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DEFENSE ACQUISITIONS

The Army's Future Combat Systems' Features, Risks, and Alternatives

Statement of Paul L. Francis, Director,
Acquisition and Sourcing Management

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Highlights

Highlights of GAO-04-635T, a testimony before the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives

Why GAO Did This Study

To become a more responsive and dominant combat force, the U.S. Army is changing its strategy from bigger and stronger weapons to faster and more agile ones. The Future Combat Systems (FCS)—which the Army calls the "greatest technology and integration challenge ever undertaken"—is expected to meet the Army's transformational objectives. Forming FCS' backbone is an information network that links 18 systems. Not only is FCS to play a pivotal role in the Army's military operations, FCS and its future iterations are expected to eventually replace most of the Army forces. For FCS' first developmental increment, the Army has set aside a 5 ½-year timetable from program start (May 2003) until the initial production decision (November 2008).

GAO was asked to testify about FCS' key features, whether the program carries any risks, and, if so, whether there are alternatives for developing FCS capabilities with fewer risks.

www.gao.gov/cgi-bin/getrpt?GAO-04-635T.

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.

What GAO Found

The FCS concept is a new generation of manned and unmanned ground vehicles, air vehicles, and munitions, each of which taps into a secure network of superior combat information. These weapon systems are to be a fraction of the weight of current weapons yet as lethal and survivable. FCS' lightweight and small size are critical to meeting the Army's goals of deploying faster and being more transportable for big or small military operations. Rather than rely on heavy armor to withstand an enemy attack, FCS' systems will depend on superior communications to kill the enemy before being detected. One of FCS' key advantages is that it provides an architecture within which individual systems will be designed—an improvement over designing systems independently and making them interoperable after the fact. Another merit is that FCS is being acquired and developed with the full cooperation of the Army's program managers, contractors, and the warfighter community.

FCS is at significant risk for not delivering required capability within budgeted resources. Three-fourths of FCS' needed technologies were still immature when the program started. The first prototypes of FCS will not be delivered until just before the production decision. Full demonstration of FCS' ability to work as an overarching system will not occur until after production has begun. This demonstration assumes complete success—including delivery and integration of numerous complementary systems that are not inherently a part of FCS but are essential for FCS to work as a whole. When taking into account the lessons learned from commercial best practices and the experiences of past programs, the FCS strategy is likely to result in cost and schedule consequences if problems are discovered late in development.

Because it is promising to deliver unprecedented performance capabilities to the warfighter community, the Army has little choice but to meet a very high standard and has limited flexibility in cutting FCS requirements. Because the cost already dominates its investment budget, the Army may find it difficult to find other programs to cut in order to further fund FCS. To avoid unanticipated cost and schedule problems late in development, several alternatives can be considered:

- add time to FCS' acquisition schedule to reduce concurrent development;
- take the time to develop and demonstrate the most critical capabilities first, such as the FCS network, then proceed with an acquisition program; and
- focus on maturing the most critical technologies first, then bundle them in demonstrations of capabilities, and ensure that decision makers have attained the knowledge they need at critical junctures before moving forward.

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the Department of the Army's Future Combat Systems (FCS), a networked suite of weapons and other systems. FCS is the centerpiece of the Army's plan to transform to a lighter, more agile, and more capable force. The Army plans to develop and field FCS in increments, but has only defined the first increment at this time. Increment 1 of FCS began system development and demonstration in May 2003. The production decision is currently planned for November 2008 and initial operational capability is slated for December 2010. This first increment will equip 15 brigade-sized Units of Action by 2020—about one third of the active force. Total costs to develop and produce Increment 1 are estimated at $92 billion, in then year dollars. The fiscal year 2004 budget provides $1.7 billon in research and development funds for FCS; the fiscal year 2005 budget requests a substantial increase to $3.2 billion.

Today I would like to cover (1) the features of the FCS concept, (2) the prospects for delivering a capable FCS within budgeted cost and schedule, and (3) whether alternatives to the current FCS strategy are worth considering.

Summary

FCS is an information network linking a suite of 18 new manned and unmanned ground vehicles, air vehicles, sensors, and munitions. They are to be a fraction of the weight of current weapons, yet are to be as lethal and survivable. Their lightweight and small size are critical to meeting the other goals of the Army's future force: better responsiveness and enhanced sustainability. At a fundamental level, the FCS concept is replacing mass with superior information; that is, to see and hit the enemy first, rather than to rely on heavy armor to withstand an attack. The ability to make this leap depends on (1) the ability of the network to collect, process, and deliver vast amounts of information such as imagery and communications and (2) the performance of the individual systems themselves. This concept has a number of progressive features. It provides an architecture within which individual systems will be designed—an improvement over designing systems independently and making them interoperable after the fact. It includes sustainability as a design characteristic versus an afterthought. It has galvanized relationships between users and developers. It also shows a willingness on the part of Army leaders not to be bound by tradition.

FCS is at significant risk for not delivering required capability within budgeted resources. At conflict are the program's unprecedented technical challenges and time. At a top level, the technical challenges are: development of a first-of-a-kind network, 18 advanced systems, 53 critical technologies, 157 complementary systems, and 34 million lines of software code. From a time standpoint, the Army allows only 5 ½ years between program start and the production decision. This is faster than it has taken to develop a single major system, and FCS has several systems including the network, an Abrams replacement, a Bradley replacement, and a Crusader replacement. To meet this timetable, FCS is proceeding on a highly concurrent strategy that started with over 75 percent of critical technologies immature. Assuming everything goes as planned, the FCS program will begin production before all of its systems have been demonstrated. If all FCS elements are not ready at the production decision, Army plans still call for going forward with production and fielding. Based on the lessons learned from best practices and the experiences of past programs, FCS is susceptible to discovering costly problems in late development and early production, as the demonstration of multiple technologies, individual systems, the network, and the system of systems will all culminate.

Alternatives to the current FCS strategy are worth considering in light of these risks. The tools normally employed to accommodate problems in weapon systems—relaxing performance requirements and adding funds—may not be available to the FCS program. The opportunity for making performance trade-offs on FCS is limited by the fact that it must be transportable by the C-130 aircraft yet be as lethal and survivable as the current force. On the funding side, the $92 billion cost estimate only allows for 14 of the 18 systems to be acquired, despite being based on an immature program and assuming full success in development. A modest delay late in development could cost $5 billion; a similarly modest 10-percent increase in production cost would amount to $7 billion. Providing more money on this scale after problems have occurred may not be feasible given the fiscal pressures the government in general—and DOD in particular—faces. Several alternatives that would enable a less concurrent—and more predictable—strategy are possible, if acted upon early. Alternatives should have several things in common: building more knowledge before commitments like production are made; preserving the advantages of the FCS concept, such as defining an architecture to guide the design of individual systems; and the ability to spin off mature technologies to existing systems.

Army Transformation and the FCS Program

The Army plans to develop and acquire FCS in at least two increments but, according to program officials, only the first one has been defined at this point. The first increment is an information network linking a new generation of 18 manned and unmanned ground vehicles, air vehicles, sensors, and munitions. The manned ground vehicles are to be a fraction of the weight of current weapons such as the Abrams tank and Bradley Fighting Vehicle, yet are to be as lethal and survivable. At a fundamental level, the FCS concept is replacing mass with superior information; that is, to see and hit the enemy first, rather than to rely on heavy armor to withstand attack. The ability to make this leap depends on (1) the ability of the network to collect, process, and deliver vast amounts of information such as imagery and communications and (2) the performance of the individual systems themselves. The concept has a number of progressive features. For example, it provides an architecture within which individual systems will be designed—an improvement over designing systems independently and making them interoperable after the fact.

Army Transformation

A decade after the cold war ended, the Army recognized that its combat force was not well suited to perform the operations it faces today and is likely to face in the future. The Army's heavy forces had the necessary firepower but required extensive support and too much time to deploy. Its light forces could deploy rapidly but lacked firepower. To address this mismatch, the Army decided to radically transform itself into a new "Future Force."

The Army expects the Future Force to be organized, manned, equipped, and trained for prompt and sustained land combat, requiring a responsive, technologically advanced, and versatile force. These qualities are intended to ensure the Future Force's long-term dominance over evolving, sophisticated threats. The Future Force will be offensively oriented and will employ revolutionary operational concepts, enabled by new technology. This force will fight very differently than the Army has in the past, using easily transportable lightweight vehicles, rather than traditional heavily armored vehicles.[1] A key characteristic of this force is agility. Agile forces would possess the ability to seamlessly and quickly transition among various types of operations from support operations to warfighting and back again. They would adapt faster than the enemy, thereby denying

[1] As an interim step toward transformation, the Army is organizing medium weight, rapidly deployable brigades around 19-ton Stryker armored vehicles.

it the initiative. In an agile force, commanders of small units may not have the time to wait on higher command levels; they must have the authority and high quality information at their level to act quickly to respond to dynamic situations.

Thus, to be successful, the transformation must include more than new weapons. The transformation is extensive, encompassing tactics and doctrine, as well as the very culture and organization of the Army.

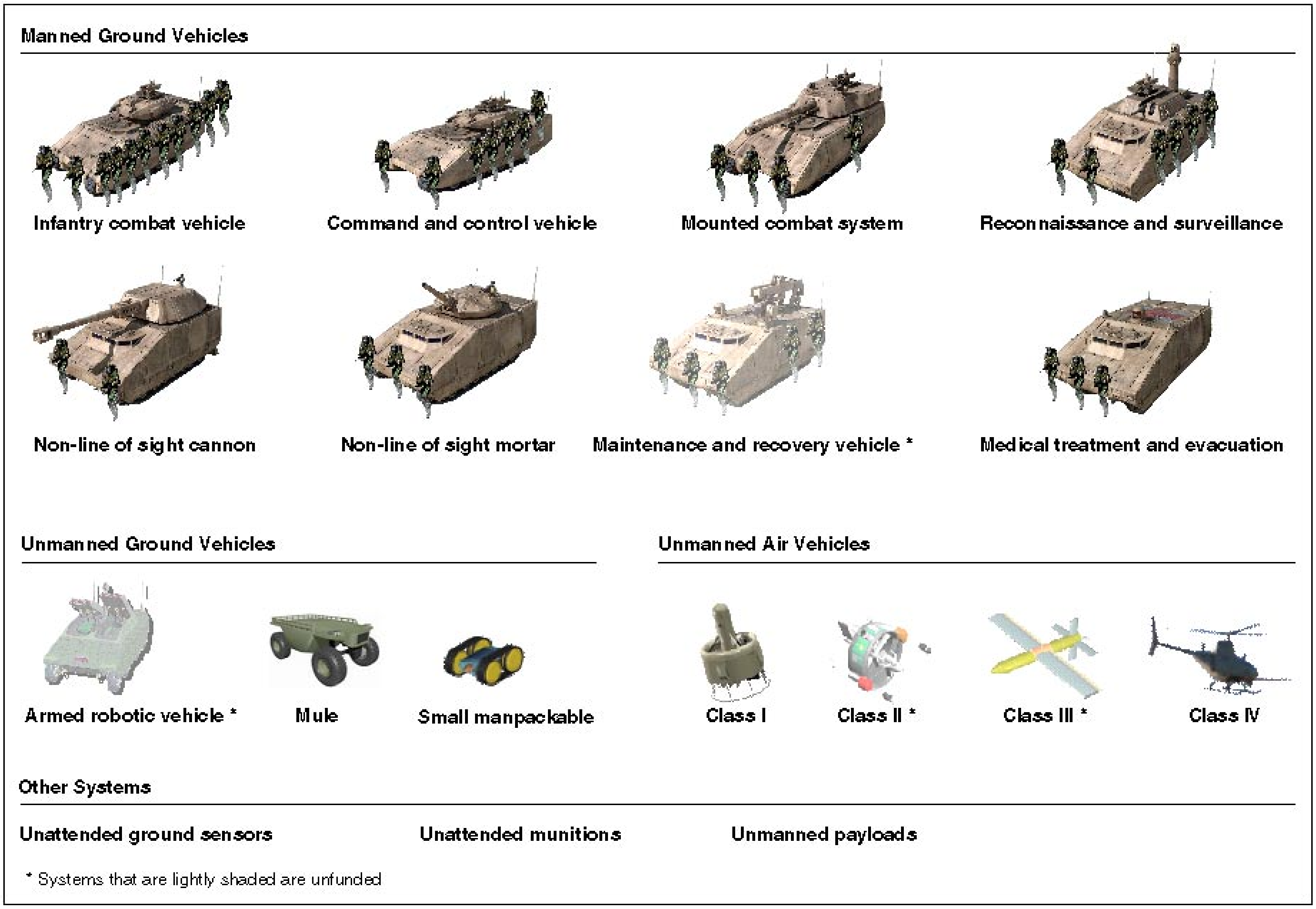
Against that backdrop, today, I will focus primarily on the equipment element of the transformation, represented by FCS.

The FCS Solution

FCS will provide the majority of weapons and sensor platforms that comprise the new brigade-like modular units of the Future Force known as Units of Action. Each unit is to be a rapidly deployable fighting organization about the size of a current Army brigade but with the combat power and lethality of a current (larger) division. The Army also expects FCS-equipped Units of Action to provide significant war-fighting capabilities to the Joint Force.

The first FCS increment will ultimately be comprised of an information network and 18 various systems—which can be characterized as manned ground systems, unmanned ground systems, and unmanned air vehicles. While some systems will play a larger role in the network than others, the network will reside in all 18 systems, providing information to them as well as taking information from them. Figure 1 shows FCS Increment 1.

Figure 1: Basic Composition of FCS Increment 1



Source: U.S. Army

The Joint Tactical Radio System and the Warfighter Information Network-Tactical are two programs outside of FCS that integrate all the various systems and soldiers together. As such, their development is crucial to the FCS network. The communications backbone of the Unit of Action will be a multi-layered mobile network centered on the Joint Tactical Radio System. According to program officials, all soldiers and FCS vehicles, including the unmanned vehicles, will employ these radios. Beyond being the primary communications component within the unit, the Joint Tactical Radio System also will assist with communications beyond the unit, to assets at higher echelons. Communications with those echelons will be enabled through the Warfighter Information Network-Tactical, which provides the overarching network background for the FCS network and is expected to conform to DOD's interoperability and network architecture directives.

Increment 1 began system development and demonstration in May 2003. Currently, only the network and 14 systems are funded. The remaining 4 systems will be introduced as funding becomes available. Current estimates are for the acquisition of Increment 1 to cost $92 billion (then-year dollars) and to achieve an initial operational capability by the end of 2010. Although the Under Secretary of Defense approved the Army's request to begin the system development and demonstration phase, he directed the Army to prepare for a full program review in November 2004. Increment 1 is expected to replace roughly one-third of the active force through about 2020, when the first 15 Units of Action are fielded.

According to program officials, the Army has not yet defined future FCS increments. However, it is important to note that the Army expects to eventually replace most of its current forces with the FCS. Much of the current Army heavy force is expected to remain in the inventory—needing to be maintained and upgraded—through at least 2020. We recently reported[2] that costs of maintaining legacy systems would be significant, but funding is likely to be extremely limited, particularly given competition for funds from transformation efforts. We concluded that maintaining legacy equipment will likely be a major challenge, necessitating funding priorities to be more clearly linked to needed capability and to long-range program strategies.

The Army intends to employ a single Lead Systems Integrator throughout the completion of Increment 1. The Lead System Integrator will be the single accountable, responsible contractor to integrate FCS on time and within budget. It will act on behalf of the Army throughout the life of the program to optimize the FCS capability, maximize competition, ensure interoperability, and maintain commonality in order to reduce life-cycle cost. In order to quickly transition into system development and demonstration and to manage the multitude of tasks associated with FCS

[2] See U.S. General Accounting Office, *Military Readiness: DOD Needs to Reassess Program Strategy, Funding Priorities, and Risks for Selected Equipment*, GAO-04-112 (Washington, D.C.: Dec. 19, 2003).

acquisition, the Army chose the Lead System Integrator approach to capitalize on industry's flexibility.

The Requirements Challenge

The Army wants the FCS-equipped Unit of Action to have a number of features. These can be described in four characteristics: lethality, survivability, responsiveness, and sustainability. The Unit of Action is to be as lethal as the current heavy force. It must have the capability to address the combat situation, set conditions, maneuver to positions of advantage, and close with and destroy enemy formations at longer ranges and greater precision than the current force. To provide this level of lethality and reduce the risk of detection, FCS must provide high single-shot effectiveness. To be as survivable as the current heavy force, the Unit of Action is primarily dependent upon the ability to kill the enemy before being detected. This depends on unit's ability to see first, understand first, act first, and finish decisively. The individual FCS systems will also rely on a layered system of protection involving several technologies that lowers the chances of a vehicle or other system being seen by the enemy; if seen, lowers the chances of being acquired; if acquired, lowers the chances of being hit; if hit, lowers the chances of being penetrated; and finally, if penetrated, increases the chances of surviving. To be responsive, Units of Action must be able to rapidly deploy anywhere in the world, be rapidly transportable via various transport modes, and be ready to fight upon arrival. To facilitate rapid transportability, FCS vehicles are being designed to match the weight and size constraints of the C-130 aircraft. The Unit of Action is to be capable of sustaining itself for periods of 3 to 7 days depending on the level of conflict. This sustainability requires subsystems with high reliability and low maintenance, reduced demand for fuel and water, highly effective offensive weapons, and a fuel-efficient engine.

Meeting all these requirements will be a difficult challenge because the solution to meet one requirement may work against another requirement. For example, the FCS vehicles' small size and lighter weight are factors that improve agility, responsiveness, and deployability. However, their lighter weight precludes the use of the traditional means to achieve survivability—heavy armor. Instead, the FCS program must use cutting-edge technology to develop systems, such as an active protection system, to achieve survivability. Yet such technology cannot be adopted if it impairs the new systems' reliability and maintainability. Weight, survivability, and reliability will have to be kept in balance.

Merits of the Concept

The essence of the FCS concept itself—to provide the lethality and survivability of the current heavy force with the sustainability and deployability of a force that weighs a fraction as much—has the intrinsic attraction of doing more with less. The concept has a number of merits, which demonstrate the Army's desire to be proactive in its approach to preparing for potential future conflicts and its willingness to break with tradition in developing an appropriate response to the changing scope of modern warfare.

- If successful, the architecture the program is developing will leverage individual capabilities of weapons and platforms and will facilitate interoperability and open systems. This architecture is a significant improvement over the traditional approach of building superior individual weapons that must be netted together after the fact. Also, the system of systems network and weapons could give acquisition managers the flexibility to make best value trade-offs across traditional program lines.
- This transformation of the Army, both in terms of operations and in equipment, is underway with the full cooperation of the Army warfighter community. In fact, the development and acquisition of FCS are being done using a collaborative relationship between the developer (program manager), the contractor, and the warfighter community. For example, the developer and the warfighter are using a disciplined approach to decompose the Unit of Action Organizational and Operational Plan and the FCS Operational Requirements Document into detailed specifications. This work is defining in detail the requirements for a Unit of Action to operate in a network-centric environment. This approach is in line with best practices to ensure that specific technical issues are understood before significant design work is done.[3]
- The Army has established sustainability as a design characteristic equal to lethality and survivability. This is an improvement over past programs, such as the Apache helicopter and the Abrams tank. These programs did not emphasize sustainability, to less than desirable results, including costly maintenance problems and low readiness rates, which persisted even after the systems were fielded. FCS' approach of emphasizing sustainability from the outset should allow operating and support costs and readiness to be evaluated early in development, when there is a

[3] Over the past 8 years, we have completed a number of reviews of best practices for managing new product developments. For a broader discussion on best practices in relation to user or warfighter involvement, see U.S. General Accounting Office, *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, D.C.: Mar. 8, 2001).

greater chance to affect those costs positively. This approach is also in line with best practices.[4]

FCS at Significant Risk of Not Delivering Required Capability Within Estimated Resources

The FCS program has yet to—and will not—demonstrate high levels of knowledge at key decision points. It thus carries significant risks for execution. At conflict are the program's technical challenges and limited time frame. The Army began system development and demonstration in May 2003 and plans to make its initial FCS production decision in November 2008—a schedule of about 5 ½ years. Seventy-five percent of the technologies were immature at the start of system development and demonstration and some will not be proven mature until after the scheduled initial production decision. First prototypes for all 14 funded systems and the network will not be demonstrated together until after the production decision and will serve both as technology demonstrators and system prototypes. They will represent the highest level of FCS demonstration before production units are delivered, as no production-representative prototypes are planned. Even this level of demonstration assumes complete success in maturing the technologies, developing the software, and integrating the systems—as well as the delivery and integration of the complementary systems outside of FCS. While the Army is embarking on an impressive array of modeling, simulation, emulation, and other demonstration techniques, actual demonstration of end items is the real proof, particularly for a revolutionary advance, such as FCS.

If the lessons learned from best practices and the experiences of past programs have any bearing, the FCS strategy is susceptible to "late cycle churn," a phrase used by private industry to describe the discovery of significant problems late in development and the attendant search for fixes when costs are high and time is short. FCS is susceptible to this kind of experience as the demonstration of multiple technologies, individual systems, the network, and the system of systems will all culminate late in development and early production.

FCS Is an Unprecedented Technical Challenge

In the Army's own words, FCS is "the greatest technology and integration challenge the Army has ever undertaken." It intends to develop a complex,

[4] See U.S. General Accounting Office, *Best Practices: Setting Requirements Differently Could Reduce Weapon Systems' Total Ownership Costs*, GAO-03-57 (Washington, D.C.: Feb. 11, 2003).

family of systems–an extensive information network and 14 major weapon systems—in less time than is typically taken to develop, demonstrate, and field a single system. The FCS Acquisition Strategy Report describes this scenario as a "dramatically reduced program schedule (which) introduces an unprecedented level of concurrency." Underscoring that assessment is the sheer scope of the technological leap required for the FCS. For example:

- A first-of-a-kind network will have to be developed.
- The 14 major weapon systems or platforms have to be designed and integrated simultaneously and within strict size and weight limitations.
- At least 53 technologies that are considered critical to achieving critical performance capabilities will need to be matured and integrated into the system of systems.
- The development, demonstration, and production of as many as 157 complementary systems will need to be synchronized with FCS content and schedule. This will also involve developing about 100 network interfaces so the FCS can be interoperable with other Army and joint forces.
- An estimated 34 million lines of software code will need to be generated (5 times that of the Joint Strike Fighter, which had been the largest defense undertaking in terms of software to be developed).

Some of these technical challenges are discussed below.

Network Development Challenges

The overall FCS capabilities are heavily dependent on a high quality of service—good information, delivered fast and reliable—from the network. However, the Army is proceeding with development of the entire FCS system of systems before demonstrating that the network will deliver as expected. Many developmental efforts will need to be successful for the network to perform as expected. For each effort, a product—whether software or hardware—must first be delivered and then demonstrated individually and collectively. The success of these efforts is essential to the high quality of service the network must provide to each Unit of Action. In some cases, an individual technology may be a linchpin—that is, if it does not work, the network's performance may be unacceptable. In other cases, lower than expected performance across a number of individual technologies could collectively degrade network performance below acceptable levels. Some key challenges are highlighted below:

- System of Systems Common Operating Environment is a software layer that enables interoperability with external systems and manages the distribution of information and software applications across the distributed network of FCS systems. According to program officials, the System of Systems Common Operating Environment is on the critical path for most FCS software development efforts.

- The Joint Tactical Radio System and the Warfighter Information Network-Tactical, and several new wideband waveforms—all in development—are essential to the operation of the FCS network. It is vital that these complementary developments be available in a timely manner for the currently planned demonstrations of the network.
- The information-centric nature of FCS operations will require a great deal of bandwidth to allow large amounts of information to be transmitted across the wireless network. However, the radio frequency spectrum is a finite resource, and there is a great deal of competition and demand for it. An internal study revealed that FCS bandwidth demand was 10 times greater than what was actually available. As a result, the program initiated a series of trade studies to examine and reassess bandwidth requirements of various FCS assets. The results of these studies may have a dramatic effect on the FCS network. The Army has already made a number of changes to the network design to use available bandwidth more efficiently and to reduce bandwidth demand.
- After determining that Unmanned Aerial Vehicle (UAV) sensor missions would constitute the largest consumption of network bandwidth, the Army started a new wideband waveform development effort, using the higher frequency bands. This effort will also require new updated Joint Tactical Radio System hardware and new antennas in addition to a new waveform.
- Sophisticated attackers could compromise the security of the FCS network, which is critical to the success of the system of systems concept. Such an attack could degrade the systems' war-fighting ability and jeopardize the security of Army soldiers. The Army is developing specialized protection techniques as there is only limited commercial or government software currently available that will adequately protect a mobile network like the one proposed for FCS.

UAV Development Challenges

FCS Increment 1 includes four classes of UAVs that cover increasing areas of responsibility. According to program officials, two of the UAV classes are currently unfunded and are currently not being developed. The Army plans to develop, produce and field them if funding becomes available. Within the FCS concept, UAV roles include reconnaissance, target acquisition and designation, mine detection, and wide-band communications relay. The required UAVs will need to be designed, developed, and demonstrated within the 5½-year period prior to the initial

FCS production decision. As we recently testified,[5] DOD's experiences show that it is very difficult to field UAVs. Over the last 5 years, only three systems have matured to the point that they were able to use procurement funding.

Manned Ground Vehicle Development Challenges

FCS Increment 1 includes eight manned ground systems, however, one—the maintenance and recovery vehicle—is unfunded. The Army plans to use the Heavy Expanded Mobility Tactical Truck-Wrecker in its place in the Unit of Action. The remaining seven manned ground systems require critical individual and common technologies to meet required capabilities. For example, the Mounted Combat System will require, among other new technologies, a newly developed lightweight weapon for lethality; a hybrid electric drive system and a high-density engine for mobility; advanced armors, an active protection system, and advanced signature management systems for survivability; a Joint Tactical Radio System with the wideband waveform for communications and network connection; a computer-generated force system for training; and a water generation system for sustainability.

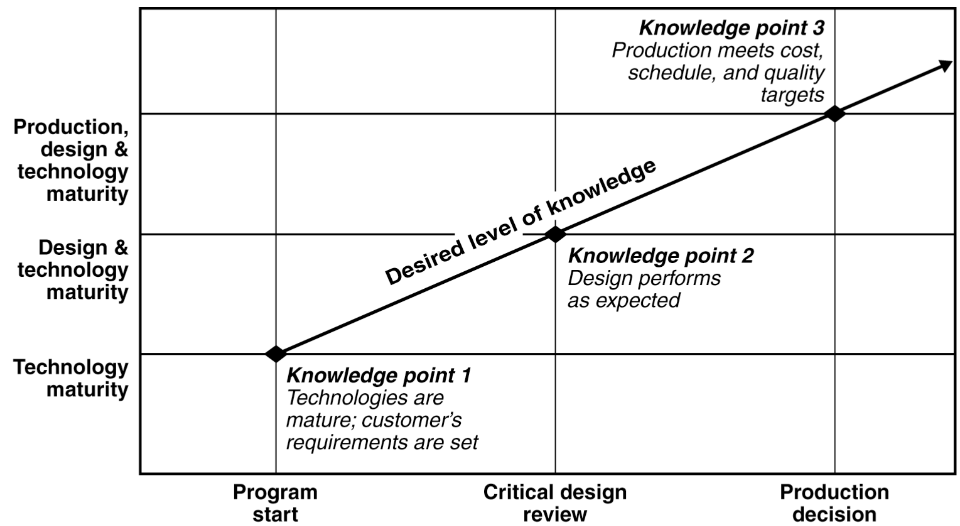
Under other circumstances, each of the seven manned ground systems would be a major acquisition program on par with the Army's past major ground systems such as the Abrams tank, the Bradley Fighting Vehicle, and the Crusader Artillery System. As such, each requires a major effort to develop, design, and demonstrate the individual vehicles. Recognizing that a number of subsystems will be common among the vehicles, meeting the Army's schedule will be a challenge as this effort must take place within the 5½-year period prior to the initial FCS production decision.

[5] See U.S. General Accounting Office, *Unmanned Aerial Vehicles: Major Management Issues Facing DOD's Development and Fielding Efforts*, GAO-04-530T (Washington, D.C.: Mar. 17, 2004).

High Levels of Demonstrated Knowledge Are Key to Getting Desired Outcomes

We have found for a program to deliver a successful product within identified resources, managers should build high levels of demonstrated knowledge before significant commitments are made.[6] Figure 2 depicts the key elements for building knowledge.

Figure 2: Best Practices Model Focuses on Three Critical Knowledge Points



Source: GAO (analysis).

This knowledge build, which takes place over the course of a program, can be broken down into three knowledge points to be attained at key junctures in the program:

- At knowledge point 1, the customer's needs should match the developer's available resources—mature technologies, time, and funding. This is

[6] See U.S. General Accounting Office, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002); *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcome*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999); and *Best Practices: Successful Application to Weapon Acquisition Requires Changes in DOD's Environment*, GAO/NSIAD-98-56 (Washington, D.C.: Feb. 24, 1998).

indicated by the demonstrated maturity of the technologies needed to meet customer needs.[7]

- At knowledge point 2, the product's design is stable and has demonstrated that it is capable of meeting performance requirements. This is indicated by the number of engineering drawings that are releasable to manufacturing.
- At knowledge point 3, the product must be producible within cost, schedule, and quality targets and have demonstrated its reliability. It is also the point at which the design must demonstrate that it performs as needed. Indicators include the number of production processes in statistical control.

The three knowledge points are related, in that a delay in attaining one delays those that follow. Thus, if the technologies needed to meet requirements are not mature, design and production maturity will be delayed. For this reason, the first knowledge point is the most important. DOD's acquisition policy has adopted the knowledge-based approach to acquisitions. Translating this approach to DOD's acquisition policy, a weapon system following best practices would achieve knowledge point 1 by the start of system development and demonstration, knowledge point 2 at critical design review (about halfway through development), and knowledge point 3 by the start of production.

For the most part, all three knowledge points are eventually attained on a completed product. The difference between highly successful product developments—those that deliver superior products within cost and schedule projections—and problematic product developments is how this knowledge is built and how early in the development cycle each knowledge point is attained. If a program is attaining the desired levels of knowledge, it has less risk—but not zero risk—of future problems. Likewise, if a program shows a gap between demonstrated knowledge and best practices, it indicates an increased risk—not a guarantee—of future problems. Typically, these problems cost more money than has been identified and take more time than has been planned.

DOD programs that have not attained these levels of knowledge have experienced cost increases and schedule delays. We have recently

[7] Technology readiness levels are a way to measure the maturity of technology. Technology is considered sufficiently mature to start a program when it reaches a readiness level of 7. This involves a system prototype demonstration in an operational environment. The prototype is near or at the planned operational system.

reported on such experiences with the F/A-22, the Advanced SEAL Delivery System, the Airborne Laser, and the Space Based Infrared System High. For example, the technology and design matured late in the F/A-22 program and have contributed to numerous problems. Avionics have experienced major development problems and have driven large cost increases and caused testing delays.

Even Assuming Success, FCS Strategy Will Not Demonstrate High Levels of Knowledge

The FCS program started system development and demonstration with significantly less knowledge than called for by best practices. This knowledge deficit is likely to delay the demonstration of subsequent design and production knowledge at later junctures and puts the program at risk of cost growth, schedule delays, and performance shortfalls. Two factors contributed to not having a match between resources and requirements at the start of system development and demonstration: 75 percent of critical technologies were not mature and requirements were not well defined. Later in the program, when the initial production decision is made, a knowledge gap will still exist even if the program proceeds on schedule. For example, prototypes of all 14 funded systems, the network, and the software version needed for initial operational capability will not be brought together and tested for the first time until after the production decision. Further, as production-representative prototypes will not be built, it does not appear that much demonstration of production process maturity can occur before the production decision.

Knowledge Gap at Start of System Development and Demonstration

Using best practices, at the start of system development and demonstration, a program's critical technologies should be demonstrated to a technology readiness level of 7. This means the technology should be in the form, fit, and function needed for the intended product and should be demonstrated in a realistic environment, such as on a surrogate platform. While DOD's policy states a preference for a technology readiness level of 7, it accepts a minimum of a level 6. According to program officials, technologies were accepted for FCS if they were at level 6 or if the Army determined that the technologies would reach a readiness level of 6 before the July 2006 critical design review. To put this discussion of technology maturity in perspective, the difficulties the F/A-22 fighter are currently experiencing with its avionics system are, in essence, the consequence of not demonstrating a technology readiness level of 7 until late in the program.

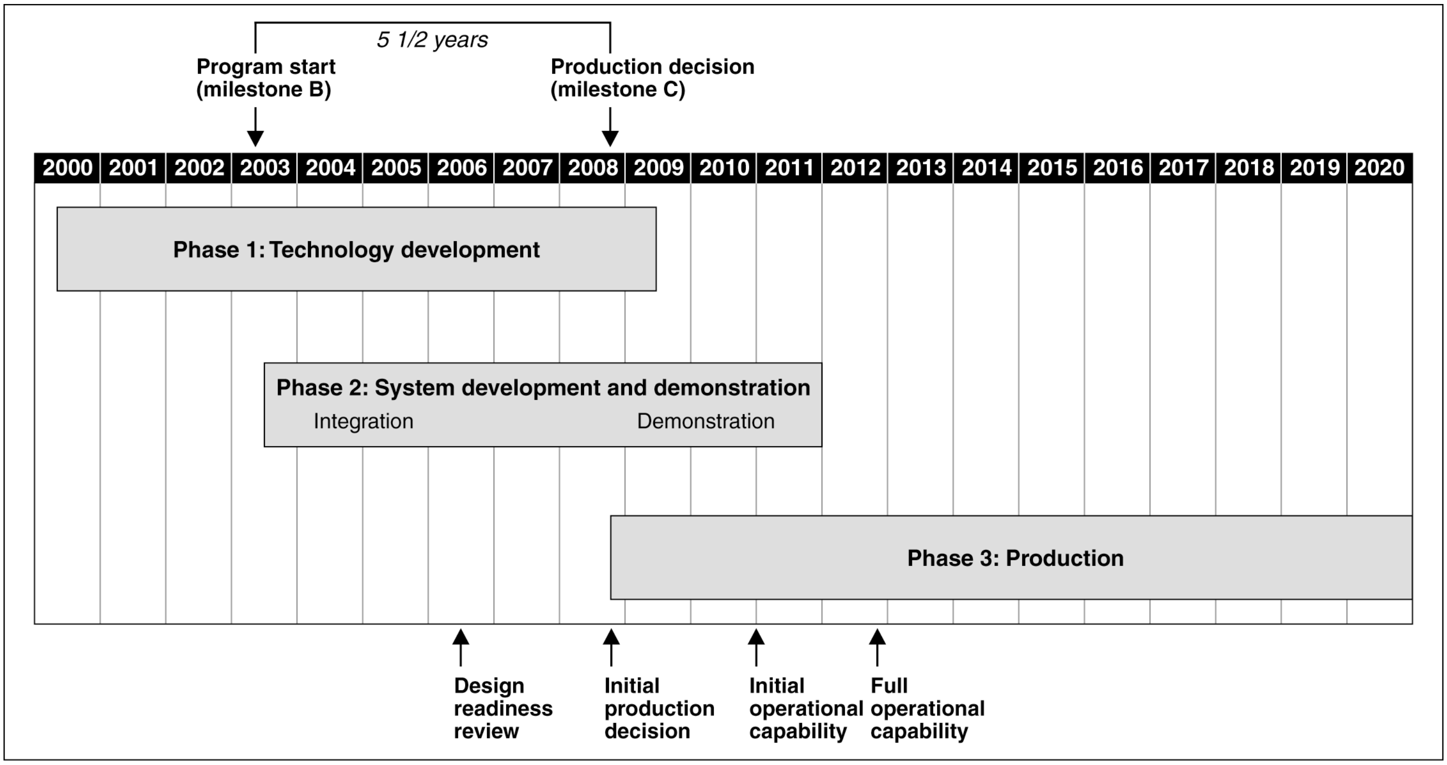
Consequently, the Army started FCS system development and demonstration phase with about 75 percent of its critical technologies below level 7, with many at level 5 and several at levels 3 and 4. Since then, progress has been made, but the Army expects that, by the full program review in November 2004, only 58 percent of the program's critical technologies would be matured to a technology readiness level of 6 or higher. The Army estimates that 95 percent of the technologies will reach level 6 by the critical design review. The program does not expect all FCS critical technologies to be demonstrated to level 7 until mid-2009, after the initial production decision and about 6 years after the start of system development and demonstration.

The second factor keeping the Army from matching resources with customer's needs before starting the system development and demonstration phase was that it did not have an adequate definition of the FCS requirements. The program continues to work on defining the requirements for the FCS system of systems and the individual systems. System requirements may not be completely defined until at least the preliminary design review in April 2005 and, perhaps, as late as the critical design review in July 2006. The program still has a number of key design decisions to be made that will have major impacts on the FCS requirements and the conceptual design of FCS Increment 1. Currently, the program has 129 trade studies underway including 5 studies that are critical and due to be completed soon. For example, a critical study with great potential impact is determining the upper weight limit of the individual FCS manned platforms. This determination could affect the FCS transportability, lethality, survivability, sustainability, and responsiveness capabilities. These and other open questions on the FCS requirements will need to be answered in order for the detailed design work to proceed and ultimately to be stabilized at the critical design review.

Demonstrated Knowledge Will Be Low at Production Decision

To go from system development and demonstration to production in 5 ½ years, the FCS program depends on a highly concurrent approach to developing technology, as well as to designing, building, testing, and producing systems. This level of concurrency resulted from the Army's establishment of 2010 as its target for initial operating capability for the first FCS Unit of Action. Army officials acknowledge that this is an ambitious date and that the program was not really ready for system development and demonstration when it was approved. However, the officials believe it was necessary to create "irreversible momentum" for the program. Army leaders viewed such momentum as necessary to change Army culture. The result is an accelerated schedule-driven program, as depicted in figure 3, rather than an event-driven program.

Figure 3: The FCS Acquisition Schedule Includes Periods of Concurrent Development



Source: U.S. Army.

Even if the program successfully completes this schedule, it will yield lower levels of demonstrated knowledge than suggested by best practices and DOD's acquisition policy. Significant commitments will thus be made to FCS production before requisite knowledge is available. For example:

- Technology development is expected to continue through the production decision.
- At the design readiness review (critical design review) in July 2006, technology development will still be ongoing, putting at risk the stability of ongoing system integration work.
- In December 2007, while technology development and system integration are continuing and first prototypes are being delivered, the Army plans to

begin long lead item procurement[8] and to begin funding for the production facilities.

- In November 2008, the initial production decision is expected to be made. However, program officials said that some technologies will not have reached level 7 by that time, and the system of systems demonstration will remain to be done.
- In early 2010, as production deliveries have started, the Army plans to finish Integrated System Development and Demonstration Test Phase 5.1, the first full demonstration of all FCS components as an integrated system. Testing and demonstration will continue until the full rate production decision in mid-2013.
- The initial operational capability is planned for December 2010.

With the FCS concurrent strategy, much demonstration of knowledge will occur late in development and early in production, as technologies mature, prototypes are delivered, and the network and systems are brought together as a system of systems. This makes the program susceptible to "late cycle churn," a condition that we reported[9] on in 2000. Late cycle churn is a phrase private industry has used to describe the efforts to fix a significant problem that is discovered late in a product's development. Often, it is a test that reveals the problem. The churn refers to the additional—and unanticipated—time, money, and effort that must be invested to overcome the problem. Problems are most devastating when they delay product delivery, increase product cost, or "escape" to the customer.

The discovery of problems in testing conducted late in development is a fairly common occurrence on DOD programs, as is the attendant late cycle churn. Often, tests of a full system, such as launching a missile or flying an aircraft, become the vehicles for discovering problems that could have been found earlier and corrected less expensively. When significant problems are revealed late in a weapon system's development, the reaction—or churn—can take several forms: extending schedules to increase the investment in more prototypes and testing, terminating the program, or redesigning and modifying weapons that have already made it

[8] Long lead items are those components or a system or piece of equipment for which the times to design and fabricate are the longest, and therefore, to which an early commitment of funds may be desirable in order to meet the earliest possible date of system completion.

[9] See U.S. General Accounting Office, *Best Practices: A More Constructive Approach is Key to Better Weapon System Outcomes*, GAO/NSIAD-00-199 (Washington, D.C.: July 31, 2000).

to the field. Over the years, we have reported numerous instances in which weapon system problems were discovered late in the development cycle.

The Army has embarked on an impressive plan to mitigate risk using modeling, simulation, emulation, hardware in the loop, and system integration laboratories throughout FCS development. This is a laudable approach designed to reduce the dependence on late testing to gain valuable information about design progress. However, on a first-of-a-kind system like FCS that represents a radical departure from current systems, actual testing of all the components integrated together is the final proof that the system works both as predicted and as needed.

If the FCS strategy does not deliver the system of systems as planned, the Army is still prepared to go forward with production and fielding. The Army's Acquisition Strategy Report states that at the Initial Production Decision, all elements of the FCS may not be ready for initial production and will require a continuation of system development and demonstration efforts to complete integration and testing in accordance with the program–tailoring plan. For those that need more time, FCS program manager will present to the Milestone Decision Authority a path forward, with supporting analysis. In addition, the Army will accept existing systems in lieu of actual FCS systems to reach initial operational capability.

Alternatives to FCS Strategy Merit Consideration

We have reported on options that warrant consideration as alternatives for developing FCS capabilities with less risk.[10] Alternatives are still viable and worth considering, particularly before major funding and programmatic commitments are made. If the FCS program proceeds as planned and does experience problems later in development, it may pose a real dilemma for decision makers. Typically, performance, schedule, and cost problems on weapon system programs are accommodated by lowering requirements and increasing funding. If the FCS program proceeds on its current path until problems occur in demonstration, traditional solutions may not be available because of the significant role it must fulfill and its financial magnitude.

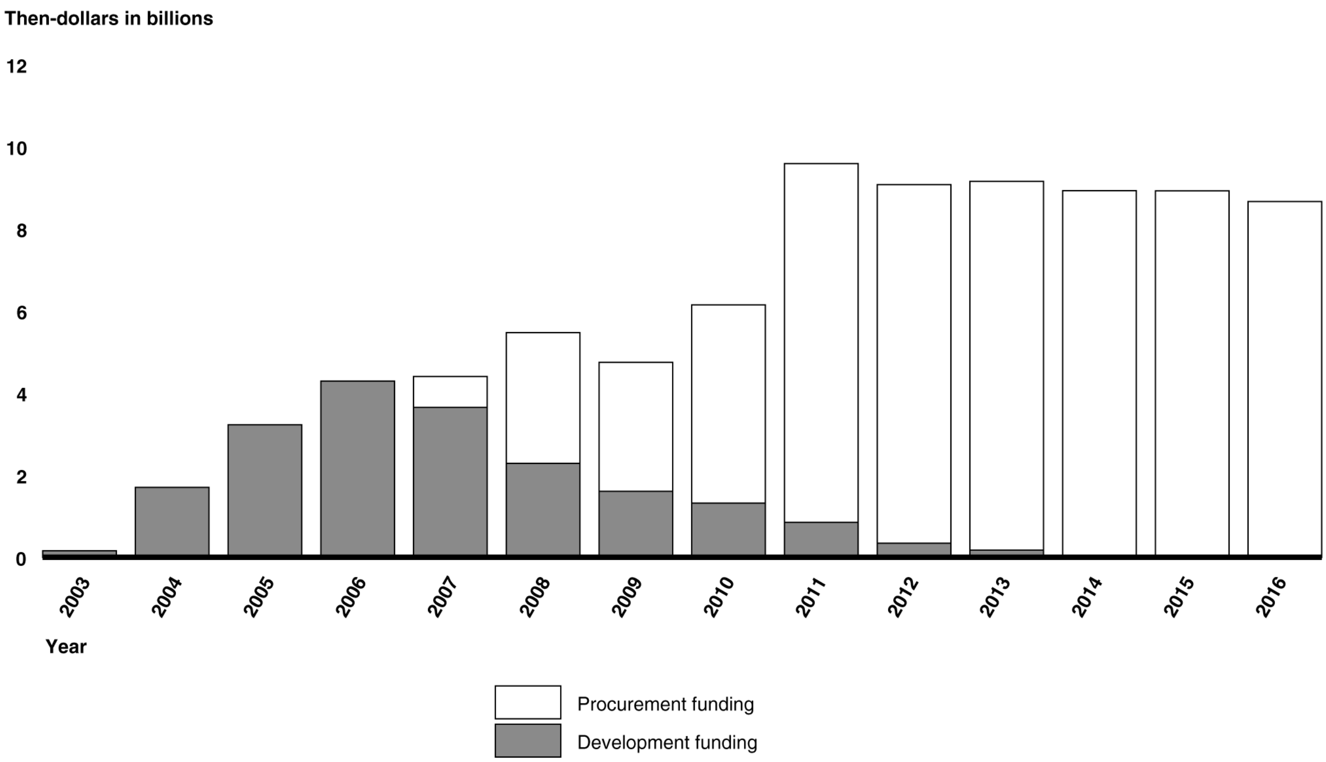
[10] See U.S. General Accounting Office, *Issues Facing the Army's Future Combat Systems Program*, GAO-03-1010R (Washington, D.C.: Aug. 13, 2003).

Alternatives Featuring Lowering FCS Performance or Increasing Funds May Be Difficult

While there is a significant amount of potential flexibility among the various FCS systems and technologies, collectively the system of systems has to meet a very high standard. It has to be as lethal and survivable as the current force and its combat vehicles have to be a fraction of the weight of current vehicles to be air transportable on the C-130 aircraft. These "must haves" constrain the flexibility in relaxing requirements for the FCS system of systems.

The opportunity for increasing funds to cover cost increases poses a challenge because FCS already dominates the Army's investment budget. It might be difficult to find enough other programs to cut or defer to offset FCS increases. Assuming the Army's acquisition cost estimates are accurate and the program will succeed according to plan, the FCS investment for even the first increment is huge—$92 billion (in then-year dollars). These assumptions are optimistic as risks make problems likely, the cost estimate was based on an immature program, and budget forecasts have already forced deferral of four FCS systems. As estimated, FCS will command a significant share of the Army's acquisition budget, particularly that of ground combat vehicles, for the foreseeable future. In fiscal year 2005, the FCS budget request of $3.2 billion accounts for 52 percent of the Army's proposed research, development, test and evaluation spending on programs in system development and demonstration and 31 percent of that expected for all Army research, development, test, and evaluation activities. See figure 4 for FCS costs through 2016.

Figure 4: FCS Funding Climbs, Then Levels Off at Nearly $9 Billion Annually



Source: U.S. Army.

The ramp up in FCS research and development funding is very steep, going from $157 million in fiscal 2003 to $1.7 billion in fiscal 2004 to a projected $3.2 billion in fiscal years 2005 and topping out at about $4.3 billion in fiscal 2006. FCS procurement funding is projected to start in fiscal 2007 at $750 million and ramp up to an average of about $3.2 billion in fiscal years 2008 and 2009. In late development (2008-2009) the total FCS costs will run about $5 billion per year. After 2008, FCS will command nearly 100 percent of the funding for procurement of Army ground combat vehicles. After 2011, FCS costs will run nearly $9 billion annually to procure enough FCS equipment for two Units of Action per year. According to Army officials, it is not yet clear that the Army can afford this level of annual procurement funding for FCS. The consequences of even modest cost increases and schedule delays for FCS would be dramatic. For example, we believe that a 1-year delay late in FCS development, not an uncommon occurrence for other DOD programs, could cost $4 billion to $5 billion. A modest 10 percent increase in production cost would amount to over $7 billion.

In a broader context, any discussion of DOD's sizeable investment that remains in the FCS program must also be viewed within the context of the fiscal imbalance facing the nation within the next 10 years. There are important competing priorities, both within and external to DOD's budget, that require a sound and sustainable business case for DOD's acquisition programs based on clear priorities, comprehensive needs assessments, and a thorough analysis of available resources. Funding specific program or activities will undoubtedly create shortfalls in others.

Alternatives for Proceeding

Alternatives to developing FCS capabilities that do not follow a concurrent strategy are feasible, if acted upon early enough. Alternatives should have the common elements of building more knowledge before making program commitments; preserving the advantages of the FCS concept, such as defining an architecture before individual systems are developed; and spinning off mature technologies to systems already fielded. Alternatives that would allow for building such knowledge include:

- Adding more time to the FCS program with its scope intact to reduce concurrency would lower risk. However, until technologies are mature and more is known about whether the FCS concept will work, there still would not be a sound basis for estimating how much time will be needed to build the knowledge needed to complete system development and demonstration.
- Focus on the development and demonstration of its most critical capabilities first, such as the network. This could be done by conducting one or more advanced technology demonstrations[11] to reduce technical and integration risks in critical areas, then proceed with an acquisition program. This would take more time than if the current FCS schedule were successfully carried out.
- Focus on maturing the most critical technologies first, then bundle them in demonstrations of capabilities, such as Advanced Concept Technology Demonstrations,[12] then proceed with an acquisition program that would attain sufficient knowledge at the right acquisition junctures. This would

[11] Advanced technology demonstrations are used to demonstrate the maturity and potential of advanced technologies for enhanced military operational capability or cost-effectiveness and reduce technical risks and uncertainties at the relatively low costs of informal processes.

[12] An Advanced Concept Technology Demonstration is a demonstration of the military utility of a significant new capability and an assessment to clearly establish operational utility and system integrity.

also take more time than if the current FCS schedule were successfully carried out.

Objectives, Scope, and Methodology

To develop the information on whether the FCS program was following a knowledge-based acquisition strategy and the current status of that strategy, we contacted, interviewed, and obtained documents from officials of the Offices of the Under Secretary of Defense (Acquisition, Technology, and Logistics); the Secretary of Defense Cost Analysis Improvement Group; the Assistant Secretary of the Army (Acquisition, Logistics, and Technology); the Program Executive Officer for Ground Combat Systems; the Program Manager for Future Combat Systems; and the Future Combat Systems Lead Systems Integrator. We reviewed, among other documents, the Objective Force Operational and Organizational Plan for Maneuver Unit of Action and the Future Combat Systems' Operational Requirements Document; the Acquisition Strategy Report, the Baseline Cost Report, the Critical Technology Assessment and Technology Risk Mitigation Plans, and the Integrated Master Schedule. We attended the FCS Business Management Quarterly Meetings, Management Quarterly Review Meetings, and Directors Quarterly Review Meetings.

In our assessment of the FCS, we used the knowledge-based acquisition practices drawn from our large body of past work, as well as DOD's acquisition policy and the experiences of other programs. We discussed the issues presented in this statement with officials from the Army and the Secretary of Defense, and made several changes as a result. We performed our review from July 2003 to March 2004 in accordance with generally accepted auditing standards.

Mr. Chairman, this concludes my prepared statement. I would be happy to answer any questions that you or members of the subcommittee may have.

Contacts and Staff Acknowledgments

For future questions about this statement, please contact me at (202) 512-4841. Individuals making key contributions to this statement include Lily J. Chin, Marcus C. Ferguson, Lawrence Gaston, Jr., William R. Graveline, W. Stan Lipscomb, John P. Swain, and Carrie R. Wilson.

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