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DEFENSE ACQUISITIONS

Future Combat Systems Challenges and Prospects for Success

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Highlights of [GAO-05-428T](#), a testimony before the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives

Why GAO Did This Study

FCS is the core of Army efforts to create a lighter, more agile, capable force: a \$108 billion investment to provide a new generation of 18 manned and unmanned ground vehicles, air vehicles, sensors, and munitions linked by an information network. Although system development and demonstration began in May 2003, the program was restructured in July 2004, including processes to make FCS capabilities available to current forces.

GAO has been asked to assess (1) FCS technical and managerial challenges; (2) prospects for delivering FCS within cost and scheduled objectives; and (3) options for proceeding.

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Future Combat Systems Challenges and Prospects for Success

What GAO Found

In its unprecedented complexity, FCS confronts the Army with significant technical and managerial challenges in its requirements, development, finance, and management. Technical challenges include the need for FCS vehicles to be smaller, weigh less, and be as lethal and survivable as current vehicles, which requires (1) a network to collect and deliver vast amounts of intelligence and communications information and (2) individual systems, such as manned ground vehicles, that are as complex as fighter aircraft. Its cost will be very high: its first increment—enough to equip about 1/3 of the force—will cost over \$108 billion, with annual funding requests running from \$3 billion to \$9 billion per year. The program's pace and complexity also pose significant management challenges. The Army is using a Lead System Integrator to manage FCS and is using a contracting instrument—Other Transaction Agreement—that allows for more flexible negotiation of roles, responsibilities, and rights with the integrator.

The FCS is at significant risk for not delivering required capability within budgeted resources. Currently, about 9½ years is allowed from development start to production decision. DOD typically needs this period of time to develop a single advanced system, yet FCS is far greater in scope. The program's level of knowledge is far below that suggested by best practices or DOD policy: Nearly 2 years after program launch and with \$4.6 billion invested, requirements are not firm and only 1 of over 50 technologies are mature. As planned, the program will attain the level of knowledge in 2008 that it should have had in 2003, but things are not going as planned. Progress in critical areas—such as the network, software, and requirements—has in fact been slower, and FCS is therefore likely to encounter problems late in development, when they are very costly to correct. Given the scope of the program, the impact of cost growth could be dire.

To make FCS an effective acquisition program different approaches must be considered, including (1) setting the first stage of the program to demonstrate a worthwhile military capability, mature technology, and firm requirements; and (2) bundling its other capabilities into advanced technology demonstrators until they can be put in a future stage, which will provide guidance for decisions on requirements, lower the cost of development, and make for more reasonable cost and schedule estimates for future stages.

www.gao.gov/cgi-bin/getrpt?GAO-05-428T.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Paul Francis at (202) 512-2811 or francisp@gao.gov.

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 family 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. It consists of an information network linking a new generation of 18 manned and unmanned ground vehicles, air vehicles, sensors, and munitions. FCS began system development and demonstration in May 2003. In July 2004, the Army announced a major restructuring of the program, including plans for transitioning FCS capabilities to current forces. Total costs of the restructured program have not yet been estimated but will be at least \$108 billion, in fiscal year 2005 dollars. The fiscal year 2005 budget provides \$2.8 billion in research and development funds for FCS; the fiscal year 2006 budget requests an increase to \$3.4 billion.

Today, I would like to discuss (1) the technical and managerial challenges of the FCS program; (2) the prospects for delivering FCS capabilities within cost and scheduled objectives; and (3) considerations on how to proceed.

Summary

The FCS program faces significant challenges in setting requirements, developing systems, financing development, and managing the effort. The Army has set the bar for requirements very high. FCS vehicles are to be a fraction of the weight of current vehicles, yet are to be as lethal and survivable. Their light weight and small size are critical to meeting the other Army goals: more mobile forces that are easier to sustain in combat. For FCS-equipped units to see and hit the enemy first, rather than to rely on heavy armor to survive, the Army must develop (1) a network to collect, process, and deliver vast amounts of intelligence and communications information and (2) individual systems, such as manned ground vehicles, that have been likened in complexity to fighter aircraft. FCS is a development of unprecedented complexity for the Army. From a financial standpoint, the first increment of FCS—enough to equip about 1/3 of the force—will cost at least \$108 billion. Funding requests will run from over \$3 billion per year to about \$9 billion per year at a time when the Army faces the competing demands of sustaining current operations, recapitalizing the current force, and paying for modularization. Finally, because of the management challenge the program's pace and complexity pose, the Army has turned to a Lead System Integrator to manage the entire effort and is making use of a contracting instrument known as Other

Transaction Agreement, which allows the parties to negotiate contract terms based on the program requirements and their needs.

As restructured, the FCS strategy includes 4 additional years to reduce risk, increase the demonstration of FCS capabilities, and harvest successes for the current force. Even with these improvements, the FCS is still at significant risk for not delivering planned capability within budgeted resources. This risk stems from the scope of the program's technical challenges and the low level of knowledge demonstrated at this point. The current schedule allows about 9½ years from development start to the production decision. FCS is developing multiple systems and a network within a period of time that DOD typically needs to develop a single advanced system. The FCS has demonstrated a level of knowledge far below that suggested by best practices or DOD policy. Nearly 2 years after program launch and about \$4.6 billion invested to date, requirements are not firm and only 1 of over 50 technologies are mature—activities that should have been done before the start of system development and demonstration. If everything goes as planned, the program will attain the level of knowledge in 2008 that it should have had before it started in 2003. But things are not going as planned. Progress in critical areas, such as the network, software, and requirements has been slower than planned. Proceeding with such low levels of knowledge makes it likely that FCS will encounter problems late in development, when they are costly to correct. The relatively immature state of program knowledge at this point provides an insufficient basis for making a good cost estimate. Independent estimates should provide more information but are not yet completed. If the cost estimate for FCS is no more accurate than traditional estimates, the impact of cost growth could be substantial, given the program's magnitude.

At this point, the FCS provides a concept that has been laid out in some detail, an architecture or framework for integrating individual capabilities, and an investment strategy for how to acquire those capabilities. It is not yet a good fit as an acquisition program. If FCS-like capabilities are to be made acquirable—for which the Army has made a compelling case—then different approaches for FCS warrant consideration because they offer building higher levels of knowledge and thus lower risk. One approach, in keeping with DOD acquisition policy and best practices, would be to set the first spiral as the program of record for system development and demonstration. To make such a spiral executable, it should meet the standards of providing a worthwhile military capability, having mature technology, and having firm requirements. Other capabilities currently in the FCS program could be taken out of system development and

demonstration and instead be bundled into advanced technology demonstrations that could develop and experiment with advanced technologies in the more conducive environment of science and technology until they are ready to be put into a future spiral. Advancing technologies in this way will enable knowledge to guide decisions on requirements, lower the cost of development, and make for more reasonable cost and schedule estimates for future spirals.

Background

Army Transformation and the FCS Concept

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. This translates into a force that is responsive, technologically advanced, and versatile. These qualities are intended to ensure the Future Force's long-term dominance over evolving, sophisticated threats. The Future Force is to be offensively oriented and will employ revolutionary operational concepts, enabled by new technology. This force is to fight very differently than the Army has in the past, using easily transportable lightweight vehicles, rather than traditional heavily armored vehicles. The Army envisions a new way of fighting that depends on networking the force, which involves linking people, platforms, weapons, and sensors seamlessly together.

The Army has determined that it needs more agile forces. 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 it the initiative. Agile forces would allow commanders of small units the authority and high quality information to act quickly to respond to dynamic situations.

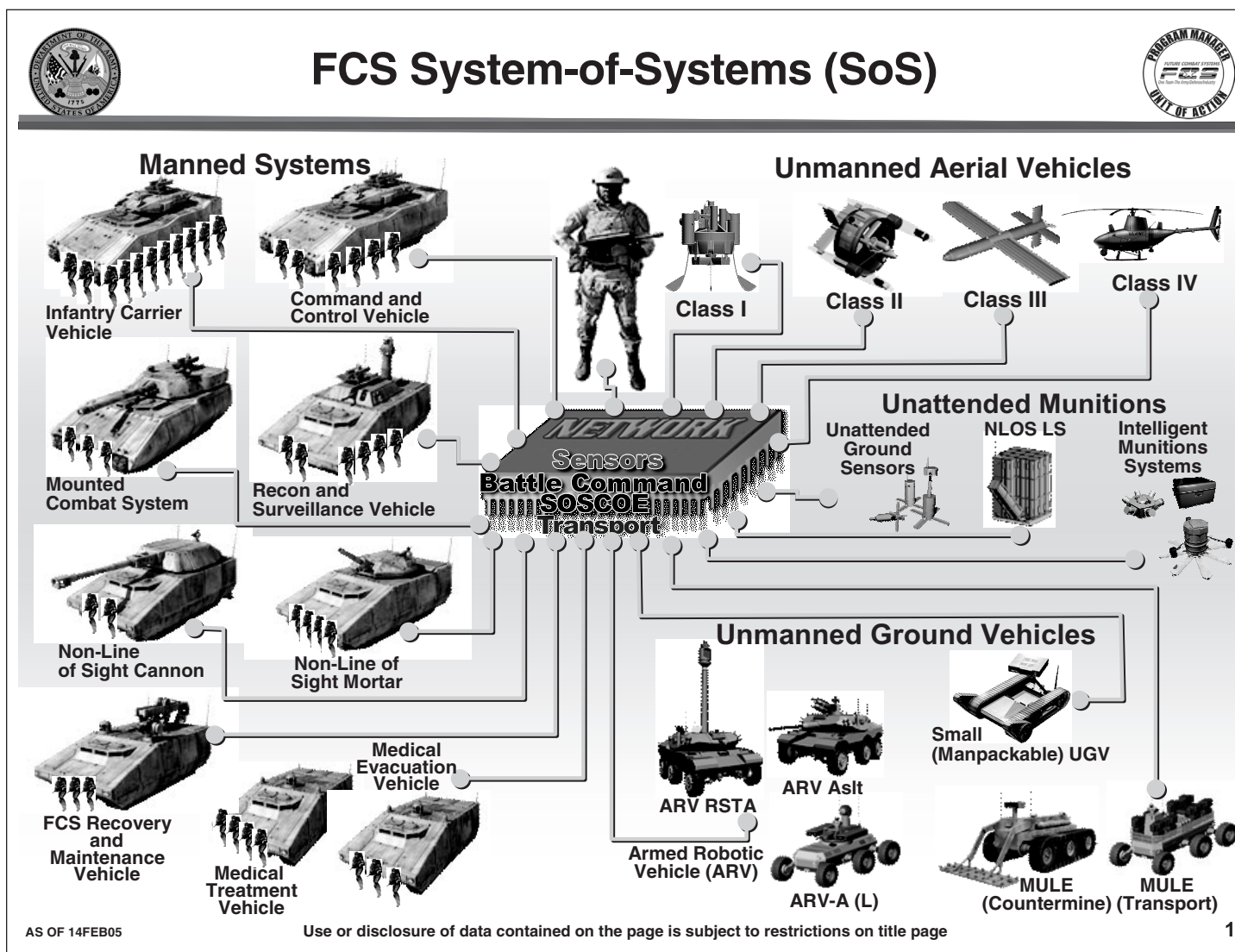
To be successful, therefore, the transformation must include more than new weapons. It must be extensive, encompassing tactics and doctrine as well as the very culture and organization of the Army.

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 the current larger division. The Army also expects FCS-equipped units of action to provide significant warfighting capabilities to the overall joint force. The Army is reorganizing its current forces into modular, brigade-based units akin to units of action.

FCS is a family of 18 manned and unmanned ground vehicles, air vehicles, sensors, and munitions that will be linked by an information network. These include, among other things, eight new ground vehicles to replace current vehicles such as tanks, infantry carriers and self-propelled howitzers, four different unmanned aerial vehicles, several unmanned ground vehicles, and attack missiles that can be positioned in a box-like structure.

Figure 1: FCS Increment 1



Source: U.S. Army.

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 a hit.

The essence of the FCS concept itself—to provide the lethality and survivability of the current heavy force with the sustainability and responsiveness of a force that weighs a fraction as much—has the intrinsic attraction of doing more with less. The FCS concept has a number of progressive features, 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 program will leverage individual capabilities of weapons and platforms and will facilitate interoperability and open system designs. This 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 managers the flexibility to make best value tradeoffs across traditional program lines. This transformation of the Army, both in terms of operations and equipment, is underway with the full cooperation of the Army warfighter community. In fact, the development and acquisition of FCS is being accomplished using a collaborative relationship between the developer (program manager), the contractor, and the warfighter community.

FCS Program Has Been Restructured During the Last Year

The FCS program was approved to start system development and demonstration in May 2003. On July 21, 2004, the Army announced its plans to restructure the program. The restructuring responded to direction from the Army Chief of Staff and addresses risks and other issues identified by external analyses. Its objectives include:

- Spinning off ripe FCS capabilities to current force units;
- Meeting Congressional language for fielding the Non-Line of Sight Cannon;
- Retaining the system-of-systems focus and fielding all 18 systems;
- Increasing the overall schedule by 4 years; and
- Developing a dedicated evaluation unit to demonstrate FCS capabilities

The program restructuring contained several features that reduce risk—adding four additional years to develop and mature the manned ground vehicles; adding demonstrations and experimentation; and establishing an evaluation unit to demonstrate FCS capabilities. The program restructuring also adds scope to the program by reintroducing four deferred systems, adding four discrete spirals of FCS capabilities to the current force, and accelerating the development of the network. About \$6.1 billion was added to the system development and demonstration contract and the Army has recently announced that the detailed revision of the contract has been completed.

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 interviewed officials of the Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics); the Secretary of Defense's Cost Analysis Improvement Group; the Assistant Secretary of the Army (Acquisition, Logistics, and Technology); the Army's Training and Doctrine Command; Surface Deployment and Distribution Command; the Program Manager for the Unit of Action (previously known as Future Combat Systems); the Future Combat Systems Lead Systems Integrator; and LSI One Team contractors. We reviewed, among other documents, 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 Management Quarterly Reviews, In-Process Reviews, and Board of Directors Reviews.

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 May 2004 to March 2005 in accordance with generally accepted auditing standards.

The FCS Program Is An Unprecedented Challenge

The FCS program faces significant challenges in setting requirements, developing systems, financing development, and managing the effort. It is the largest and most complex acquisition ever attempted by the Army.

The Requirements Challenge

The Army wants the FCS-equipped unit of action to be as lethal and survivable as the current heavy force, but to be significantly more responsive and sustainable. For the unit of action to be lethal, it must have the capability to address the combat situation, set conditions, maneuver to positions of advantage, and to engage enemy formations at longer ranges and with greater precision than the current force. To provide this level of lethality and reduce the risk of detection, FCS must provide high single-shot weapon effectiveness. To be as survivable as the current heavy force, the unit of action must find and kill the enemy before being seen and identified. 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 and hit by the enemy. To be responsive, the unit of action must be able to rapidly deploy anywhere in the world and be rapidly transportable by various means—particularly by the C-130 aircraft—and ready to fight upon arrival. To facilitate rapid transportability on the battlefield, FCS vehicles are 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—necessitating a small logistics footprint. This requires subsystems with high reliability and low maintenance, reduced demand for fuel and water, highly effective weapons, and a fuel-efficient engine.

Meeting all these requirements is unprecedented not only because of the difficulty each represents individually, but because the solution for one requirement may work against another requirement. For example, solutions for lethality could increase vehicle weight and size. Solutions for survivability could increase complexity and lower reliability. It is the performance of the information network that is the linchpin for meeting the other requirements. It is the quality and speed of the information that will enable the lethality and survivability of smaller vehicles. It is smaller vehicles that enable responsiveness and sustainability.

The Development Challenge

In the Army's own words, the FCS is "the greatest technology and integration challenge the Army has ever undertaken." It intends to concurrently develop a complex, system-of-systems—an extensive information network and 18 major weapon systems. The sheer scope of the technological leap required for the FCS involves many elements. For example:

- First-of-a-kind network will have to be developed that will entail development of unprecedented capabilities—on-the-move communications, high-speed data transmission, dramatically increased bandwidth, and simultaneous voice, data and video;
- The design and integration of 18 major weapon systems or platforms has to be done simultaneously and within strict size and weight limitations;
- At least 53 technologies that are considered critical to achieving FCS' critical performance capabilities will need to be matured and integrated into the system-of-systems;
- Synchronizing the development, demonstration, and production of as many as 157 complementary systems with the 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; and

- At least an estimated 34 million lines of software code will need to be generated (about double that of the Joint Strike Fighter, which had been the largest defense undertaking in terms of software to be developed).

The Financial Challenge

Based on the restructured program, the FCS program office initially estimated that FCS will require \$28.0 billion for research and development and around \$79.9 billion for the procurement of 15 units of action. The total program cost is expected to be at least \$107.9 billion. These are fiscal year 2005 dollars. Since this estimate, the Army has released an updated research and development cost estimate of \$30.3 billion in then-year dollars. An updated procurement estimate is not yet available. The Army is continuing to refine these cost estimates. As estimated, the 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 2006, the FCS budget request of \$3.4 billion accounts for 65 percent of the Army's proposed spending on programs in system development and demonstration and 35 percent of that expected for all research, development, test and evaluation activities.

As the FCS begins to command large budgets, it will compete with other major financial demands. Current military operations, such as in Afghanistan and Iraq, require continued funding. Since September 2001, DOD has needed over \$240 billion in supplemental appropriations to support the global war on terrorism. Current operations are also causing faster wear on existing weapons, which will need refurbishment or replacement sooner than planned. The equipment used by the current force, such as Abrams tanks and Bradley Fighting Vehicles, is expected to remain in the active inventory until at least 2030. The cost to upgrade and maintain this equipment over that length of time has not been estimated but could be substantial. Also, the cost of converting current forces to new modular, brigade-based units is expected to be at least \$48 billion. Further, FCS is part of a significant surge in the demand for new weapons. Just 4 years ago, the top 5 weapon systems cost about \$280 billion; today, in the same base year dollars, the top 5 weapon systems cost about \$521 billion. If megasystems like FCS are estimated and managed with traditional margins of error, the financial consequences are huge, especially in light of a constrained discretionary budget.

The Management Challenge

The Army has employed a management approach that centers on a Lead System Integrator (LSI) and a non-standard contracting instrument, known as an Other Transaction Agreement (OTA). The Army advised us that it did not believe it had the resources or flexibility to use its traditional acquisition process to field a program as complex as FCS under the aggressive timeline established by the then-Army Chief of Staff.

Although there is no complete consensus on the definition of LSI, those we are aware of appear to be prime contractors with increased program management responsibilities. These responsibilities have included greater involvement in requirements development, design and source selection of major system and subsystem subcontractors. The government also has used the LSI approach on programs that require system-of-systems integration.

The Army selected Boeing as the LSI for the FCS system development and demonstration in May 2003. The Army and Boeing established a One-Team management approach with several first tier subcontractors to execute the program. According to the Army, Boeing has awarded 20 of 24 first tier subcontracts, to 17 different subcontractors. The One-Team members and their responsibilities are depicted in table 1.

Table 1: One-Team Members

One-Team Member	Responsibility
Army	Program Oversight and Insight
Boeing/SAIC	Program Management (including source selection), Development of System-of-Systems Common Operating Environment, System Integration
General Dynamics Land Systems	Manned Ground Vehicles
General Dynamics C4 Systems	Planning and Preparation Services, Sensor Data Management
General Dynamics Robotics Systems	Autonomous Navigation System
General Dynamics Advanced Information Systems	Integrated Computers
United Defense, LP	Manned Ground Vehicles, Armed Robotic Vehicle
iRobot Corporation	Small Unmanned Ground Vehicle
Lockheed Martin Missiles and Fire Control	Multifunction Utility/Logistics and Equipment Vehicle
Lockheed Martin, Orincon	Intelligence, Surveillance and Reconnaissance Sensor Fusion
Austin Information Systems	Situational Understanding
BAE Systems CNI	Ground Platform Communication
BAE Systems IESI	Air Platform Communication
Computer Sciences Corporation	Training Support
Dynamics Research Corporation	Training Support
Honeywell Defense and Space Electronic Systems	Platform Soldier Mission Readiness System
Northrop Grumman	Air Sensor Integrator, Class IV Unmanned Aerial Vehicle, Logistics Decision Support Systems, Network Management, Training Support
Raytheon Network Centric Systems	Battle Command and Mission Execution, Ground Sensor Integrator
Textron Systems	Unattended Ground Sensors, Tactical and Urban Sensors

Source: U.S. Army

Boeing was awarded the LSI role under an OTA which is not subject to the Federal Acquisition Regulation (FAR). Consequently, when using an OTA, DOD contracting officials have considerable flexibility to negotiate the agreement terms and conditions. This flexibility requires DOD to use good business sense and to incorporate appropriate safeguards to protect the

government's interests. The OTA used for FCS includes several FAR or Defense FAR Supplement clauses, many of which flow down to subcontracts. The value of the agreement between the Army and Boeing is approximately \$21 billion. It is a cost reimbursement contract.

Congress has incrementally expanded the use and scope of other transaction authority since first authorizing its use more than a decade ago. In 1989, Congress gave DOD, acting through the Defense Advanced Research Projects Agency, authority to temporarily use other transactions for basic, applied, and advanced research projects. In 1991, Congress made this authority permanent and extended it to the military departments. In 1993, Congress enacted Section 845 of the National Defense Authorization Act for Fiscal Year 1994, which provided DARPA with authority to use, for a 3-year period, other transactions to carry out prototype projects directly relevant to weapons or weapon systems proposed to be acquired or developed by DOD. Subsequent amendments have extended this authority to the military departments and other defense agencies. Most recently, the National Defense Authorization Act for Fiscal Year 2004 extended the prototype project authority until 2008 and provided for a pilot program to transition some other transaction prototype projects to follow-on production contracting.

According to program officials, under the LSI and OTA arrangement on FCS, the Army primarily participates in the program through Integrated Product Teams that are used to make coordinated management decisions in the program about issues related to requirements, design, horizontal integration and source selection.

FCS Remains At Risk of Not Delivering Planned Capability Within Estimated Resources

During the past year, the FCS underwent a significant restructuring, which added 4 years to the schedule for reducing risk, increasing the demonstration of FCS capabilities, and harvesting successes for the current force. Yet, even with these improvements, the FCS is still at significant risk for not delivering planned capability within budgeted resources. This risk stems from the scope of the program's technical challenges and the low level of knowledge demonstrated thus far.

High Levels of Demonstrated Knowledge Are Key to Getting Desired Outcomes

Our previous work has shown that program managers can improve their chances of successfully delivering a product if they employ a knowledge-based decision-making process. We have found for a program to deliver a successful product within available resources, managers should build high levels of demonstrated knowledge before significant commitments are

made.¹ In essence, knowledge supplants risk over time. This building of knowledge can be described in three levels that should be attained over the course of a program:

- First, at program start, the customer's needs should match the developer's available resources—mature technologies, time, and funding. An indication of this match is the demonstrated maturity of the technologies needed to meet customer needs.²
- Second, about midway through development, the product's design should be stable and demonstrate that it is capable of meeting performance requirements. The critical design review is the vehicle for making this determination and generally signifies the point at which the program is ready to start building production-representative prototypes.
- Third, by the time of the production decision, the product must be shown to 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 through realistic system level testing.

The three levels of knowledge 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. On the successful commercial and defense programs we have reviewed, managers were careful to conduct development of technology separately from and ahead of the development of the product. For this reason, the first knowledge level is the most important for improving the chances of developing a weapon system within cost and schedule estimates. DOD's acquisition policy has adopted the knowledge-based approach to acquisitions. DOD policy requires program managers to provide knowledge about key aspects of a system at key points in the

¹GAO, *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 Outcomes*. [GAO/NSIAD-99-162](#). (Washington, D.C.: July 30, 1999); *Best Practices: Successful Application to Weapon Acquisition Requires Changes in DOD's Environment*. [GAO/NSIAD-98-56](#). (Washington, D.C.: February 24, 1998).

²Technology readiness levels are a way to measure the maturity of technology. According to best practices, technology is considered sufficiently mature to start a program when it reaches a readiness level of 7. This involves a system or prototype demonstration in an operational environment. The prototype is near or at the planned operational system.

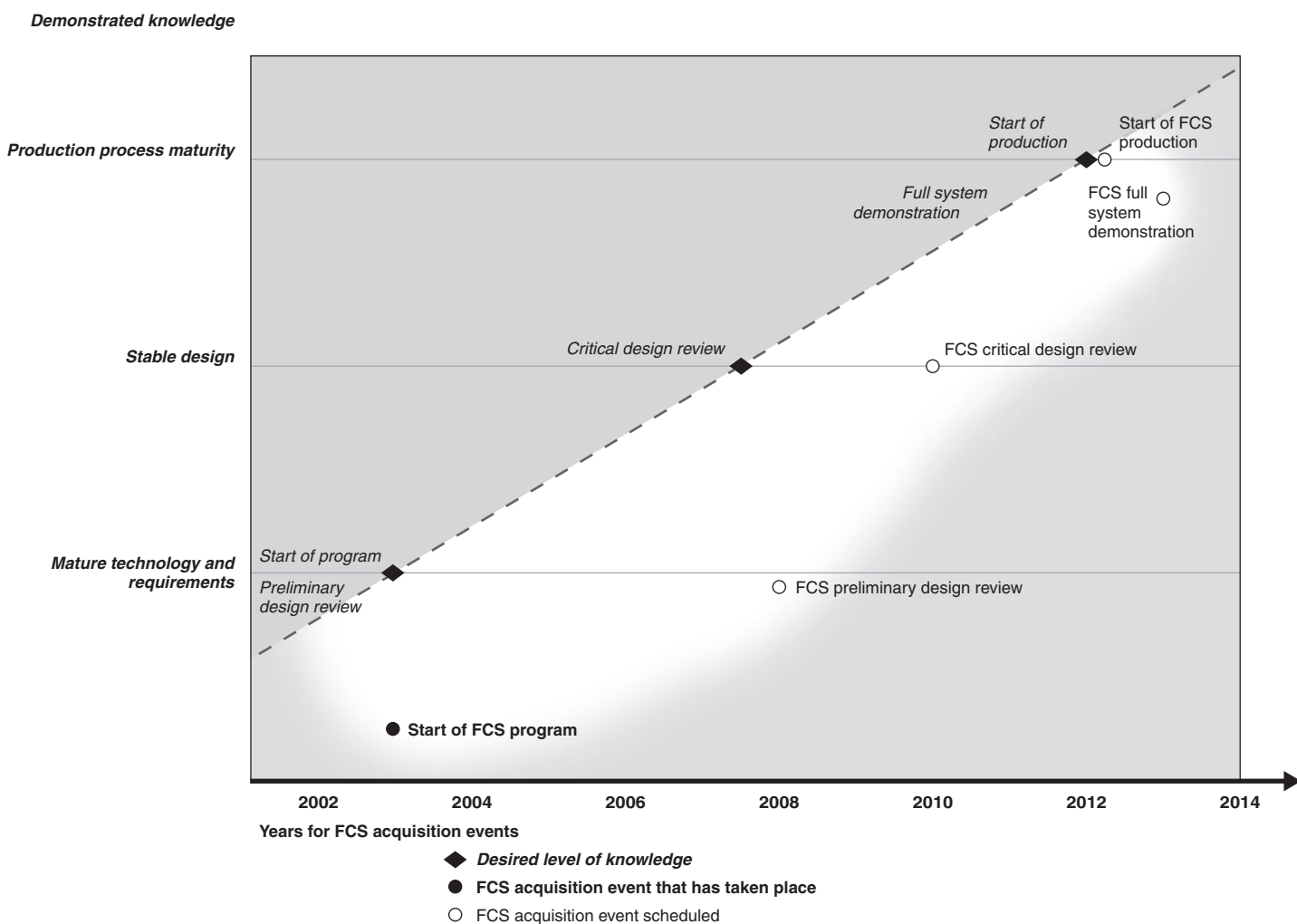
acquisition process. Program managers are also required to reduce integration risk and demonstrate product design prior to the design readiness review and to reduce manufacturing risk and demonstrate producibility prior to full-rate production.

DOD programs that have not attained these levels of knowledge have experienced cost increases and schedule delays. We have recently reported on such experiences with the F/A-22, the Joint Strike Fighter, the Airborne Laser, and the Space Based Infrared System High. For example, the \$245 billion Joint Strike Fighter's acquisition strategy does not embrace evolutionary, knowledge-based techniques intended to reduce risks. Key decisions, such as its planned 2007 production decision, are expected to occur before critical knowledge is captured. If time were taken now to gain knowledge it could avoid placing sizable investments in production capabilities at risk of expensive changes.

FCS Strategy Will Not Demonstrate High Levels of Knowledge Consistent With DOD Policy or Best Practices

The FCS program has proceeded with low levels of knowledge. In fact, most of the activities that have taken place during its first 2 years should have been completed before starting system development and demonstration. It may be several years before the program reaches the level of knowledge it should have had at program start. Consequently, the Army is depending on a strategy that must concurrently define requirements, develop technology, design products, and test products. Progress in executing the program thus far does not inspire confidence: the requirements process is taking longer than planned, technology maturity may actually have regressed, and a program that is critical for the FCS network has recently run into problems and has been delayed. Figure 2 depicts how the FCS strategy compares with the best practices described above.

Figure 2: Comparison of FCS Strategy with Best Practices



Source: U.S. Army and GAO (data); GAO (presentation).

The white space in figure 2 suggests the knowledge between best practices and the FCS program. Clearly, the program has a tremendous amount of ground to cover to close its knowledge gaps to the point that it can hold the design reviews as scheduled and make decisions on building prototypes, testing, and beginning production with confidence.

Several other observations can be made from the figure:

- A match between mature technologies and firm requirements was not made at program start.

Requirements and Resources Gap

- The preliminary design review, which ideally is conducted near the program start decision to identify disconnects between the design and the requirements, will be held 5 years into the program.
- The critical design review, normally held midway through development, is scheduled to take place in the seventh year of a nine-year program.
- The first test of all FCS elements will take place after the production decision.

The FCS program entered system development and demonstration without demonstrating a match between resources and requirements, and will not be in a position to do so for a number of years. The Army now expects to have a reasonably well defined set of requirements by the October 2006 interim preliminary design review. The Army has been working diligently to define these requirements, but the task is very difficult given that there are over 10,000 specific system-of-systems requirements that must collectively deliver the needed lethality, survivability, responsiveness, and sustainability. For example, the Army is conducting at least 120 studies to identify the design tradeoffs necessary before firming up requirements. As of December 2004, 69 remain to be completed. Those to be completed will guide key decisions on the FCS, such as the weight and lethality required of the manned ground vehicles.

On the resources side, last year we reported that 75 percent of FCS technologies were immature when the program started in 2003; a September 2004 independent assessment has since shown that only one of the more than 50 FCS critical technologies is fully mature. The Army employed lower standards than recommended by best practices or DOD policy in determining technologies acceptable for the FCS program³. As a result, it will have to develop numerous technologies on a tight schedule and in an environment that is designed for product development. If all goes as planned, the Army estimates that most of the critical technologies will reach a basic level of maturity by the 2010 Critical Design Review and full maturity by the production decision. This type of technical knowledge is critical to the process of setting realistic requirements, which are needed now. In addition, a program critical to the FCS network and a key

³To achieve full maturity at TRL 7, the technology should be in the form, fit, and function needed for the intended product and should be demonstrated in a realistic environment. For a basic level of maturity at TRL 6, the technology is not necessarily in the form, fit, and function for the intended product.

element of FCS' first spiral, the Joint Tactical Radio System, recently encountered technical problems and may be delayed 2 years. We provide more detail on this program later.

Late Demonstrations of FCS Performance Could Prove Costly

The FCS strategy will result in much demonstration of actual performance late in development and early in production, as technologies mature, prototypes are tested, and the network and systems are brought together as a system-of-systems. A good deal of the demonstration of the FCS design will take place over a 3-year period, starting with the critical design review in 2010 through the first system level demonstration of all 18 FCS components and the network in 2013. This compression is due to the desired fielding date of 2014, coupled with the late maturation of technologies and requirements previously discussed.

Ideally, a critical design review should be held midway through development—around 2008 for FCS—to confirm the design is stable enough to build production representative prototypes for testing. DOD policy refers to the work up to the critical design review as system integration, during which individual components of a system are brought together. The policy refers to the work after the critical design review as system demonstration, during which the system as a whole demonstrates its reliability as well as its ability to work in the intended environment. The building of production representative prototypes also provides the basis to confirm the maturity of the production processes. For the FCS, the critical design review will be held just 2 years before the production decision. The FCS program is planning to have prototypes available for testing prior to production but they will not be production-representative prototypes. The Army does not expect to have even a preliminary demonstration of all elements of the FCS system-of-systems until sometime in 2013, the year after the production decision.

This makes the program susceptible to “late cycle churn,” a condition that we reported on in 2000⁴. 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

⁴GAO, *Best Practices: A More Constructive Approach is Key to Better Weapon System Outcomes*, [GAO/NSIAD-00-199](#) (Washington, D.C., July 31, 2000).

most serious 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 out 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 to the field. While DOD has found it acceptable to accommodate such problems over the years, this will be a difficult proposition for the FCS given the magnitude of its cost in an increasingly competitive environment for investment funds.

The Army has made some concrete progress in building some of the foundation of the program that will be essential to demonstrating capabilities. For example, the System-of-Systems Integration Lab—where the components and systems will be first tested—has been completed. Initial versions of the System-of-Systems Common Operating Environment, the middleware that will provide the operating system for FCS software, have been released. Several demonstrations have taken place, including the Precision Attack Munition, the Non-Line of Sight Cannon, and several unmanned aerial vehicles.

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 credible 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 the 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.

Examples of Execution Challenges for Two Key FCS Elements

Network

The risks the FCS program faces in executing the acquisition strategy can be seen in the information network and the manned ground vehicles. These two elements perhaps represent the long poles in the program and upon which the program’s success depends.

The Joint Tactical Radio System (JTRS) and Warfighter Information Network-Tactical (WIN-T) are central pillars of the FCS network. If they do not work as intended, battlefield information will not be sufficient for

the Future Force to operate effectively. They are separate programs from the FCS, and their costs are not included in the costs of the FCS. Both JTRS and WIN-T face significant technical challenges and aggressive schedules, which threaten the schedule for fielding Future Force capabilities and make their ultimate ability to perform uncertain.

JTRS is a family of radios that is to provide the high capacity, high-speed information link to vehicles, weapons, aircraft, and soldiers. Because they are software-based, they can also be reprogrammed to communicate with the variety of radios currently in use. JTRS is to provide the warfighter with the capability to access maps and other visual data, communicate on-the-move via voice and video with other units and levels of command, and obtain information directly from battlefield sensors. JTRS can be thought of as the information link or network to support FCS units of action and the combat units on the scene that are engaged directly in an operation. In particular, its wideband networking waveform provides the “pipe” that will enable the FCS vehicles to see and strike first and avoid being hit. The WIN-T program is to provide the information network for higher military echelons. WIN-T will consist of ground, airborne, and space-based assets within a theater of operations for Army, joint, and allied commanders and provide those commanders with access to intelligence, logistics, and other data critical to making battlefield decisions and supporting battlefield operations. This is information the combat units can access through WIN-T developed equipment and JTRS.

The JTRS program to develop radios for ground vehicles and helicopters—referred to as Cluster 1—began system development in June 2002 with an aggressive schedule, immature technologies, and lack of clearly defined and stable requirements. These factors have contributed to significant cost, schedule, and performance problems from which the program has not yet recovered. The Army has not been able to mature the technologies needed to provide radios that both generate sufficient power as well as meeting platform size and weight constraints. Changes in the design are expected to continue after the critical design review, and unit costs may make the radios unaffordable in the quantities desired. Given these challenges, the Army has proposed delaying the program 24 months and adding \$458 million to the development effort. However, before approving the restructure, the Office of the Secretary of Defense directed a partial work stoppage, and the program is now focusing its efforts on a scheduled operational assessment of the radio’s functionality to determine the future of the program. Consequently, the radio is not likely to be available for the first spiral of the FCS network, slated for fiscal year 2008, and surrogate radios may be needed to fill the gap.

A second JTRS program, to develop small radios including those that soldiers will carry (referred to as Cluster 5), also entered system development with immature technologies, lack of well-defined requirements, and faces even greater technical challenges due to the smaller size, weight, power, and large data processing requirements for the radios. For example, the Cluster 5 program has a requirement for a wideband networking waveform despite its demanding size and power constraints. In addition, the program was delayed in starting system development last year because of a contract bid protest. Consequently, the Cluster 5 radios are not likely to be available for the first FCS spiral either. The Army has acknowledged that surrogate radios and waveforms may be needed for the first spiral of FCS.

The WIN-T program also began with an aggressive acquisition schedule and immature technologies that are not scheduled to mature until after production begins. Backup technologies have been identified, but they offer less capability and most are immature as well. In addition, the schedule leaves little room for error correction and rework that may hinder successful cost, schedule and performance outcomes. More recently, the program strategy was altered to identify a single architecture as soon as possible and to deliver networking and communications capabilities sooner to meet near term warfighting needs. Specifically, the Army dropped its competitive strategy and is now having the two contractors work together to develop the initial network architecture. A plan for how to develop and field capabilities sooner is still to be determined.

Manned Ground Vehicles

FCS includes eight manned ground vehicles, which 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. At the same time, concepts for the manned ground vehicles have not been decided and are awaiting the results of trade studies that will decide critical design points such as weight and the type of drive system to be used. Under other circumstances, each of the eight manned ground systems would be a major defense 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.

Developing these technologies and integrating them into vehicles is made vastly more difficult by the Army's requirement that the vehicles be transportable by the C-130 cargo aircraft. However, the C-130 can carry the FCS vehicles' projected weight of 19 tons only 5 percent of the time. In 2004, GAO reported a similar situation with the Stryker vehicles. The 19-ton weight of these vehicles significantly limits the C-130's range and the size of the force that can be deployed⁵. Currently, FCS vehicle designs are estimated at over 25 tons. To meet even this weight, the advanced technologies required put the sophistication of the vehicles on a par with fighter aircraft, according to some Army officials. This is proving an extremely difficult requirement to meet without sacrificing lethality, survivability, and sustainability. Currently, program officials are considering other ways to meet the C-130 weight requirement, such as transporting the vehicles with minimal armor and with only a minimal amount of ammunition. As a result, vehicles would have to be armored and loaded upon arrival to be combat ready.

FCS Cost and Affordability Still to Be Determined

The low levels of knowledge in the FCS program provide an insufficient basis for making cost estimates. The program's immaturity at the time system development and demonstration began resulted in a relatively low-fidelity cost estimate and open questions about the program's long-term affordability. Although the program restructuring provides more time to resolve risk and to demonstrate progress, the knowledge base for making a confident estimate is still low. If the FCS cost estimate is not better than past estimates, the likelihood for cost growth will be high while the prospects for finding more money for the program will be dim.

The estimates for the original FCS program and the restructured program are shown in table 2 below.

⁵GAO, *Military Transformation: Fielding of Army's Stryker Vehicles Is Well Under Way, but Expectations for Their Transportability by C-130 Aircraft Need to Be Clarified*, [GAO-04-925](#) (Washington, D.C., August 12, 2004).

Table 2: Increased Cost from Original to Restructured FCS Program

2005 BY\$ (millions)	Research and Development	Procurement	Total
Original	18,574	60,647	79,836^a
Restructured	28,007 ^b	79,960	107,967
Dollar increase	9,433	19,313	28,131
Percent increase	50.79%	31.84%	35.24%

Sources: GAO.

^aBoth the original and the restructured figures are for about 15 Units of Action (i.e., 1/3 of the current active force).

^bIncludes four originally deferred systems, a lengthened schedule, additional tests, and the addition of the four spirals.

At this point, the FCS cost estimate represents the position of the program office. The Army and the Office of the Secretary of Defense's Cost Analysis Improvement Group will provide their independent estimates for the May 2005 Milestone B update review. It is important to keep in mind that the FCS program cost estimate does not reflect all of the costs needed to field FCS capabilities. The costs of the complementary programs are separate and will be substantial. For example, the research and development and procurement costs for the JTRS (Clusters 1 and 5) and the WIN-T programs are expected to be about \$34.6 billion (fiscal year 2005 dollars).

In addition, by April 2005, the Army has been tasked to provide an analysis of FCS affordability considering other Army resource priorities, such as modularity. This will be an important analysis given that estimates of modularity costs have been put at about \$48 billion, and costs of current operations and recapitalizing current equipment have been covered by supplemental funding.

As can be seen in table 3, substantial investments will be made before key knowledge is gained on how well the system can perform. For example, by the time of the critical design review in 2010, over \$20 billion of research and development funds will have been spent.

Table 3: Annual and Cumulative FCS Funding and Planned Events and Achievements (\$millions)

Fiscal year	Annual Research and Development Funding	Cumulative Research and Development Funding	Planned Events/Achievements
2003	158.9	158.9	Systems development and demonstration Start
2004	1,637.3	1,796.2	Program restructured
2005	2,800.8	4,597.0	Contract redefinitized Milestone B Update Updated cost estimate
2006	3,404.8	8,001.8	Requirements firmed up Interim preliminary design review
2007	3,742.0	11,743.8	
2008	3,682.3	15,426.1	System preliminary design review Interim critical design review
2009	3,460.0	18,886.1	
2010	3,181.5	22,067.6	Technologies reach basic maturity; system critical design review
2011	2,690.7	24,758.3	Design readiness review
2012	1,949.6	26,707.9	Technologies reach full maturity Production decision
2013	1,412.0	28,119.9	Initial System-of-Systems demonstration
2014	1,169.0	29,288.9	Initial Operational Capability
2015	901.0	30,189.9	
2016	111.0	30,300.9	Full Operational Capability

Source: U.S. Army.

The consequences of even modest cost increases and schedule delays for the FCS would be dramatic. For example, a one-year delay late in FCS development, not an uncommon occurrence for other DOD programs, could cost over \$3 billion. Given the size of the program, financial consequences of following historical patterns of cost and schedule growth could be dire.

Alternatives to Current FCS Acquisition Strategy Still Warrant Consideration

For any acquisition program, two basic questions can be asked. First, is it worth doing? Second, is it being done the right way? On the first question, the Army makes a compelling case that something must be done to equip its future forces and that such equipment should be more responsive but as effective as current equipment. The answer to the second question is problematic. At this point, the FCS presents a concept that has been laid out in some detail, an architecture or framework for integrating individual capabilities, and an investment strategy for how to acquire those capabilities. There is not enough knowledge to say whether the FCS is doable, much less doable within a predictable frame of time and money. Yet making confident predictions is a reasonable standard for a major acquisition program given the resource commitments and opportunity costs they entail. Against this standard, the FCS is not yet a good fit as an acquisition program.

That having been said, another important question that needs to be answered is: if the Army needs FCS-like capabilities, what is the best way to advance them to the point to which they can be acquired? Efforts that fall in this area—the transition between the laboratory and the acquisition program—do not yet have a place that has right organizations, resources, and responsibilities to advance them properly.

At this point alternatives to the current FCS strategy warrant consideration. For example, one possible alternative for advancing the maturity of FCS capabilities could entail setting the first spiral or block as the program of record for system development and demonstration. Such a spiral should meet the standards of providing a worthwhile military capability, having mature technology, and having firm requirements. Other capabilities currently in the FCS program could be moved out of system development and demonstration and instead be bundled into advanced technology demonstrations that could develop and experiment with advanced technologies in the more conducive environment of “pre-acquisition” until they are ready to be put into a future spiral. Advancing technologies in this way will enable knowledge to guide decisions on requirements, lower the cost of development, and make for more reasonable cost and schedule estimates for future spirals.

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 Acknowledgements

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 D. Gaston, Jr., William R. Graveline, John P. Swain, Robert S. Swierczek, and Carrie R. Wilson.

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