them into the product quickly.

Figure 3: Knowledge-Based Development Compared with JTRS Cluster 1 Development



Source: GAO analysis of Army data.

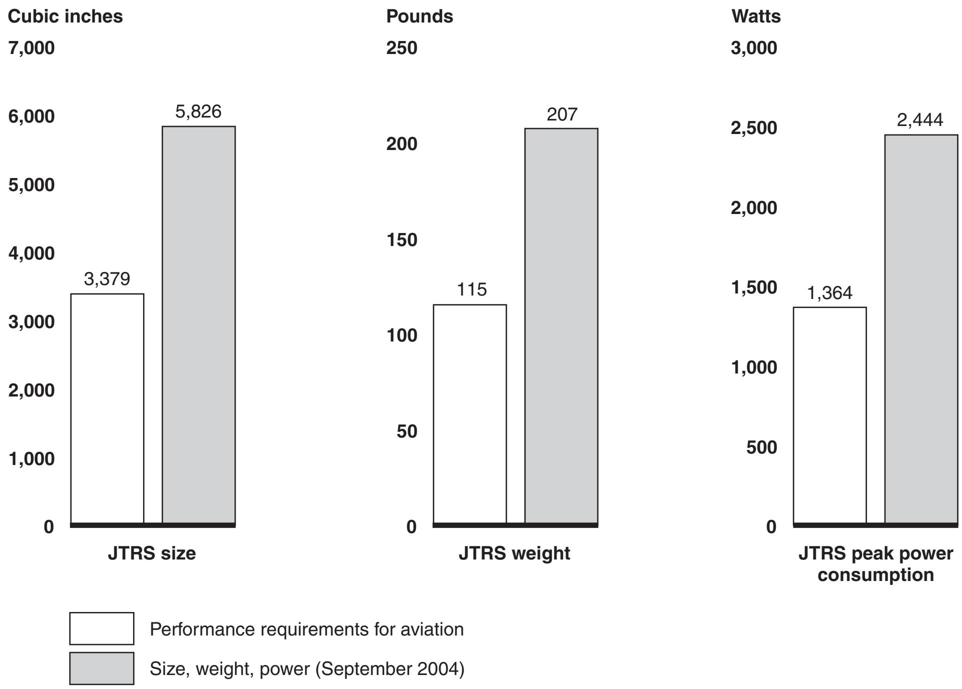
Despite the Army's expectations to leverage current and emerging radio technologies, the critical technologies for the JTRS Cluster 1 radio have generally not matured. The program is also struggling to derive detailed specifications for Cluster 1 requirements. Despite the lack of mature technologies and detailed specifications, the Army held the program's critical design review—the point at which design stability is to be achieved and demonstrated—in December 2003. However, with the requirements still evolving, the program expects to make several costly hardware and software design modifications. For example:

- The current processing and memory capacity of the Network INFOSEC Unit, which contains the operating software, is insufficient to support full systems operation, including waveform processing, enhanced security, and power management. The program plans to double the Network INFOSEC Unit's capacity from 256 megabytes of memory to 512 megabytes, which will require changes to the hardware design.
- The National Security Agency has recently determined that the current design is not sufficient to meet security requirements to operate in an open networked environment. Specifically, particular versions of JTRS radios will be used by allied and coalition forces, requiring the Army to release specific source code of the software architecture to these forces. To address the release, the National Security Agency has required changes to the security architecture. While the program has not finalized or funded the changes, the current plan is to separate the networking and radio functions into two separate processors.

Size, Weight, and Power Requirements for Key Platform Users Have Presented a Significant Challenge for Cluster 1

A key technical challenge in developing the Cluster 1 radio is meeting the size, weight, and power requirements for ground vehicles and helicopters. To realize the full capabilities of the Wideband Networking Waveform, including transmission range, the Cluster 1 radio requires significant amounts of memory and processing power, which add to the size, weight, and power consumption of the radio. The added size and weight are the result of efforts to ensure electronic parts in the radio are not overheated by the electricity needed to power the additional memory and processing. Thus far, the program has not been able to develop radios that meet size, weight, and power requirements, and the current projected transmission range is only 3 kilometers—well short of the 10-kilometer range required for the Wideband Networking Waveform. As a consequence, more unmanned aerial vehicles may be needed to relay information. Intended ground vehicle users have accepted a deviation in the design—to have some of the radio's hardware mounted separately outside the vehicle—with the expectation that the contractor will develop a better solution later on. However, deviations were not accepted for the helicopters because it would necessitate major design changes to the aircraft and adversely affect the aircraft modernization schedules. Unlike ground vehicles, aviation platforms are limited in their ability to compromise on size, weight, and power issues because of the difficulty in maintaining equilibrium while airborne. The Cluster 1 radio's size, weight, and peak power consumption exceeds helicopter platform requirements by as much as 80 percent (see fig. 4).

Figure 4: JTRS Current Cluster 1 Size, Weight, and Power Compared with Helicopter Requirements



Source: Department of Defense.

To meet the JTRS size, weight, and power requirements and realize the full capabilities of the Wideband Networking Waveform, significant technology advances in power amplification and cooling are essential. The Army has initiated science and technology development efforts to address these issues, but it will take time to evolve the technologies to an acceptable level of maturity. In addition to conducting other research, the Army is evaluating technologies associated with a communications and navigation system that was being developed as part of the Comanche helicopter program. The Army approved further development of this system and plans to integrate it into the JTRS system and conduct a demonstration of its capabilities later this year. However, the Army will not be able to deliver Cluster 1 radios to support the helicopter fielding schedules and will have to purchase legacy radios instead.

The FCS program is exploring solutions to meet a key transportability requirement that FCS vehicles must be limited to 19 tons in order to be airlifted by a C-130 transport aircraft. To meet this transportability requirement, the program recently proposed significant size and weight reductions for vehicle components, including communications equipment. While Cluster 1 currently has no size, weight, and power requirements for the systems to be fielded in FCS, the JTRS radios may require further redesign to meet FCS's aggressive weight requirements. Such a reduction would likely have a significant impact on the design of JTRS radios for the FCS vehicles.

Cluster 1 Has Experienced Significant Cost and Schedule Growth

Since the program entered systems development, in 2002, the contractor has overrun cost estimates by $93 million—nearly 28 percent above what was planned (see app. II). Although the program attempted to stabilize costs by adding approximately $200 million to the contract in January 2004, costs continued to grow steadily thereafter. In addition, the contractor has increasingly fallen behind schedule and has had to devote more resources than originally planned. In January 2005, the prime contractor estimated that the total costs for the Cluster 1 radio and waveform development would be $531 million more than what was originally budgeted, reaching about $898 million at completion. However, according to program officials, since contract award, the prime contractor has not demonstrated strong cost estimating and cost management techniques, and it is difficult to estimate with any confidence what the overall program is likely to cost. Key issues driving the cost growth are unanticipated complexity associated with developing the hardware, Wideband Networking Waveform, and other software. As a result, the unit costs for early prototypes have increased from the prime contractor's original proposal. According to one DOD official, until the requirements' specifications are stabilized, cost and schedule problems are likely to continue. For example, according to the Defense Contract Management Agency, meeting the design changes for security requirements is expected to cost an estimated $80 million.

Future of Cluster 1 is Uncertain

In light of the technical problems and cost growth, the Army in December 2004 delayed the initial production decision, which was scheduled for the third quarter of fiscal year 2005, and proposed to add $458 million and 24 months to the program. Before carrying out this restructure, the Office of the Secretary of Defense directed the Army in January 2005 to stop work on portions of the Cluster 1 development and focus on preparing for an early operational assessment of the radio, which was intended to test the basic functionality of pre-engineering development models of the radio.[3] In April 2005, however, the Army suspended the operational assessment and notified the contractor that it was considering contract termination. This action was taken based on initial findings of an assessment of the Cluster 1 program conducted by a newly established JTRS Joint Program Executive Office, which concluded that the current program structure is not executable and the contractor's ability to develop the radio is questionable.

At this point it is not clear whether the contract will be terminated and what impact a termination would have on the future of the program. The Joint Program Executive Office is expected to complete its assessment of the program, and a Defense Acquisition Board review will be held at the end of fiscal year 2005 to determine the future of the program. Program officials anticipate a new program acquisition strategy will evolve, with greater emphasis on developing the radio in blocks. If development resumes, it is anticipated that there will be start-up delays—3 to 12 months, according to agency officials—associated with restaffing the contractor's development team and bringing the team up the learning curve.

Adding to the program's uncertainty is the impact of pending requirements on program cost and schedule. According to agency officials, the program will likely be tasked with new requirements from key stakeholders. For example:

- To meet FCS requirements for accessing intelligence, surveillance, and reconnaissance data on the battlefield, FCS will need a new network data link operating in the radio frequency range above 2 GHz. According to the Army, developing the new network data link is expected to cost approximately $170 million. Furthermore, additional costs are likely because the new network data link may require changes to the already challenging JTRS Cluster 1 radio design—which operates over a large 2 MHz to 2 GHz range—to operate at an even higher frequency. An analysis of alternatives is currently under way to determine how best to meet this requirement. According to FCS officials, a decision on the new network data link is needed by the end of the year to keep the FCS program on track.

[3]The early operational assessment was originally scheduled for August 2004 but was rescheduled for December 2004 as a result of the Over Target Baseline in January 2004. Because of further technical challenges, the assessment was postponed to April 2005.

- To comply with the standards of the Global Information Grid, DOD has directed all systems to transition to the use of Internet Protocol Version 6 in the future. Cluster 1, which has been designed with Version 4, not only will need to upgrade but will need additional hardware and software to ensure Version 4 and Version 6 systems can interoperate. Reconciling security requirements for Version 6 is also expected to be a challenge.

Given the many program uncertainties, it is unlikely that JTRS radios will be available to support intended users: the first increment of the FCS network slated for fiscal year 2008, Stryker Brigade Combat Team ground vehicles, and helicopters. The Army plans to purchase legacy radios, which have limited capabilities, for the Stryker Brigade Combat Teams and helicopters. According to Army officials, FCS is planning to experiment with early prototypes of JTRS radios and the Wideband Networking Waveform, but they will not know when the fully capable Cluster 1 radios would be available until after the program is restructured at the end of fiscal year 2005. In addition, because of ongoing military operations in Afghanistan and Iraq, the Army has purchased a large number of legacy radios over the past few years. The fielding of so many new radios to the current force may call into question the affordability of replacing them prematurely with JTRS sets. The Army is assessing JTRS fielding plans in light of the additional investments in legacy radios and JTRS Cluster 1 cost, schedule, and technical problems.

Technical Challenges and Program Changes Have Impeded Cluster 5 Progress

As with the Cluster 1 program, radio size, weight, power, and data-processing requirements have presented significant technical challenges for the JTRS Cluster 5 program, which is developing a series of radios much smaller than those for the Cluster 1 program. Several programmatic changes and a contract award bid protest have contributed to disruptions in the progress of the Cluster 5 program. As a result, the Cluster 5 program is no longer synchronized with the FCS program. The Army is currently assessing the feasibility of accelerating the development of selected small form Cluster 5 radios. However, in light of the unresolved technical issues with the Cluster 1 program, the JTRS Joint Program Executive Office has initiated an assessment to restructure the Cluster 5 program into increments. In the event that Cluster 5 radios are not available, the Army plans to use surrogate radios for the initial spiral of FCS. In addition, users depending on the Cluster 5 radios, such as the Army's Land Warrior program, have decided to move forward with surrogate radios.

Technical Challenges Have Impeded Cluster 5 Program Progress

Meeting requirements for Cluster 5 radios is even more challenging than for Cluster 1 because of their smaller size, weight, power, and large data-processing requirements. For example, a one-channel handheld version of the Cluster 5 radios has a maximum weight specification of 2 pounds and a volume of 40 cubic inches (see table 2). A two-channel manpack radio has weight and volume of 9 pounds and 400 cubic inches, respectively. A one-channel small form radio weighs about 1 pound and occupies 40 cubic inches. In comparison, a Cluster 1 two-channel radio weighs 84 pounds and occupies 1,732 cubic inches. Despite their extreme size and weight limitations, Cluster 5 radios are still required to store multiple waveforms. For instance, manpack radios will be required to store at least 10 waveforms, handheld sets 6 waveforms, and the small form sets 2 waveforms.

Table 2: A Comparison of Size, Weight, Power, and the Number of Stored Waveforms for Selected Cluster 5 and Cluster 1 Radios

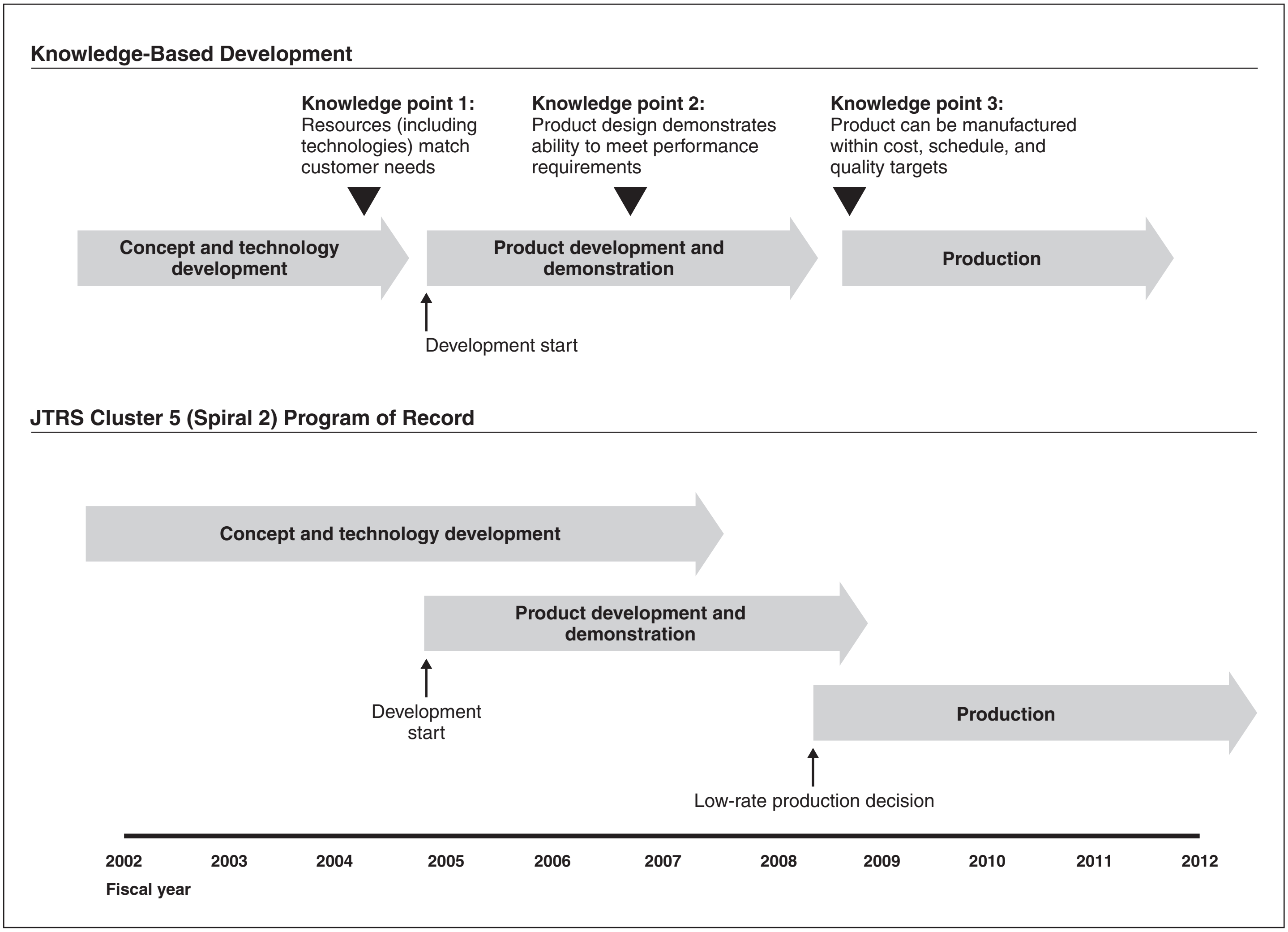
Cluster	Radio type	Size in cubic inches	Weight in pounds	Number of stored waveforms	Power in watts
Cluster 5	two-channel manpack	400	9	10	20
Cluster 5	one-channel handheld	40	2	6	5
Cluster 5	one-channel small form	40	1.2	2	N/A
Cluster 1	two-channel	1,732	84	10	838

Source: Army documents.

Note: N/A = not available.

The Cluster 5 program began system development and demonstration with immature technologies, especially those related to the handheld and smaller variants because of the limited size, weight, and power allowances (see fig. 5). According to the Army, the requirements for two-channel small form radios—wideband radio frequency capabilities up to 2500 MHz, thermal management and packaging, and complex security architecture—all introduce unique technological challenges. Cluster 5 program officials had expected to leverage technology from the Cluster 1 program. However, the Cluster 1 technologies have not matured as anticipated. Program officials stated that backup technology will be identified as a part of a risk mitigation plan.

Figure 5: Knowledge-Based Development Compared with JTRS Cluster 5 Development



Source: GAO analysis of Army data.

The JTRS Cluster 5 program has identified six critical technologies as follows:

- *Microelectronics*: Microelectronics addresses the processes for producing and packaging the electronic circuits and systems that make up the Cluster 5 radios. Miniaturization technology and microelectronics components are critical to the feasibility of Cluster 5 radios because of their extremely small size.

- *Environmental protection*: Environmental protection describes the technologies, tools, or design considerations necessary to protect the radios from potentially harsh effects of the operational environment, including, for example, lightning, short-duration force impacts, or radioactive contaminants.

- *Power management*: One of the greatest challenges in designing and implementing the Cluster 5 radios is the management and conservation of the limited amount of available battery power. Power management refers to the set of technologies that facilitate a reduction in energy consumption or an increase in battery capacity with the goal of obtaining longer operating time and a reduced battery size and weight.

- *Multichannel architecture*: Multichannel JTRS radios are required to provide multiple, independent channels to simultaneously transmit and receive information using different waveforms. The compact size of the Cluster 5 radios and requirement for simultaneous multichannel operation present a co-site interference mitigation challenge.

- *Antennas*: Cluster 5 JTRS radios are required to transmit and receive multiple waveforms over the large frequency range 2 MHz to 2.5 GHz and are further required to transmit and receive two separate waveforms simultaneously with a maximum of three antennas. The requirements impose unique technical challenges for both antenna and radio designs.

- *Security*: Cluster 5 security framework must support Multiple Single Levels of Security to allow the processing of information with different classifications and categories. It also must support an over-the-air download capability of waveforms, which will entail large software files. It has yet to be demonstrated in a relevant environment.

The Cluster 5 radios are required to store and operate the Wideband Networking Waveform. This will provide high data rates and networking capabilities for mobile forces. The full Wideband Networking Waveform requires significant amounts of memory and processing power, which may not be available for the Cluster 5 radios. According to the program office, the principal challenge in operating the Wideband Networking Waveform on Cluster 5 radios stems from the significantly smaller size, weight, and power requirements when compared with those for Cluster 1, as well as safety and heat considerations for the soldier. Because of the difficulties in overcoming these challenges, the Cluster 5 program is seeking to ease the waveform's requirements and reduce the power demands of the software.

The Cluster 5 program is also developing another new, wideband waveform called the Soldier Radio Waveform. Although less powerful than the Wideband Networking Waveform, it is expected to provide the needed network services for battery-powered radios with limited power and antenna size such as the handheld and the small form varieties. Cluster 5 radios with the Soldier Radio Waveform will enable squad-level communications and interoperability with other radios and work on a network based on the Wideband Networking Waveform. The Soldier Radio Waveform is expected to be available in 2008. However, the development of this waveform is being managed as a science and technology effort by the Army's Communications-Electronics Research Development and Engineering Center until it is matured and can be transitioned into the JTRS program. To support the first FCS spiral in the 2008-2010 timeframe, the Army has acknowledged that it may have to use an early version of the Soldier Radio Waveform and a surrogate radio to operate the waveform. Compounding the challenges in developing the waveform is the Army's assessment that developing the Soldier Radio Waveform's network manager is high risk and has yet to be funded.[4] Without the network manager functionality, the Soldier Radio Waveform will not be able to interface with the Wideband Networking Waveform.

A number of JTRS Cluster 5 technologies are interdependent (see fig. 6) that, in our opinion, can exacerbate the technical and program risks of moving forward with immature technologies. For example, power management is dependent upon microelectronics, multichannel architecture, antennas, and security. A lag in the development of any of these technologies could result in a lag in the development of power management.

[4]Network management is execution of a set of functions required for controlling, planning, allocating, deploying, coordinating, and monitoring the resources of a telecommunications network.

Figure 6: Interdependencies among Cluster 5 Critical Technologies

	Microelectronics	Environmental protection	Power management	Multichannel architecture	Antennas	Security
Microelectronics			●			
Environmental protection	●					
Power management	●			●	●	●
Multichannel architecture	●		●		●	●
Antennas						
Security				●		

Source: U.S. Army.

Because of the criticality of the size, weight, and power challenge faced by all variants of the JTRS radios, the program office is pursuing various solutions to the problem. The program, for example, hopes to benefit from the Army's science and technology research on developing wideband power amplifiers and advanced passive cooling technology.

Cluster 5 Schedule No Longer Synchronized with FCS Schedule

Several programmatic changes have significantly affected the Cluster 5 schedule, and the program has focused on delivering manpack radios for the near term and handheld and small form radios later. However, the availability of small form JTRS radios is of greater importance to FCS because they are needed for the planned fielding of three core systems in FCS spiral 1. The Army has concluded that the small form radios may not be able to meet the FCS schedule and may need to use surrogate radios to support the first FCS spiral.

In May 2003, the responsibility for developing the JTRS handheld and manpack radios was shifted from the Special Operations Command to the Army because of difficulties in resolving differences over requirements and funding among the services. At the same time, the Acting Under Secretary of Defense for Acquisition, Technology, and Logistics noted that the Cluster 5 capabilities would have to be delivered in at least two spirals and set an expectation that the Army would deliver prototype handheld and manpack radios in the third quarter of fiscal year 2005 and low rate initial production would begin by the fourth quarter of fiscal year 2006.

In May 2004, the Army Acquisition Executive approved the Cluster 5 program for the system development and demonstration phase of acquisition. The Army Acquisition Executive moved the Cluster 5 handheld radios to spiral 2, and it delayed the delivery of the spiral 1 prototype manpack radios to the fourth quarter of fiscal year 2005 and the low-rate initial production manpack radios to the first quarter of fiscal year 2007. The Army awarded the Cluster 5 contract in the middle of July 2004, but had to issue a stop-work order to the contractor by the end of July because of the filing of a bid protest by the losing contractor. The bid protest was not upheld, but the program was delayed another 3 months while the protest was decided.

In authorizing the May 2004 Cluster 5 program's entry into the system development and demonstration phase, the Army Acquisition Executive noted the criticality of the JTRS Cluster 5 radio and directed that a review be conducted to assess the plans for the spiral 2 portion of the program. At a minimum, the review was to assess development schedule synchronization, technical performance expectations, integration and performance risks, waveform development, maturity, baseline, and program affordability. The review was scheduled for the spring of 2005. However, because of the ongoing cost, schedule, and technical problems with the Cluster 1 program, the JTRS Joint Program Executive Office has begun a broader assessment of the Cluster 5 program. On the basis of the initial findings of the assessment, development work on the Cluster 5 spiral 1 radios has been suspended because the office determined that key waveforms being developed as part of the Cluster 1 program would not be delivered to Cluster 5 when needed. According to the JTRS Joint Program Executive Office, a restructuring of Cluster 5 spiral 1 and 2 is being developed, and it will identify more well defined and executable increments.

While the Cluster 5 manpack and handheld radios are important deliverables, of greater urgency for the first spiral of FCS is the availability of the small form Cluster 5 radios. These radios will be embedded in a variety of sensors and weapons systems. In fact, three FCS core systems—Unattended Ground Sensors, Intelligent Munitions Systems, and the Non Line of Sight Launch System—need Cluster 5 small form radios to support their planned inclusion in the first FCS spiral scheduled for the 2008-2010 timeframe. The Army has concluded that the schedule for the small form radios is not synchronized with the FCS schedule and has asked the contractor for a plan to accelerate deliveries. The Army has acknowledged that it may have to use surrogate radios, which have limited capabilities, if the Cluster 5 small form radios are not available to support the initial fielding of the three FCS core systems. In addition, other users depending on the Cluster 5 radios, such as the Army's Land Warrior program, have decided to move forward with surrogate radios.

Ambitious WIN-T Acquisition Approach Puts Program At Risk of Cost and Schedule Growth

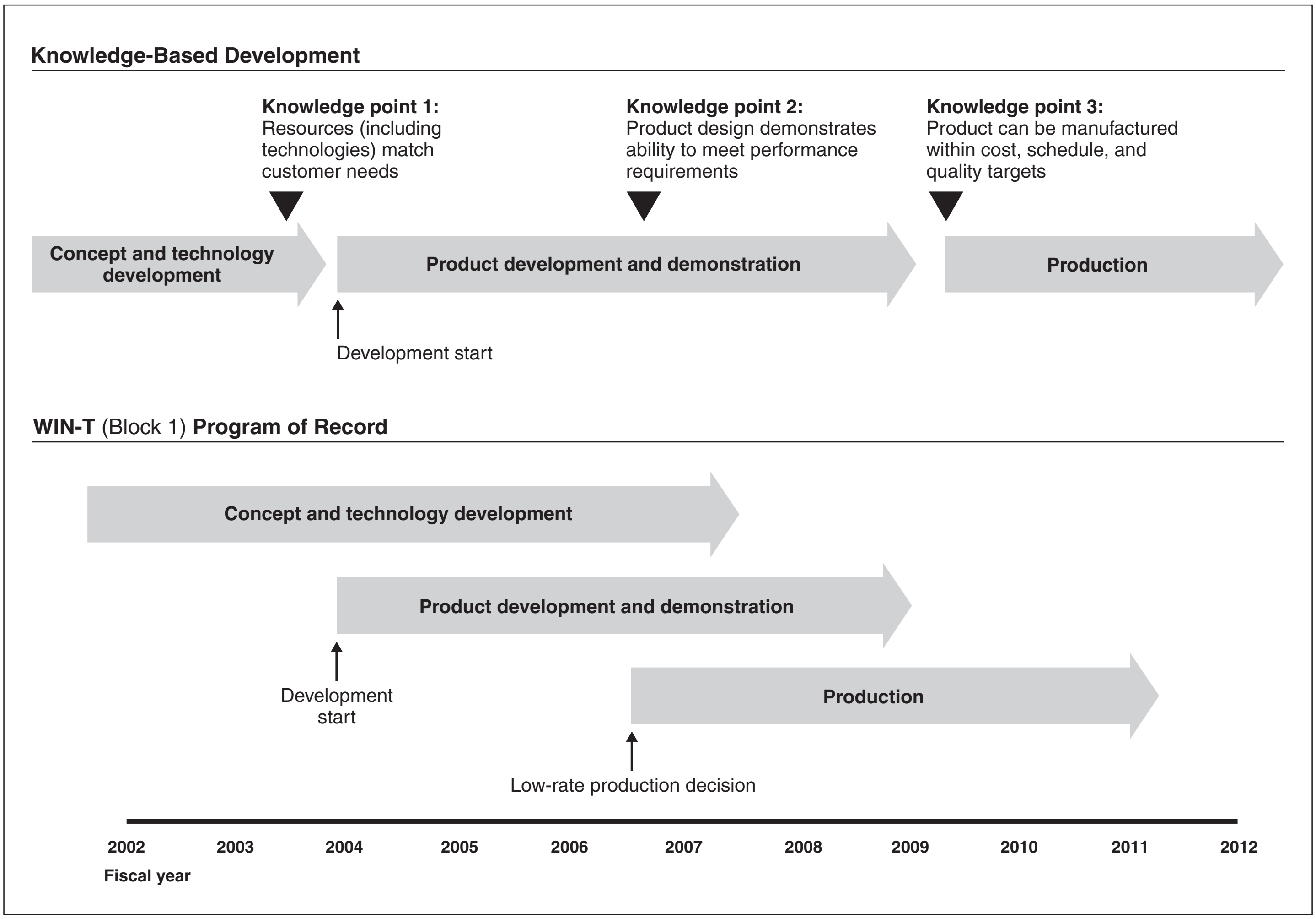
The WIN-T program entered the system development and demonstration phase with only 3 of its 12 critical technologies close to full maturity. None of the critical technologies will be fully mature at the time production begins in March 2006. Because there are significant interdependencies among critical technologies, any delay in maturing an individual technology further increases overall program risk. WIN-T has gone through a number of program changes, including shifts in the program's focus. In the fall of 2004, the Office of the Secretary of Defense approved the Army's proposal to combine the work of two contractors to facilitate early delivery of WIN-T capabilities to the warfighter while continuing to focus on the restructured FCS program. A decision has recently been made not to accelerate the program or develop capabilities sooner. It remains unclear what WIN-T capabilities will be provided to the first FCS spiral. The changes, along with existing technical challenges, put the program at risk of cost and schedule overruns and failure to achieve performance objectives.

Uncertainties about Technology Development Persist

During WIN-T's 32-month systems development and demonstration schedule, the program must mature 9 of its 12 critical technologies. Although risk mitigation plans were developed in mid-2003 for the 9 immature technologies, a program review sponsored by the Army in July 2004 concluded that the plans lacked sufficient detail. Eight backup technologies have been identified, but they are less robust and only 3 are close to full maturity. Relying on these substitutes may degrade network performance resulting in reduced operational capability.

Contrary to best practices under knowledge-based development, the program will continue technology development concurrently with the product development and demonstration phase (see fig.7). The tightly compressed schedule also assumes nearly flawless execution and may not allow sufficient time for correcting problems. For example, the combined testing to demonstrate system performance and operational functionality is slated to occur just 1 month after critical design review. With immature technologies, it will be difficult, at best, to demonstrate the system's design stability and determine whether the system can be produced affordably and work reliably. In fact, WIN-T program officials may be unable to conclude a reliable operational capability of on-the-move communications until the system is demonstrated in an operational environment early in fiscal year 2009—long after production begins.

Figure 7: Knowledge-Based Development Compared with WIN-T Development



Source: GAO analysis of Army data.

The significant interdependencies among WIN-T's critical technologies exacerbate the technical and program risks of moving forward with immature technologies. For example, the on-the-move satellite communications technologies rely on wideband waveforms, antennas, and other technologies to achieve their performance objectives. Therefore, a lag in the development of any of these technologies may result in a lag in the overall development of mobile communications technologies—a critical component of the operational concept for WIN-T.

Dependence on External Programs May Hinder the System's Performance

Not only is the program faced with technical challenges, but its dependence on other programs puts the WIN-T program at risk. WIN-T's ability to significantly improve upon current communications capabilities relies on demonstrating integrated network operations and the ability to work on the move. The WIN-T system depends on other programs to provide needed capabilities. Although separate from the WIN-T program, changes or delays in these external programs may impair WIN-T's ability to perform.

For WIN-T, unmanned aerial vehicles are fundamental to the program as they route information and extend transmission range that ground systems are constrained by—preserving network reliability, connectivity, and mobile throughput. Citing their capacity to fly at high altitudes, program officials have identified two platforms to support WIN-T, the Extended Range Multi-Purpose Unmanned Aerial Vehicle or the High Altitude Airship. However, one is not adequately funded for a dedicated communications capability, and the other is still in the concept development phase. Therefore, a study is under way to assess the consequence of not having unmanned aerial vehicles and its resulting effect on the network. It is unclear whether the issue will be resolved in time for the upcoming development test/operational test event. The program plans to use a surrogate plane, but it is unknown whether this will adequately assess network reliability and critical on-the-move communications.

Central to the WIN-T operational effectiveness is the development of a software-programmable radio and wideband waveforms. Together, the radio and waveforms are expected to allow warfighters to receive large volumes of data while moving around the battlefield at increasing speeds. However, given the uncertainty of whether a JTRS radio would be available to support WIN-T, the program plans to develop its own high-capacity radio, operating above the 2 GHz radio frequency range. To meet FCS requirements, the WIN-T radio is expected to run above 2 GHz with two new waveforms—a net-centric waveform and a high-capacity waveform--and the existing Global Broadcast Service waveform. In particular, these waveforms enable distribution of intelligence, surveillance, and reconnaissance data to provide a more detailed picture of the battlefield. To address the need for waveforms operating above 2 GHz, the Office of the Secretary of Defense is conducting an assessment to identify solutions. However, the results of the study may not be available by the critical design review.

Program Has Undergone Several Strategy Changes

Since the WIN-T program was conceived nearly 5 years ago, the program strategy has shifted several times. Originally, the program focused on designing a network that would meet current force needs. In 2002, the program was realigned to focus on a network that would support future force needs. Two contractors were to work independently on designing the future force network architecture, and the program office would select the better of the two. The contractors were given significant flexibility in designing the network architecture and developing system performance specifications. Two years later, with the global war on terrorism and military operations in Afghanistan and Iraq, WIN-T was directed to focus on developing and fielding network capabilities to meet both current and future force needs. To expedite completion of the architecture's design, the Army eliminated competition between the two contractors in September 2004. Army officials believe that the combined team provides a stronger technical solution by taking the best elements of each contractor's proposed architecture and maintains some competition because over 50 percent of the work will still be competed among sub-contractors. In fact, the contractors working together completed the network architecture by January 2005—a year earlier than previously planned. According to Army officials, the early completion of the network architecture allows other Army programs, particularly FCS, to stabilize their network designs earlier than planned.

In conjunction with the WIN-T program's shift in focus to address both current and future force needs, the Army fielded a separate program, in 2004, a beyond-line-of-sight communications network to units deployed in Iraq: the Joint Network Transport Capability-Spiral (JNTC-S). Although an improvement over past capabilities, JNTC-S is stationary —units must come to a standstill and set up their satellite equipment to communicate. In contrast, WIN-T is expected to maintain satellite connection—regardless of distance, weather conditions, or terrain—–while units are in motion. Currently, the Army is assessing how best to transition JNTC-S to WIN-T. In addition, the Army is assessing whether the WIN-T program can be modified to address the restructured FCS plan to field communications and networking capabilities in spirals. Army officials concede that, based on available technologies and resources, WIN-T block 1 performance requirements may need to be scaled back to meet the FCS spiral 1 time frame. For example, the data rate requirements for block 1 WIN-T—which calls for an unprecedented data throughput rate of 256 kilobits per second while units are moving at 25 miles per hour—may need to be reduced.

Although the Army has decided not to accelerate development of WIN-T, it is unclear when plans to migrate from the JNTC-S program and address FCS needs will be completed.

SOSCOE Development at Risk because of Software Maturity and Evolving Requirements

The Army assesses SOSCOE as high-risk. SOSCOE software may not reach the necessary technical maturity level required to meet FCS milestones. In addition, FCS system-level requirements are still being defined, which could affect the SOSCOE design. Consequently, it is unclear whether SOSCOE will be sufficiently developed to support the initial fielding of FCS beginning in fiscal year 2008.

SOSCOE Software Availability and Maturity are High-Risk

Because SOSCOE software will tie together FCS systems, support battle command applications, and enable interoperability with current and future forces, it is the fundamental building block upon which a substantial portion of FCS will be built. Thus, delays in SOSCOE software development could affect FCS' ability to meet production and fielding milestones. Since the start of system development, the Army has assessed SOSCOE software availability and maturity as high-risk. According to program officials, SOSCOE development does not require "cutting edge" software technology. However, there are some aspects of particular service families that are more challenging than others and result in an overall SOSCOE development effort that varies in complexity. The key to SOSCOE development is the "threading model," which is intended to allow an interface between different subsystem operating systems. The high risk is derived from the fact that SOSCOE may not reach the necessary technical maturity level required to meet program milestones.

The SOSCOE risk mitigation strategy is to develop and deliver the software in increments to provide the functionality required by SOSCOE users when they need it. Specifically, the SOSCOE software is scheduled for delivery in a series of seven software builds between the end of 2005 and 2011. FCS functionality will increase with each successive software build. The Army will need about one-half of the SOSCOE software in time for the fielding of the initial FCS capability in fiscal year 2008. If the software risks materialize, the SOSCOE build plan may have to be modified, deferring some functionality to later software builds.

FCS Program Requirements Are Still Evolving

Higher-level FCS specifications are still evolving nearly 2 years after the program started development. As in most engineering efforts, FCS requirements are first defined at a general or high level. Once these are defined, more detailed specifications that flow down to the subsystem level are derived. It is the specifications that provide the details necessary to design subsystems like SOSCOE. In the case of FCS, very few specifications have flowed to SOSCOE, as higher-level specifications are still being defined. The lack of specific requirements flow-down could affect the SOSCOE software build needed to support the first FCS spiral.

In addition, program officials are concerned that SOSCOE will have difficulty meeting emerging requirements without significant cost and schedule impacts. Costs are likely to grow as SOSCOE is reworked to meet new requirements, or applications software is reworked to accommodate the limitations of SOSCOE. Further, if design assumptions underlying SOCOE during the spiral 1 and 2 builds are wrong, because of incomplete technical information, requirements for future software builds might not be met or the software could require extensive rework, resulting in cost and schedule problems.

FCS Restructuring Reduced SOSCOE Development Concurrency

As part of the original FCS schedule, a DOD-level Network Maturity Milestone Decision was scheduled for 2008 to assess demonstrated communications and networked functions. The demonstration was to verify the performance of FCS software, including SOSCOE. The purpose of the demonstration would have been to provide confidence that all networked operations software would meet initial operational capability objectives and to use the results of the milestone decision to initiate long-lead production for the network equipment. However, the restructuring of the overall FCS program allowed the reduction of the high concurrency in the SOSCOE development and fielding schedule. The development schedule has now been extended to 2011. The DOD-level assessment of demonstrated network capabilities will be deferred until the formal FCS production milestone decision in 2012.

Conclusions

Although DOD and the military services have produced the best armed forces in the world, their effectiveness in carrying out military operations has been hampered by communications and networking systems that lack interoperability and have limited capacity to transfer information where and when it is needed. The Army's efforts to develop JTRS, WIN-T, and the SOSCOE as components of the network are essential to overcoming these limitations. However, to achieve the desired capabilities, not only must each program be successfully executed, but because the programs are interdependent, they must be closely synchronized. In particular, the successful fielding of FCS capabilities is critically dependent on the outcome of the JTRS and WIN-T programs. If they do not work as intended, there will not be sufficient battlefield information for the future force to operate effectively.

As currently structured, the JTRS, WIN-T, and SOSCOE programs are at risk of not delivering intended capabilities when needed, particularly for the first spiral of FCS. They continue to struggle to meet an ambitious set of user requirements, steep technical challenges, and stringent timeframes. While the Army's restructuring of the FCS program last year into spiral increments was a positive step, the first spiral may not demonstrate key networking capabilities. The first spiral of FCS should provide a meaningful demonstration of the networking capabilities that can then serve as a basis to support further development of the future force. In particular, demonstrating the capability of the Wideband Networking Waveform is important, given that the design of FCS vehicles and systems in later spirals is predicated on this capability. It is reasonable that such a demonstration should include JTRS with the Wideband Networking Waveform, WIN-T, and basic capability from SOSCOE.

Recommendations for Executive Action

Since (1) an enhanced Army communications network is critical for a successful transformation to FCS and (2) JTRS, including the advanced wideband waveforms, WIN-T, and SOSCOE are the key pillars of the communications network, the timing of the first FCS spiral should be based on when the pacing capabilities to be provided by JTRS and WIN-T will be demonstrated. Therefore, we recommend that the Secretary of Defense:

- establish low-risk schedules for demonstrating JTRS, WIN-T, and SOSCOE capabilities;
- synchronize the FCS spiral schedule with such schedules for JTRS, WIN-T, and SOSCOE; and
- develop an operational test and evaluation strategy that supports an evaluation of network maturity as part of FCS spiral production decisions.

In addition, in light of the delays in JTRS Cluster 1 and the criticality of the Wideband Networking Waveform for FCS, we recommend the Secretary of Defense assess whether a greater priority should be placed on demonstrating the Wideband Networking Waveform on a JTRS radio prototype over other Cluster 1 capabilities in the remainder of the Cluster 1 development program.

Agency Comments and Our Evaluation

In its letter commenting on a draft of our report, DOD concurred with our findings and three of our recommendations and partially concurred with a fourth recommendation. (DOD's letter is reprinted in app III.) As part of its comments, DOD provided some information on actions it has begun to take to address each of our recommendations. While these actions should help strengthen the management of JTRS, WIN-T, and SOSCOE, we remain concerned that a demonstration of FCS's communications and networking capabilities will not be known for some time. Until these capabilities are demonstrated, investment in FCS platforms and systems carries substantial risk. DOD also provided technical comments, which we incorporated where appropriate.

Regarding our first recommendation—that the Secretary of Defense establish low-risk schedules for demonstrating JTRS, WIN-T, and SOSCOE capabilities—DOD concurred, noting (1) that its newly established JTRS Joint Program Executive Office is evaluating the condition of each JTRS product line and will make recommendations to ensure effective control of cost, schedule, and performance and (2) that the Army is managing risks associated with WIN-T and SOSCOE and the Office of the Secretary of Defense is applying the appropriate level of oversight. While the actions being taken by DOD and the Army will help, it remains unclear whether they will be sufficient to ensure JTRS, WIN-T, and SOSCOE—the critical components of the enhanced communications network—are successfully executed. We remain concerned that the requisite knowledge needed to effectively manage program development risks has not been sufficiently developed. A low-risk fielding schedule for each of the components should set the pace for the Army's transformation to FCS.

Regarding our second recommendation—that the Secretary of Defense synchronize the FCS spiral schedule with the fielding schedules for JTRS, WIN-T, and SOSCOE—DOD partially concurred, but stated that "the Army's strategy for spiraling out FCS technology is not constrained to any one particular element of the program. The strategy aims to make available mature and military useful system capability in increments, leveraging opportunities to integrate new and mature technology with current force capability." DOD further stated that "the FCS spirals will make use of technologies as they become available or leverage the use of surrogate applications where they apply." DOD also noted that the Army did not define the first FCS spiral around the main components of the communications network, but around the capabilities needed by the current force. While we agree with DOD that mature and military useful capabilities should be fielded as expeditiously as possible, we believe that the first spiral should demonstrate meaningful capabilities for FCS. In particular, we believe that the first spiral of FCS should demonstrate critical networking capabilities, and that its schedule be predicated on demonstrating core capabilities, such as the JTRS Wideband Networking Waveform. Progress made on these capabilities should guide the future investments, such as on ground vehicles that depend on network performance. In addition, reliance on surrogate applications has the potential to result in costly replacement of the surrogate applications once the target applications are fully mature.

Regarding our third recommendation—that the Secretary of Defense develop an operational test and evaluation strategy that supports an evaluation of network maturity as part of FCS spiral production decisions—DOD concurred, stating that FCS will initially field a mix of both new and legacy communications and network capabilities, and that iterative operational test and evaluation will be stressed to ensure strong capability verification and validation. DOD also noted that network maturity will be assessed at each spiral's production decision. While it is appropriate to assess network maturity at each spiral's production decision, to measure progress in developing the FCS communications network, these assessments will need to culminate in a full demonstration that the network will perform as intended before committing to produce equipment for FCS units of action.

Finally, regarding our fourth recommendation—that the Secretary of Defense assess whether a greater priority should be placed on demonstrating the Wideband Networking Waveform on a JTRS radio prototype over other Cluster 1 capabilities in the remainder of the Cluster 1 development program—DOD concurred, noting that the newly established JTRS Joint Program Executive Office is assessing the JTRS Cluster 1 development path and that the development of the Wideband Networking Waveform will be included in the assessment.

As agreed with your office, unless you announce its contents, we will not distribute this report further until 30 days after the date of this letter. At that time, we will send copies to the Chairmen and Ranking Minority Members of other Senate and House committees and subcommittees that have jurisdiction and oversight responsibilities for DOD. We will also send copies to the Secretary of Defense, the Secretary of the Army, and the

Director, Office of Management and Budget. Copies will also be available at no charge on GAO's Web site at http://www.gao.gov. If you or your staff have any questions about this report, please contact me at (202) 512-2811, or Assistant Director John Oppenheim at (202) 512-3111. Major contributors to this report were Ridge Bowman, Subrata Ghoshroy, Karen Sloan, Hai Tran, Paul Williams, and Candice Wright.

Sincerely yours,

Paul L. Francis, Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To determine the development risks associated with the Joint Tactical Radio System-Tactical (JTRS) Cluster 1, JTRS Cluster 5, and WIN-T programs, we obtained briefings on acquisition plans, analyzed documents describing the maturity of critical technologies, and interviewed project and product officials from the Warfighter Information Network-Tactical (WIN-T) Program Management Office, Fort Monmouth, New Jersey. To determine the status of JTRS waveforms, we obtained briefings on wideband waveform development efforts and interviewed officials from the JTRS Joint Program Office, Arlington, Virginia. We also reviewed selected acquisition reports, technology readiness assessments, test and evaluation plans, defense acquisition executive summaries, and acquisition decision memorandums for individual programs. To obtain information related to the planned use of JTRS Cluster 1 radios in rotary wing platforms, we interviewed officials from the Program Executive Office, Aviation, Arlington, Virginia. To obtain information related to JTRS Cluster 1 contract performance data, we interviewed Defense Contract Management Agency officials in Anaheim, California, and obtained cost performance reports and other cost analysis documentation.

To assess cost and schedule performance for JTRS Cluster 1 and waveform development for the period between August 2003 and January 2005, we used cost and schedule variances reported in contractor cost performance reports. Results were presented in graphical form to determine the period's trends. We also obtained likely cost at the completion of the prime contract from the reports. We confirmed that the prime contractor's earned value management system had been validated by the Defense Contract Management Agency. The cost and schedule results include both prime and subcontractors. The development of the waveforms was included in our analysis of Cluster 1 because, although the effort is managed separately under the Joint Program Office, it is being executed under the same contract.

To determine the development risks associated with the System of Systems Common Operating Environment (SOSCOE), we obtained briefings on fielding plans, analyzed documents describing SOSCOE software availability and maturity, and interviewed project officials from the Project Manager for FCS Network Systems Integration, Fort Monmouth, New Jersey. We also attended FCS in-process reviews and a board of directors meeting in St. Louis, Missouri, organized by the Program Manager, Unit of Action.

To obtain the perspective of organizations that provide policy guidance, oversight, and technology support for the JTRS, WIN-T, and Future

Combat Systems (FCS) programs, we interviewed officials from the Office of the Secretary of Defense, Networks and Information Integration, Arlington, Virginia; Assistant Secretary of the Army for Acquisition, Logistics, and Technology, Arlington, Virginia; and, the Army's Communications-Electronics Research, Development and Engineering Center, Fort Monmouth, New Jersey.

Our review was conducted from January 2004 through May 2005 in accordance with generally accepted government auditing standards.

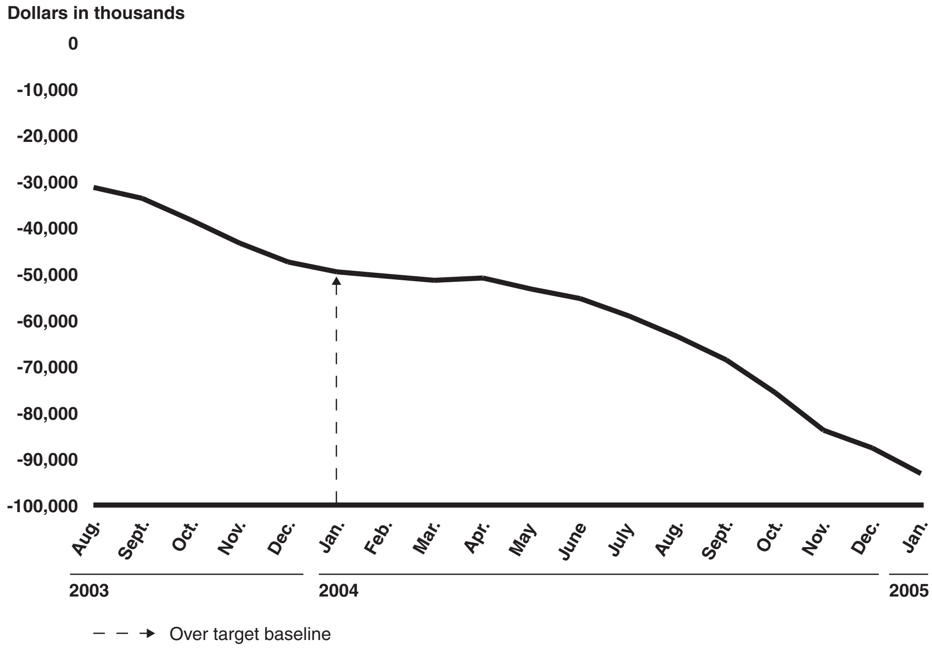
Appendix II: JTRS Cluster 1 Cost and Schedule Variance

Since Cluster 1 entered systems development, in 2002, the contractor has overrun cost estimates by almost $93 million—nearly 28 percent above what was planned. We used contractor cost performance reports to assess the prime contractor's progress toward meeting the Army's cost and schedule goals during the period August 2003-January 2005. The government routinely uses such reports to independently evaluate the prime contractor's performance. Generally, the reports detail deviations in cost and schedule relative to expectations established under the contract. Deviations are referred to as variances. Positive variances—activities costing less or completed ahead of schedule—are considered as good news, and negative variances—activities costing more or falling behind schedule—as bad news.

Although the program attempted to stabilize cost growth by adding approximately $200 million to the contract in January 2004, the cost variance continued to decline steadily thereafter.[1] Key issues driving the cost growth are unanticipated complexity associated with developing the hardware, Wideband Networking Waveform, and other software. As a result, the unit costs for early prototypes have increased from the prime contractor's original proposal. In January 2005, the prime contractor estimated that the total costs for the Cluster 1 radio and waveform development would be $531 million more than was originally budgeted, reaching about $898 million at completion (see fig. 8). However, the program office noted that, since contract award, the prime contractor has not demonstrated strong cost estimating and cost management techniques.

[1]The program attempted to stabilize the contractor cost variance by initiating an over-the-target baseline (OTB) in January 2004. An OTB is a reprogramming effort or "recovery plan" that adds budget to a contract for either future work or in-process work when the original objectives cannot be met. The primary purpose of an OTB is to improve managerial control over the execution of the remaining work in a project. A project manager may conclude that the baseline is no longer adequate to provide valid performance measurement information relative to the remaining work and therefore consider initiating an OTB.

Figure 8: Cost Performance of JTRS Cluster 1 and Waveform Development from August 2003 to January 2005

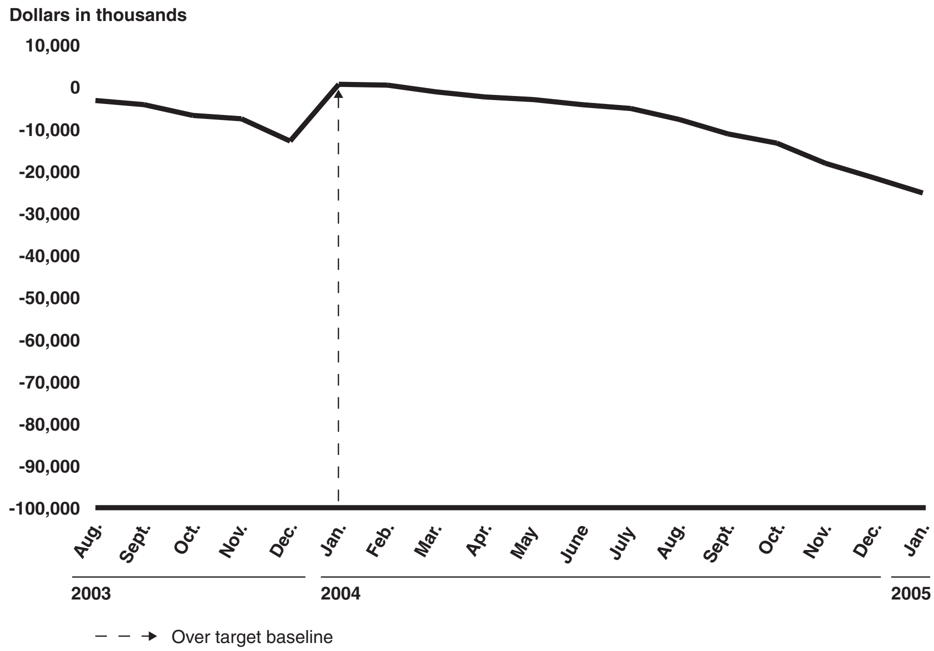


Source: GAO analysis based on data provided by Defense Contract Management Agency.

Cluster 1 has also experienced unfavorable schedule variance. Figure 9 indicates that the contractor increasingly fell behind schedule during the period August 2003-January 2005. If a program is not only overrun in costs, but is also behind schedule, additional costs can be expected because of potential schedule slippage or from acceleration of the effort to finish on time. The schedule variance stabilized briefly after the program rebaselined in January 2004, but then it continued to increase again. [2] By January 2005, the value of planned work that the contractor was behind schedule was about $25 million. Delays in software build completions, software/hardware integration, and the delivery of key technologies to the waveform developers have contributed to schedule problems.

[2]The OTB added 4 months to the acquisition schedule.

Figure 9: Schedule Performance of JTRS Cluster 1 and Waveform Development from August 2003 to January 2005



Source: GAO analysis based on data provided by Defense Contract Management Agency.

Appendix III: Comments from the Department of Defense

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

NETWORKS AND INFORMATION INTEGRATION

JUN 9 2005

Mr. Paul L. Francis
Director, Acquisition and Sourcing Management
US General Accounting Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Francis,

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report "Resolving Developmental Risks in the Army's Networked Communications Capabilities Is Key to Fielding Future Force," dated May 6th, 2005 (GAO Code 120283/GAO 05-669).

The DoD has reviewed the findings of the report and appreciates the efforts of the GAO staff to present objective viewpoints regarding Army Networking capabilities and dependencies for the Future Combat System. We have reviewed the draft report and with the consideration of the enclosed comments concur with the findings and recommendations.

My point of contact for GAO Code 120283/GAO 05-669 is COL Randall Conway, Communications Programs Directorate. He can be reached at 703-607-0277 or via email at randall.conway@osd.mil.

Sincerely,

For
Ronald C. Jost
Acting Deputy Assistant Secretary
of Defense (C3 Policies, Programs
and Space Programs)

Enclosure:
As Stated

GAO DRAFT REPORT DATED MAY 6, 2005
GAO-05-669 (GAO CODE 120283)

"DEFENSE ACQUISITIONS: Resolving Development Risks in the Army's Networked Communications Capabilities Is Key to Fielding Future Force"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense establish low-risk schedules for demonstrating JTRS, WIN-T, and SOSCOE capabilities. (p. 32/GAO Draft Report)

DOD RESPONSE: DoD concurs with the recommendation. The newly established JTRS Joint Program Executive Office is evaluating the condition of each JTRS product line and will make recommendations to the USD (AT&L) to ensure effective control of cost, performance, and schedule. The Department acknowledges that there are additional risks associated with WIN-T and SOSCOE. The Army is managing that risk and OSD is applying the appropriate level of oversight. Additionally, the JPEO JTRS recently began discussions with the FCS program to determine their dependencies on JTRS. These discussions will be a recurring event to insure coordination of these key net-centric programs. Some specific comments regarding SOSCOE, JTRS, and WIN-T follow:

RE: Establishing low-risk SOSCOE schedule:
SOSCOE has four integration phases, each supported prior to integration by analysis, modeling and simulation, assessment and experimentation. Each Integration Phase is comprised of an Engineering Iteration (EI), Integration and Verification Iteration (IVI) and Spiral Out (SO). Thus, a low risk schedule is achieved through successive integration phases. Furthermore, Spiral Out products will be developed over a minimum of 2 engineering iterations.

RE: Establishing a low-risk JTRS schedule:
The JPEO is de-risking JTRS plans. FCS will be using pre-EDM cluster one and cluster five radios in the first spiral out. The pre-EDM Cluster five plan is to have the pre-EDM radios run SRW INC 1.0. The pre-EDM and EDM units will be produced by different contractors to reduce risk. SRW will be demonstrated this summer (2005).

RE: Establishing a low-risk WIN-T schedule:
OASD-NII in cooperation with PM WIN-T established a WIN-T IIPT with Systems Engineering, Network, Test WIPT and other WIPTs reporting to the IIPT. OSD-NII will work with WIN-T to assure design and schedule integrity as well as execution of appropriate risk management processes.

Enclosure
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RECOMMENDATION 2: The GAO recommended that the Secretary of Defense synchronize the FCS spiral schedule with such schedules for JTRS, WIN-T, and SOSCOE. (p. 32/GAO Draft Report)

DOD RESPONSE: DoD partially concurs with the recommendation. The Army's strategy for spiraling-out FCS technology is not constrained to any one particular element of the program. The strategy aims to make available mature and military useful system capability in increments, leveraging opportunities to integrate new and mature technology with current force capability. Program synchronization efforts are an ongoing process that will ensure that FCS spirals are effectively supported by the minimum essential functionality of JTRS, WIN-T, and SOSCOE. The FCS spirals will make use of technologies as they become available or leverage the use of surrogate applications where they apply. The FCS Network IIPT and WIPT will continue to review FCS progress and establish a Milestone C for every FCS Spin out and FCS end-state. Program synchronization will also be examined by the OASD NII led acquisition WIN-T IIPT. Further, OASD NII and Army G6 led task force will be established to assure synchronization of FCS and WIN-T and their interoperability with complementary programs.

RECOMMENDATION 3: The GAO recommended that the Secretary of Defense develop an operational test and evaluation strategy that supports an evaluation of network maturity as part of FCS spiral production. (p. 33/GAO Draft Report)

DOD RESPONSE: DoD concurs with the recommendation. In recognition that FCS will initially field a mix of both new and legacy communications and network capabilities, DoD will stress iterative operational test and evaluation that ensures strong capability verification and validation. Also, NII plans to convene an FCS Network WIPT in addition to a Net Centric Review in conjunction with each Milestone C decision to assess network maturity. System and user test results will be evaluated at each Milestone C decision for each FCS spiral.

RECOMMENDATION 4: The GAO recommended that the Secretary of Defense assess whether a greater priority should be placed on demonstrating the Wideband Networking Waveform on a JTRS radio prototype over other Cluster 1 capabilities in the remainder of the Cluster 1 development program. (p. 33/GAO Draft Report)

DOD RESPONSE: DoD concurs with the recommendation. The newly established JTRS Joint Program Executive Office is assessing the JTRS Cluster 1 development path and will recommend to the USD (AT&L) a re-prioritization of development efforts to maximize resource investments and satisfy user needs. Development of the Wideband Networking Waveform will be included in the assessment. The JPEO also agrees that force transformation is directly related to providing IP mobile adhoc networking to the warfighters. This will include working with the requirements community to develop common approaches across all domains.

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TECHNICAL COMMENTS:

Page 10, last paragraph: "The Army has defined the initial spiral of FCS around the main components of the communications network,..."

DOD RESPONSE: The Army defined the initial spiral of FCS around the capabilities needed by the current force, to include the requirement to satisfy U.S. Landmine Policy.

Page 26, paragraph 2: "Recently, the Army directed the program to determine whether capabilities can be developed sooner to address the needs of the current force and the restructured FCS program. A plan for how to do this remains undetermined."

DOD RESPONSE: This is no longer an accurate statement. The decision has been made not to accelerate the program.

Page 28 and 29, 3rd and 1st paragraphs: "However, given the uncertainty of whether a JTRS radio would be available to support WIN-T, the program plans to develop its own high capacity radio, operating above the 2GHz radio frequency range. To meet FCS requirements, the WIN-T radio is expected to run above 2GHz with two waveforms—one both net centric and high capacity and the other the existing Global Broadcast Service waveform. ....to address the need for waveforms operating above 2 GHz, the Office of the Secretary of Defense is conducting an assessment to identify solutions. However, the results of the study may not be available by the critical design review."

DOD RESPONSE: There are two waveforms that WIN-T is developing to support the Communications on the Move (COTM) requirement. The first waveform is called the Net-Centric Waveform and is Ka/Ku SATCOM based. The other waveform is called the High Capacity Networking Waveform and is line-of-sight based. Additionally, WIN-T will use the GBS broadcast receive only waveform.

Page 29, paragraph 2: "to expedite completion of the architecture's design, the Army eliminated competition between the two contractors in September 2004. ..... On the other hand, without competition, the government has less assurance that cost and schedule risks will be sufficiently controlled."

DOD RESPONSE: Competition was not entirely eliminated. Over 50% of work share is still competed among sub-contractors.

Enclosure
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