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Report to Congressional Committees

March 2009

DEFENSE ACQUISITIONS

Decisions Needed to Shape Army's Combat Systems for the Future

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GAO-09-288

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Highlights

Highlights of GAO-09-288, a report to congressional committees

Why GAO Did This Study

The Future Combat System (FCS) program is the centerpiece of the Army's effort to transition to a lighter, more agile, and more capable combat force. By law, GAO is to report annually on the FCS program. Also, law requires the Department of Defense (DOD) to hold a milestone review of the FCS program, now planned for 2009. This report addresses (1) what knowledge will likely be available in key areas for the review, and (2) the challenges that lie ahead following the review. To meet these objectives, GAO reviewed key documents, performed analysis, attended demonstrations and design reviews, and interviewed DOD officials.

What GAO Recommends

GAO suggests Congress consider not approving full funds for the program until several conditions are met, such as preparation of a complete budget for any program emerging from the milestone review. GAO also recommends the Secretary of Defense, among other things, ensure: the program that emerges conforms to current defense acquisition policy, such as technology maturity; any spin out approach is based on fully tested results; and any incremental strategy involves free-standing, justifiable increments. DOD concurred with GAO's recommendations.

To view the full product, including the scope and methodology, click on GAO-09-288. For more information, contact Paul Francis at (202) 512-4841 or francisp@gao.gov.

What GAO Found

The Army will be challenged to demonstrate the knowledge needed to warrant an unqualified commitment to the FCS program at the 2009 milestone review. While the Army has made progress, knowledge deficiencies remain in key areas. Specifically, all critical technologies are not currently at a minimum acceptable level of maturity. Neither has it been demonstrated that emerging FCS system designs can meet specific requirements or mitigate associated technical risks. Actual demonstrations of FCS hardware and software—versus modeling and simulation results—have been limited, with only small scale warfighting concepts and limited prototypes demonstrated. Network performance is also largely unproven. These deficiencies do not necessarily represent problems that could have been avoided; rather, they reflect the actual immaturity of the program. Finally, there is an existing tension between program costs and available funds that seems only likely to worsen, as FCS costs are likely to increase at the same time as competition for funds intensifies between near- and far-term needs in DOD and between DOD and other federal agencies.

DOD could have at least three programmatic directions to consider for shaping investments in future capabilities, each of which presents challenges. First, the current FCS acquisition strategy is unlikely to be executed within the current $159 billion cost estimate and calls for significant production commitments before designs are demonstrated. To date, FCS has spent about 60 percent of its development funds, even though the most expensive activities remain to be done before the production decision. In February 2010, Congress will be asked to begin advancing procurement funds for FCS core systems before most prototype deliveries, critical design review, and key system tests have taken place. By the 2013 production decision, Congress will have been asked for over $50 billion in funding for FCS. Second, the program to spin out early FCS capabilities to current forces operates on an aggressive schedule centered on a 2009 demonstration that will employ some surrogate systems and preliminary designs instead of fully developed items, with little time for evaluation of results. Third, the Army is currently considering an incremental FCS strategy—this is to develop and field capabilities in stages versus in one step. Such an approach is generally preferable, but would present decision makers with a third major change in FCS strategy to consider anew. While details are yet unavailable, it is important that each increment be justified by itself and not be dependent on future increments.

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Abbreviations

ARV-A-L	Armed Robotic Vehicle – Assault (Light)
C2V	Command and Control Vehicle
CDR	Critical Design Review
Cl. I UAV	Class I Unmanned Aerial Vehicle
Cl. IV UAV	Class IV Unmanned Aerial Vehicle
DAB	Defense Acquisition Board
DOD	Department of Defense
FCS	Future Combat System
FRMV	FCS Recovery and Maintenance Vehicle
GAO	Government Accountability Office
ICV	Infantry Carrier Vehicle
JTRS	Joint Tactical Radio System
KP	Knowledge Point
LSI	Lead System Integrator
LUT	Limited User Test
MCS	Mounted Combat System
MSC	Milestone C
MULE-C	Multifunction Utility / Logistics and Equipment Countermine
MULE-T	Multifunction Utility / Logistics and Equipment Transport
MV-E	Medical Vehicle Evacuation
MV-T	Medical Vehicle Treatment
NLOS-C	Non-Line of Sight Cannon
NLOS-LS	Non-Line of Sight Launch System
NLOS-M	Non-Line of Sight Mortar
PDR	Preliminary Design Review
SUGV	Small Unmanned Ground Vehicle
TRL	Technology Readiness Level
T-UGS	Tactical Unattended Ground Sensor
UAS	Unmanned Aerial Systems
UGS	Unattended Ground Sensors
UGV	Unmanned Ground Vehicles
U-UGS	Urban Unattended Ground Sensor
WIN-T	Warfighter Information Network-Tactical

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Congressional Committees

The Future Combat System (FCS) program—which comprises 14 integrated weapon systems and an advanced information network needed for a brigade combat team—is the centerpiece of the Army's efforts to transition to a lighter, more agile, and more capable combat force and according to the Army, the greatest technology and integration challenge it has ever undertaken. The Army seeks to develop and then integrate dozens of new technologies in the FCS program and ultimately create a force in which people, platforms, weapons and sensors are linked seamlessly together in a system-of-systems.

The Army started the FCS program in May 2003 without having fully defined the individual systems, their functions, or how they would interact. The Army moved ahead without determining whether the concept could be successfully developed with existing resources—without proven technologies, a stable design, and available funding and time. The Army currently projects the program will cost $159 billion, although the Army has indicated that cost increases are likely. The program is also using a unique partner-like arrangement with a lead system integrator (LSI), the Boeing Company, to manage and produce the FCS. For these and other reasons, the program is recognized as being high risk and in need of special oversight. Accordingly, in 2006, Congress mandated that the Department of Defense (DOD) hold a milestone review (also called go/no-go review) following the FCS preliminary design review, which is now tentatively scheduled for May 2009.[1] Congress directed that the review include an assessment of whether (1) the needs are valid and can best be met with the FCS concept, (2) the FCS program can be developed and produced within existing resources, and (3) the program should continue as currently structured, be restructured, or be terminated. Congress required the Secretary of Defense to review and report on specific aspects of the program, including the maturity of critical technologies, program risks, demonstrations of the FCS concept and software, and a cost estimate and affordability assessment.

[1]John Warner National Defense Authorization Act for Fiscal Year 2007, Pub. L. No. 109-364, § 214 (2006).

Given the cost, scope, and technical challenges, section 211 of the National Defense Authorization Act for Fiscal Year 2006 requires GAO to report annually on the FCS program.[2] The objectives of this report are to determine (1) to what extent knowledge will likely be available to DOD, the Army, and the Congress in the key areas of technology, design, demonstrations, network performance, and cost and affordability to support the 2009 milestone review and (2) the challenges that a program (or programs) to furnish the Army with future capabilities will face following the milestone review.

In conducting our work, we reviewed documents pertaining to the FCS program, including the Operational Requirements Document, the Acquisition Strategy Report, technology assessments, and modeling and simulation results; attended meetings at which DOD and Army officials reviewed program progress; and held discussions with key DOD and Army officials on various aspects of the program. Officials from DOD and the Army have provided us access to sufficient information to make informed judgments on the matters in this report. In addition, we drew from our body of past work on weapon system acquisition practices and conducted our own analyses in key areas such as cost and technology. We conducted this performance audit from March 2008 to March 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. Appendix I further discusses our scope and methodology.

Background

The FCS concept is designed to be part of the Army's Future Force, which is intended to transform the Army into a more rapidly deployable and responsive force that differs substantially from the large division-centric structure of the past. The Future Force is to be offensively oriented and will employ revolutionary concepts of operations, enabled by new technology. The Army envisions a new way of fighting that depends on networking the force, which involves linking people, platforms, weapons, and sensors seamlessly together in a system-of-systems. If successful, the FCS system-of-systems concept would integrate individual capabilities of weapons and platforms, thus facilitating interoperability and open system

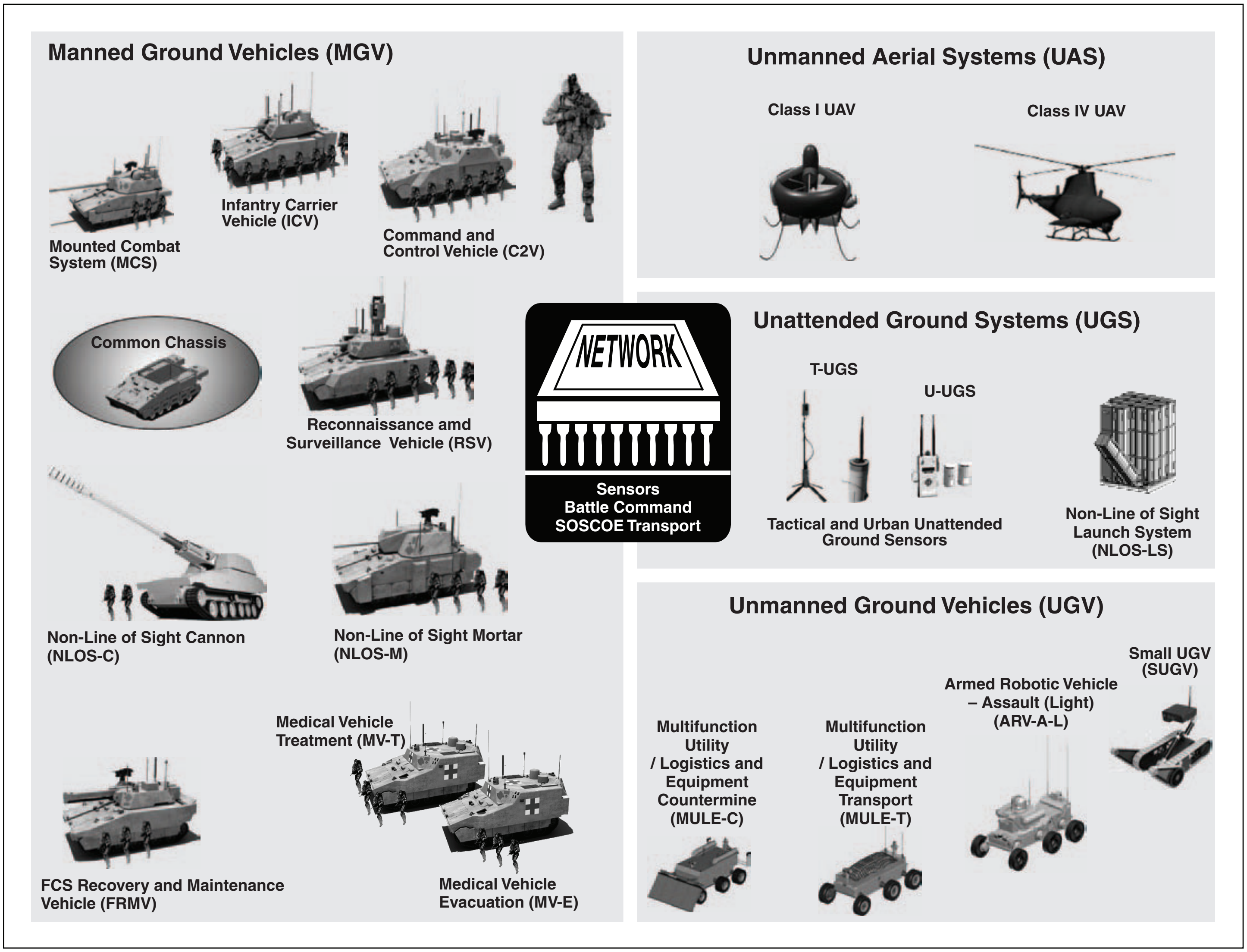
[2]Pub. L. No. 109-163, § 211.

designs. This concept would represent a significant improvement over the traditional approach of building superior individual weapons that must be retrofitted and netted together after the fact.

The Army is reorganizing its current forces into modular brigade combat teams, each of which is expected to be highly survivable and the most lethal brigade-sized unit the Army has ever fielded. The Army expects FCS-equipped brigade combat teams to provide significant warfighting capabilities to DOD's overall joint military operations. The Army is implementing its transformation plans at a time when current U.S. ground forces continue to play a critical role in ongoing conflicts in Iraq and Afghanistan. The Army has instituted plans to spin out selected FCS technologies and systems to current Army forces throughout the program's system development and demonstration phase.

FCS is to be composed of advanced, networked air and ground-based combat and maneuver sustainment systems, unmanned ground and air vehicles, and unattended sensors and munitions. (See fig. 1.) The soldier is the centerpiece of the system-of-systems architecture and is networked with 14 FCS core systems and numerous other enabling systems referred to as complementary programs. FCS is expected to be networked via a command, control, communications, computers, intelligence, surveillance, and reconnaissance architecture, including networked communications, network operations, sensors, battle command systems, training, and both manned and unmanned reconnaissance and surveillance capabilities that will enable improved situational understanding and operations at a level of synchronization heretofore unachievable. With that, FCS brigade combat teams are expected to be able to execute a new tactical paradigm based on the quality of firsts—the capability to see first, understand first, act first, and finish decisively. Fundamentally, the FCS concept is to replace mass with superior information—allowing the soldier to see and hit the enemy first rather that to rely on heavy armor to withstand a hit.

Figure 1: FCS's Core Systems



Source: U.S. Army.

The Army is using a management approach for FCS that centers on an LSI to provide significant management services to help the Army define and develop FCS and reach across traditional Army mission areas. Because of its partner-like relationship with the Army, the LSI's responsibilities include requirements development, design, and selection of major system and subsystem contractors. The team of Boeing and its subcontractor, Science Applications International Corporation, is the LSI for the FCS system development and demonstration phase of acquisition, which is expected to extend until 2017. The FCS LSI is expected to act on behalf of the Army to optimize the FCS capability, maximize competition, ensure interoperability, and maintain commonality in order to reduce life-cycle costs, and for overall integration of the information network. Boeing also acts as an FCS supplier in that it is responsible for developing two important software subsystems. Army officials have stated they did not believe the Army 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. The Army will maintain oversight and final approval of the LSI's subcontracting and competition plans.

Legislative Requirements for FCS Milestone Review

The John Warner National Defense Authorization Act for Fiscal Year 2007 mandated that the Secretary of Defense carry out a Defense Acquisition Board milestone review of FCS not later than 120 days after the system-of-systems preliminary design review, which is now tentatively scheduled for May 2009.[3] The legislation is consistent with our 2006 report on FCS wherein we recommended that the Secretary of Defense establish a Defense Acquisition Board milestone review following the Army's design review.[4] Moreover, we recommended that this should be a go/no-go review of the FCS program based on its ability to meet knowledge markers consistent with DOD acquisition policy and best practices and demonstrate the availability of funds necessary to meet program costs. According to the law, DOD's 2009 milestone review of FCS should include an assessment for each of the following:

(1) whether the warfighter's needs are valid and can be best met with the concept of the program;
(2) whether the concept of the program can be developed and produced within existing resources; and
(3) whether the program should

[3]Pub. L. No. 109-364, § 214 (2006).

[4]GAO, *Defense Acquisitions: Improved Business Case Is Needed for Future Combat System's Successful Outcome*, GAO-06-367 (Washington, D.C.: Mar. 14, 2006).

(a) continue as currently structured;
(b) continue in restructured form; or
(c) be terminated.

Furthermore, the Congress stipulated that the Secretary make specific determinations when making the assessment concerning the future course of the FCS program. The original language contained six criteria the Secretary was to use when answering the three assessment questions. In our 2008 report on the FCS program, we recommended that the Secretary establish objective and quantitative criteria that the FCS program will have to meet in order to justify its continuation and gain approval for the remainder of the acquisition strategy.[5] Subsequently, the Duncan Hunter National Defense Authorization Act for Fiscal Year 2009 amended and expanded the existing requirements and added four new criteria.[6] These changes expand the scope of supporting information the Congress mandated to be included with the DOD milestone review report. For example, the 2009 Act requires the Secretary, when making his assessment of the program, to determine whether actual demonstrations, rather than simulations, have shown that the software for the program is on path to achieve threshold requirements on cost and schedule. Appendix III contains the legislative requirements for the 2009 milestone review. For the purposes of our analysis, we aggregated the congressional criteria into four key areas: technology maturity, requirements/design, demonstrations (FCS concept and network), and cost.

In 2008, we found that the progress made by FCS, in terms of knowledge gained, was commensurate with a program in early development but was well short of a program halfway through its development schedule and its budget. In view of these findings, we recommended, in part, that the Secretary of Defense establish criteria that the FCS must meet in the 2009 milestone review in order to justify continuation along with identifying viable alternatives to FCS.[7]

In response to this recommendation, and to facilitate the Secretary's assessment of the status of FCS and to decide the program's future, the

[5]GAO, *Defense Acquisitions: 2009 Is a Critical Juncture for the Army's Future Combat System*, GAO-08-408 (Washington, D.C.: Mar. 7, 2008).

[6]Pub. L. No. 110-417, § 211 (2008).

[7]GAO-08-408.

Under Secretary of Defense for Acquisitions, Technology and Logistics issued an acquisition decision memorandum in August 2008 to the Secretary of the Army outlining the information the Army must provide. The Under Secretary established criteria for supporting information in five program areas: program execution, unmanned systems, manned ground vehicles, network, and test/experimentation/demonstration. The Under Secretary has established specific criteria within each of the five areas, as shown in Appendix IV. For example, in the area of program execution, the Army must demonstrate that the FCS, Joint Tactical Radio System (JTRS), and Warfighter Information Network Tactical (WIN-T) programs' development, build, and test schedules are aligned and executable. The Under Secretary's memorandum also instructed the Army to mature its acquisition approach to deliver initial increments of FCS capability to infantry brigade combat teams rather than the originally planned heavy brigades. For the FCS core program, the Under Secretary stated that the Army shall pursue an incremental or block approach to acquiring FCS capability.

Along with the mandated 2009 milestone review of FCS, the Congress has required the DOD and the Army to perform analyses and report separately on two core systems of the FCS system-of-systems.[8] Specifically, the Assistant Secretary of Defense for Networks and Information Integration is to report on an analysis of the FCS communications network and software. This report, due not later than September 30, 2009, will include assessments of issues such as network vulnerability to enemy attack, electronic warfare, jamming, and adverse weather. (See app. V.)

Significant Knowledge Gaps Persist in Key Areas

Compared with the criteria to be used for the milestone review, the FCS program has significant knowledge gaps. Specifically, the program has yet to show that critical technologies are mature, design issues have been resolved, requirements and resources are matched, performance has been demonstrated versus simulated, and costs are affordable. The Army will be challenged to convincingly demonstrate the knowledge necessary to warrant an unqualified commitment to FCS at the 2009 milestone review. Four of the critical technologies have not yet achieved minimally acceptable maturity levels despite being in development for at least 6 years. The schedule to complete the remaining preliminary design reviews is aggressive, and it seems clear from the results of the initial system-level

[8]Pub. L. No. 110-417, § 212.

preliminary design reviews that numerous performance trade-offs will be needed to close gaps between FCS requirements and designs. Actual demonstrations (versus modeling and simulation) of the FCS concept, including its critical survivability aspects, have been limited to date; demonstrated network performance is particularly limited with many key questions yet to be answered. Finally, FCS costs appear likely to increase again at a time when available funds may decline.

Major Risks Remain in the Maturation of FCS Technologies

In making the assessment of whether the FCS program should continue, DOD is required by congressional direction to make a determination of whether each critical technology for the program is at least TRL 6. The Army has struggled to attain this level of maturity, despite being a lower standard than preferred by DOD policy and falling short of best practices. At TRL 6, a representative model or prototype exists and is tested in a relevant environment—a maturity level well beyond TRL 5 where the technology demonstrates functionality in a laboratory environment but does not have the physical form or fit of the finished product. Appendix VI contains a complete listing and description of TRLs. Army technology officials stated the purpose of TRL 6 demonstrations is to build confidence the concept is technically feasible, and TRL 6 actually means extensive testing remains before TRL 7 can be achieved. Maturing technologies to TRL 7 (prototype possessing the form, fit, and function of the finished product that is demonstrated in a realistic environment) prior to starting product development is a best practice and a DOD policy preference.[9] Against these standards, all FCS technologies should have achieved TRL 7 as the program proceeded into the system development and demonstration phase in May 2003. Even if the Army does demonstrate TRL 6 in 2009, extending technology development this late into the acquisition process puts FCS at risk for experiencing problems that may require large amounts of time and money to fix.

The Army anticipates that all the critical technologies will reach TRL 6 by the milestone review, but this projection deserves closer examination and perspective. The Army may be unable to demonstrate technology maturity as quickly as it plans. Based on Army assessments from January 2009, three of the 44 FCS critical technologies were rated TRL 7 and 37 were rated TRL 6. The remaining technologies are expected to complete TRL 6

[9] GAO, *Defense Acquisitions: DOD's Revised Policy Emphasizes Best Practices, but More Controls Are Needed*, GAO-04-53 (Washington, D.C.: Nov. 10, 2003).

demonstrations prior to the system-of-systems preliminary design review, but some of those scheduled demonstrations are slipping. Appendix VII contains a list of all FCS critical technologies with their 2007 and 2008 TRL ratings and Army projections for attaining TRL 6.

Thirteen of the technologies that the Army rated at TRL 6 are awaiting validation from technology review authorities—independent teams convened by the FCS program manager and from the Director, Defense Research and Engineering. These reviews could actually downgrade maturity levels if demonstration results do not support the Army's TRL designation. This occurred in 2007 with the mid-range munition's terminal guidance.[10] In 2008, independent reviewers cautioned the Army about the maturity levels of three technologies: (1) JTRS ground mobile radio, (2) Mobile Ad-hoc Networking Protocols, and (3) Wideband Networking Waveforms. According to Army officials, the Army had claimed these technologies had demonstrated TRL 6; however, the independent reviewers suggested the Army consider providing additional justification to strengthen the case for a TRL 6. Consequently, it is not clear whether independent reviewers will concur with the Army's assertion that these technologies have demonstrated TRL 6 maturity. Table 1 illustrates both the actual progress the Army has made maturing FCS critical technologies and projected progress through the production decision.

Table 1: Actual and Projected Maturity of FCS Critical Technologies

	Actual progress				Projected progress		
	Program start 2003	August 2006 [a]	July 2007 [a]	January 2009	2009 Preliminary design review	2011 Critical design review	2013 Production decision
TRLs $\geq$ 7	0	1	2	3	3	6	44
TRLs = 6	10	34	30	37	40	38	0
TRLs $\leq$ 5	42	11	12	4	1	0	0

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

[a]In these years, the Army removed technologies from its assessments.

As we have shown in the past, accepting lower technology levels in development frequently increases program schedule and cost. In the case of FCS, the downgrade in TRLs is particularly troublesome because TRL 6

[10]The Army subsequently provided additional information to support the independent review team's validation of TRL 6 for the mid-range munition.

represents a significant development step over TRL 5. Army engineers maintain that anything beyond TRL 6 is a system integration matter and not necessarily technology development. Leading commercial firms treat adapting the technologies to the space, weight, and power demands of their intended environment—in essence, TRL 7—as part of technology development. Even if one accepts the lower standard of TRL 6 at program start, the integration of these technologies into systems and subsystems should have taken place in the first half of development, which DOD refers to as "system integration." As a complex, networked system-of-systems, FCS will have unprecedented integration issues. Yet, FCS system integration will have to occur in the second half of development, where it will compete for resources that are intended to be for demonstration of the system.

As we have previously reported, advancing technologies to TRL 6 has been especially challenging.[11] The Army's history of maturing FCS technologies does not inspire confidence that it will be able to execute the optimistic and challenging integration plans involved with advancing technologies to a TRL 7 before the production decision in 2013.

Technologies critical to FCS survivability are illustrative of the program's technology maturity issues. FCS survivability involves a layered, network-centric approach that consists of detecting the enemy first to avoid being fired upon; if fired upon, neutralizing the incoming munition before it hits an FCS vehicle; and finally, having sufficient armor to defeat those munitions that make it through the preceding layers. Each of these layers depends on currently immature technologies to provide the aggregate survivability needed for FCS vehicles. Many of the technologies intended for survivability have experienced developmental delays. As a key component of FCS survivability, the short range active protection system is intended to neutralize incoming munitions and help protect vehicles from threats such as rocket-propelled grenades. Initially, Army requirements for the system included the ability to defeat long-range anti-armor threats, such as antitank missiles. However, Army officials have decided to delay demonstration of this capability until 2011 or 2012. The Army held a short-range active protection system demonstration in the latter part of 2008 and declared that the system had reached TRL 6. The results of these demonstrations are pending validation from technology review authorities. It is important to note that the Army plans to continue

[11] GAO-08-408.

active protection system technology development and demonstration for some time to ensure that it is an operationally effective and safe capability. This is challenging because the active protection system is to provide 360-degree protection for the relatively lightly-armored FCS manned ground vehicles by using, among other things, sensors, processors, rocket motors, and a counter-munition warhead to counter multiple threats.

Lightweight hull and vehicle armor technology for FCS vehicles is also problematic because it will not be sufficiently advanced to provide military usefulness for several years. The Army is developing armor-related critical technologies in a phased approach. The initial phase of armor development only recently demonstrated TRL 6. The results of these demonstrations are also pending validation from technology review authorities. The Army intends for that initial version to satisfy threshold (or minimally acceptable) survivability requirements and plans to use it only in prototypes of manned ground vehicles. The second phase of armor is expected to meet objective (or desired) survivability requirements but is not scheduled to reach TRL 5 until fiscal year 2011. Even then, Army engineers do not believe that armor design will meet weight requirements. The third phase will be used for low-rate production vehicles and is scheduled to demonstrate TRL 6 in 2012. This armor is expected to satisfy objective threat requirements and be 25 percent lighter than the second armor iteration. The Army plans to mature the fourth and final phase of armor to a TRL 6 in fiscal year 2014. The Army also plans to make manufacturing technology investments in the armor area in order to reduce its production costs.

Trade-offs Needed to Close Gaps between FCS Requirements and Designs

For the 2009 milestone review, Congress has directed DOD, for each system and network component of the program, to assess key design knowledge and risks, based on system functional reviews, preliminary design reviews, and technical readiness levels. Now tentatively scheduled for May 2009, the system-of-systems preliminary design review is a major technical review to assess whether the full suite of FCS systems and information network are ready for detailed design and that the FCS detailed performance requirements can be obtained within cost, schedule, risk, and other system constraints.

The Army has continued to gain knowledge about FCS development, but design knowledge expected to be available at the time of the 2009 milestone review may not provide confidence that FCS design risks are at acceptable levels. Key design risks include the Army's ability to accomplish all system-level design work in the time remaining before the

2009 system-of-systems preliminary design review, demonstrate that emerging system designs match detailed requirements, and mitigate recognized technical risks to acceptable levels. This challenge has its roots in the fact that the Army started FCS development in 2003 without establishing firm requirements and preliminary designs to meet those requirements; that is, demonstrating a match between customer needs and available resources. Consequently, the Army is still seeking to stabilize FCS designs at a time when the program is already past the mid-point of development phase—the point when a program following best practices and DOD policy would normally conduct a critical design review demonstrating a stable, producible design capable of meeting performance requirements. Having passed that mid-point, FCS is now far out of alignment with current DOD policy, which requires a program to show a match between requirements and resources at or shortly after development start.

Over the past year, the Army has continued the process of setting and refining requirements in order to establish system designs. At the system-of-systems level, requirements are relatively stable. At the individual system level, requirements continue to evolve. The Army scheduled a series of 15 system-level preliminary design reviews, with the first held in 2007 and the last expected to occur in March 2009, in order to assess whether individual systems are ready to proceed into detailed design. Although the Army plans to conduct all system design reviews by the end of March 2009, the schedule to close out all the reviews may take some time, and requirements and design trade-offs will be necessary. Several examples are illustrative:

- The preliminary design review for the Multi-Function Utility/Logistics and Equipment Vehicle occurred in December 2007 and noted critical design problems regarding vehicle weight reduction. The Army did not close the weight issue until some 10 months later, in October 2008.
- The Small Unmanned Ground Vehicle had its preliminary design review in October 2008 and has now entered into detailed design. Operational requirements call for the vehicle to operate for 6 hours between battery changes within a temperature range of minus 25 degrees and 120 degrees. However, the vehicle does not meet those requirements at any temperature. Even with optimum operating temperature, mission length is no longer than 5.4 hours. Additionally, the vehicle cannot satisfy operational requirements for storage at temperatures of 60 degrees below zero because its motor lubricant decomposes and battery becomes useless.

Consequently, the Army now plans to remove the batteries and provide for special storage.

- During the first part of the network preliminary design review held in November 2008, the Army recognized that there are significant gaps between the FCS requirements and the emerging network design. These include the JTRS handheld radio; ground mobile radio; and airborne, maritime, and fixed-station radios; the WIN-T increment 3; and the Wideband Networking Waveform and Soldier Radio Waveforms. The Army has not yet been able to obtain validation of its TRL 6 rating for JTRS ground mobile radio; the mobile, ad-hoc networking protocols; and Wideband Networking Waveforms. According to Army officials, if additional funding is provided and developments are fully successful, they will not fully meet FCS requirements until about 2017 or 2018. The Army conducted the second part of its network preliminary design review in January 2009. The results were not available for inclusion in this report.

For several months, the Army has been conducting a series of technical reviews of various aspects of the FCS manned ground vehicle requirements and designs. Those efforts culminated at the manned ground vehicle preliminary design review in January 2009. The results of that review were not available in time for inclusion in this report.

According to Army assessments, key risks remain within several areas: software development and integration, network and transport, manned and unmanned platforms, and average unit production cost. Many risks involve the likelihood that requirements may be unachievable when or as expected. The assessment of these risks will be a key determinant in the overall feasibility of the FCS concept and the ability to execute the FCS acquisition strategy going forward. FCS is also working to address significant areas of high risk such as network performance and scalability, immature network architecture, and synchronization of FCS with the JTRS and WIN-T programs. JTRS and WIN-T are also having difficulty with technology maturation and are at risk of being delayed or delivering incomplete capabilities to FCS.

In a 2007 acquisition memorandum, DOD stated that its acquisition policy was to adjust requirements and technical content to deliver as much as possible of planned capability within budgeted cost. At the same time, it directed the services to establish Configuration Steering Boards in order to review all requirements changes and any significant technical configuration changes that have the potential to result in cost and schedule impacts. Despite this direction, the Army has not established a steering board for FCS. DOD officials told us that such a board would be useful for providing input to FCS requirements and design trade-offs.

Army Has Not Yet Convincingly Demonstrated FCS Concept

In making the assessment of whether the FCS program should continue, Congress required DOD to make a determination on whether actual demonstrations, rather than simulations, have shown that the concept of the program will work. FCS brigade combat teams are expected to be able to execute a new tactical paradigm based on what the Army refers to as "the quality of firsts"—the capability to see first, understand first, act first, and finish decisively. Because this paradigm depends on the aggregate performance of interdependent FCS systems versus the performance of any single system, it is essential that this concept be proven through demonstrations. While modeling and simulation are essential to assessing the performance of FCS, they must be anchored in actual demonstrations.

DOD will be challenged to meet the congressional direction to demonstrate (versus simulate) that the FCS warfighting concept will work by the time of the 2009 milestone review. At this point in the program, the FCS concept has been simulated but has not been convincingly demonstrated in any sort of field event. This stems from the fact that technologies have not finished development and prototype systems with the essential network components are not ready to be built yet. In preliminary field demonstrations, some people, sensors, and platforms have been connected and information was transferred from one to the other. Basic capabilities of the unmanned aerial and ground vehicles, as well as some of the unattended sensors and munitions, have been demonstrated. The manned ground vehicles have demonstrated some of their mobility and lethality capabilities. There have been some technology demonstrations of early versions of the lightweight armor and an active protection system, but the feasibility of the FCS survivability concept remains uncertain. Nothing approaching a demonstration of the "quality of firsts" paradigm has yet been attempted nor will it be before the 2009 milestone review.

The Defense Acquisition Board has established criteria for the 2009 Review including several in a category entitled "Test/Experimentation/Demonstration." (See app. IV.) However, none of the criteria address the issue of demonstrating that the FCS concept will work. Instead, the criteria call for the demonstration of some early FCS prototypes and the completion of some events such as a 2008 joint service experiment. The Defense Acquisition Board criteria also include several that call for delivery of certain early prototypes and others that call for demonstration of selected capabilities. Without questioning the value of these individual criteria, it is not clear what they will tell decision makers about the value or demonstration of the FCS concept as a whole.

Demonstrations of FCS Network Performance Very Limited

In making the assessment of whether the FCS program should continue, Congress required DOD to make several determinations, including (1) whether actual demonstrations, rather than simulations, have shown that the software for the program is on a path to achieve threshold requirements on cost and schedule; (2) whether the program's planned major communications network demonstrations are sufficiently complex and realistic to inform major decision points; (3) the extent to which manned ground vehicle survivability is likely to be reduced in a degraded communications network environment; (4) the level of network degradation at which FCS manned ground vehicle survivability is significantly reduced; and (5) the extent to which the FCS communications network is capable of withstanding network attack, jamming, or other interference.

In addition, the Assistant Secretary of Defense for Networks and Information Integration is required to submit a report to Congress on the FCS communications network and software. That report is to be submitted by September 30, 2009 and is to include an assessment of the communications network that will specifically address areas such as vulnerability to network attack, electronic warfare, adverse weather, and terrain; dependence on satellite communications support; and operational availability and performance under degraded conditions. The report is also to include assessments of the communications network's test schedule and Army efforts to synchronize funding, schedule, and technology maturity of critical networking programs with FCS. Appendix V contains the comprehensive criteria from the legislation directing this review.

These assessments of the capabilities and vulnerabilities of the FCS network will be important in determining if the FCS concept is feasible. However, as we reported last year, the Army had an understanding of network requirements and how to build the network, but many challenges and work remained before the network would reach maturity.[12] Hence, network development and demonstration is at a very early stage and therefore, the network assessments will most likely be based on analysis

[12]GAO, *Defense Acquisitions: Significant Challenges Ahead in Developing and Demonstrating Future Combat System's Network and Software*, GAO-08-409 (Washington, D.C.: Mar. 7, 2008).

and simulations rather than demonstrated results. Even if software development proceeds on schedule and technical risks of key network elements, such as JTRS and WIN-T are successfully retired, the uncharted nature of the FCS network makes predicting its eventual performance difficult. Army test officials are assessing network scalability, which relates to increasing the number of radios, or nodes, on the network, through limited testing. However, the number of nodes used in testing to date has been limited, using only 30 nodes, while a brigade combat team may require as many as 5,000 nodes. Considering that mobile, ad-hoc networks have limited scalability, and performance decreases as more nodes are added, the ultimate FCS network performance is difficult to predict.

To date, actual demonstrations of FCS software have been limited to the early spin out tests and experiments, and it is not yet known whether the information network is technically capable of delivering the quality of service needed to make the FCS warfighting concept possible.[13] At the time of the FCS milestone review in 2009, the extent of network demonstration is expected to be very limited. For example, in 2008, the Army demonstrated, among other basic capabilities, sensor control, terrain analysis, and unmanned platform planning and operations. Other limited demonstrations are scheduled on a regular basis. For example, in the 2008 joint service experiment, several portions of the FCS network—including an early version of the system-of-systems common operating environment, the unattended sensors, and Non-Line-of-Sight Launch System—were evaluated in terms of their basic operation and interoperability with other systems. The first major demonstration of the FCS network is the limited user test scheduled for fiscal year 2012, which will be at least a year after the critical design review and only about a year before the start of low-rate initial production for the core FCS program. This event comes after the vehicle designs on manned ground platforms have been established. One of the key objectives of that test will be to identify the contributions and limitations of the network regarding the ability of the FCS brigade combat team to conduct missions across the full spectrum of operations. However, the fully automated battle command system is not expected to be available until 2013 when the Army expects 100 percent of the network capabilities, including software, to be available.

[13]Quality of Service is the capability to transport information across the network while satisfying communication performance requirements such as low delay, low loss, or high throughput.

As a key part of the overall FCS communications network, it is uncertain whether FCS software requirements can be achieved within cost and schedule estimates. The first of 4 software builds has been delivered and qualified, and build 2 is still in development, with a planned delivery in 2010. As we have reported earlier, FCS software estimates continue to grow, and the total estimate for the network and platforms is projected to total over 100 million lines of computer code, which is more than triple the size the program estimated in 2003. Army officials have identified 16 risks in the software arena, or specific areas where there is a risk of not achieving goals within cost and schedule estimates, including system-of-systems common operating environment, network management/quality of service, network security/information assurance, distributed fusion management, and estimated effective source lines of code. According to Army officials, software development costs are capped at approximately $2.6 billion. As a result, Army officials stated that they have had to defer some planned FCS capabilities to later software builds. Yet, development experience to date, coupled with the risks yet to be resolved, raise questions as to whether the necessary software can be developed within cost and schedule estimates. Alternatively, the Army may have to reduce or eliminate FCS requirements.

FCS Costs Are Expected to Increase Again and Affordability Is Still in Doubt

In making the assessment of whether the FCS program should continue, Congress required DOD to make a determination on (1) what the cost estimate for the program is, including spin outs, and an assessment of confidence levels for that estimate; and (2) what the affordability assessment for the program is, given projected Army budgets, based on that cost estimate.

For the 2009 milestone review, DOD and the Army are expected to provide the updated program cost estimate and an affordability assessment for the FCS program. The Army has indicated that the most recent cost estimate for the program is no longer valid, but it has not yet completed an official updated estimate. While full details are not yet available, the Army is considering plans to request additional funds for FCS beyond the current cost estimate of $159 billion. Those plans would involve additional development costs of about $2 billion and procurement costs of about $17 billion over the current cost estimate. Where the Army has offset some cost increases in the past with reductions in program content, we are not yet aware of any similar actions to offset the expected cost increases. According to DOD officials, DOD's Cost Analysis Improvement Group is expected to prepare an updated independent cost estimate for the milestone review. Previous estimates from the group have been significantly higher than the Army's, particularly regarding the cost to develop software. DOD officials also stated that DOD's Program Analysis and Evaluation group may be tasked to provide input for an FCS affordability assessment. These assessments are intended to cover all of the costs, including those for the spin outs, which will be necessary to fully field the FCS program. This would be the first complete cost estimate that will include spin outs and other costs. The Army now projects that the costs of its revised FCS spin out initiative will be about $21 billion beyond the core FCS program costs of $159 billion. In addition to FCS-specific costs, complementary program costs are separate from FCS and represent significant additional commitments from the Army and other services. Several of these complementary programs have funding issues of their own. For example, the JTRS and the WIN-T programs are not yet fully funded to develop the full capabilities currently required by the FCS program.

Ultimately, FCS's affordability will hinge on two factors: the actual cost of the program and the availability of funds. Heretofore, there has not been a sound basis for preparing a firm cost estimate. The preliminary design review process should provide a better foundation for one. Yet, such an estimate would have the confidence of a program in early development, with many risks and unprecedented challenges to meet. As it stands, FCS commands the largest portion of the Army's acquisition budget and, as currently planned, will continue to do so for many years. The Army continues to indicate its willingness to accept the high risks of the program and make trade-offs in both requirements and other programs to accommodate its growing costs. Since the program began, costs have increased from $92 billion to $159 billion, which only covers the cost to equip one-third of the Army's active forces. Indicative of the tension between program costs and available funds, the Army recently proposed deferring upgrades to current systems such as the Abrams Tank and Bradley Fighting Vehicle to free up funds for FCS. This tension seems only likely to worsen, as indications are that FCS costs are about to increase again at the same time competition for funds—both between near-term and far-term needs within DOD and between defense and other needs within the federal government—is intensifying. The Army's position has been that it will reduce FCS capabilities to stay within available development funds but at some point, reductions in FCS capability—whether driven by money or technical feasibility—will fall below an acceptable level. That level appears as yet indefinable.

Oversight Challenges Will Continue Beyond the Milestone Decision

The 2009 milestone review will not only require DOD to decide if FCS is technically feasible and militarily worthwhile, it will provide the opportunity to structure the emerging program so that it complies with current acquisition policy and is knowledge-based—thus more conducive to oversight. On several scores, the current FCS program falls short. Its acquisition strategy is more schedule-driven than it is knowledge–based and is unlikely to be executable, with a significant amount of development and demonstration yet to be completed. The timing of upcoming commitments to production funding puts decision makers in the difficult position of making production commitments without knowing if FCS will work as intended. For example, the Army plans for FCS core production to directly follow the early NLOS-C production, which may be premature based on design maturity and demonstrations expected to be done up to that point. Likewise, the Army's schedule for providing early FCS capabilities to current forces is hurried, as spin out systems may not be fully demonstrated before the Army commits to their production. Finally, the Army's potential adoption of an incremental approach to FCS acquisition could represent another major restructure of the program. While an incremental approach is generally preferable, it would represent the fourth different strategy for the FCS program that DOD and the Congress will be asked to evaluate and oversee.

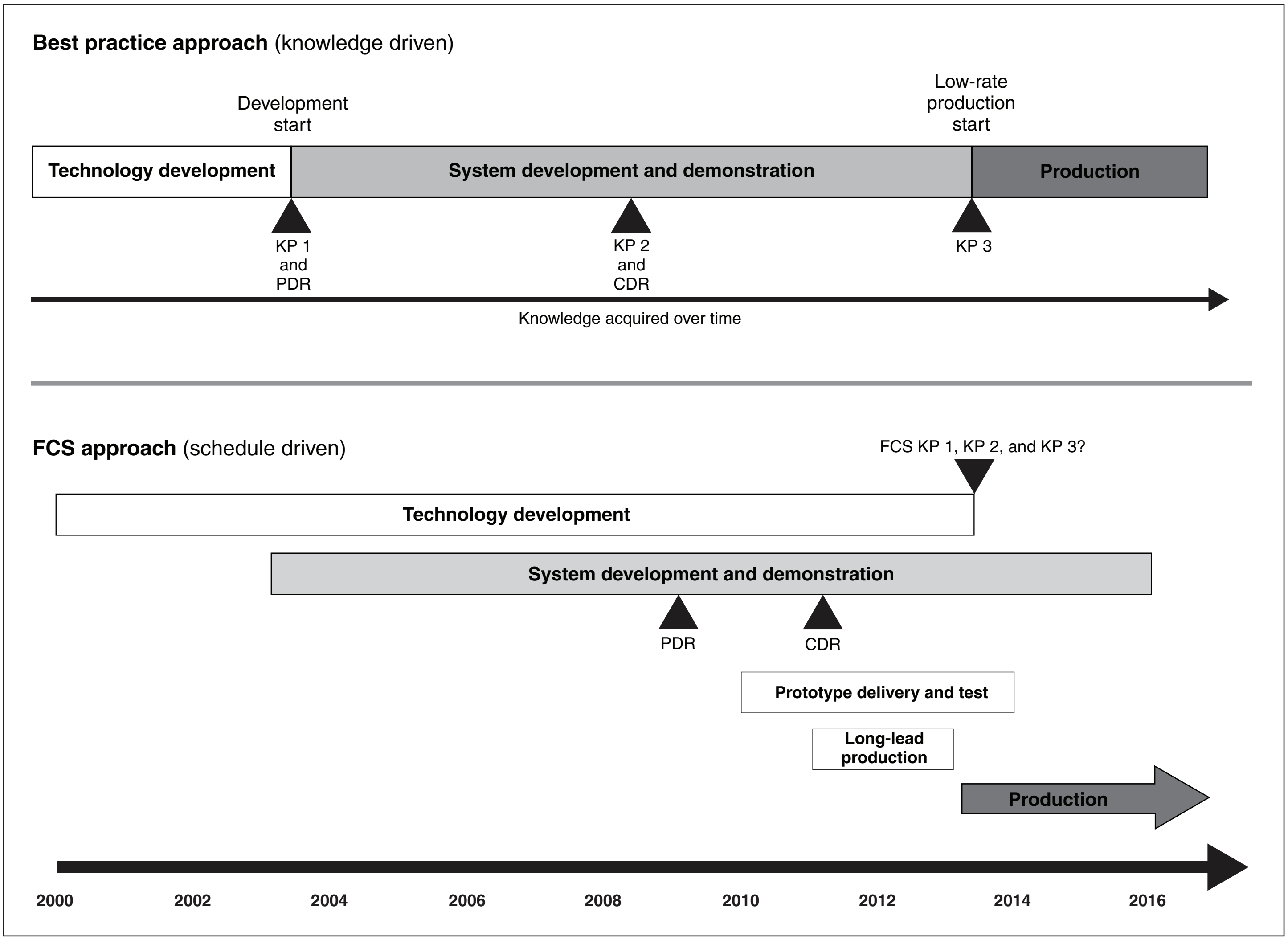
FCS Acquisition Strategy Is Not Knowledge-Based and May Not Be Executable Within Estimated Resources

We have previously reported that to date, the FCS program has advanced through acquisition milestones without having achieved the level of knowledge preferred by best practices and DOD's own policies and a commensurate level of information needed for oversight, given the scope of the program and the risks it entails.[14] The issuance of DOD's 2008 acquisition instruction underscores the wide variance between policy and the FCS acquisition strategy. Ideally, requirements trades would already have been made and a high-confidence design established. This would position the program to move toward maturity as evidenced by such measures as successful completion of subsystem critical design reviews, maturity of critical manufacturing processes, planned corrective actions to hardware and software deficiencies, and adequate developmental testing. At this point, however, FCS has yet to establish a firm system-of-systems design and is several years from any large-scale testing at the system-of-systems level. The milestone review represents an opportunity to judge FCS on critical knowledge markers and set it on a more reasonable course

[14] GAO-08-408.

with opportunities for effective and meaningful oversight from the Army, DOD, and the Congress. Under its current acquisition strategy, the FCS is neither knowledge-based nor does it lend itself to meaningful oversight. Figure 2 compares a knowledge-based approach to developing a weapon system (consistent with DOD policy) with the approach taken for FCS. Best practices for successful product development include three knowledge points (KP). Knowledge Point 1 should occur at development start and is attained when technologies and resources match requirements; KP 2 should occur at the mid-point between development and production and is attained when the product design performs as expected; and KP 3 should occur at production start and is attained when production can meet cost, schedule, and quality targets. Ideally the preliminary design review occurs at or near the start of development and the critical design review occurs mid-way through development.

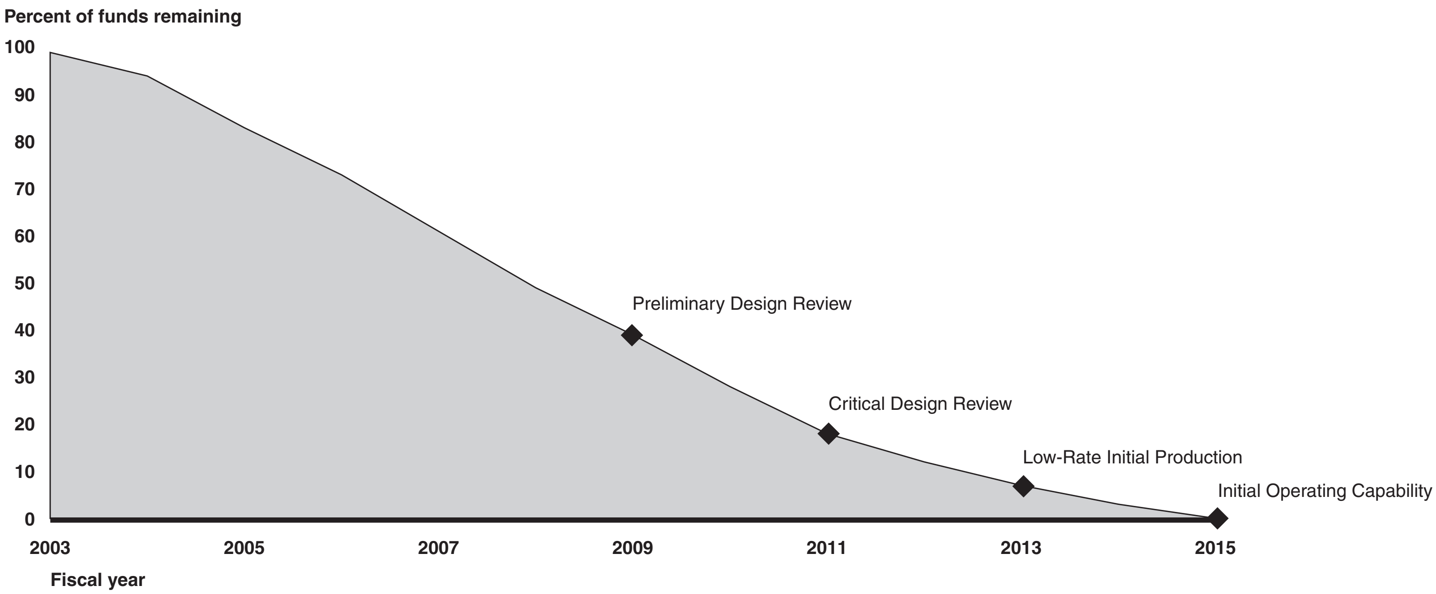
Figure 2: Differences between Best Practices Acquisition Approach and FCS Approach



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

As shown in figure 2 above, FCS technology development and system development and demonstration phases will overlap by several years. The Army has scheduled only 2 years between the critical design review in 2011 and the production decision in 2013. This leaves little time to gain knowledge between the two events, and is particularly important because the critical design review is the point at which a program begins building fully-integrated, production-representative prototypes whose testing will prove the design's maturity and form the basis for the low-rate production decision. Instead, FCS will rely on less mature prototypes and the decision to proceed into production will be made without a mature design. As a result of the current acquisition approach, the FCS program may not be executable given the amount of development budget remaining and the development work that remains to be done, as illustrated in figure 3 below.

Figure 3: Remaining FCS Research and Development Funding and Key Events



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

At the preliminary design review, the program expects to have all critical technologies mature to TRL 6, system-level requirements nearing completion, and a preliminary design available to reconcile technologies with requirements. Using DOD policy as a reference, this is about the point at which the FCS program should be ready to begin. Should the program be approved to continue on its present course at the 2009 milestone review, the Army would have to complete development—in essence, the entire system development phase—with 40 percent of its financial and schedule resources remaining. This is not to judge either the value of the work done to date or the rate of progress, but rather to underscore where the program really is in terms of the development process. Accordingly, ahead of FCS remains what is typically the most expensive part of system development: completing the detailed system and network designs and building prototypes and using them to demonstrate that the system will work. In the case of FCS, there are the added challenges of integrating multiple technologies and showing that the system of systems as a whole will work, including the unprecedented network.

The late completion of the system development activities that will demonstrate whether FCS can deliver the promised capability is at odds with the early requests for production funds. Additional maturation of critical technologies, followed by the challenging prospect of integrating FCS subsystems and systems, lies ahead. Design work is ongoing and many designs remain to be matured and verified. A key indicator of the Army's progress in this area will be the percentage of design drawings that will be released to manufacturing at the critical design review, currently scheduled for fiscal year 2011. The Army is currently fabricating key FCS prototypes, many of which are scheduled for delivery in the 2010 time frame. After they are delivered, much additional engineering work will remain to be conducted as part of a disciplined test, fix, and retest approach. For example, several prototypes will be built based on preliminary versus final designs, and will not have all key technologies integrated. In this sense, they will not be representative of production items. Many of the results of these demonstrations, and other key test and evaluation results, will not be available until late in the program, creating difficulty in applying knowledge gained from previous tests into subsequent tests. For example, a key system-of-systems test scheduled before the low-rate production decision is the limited user test 3 in 2012 to assess brigade combat team network capabilities. This test will be the first large-scale FCS test that will include a majority of the developmental prototypes and a large operational unit and occurs only one year before the low-rate initial production decision for the core FCS program. This test is important because the Congress has required a broad network demonstration to be conducted before starting low-rate production of the core FCS program. This demonstration is also expected to occur in fiscal year 2012 as part of the limited user test. Finally, the Army will have to develop and mature production processes for a wide range of FCS systems.

Our work has shown that development costs for programs with mature technologies at the start of system development increased by a modest average of 4.8 percent over the original estimate, whereas development costs for programs with immature technologies increased by 34.9 percent.[15] Our work has also shown that most development cost growth

[15] GAO, *Defense Acquisitions: Assessments of Selected Major Weapon Programs*, GAO-06-391 (Washington, D.C.: Mar. 31, 2006).

occurs after the critical design review. Specifically, of the 28.3 percent cost growth that weapon systems average in development, 19.7 percent occurs after the critical design review. In the case of FCS, the Army's strategy is schedule-driven and calls for beginning low-rate production in 2013 and initial operational capability in 2015, which leaves little time to overcome the remaining technological and engineering challenges the program faces prior to committing to production. Thus, it is likely that under the current schedule, additional cost growth would be incurred as the Army works through these remaining challenges.

According to DOD officials, the Systems and Software Engineering group, within DOD's Acquisition, Technology, and Logistics organization, has been tasked to conduct a systems engineering review of FCS that will include an evaluation of risks associated with the FCS acquisition strategy, test plans, software, and key complementary programs. According to the Systems and Software Engineering group, the assessment will also cover the FCS system engineering plan for reasonable exit criteria associated with critical design review and production readiness. The reporting objectives for this effort include, among other things, clearly illustrating the risks and challenges of proceeding to critical design review as planned. The Systems and Software Engineering group's review is expected to provide input to address three of the required congressional assessments—FCS requirements/design, concept demonstration, and software demonstration—and should provide critical information on the amount of FCS development and demonstration work yet to be completed and its expected cost and schedule.

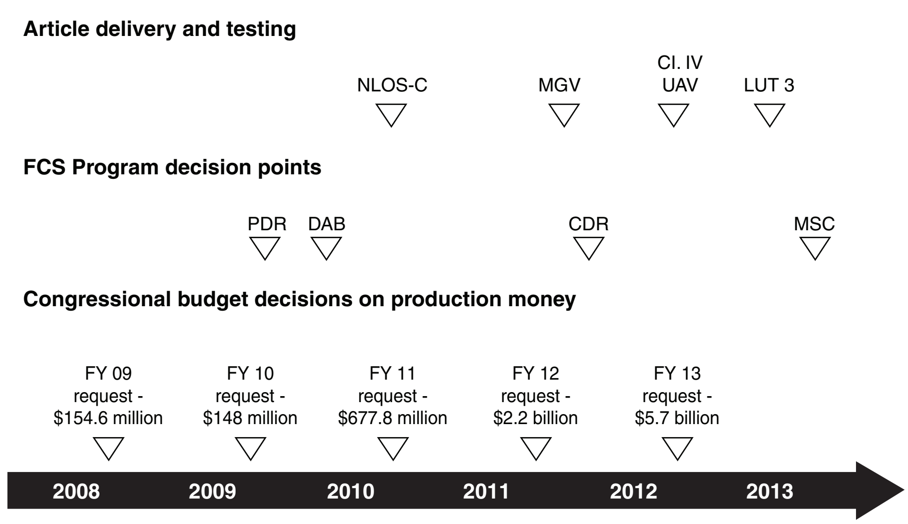
Timing of Currently Planned Funding Commitments Puts Decision Makers in Difficult Position

Funding commitments for production begin before FCS capabilities are demonstrated and even before the critical design review is held. This puts decision makers in a difficult position, particularly when considering that FCS is to deliver more than a better set of equipment—it embodies a new concept of combat. Procurement funding for core FCS production facilities will be requested for fiscal year 2011, the budget for which will be presented to Congress in February 2010—several months after the milestone review and before the stability of the FCS design is assessed at the critical design review.[16] In fact, based on results of system-level preliminary design reviews conducted to date, the Army could still be

[16] The money requested for fiscal years 2009, 2010 and a portion of the money for fiscal year 2011 is for NLOS-C production.

working to close action items resulting from the system-of-systems preliminary design review when it requests funding for FCS core production facilities. Further, when Congress is asked to approve funding for low-rate initial production of core FCS systems, the Army will not yet have proven that the FCS network and the program concept will work. A key demonstration of the FCS network, limited user test 3, is currently scheduled for later in 2012, after the Congress will have received the fiscal year 2013 budget submission. This is illustrated further in figure 4 below.

Figure 4: FCS Program Events and Congressional Budget Decisions



CDR = Critical Design Review
DAB = Defense Acquisition Board Milestone Review
LUT = Limited User Test
NLOS-C = Non-Line-of-Sight Cannon
MGV = Manned Ground Vehicle
MSC = Milestone C
PDR = Preliminary Design Review
Cl. IV UAV = Class IV Unmanned Aerial Vehicle

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

Early NLOS-C Production May Portend Risks for FCS

Since fiscal year 2003, the Army has been required by Congress to develop and field the NLOS-C early in order to provide a self-propelled indirect fire capability.[17] The Department of Defense Appropriations Act for 2008

[17] Department of Defense Appropriations Act, 2003, Pub. L. No. 107-248, § 8121 (2002), and similar provisions in subsequent defense appropriations acts.

required the Army to deliver eight NLOS-C prototypes by the end of calendar year 2008 and to field early production versions of the system by fiscal year 2010.[18] These systems are to be in addition to those needed for developmental and operational testing. The Army determined that a set of 18, a full battalion's worth, would be needed to meet the intent of the act's language in terms of the early production units. Although the NLOS-C is one of eight FCS manned ground vehicles, it is proceeding about 5 years ahead of the other vehicles.

The Army began procuring long-lead production items for the NLOS-C vehicle in 2008 to meet the requirement for the early production versions. According to program officials, an urgent need to build Mine-Resistant Ambush Protected vehicles diverted subcontractor resources away from the NLOS-C efforts. Officials further indicated that technological challenges associated with a lack of completed production facilities and specialized tooling also contributed to delays. The Army accepted delivery of the first two NLOS-C prototypes in fiscal year 2008 and the remaining six vehicles in the following two years. A Defense Acquisition Board decision to begin low-rate production for the additional set of 18 NLOS-C vehicles was expected in December 2008. Details of that decision were not available for inclusion in this report. If approved, the Army expects delivery of six early production units per year in fiscal years 2010 through 2012. None of these early NLOS-C vehicles will meet FCS threshold requirements nor will they be operationally deployable. Rather, they will be used as training assets for the Army Evaluation Task Force.

In order to meet the early fielding dates, the Army will begin production of the NLOS-C vehicles with immature technologies and designs. Several key technologies, such as lightweight armor, the active protection system, and the JTRS radios will not be fully mature for several years. Much requirements definition work remains for all the manned ground vehicles, including the NLOS-C. Software development is in its early stages. Design work on the manned ground vehicles also remains to be done, including work on the chassis and mission modules. Significant challenges involving integrating the technologies, software, and design will follow. To the extent that these aspects of the manned ground vehicles depart from the early production cannons, costly rework of the cannons may be necessary if they will ever be used for other than training purposes.

[18]Pub. L. No. 110-116, § 8088 (2007).

The Army's efforts and financial investments made on the NLOS-C vehicles could create additional pressure to proceed with FCS core production, prior to achieving a solid basis of knowledge on which to move forward. Production on the cannon is beginning 5 years in advance of the production decision on the FCS core systems. By the time of that decision, in fiscal 2013, the Army plans to have invested about $12 billion in FCS procurement funds and more than $50 billion for FCS overall. In addition, the Army also plans to invest millions in production facilities in which to build the vehicles. These activities all contribute to starting up the manned ground vehicle industrial base. If the FCS strategy goes according to plan, FCS core production would directly follow NLOS-C production, with long lead items for the FCS core program providing a transition. That may be premature based on the expected design maturity and demonstrations expected to be done to that point. DOD has attempted to make a distinction between NLOS-C and the core FCS program, but the linkages continue to exist in the FCS acquisition strategy. If decision makers were to consider delaying FCS core production because it was not ready, a gap could develop when early NLOS-C production ends. Sustaining the industrial base could then become an argument against an otherwise justified delay.

FCS Spin Outs Will Not be Proven Prior to Production

The Army initiated spin out development in 2004, when it embarked on an effort to bring selected FCS capabilities to current force heavy brigade combat teams while development of the core FCS program remained under way. In 2006, the Army established the Army Evaluation Task Force to use, evaluate, and train with the spin out capabilities, and the Task Force began its testing under that brigade construct in early 2008. In mid-2008, the Army changed its focus from fielding spin out equipment to heavy brigades and instead to field the equipment to infantry brigade combat teams beginning in fiscal year 2011.[19] Army officials stated that this change occurred because infantry brigades are the optimal forces to fight in an urban environment, are being used in combat more than other types of forces, and are the most vulnerable forces. Accordingly, the Army now proposes to have 43 infantry brigade combat teams fully equipped with spin out equipment by 2025 at a total cost of $21 billion, with over $5 billion to be provided in fiscal years 2010 to 2015. DOD officials have

[19]Heavy brigades are equipped with armor, such as the Bradley Fighting Vehicle. Light brigades are equipped with motorized infantry, such as the High Mobility Multi-purpose Wheeled Vehicle.

reviewed the Army's revised FCS spin out plans, but they have not yet made a decision to approve those plans.

The switch to infantry brigades led the Army to abandon its previous plan for a series of three spin outs and instead pursue a two-phased effort termed "early" and "threshold" with respective planned production commitment dates of fiscal years 2010 and 2013. The early spin out items are not expected to meet all FCS threshold requirements nor will the threshold spin out items have the same network and battle command capabilities as in the core FCS program. The early spin out will include:

- Non-Line-of-Sight Launch System,
- Urban and Tactical Unattended Ground Sensors,
- two types of Joint Tactical Radios,
- integrated computer system,
- early versions of the system-of-systems common operating environment and battle command software,
- Small Unmanned Ground Vehicle,
- Class I Unmanned Aerial Vehicle, and
- Ground Soldier System.[20]

The second phase of spin outs will include improved versions of the above systems as well as add the Multifunction Utility/Logistics and Equipment vehicle, Class IV Unmanned Aerial Vehicle, Armed Robotic Vehicle—Assault (Light), and Centralized Controller.[21]

With the advent of the new structure, the Army moved its initial spin out production decision from January 2009 to December 2009. However, testing to date has not made a convincing case for this production commitment for several reasons. First, the Army has conducted only one test focused on the infantry brigade combat team structure. The two initial spin out tests—a technical field test in early 2008 to verify technical aspects of the capabilities and force development test and evaluation in May 2008 to validate requirements and training associated with those capabilities—occurred prior to the restructure and therefore employed heavy brigade combat team constructs. While Army officials have

[20]The Joint Tactical Radios and Ground Soldier System are complementary programs and not directly part of the FCS program.

[21]The Centralized Controller will provide the dismounted soldier with a hand-carried device capable of enabling remote network interface with a number of FCS unmanned systems and remote control operation of manned ground vehicle functions.

indicated that the force development test results have applicability to the infantry brigades, the test's major objective in terms of construct was to confirm the organizational structure and equipment distribution for a spin out-equipped heavy brigade combat team. The third test in July 2008, a preliminary limited user test to assess maturity, interoperability, and contribution of spin out systems, did utilize the infantry brigade structure. However, because of the restructure, that test was a shortened 2-day version of an event originally planned as a much longer effort focused on the heavy brigade combat team.

Additionally, testing completed to date employed spin out systems that are not in the form that will be fielded. In fact, four of the systems planned for the early spin out have only been tested in surrogate or non-production representative forms (not in a mature or final configuration). The Ground Soldier System has not yet been included in any testing. Table 2 shows the versions of the prototypes used in each of the three tests to date.

Table 2: Surrogate, Non-Production, and Not-Yet-Tested Systems

System	Technical field test (February/March 2008)	Force development test (May 2008)	Preliminary limited user test (July 2008)
JTRS Ground Mobile Radio	Non-production representative	Non-production representative	Non-production representative
JTRS Handheld Radio	Surrogate	Surrogate	Surrogate
Small Unmanned Ground Vehicle	Not tested	Not tested	Non-production representative
Class I Unmanned Aerial Vehicle	Not tested	Not tested	Surrogate
Ground Soldier System	Not tested	Not tested	Not tested

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

Using surrogate and non-production representative systems is problematic because it does not conclusively show how well the spin out systems can address current force capability gaps in situational awareness, force protection, and lethality. Moreover, they limit the ability to translate spin out tactical operations from heavy brigade to infantry combat teams and from spin outs to the core FCS. In fact, DOD's current acquisition policy requires that systems meet approved requirements and are demonstrated in their intended environments using the selected production-representative articles before the engineering and manufacturing development phase—which precedes the production phase—can end. Army test officials and equipment users told us, and test reports for the

2008 spin out tests confirm, that the surrogates and non-production representative systems limited the ability to gauge system performance, forced adjustments in testing, and made it difficult to know whether beneficial lessons were learned in testing. Officials from the Army's independent testing organization, the Army Test and Evaluation Command, stated that prototype JTRS radios impact the ability to evaluate overall system effectiveness regarding such factors as range and reliability. They also noted that radio performance can impact tactics used by the testing unit. Army officials who actually participated in the testing expressed similar views, and noted that the surrogates limited tactical operations. As a result, they said, the Army is immature tactically in terms of what it knows about spin out operations.

The three tests scheduled for 2009 will continue to include surrogate and non-production representative systems. As in past tests, surrogates will take the place of JTRS handheld radios in all three tests. As noted by Army testers, this surrogate radio has limited basic functionality and will impact the evaluation of performance for systems used in conjunction with it, including the Non-Line-of-Sight Launch System and unattended ground sensors. According to Army officials, they will not have production representative versions of this radio to test until initial operational test and evaluation in fiscal year 2011. In addition, JTRS ground mobile radios used in 2009 testing are to consist of a mix of non-production and production representative models, but the composition will be heavily weighted toward the non-production representative models. Of the 16 total radios planned for use in the limited user test, only 4 are expected to be the production representative version. Additionally, Army officials told us that if these radios are delayed, they will not be able to properly operate and evaluate the needed networking capabilities.

The schedule for completing 2009 testing is tight, and the issues identified in the 2008 testing may not be resolved prior to the spin out production decision. According to Army and DOD officials, the Army Evaluation Task Force has proven extremely useful in identifying system issues and suggesting design changes. While the Army is working to improve spin out systems in accordance with the Task Force's testing observations and recommendations, it does not plan to prove out all final designs prior to the production decision. For example, the Army is redesigning the Tactical Unattended Ground Sensor because 2008 testing showed that it had issues with range, battery life, and hardware reliability. However, the Army does not expect to have the final version of the redesigned sensor available until February 2010, after the initial spin out production decision has been made. The Army is also redesigning the Urban Unattended Ground Sensor in accordance with testing feedback because that sensor had issues with battery life, user set-up time, and display of data. A final version of that sensor will not be available until February 2010. Additionally, the JTRS ground mobile radio may not be able to achieve its schedule for a production decision, which would impact the FCS spin out initiative.

The Army may be unable to thoroughly assess spin outs' military utility for current forces because testing planned for 2009 is very compressed and leaves little time for analysis before the production decision. Under the revised spin out structure, the Army expects to conduct technical field, force development, and limited user tests in a back-to-back period from July through September 2009. This schedule allows the Army only 12 weeks to conduct all the tests, assess tests results, and incorporate lessons learned from one test to the next. Additionally, the limited user test, the last test in the series before the production decision and arguably the most important in terms of demonstrating system interoperability and overall spin out military utility, is planned to conclude at the end of September. That means the Army only has 8 to12 weeks to assess those test results before DOD will make the expected December 2009 production decision. By comparison, the Army needed 8 months to produce its test report on the 2008 technical field test. A DOD testing official told us that, because of the testing schedule, the Army would be unable to analyze test results adequately before making decisions. Army officials acknowledged that the schedule is extremely compressed and noted that any delay in maturity or receipt of hardware and/or software would impact the test schedule. They also indicated that, because of the aggressive schedule, it might be necessary to change the order of the tests and hold the force development test after the limited user test.

Potential Incremental Acquisition Approach for FCS Would Represent Another Major Restructuring

Army officials informed the Under Secretary of Defense for Acquisition, Technology, and Logistics that they are considering an incremental or block acquisition approach to FCS. Citing the need to set a path to a stable, executable baseline for FCS—one with appropriately scoped requirements—FCS program officials believe that by adopting an incremental or block approach, they may be better able to mitigate risks in four major areas. These areas include: immaturity of requirements for system survivability, network capability, and information assurance; limited availability of performance trade space to maintain program cost and schedule given current program risks (schedule risks, weight/survivability, cost growth); program not funded to Cost Analysis Improvement Group estimates and impact of congressional budget cuts;

and continuing challenges in aligning schedules and expectations for multiple concurrent acquisitions (such as JTRS and WIN-T).

Subsequent to the mid-2008 Defense Acquisition Board meeting, where the Army presented its case for its consideration of an incremental or block approach for FCS acquisition, the Under Secretary of Defense for Acquisition, Technology, and Logistics issued a memorandum directing the Army to, among other things, pursue this initiative. Moreover, the memorandum stipulated that the incremental approach to acquire FCS must be prioritized to meet the warfighter's most critical operational needs and present a stable, executable program. The Army has been conducting an analysis to define an incremental approach, which is expected to address organizational structure, platforms, warfighter needs, and unified battle command. This analysis will be coupled with DOD assessments of FCS design maturity (including technology readiness levels, network and platform readiness, and associated risks and costs) and program maturity (including program execution feasibility, program scope, resource availability, and program alternatives). The Army was expected to present the analysis results and incremental FCS program plan to the DOD in late 2008 or early 2009, but that had not occurred at the time of this report. According to a DOD official, the adoption of an incremental approach may affect both the FCS core program and the spin out initiative. For the core FCS program, adoption of an incremental approach may involve a phased development and demonstration of individual FCS performance requirements and/or a phased fielding of individual components of the FCS family of systems. For the spin out initiative, the Army is considering if and when it should spin out FCS capabilities to the Heavy and Stryker Brigade Combat Teams.

Restructuring the FCS program around an incremental approach has the potential to alleviate the risks inherent in the current strategy. It also represents an opportunity to apply the policy and thus provide decision makers more information before key program commitments, like production funding, are made. Taking an incremental approach to new acquisitions, versus attempting to acquire full capability in one step, has been preferred by DOD policy and best practices since before FCS began in 2003. The December 2008 policy adds several key features that would benefit a restructured FCS program. These include:

- establishment of configuration steering boards that are tasked to review all requirements changes and any significant technical configuration changes that have the potential to result in cost and schedule impacts to the program;

- a post-preliminary design review assessment to be conducted where the results of the PDR and the program manager's assessment are considered to determine whether remedial action is necessary to achieve the program's objectives;
- a critical design review, which is an opportunity to assess design maturity by measures such as completion of subsystem critical design reviews, the percentage of software and hardware product specifications and drawings completed, planned corrective actions to hardware and software deficiencies; adequate developmental testing, the maturity of critical manufacturing processes, and an estimate of system reliability based on demonstrated reliability rates;
- a post-critical design review, which assesses the program manager's report on the critical design review to determine whether the program can meet its approved objectives or if adjustments should be made; and
- before production, a demonstration that the system meets requirements in its intended environment using a production-representative article, manufacturing processes have been effectively demonstrated in a pilot line environment, and industrial capabilities are reasonably available.

On the other hand, the newness of the incremental approach could complicate oversight at this important juncture. For example, its approval will lag behind the congressional schedule for authorizing and appropriating fiscal year 2010 funds. Also, a new approach to FCS could affect the scope of the milestone review. Evaluation of the new approach will involve a number of factors, including whether:

- the incremental approach adequately addresses program risks and unresolved questions on the feasibility of the FCS concept and its information network;
- the initial increment of FCS capability is justifiable on its own, without being dependent on future increments;
- each increment, including the first, will comply with current DOD policy as it applies to a new program starting at the preliminary design review stage; and
- the Army's overall investment plan and resources for FCS increments, spin outs, and its current forces is sound and affordable.

Should an incremental approach to FCS be pursued, one consideration will be the future role of the Army's contracting relationship with the LSI. We have previously reported the uniquely close relationship that exists between the Army and the LSI.[22] While this has advantages, it also has disadvantages. In the past two years, the role of the LSI, originally limited to development, has grown relative to production. It is expected to be the prime contractor for production of spin outs, the NLOS-C, and at least the low-rate production of the FCS core systems. The specific role the LSI will play in production of spin outs, NLOS-C, and FCS core production remains somewhat unclear. Statements of work for the production contracts have not yet been negotiated. According to the program officials, the LSI will contract with the first tier subcontractors, which will in turn contract with their own subcontractors. Thus, the production role of the LSI is likely to be largely in oversight of the first tier subcontractors versus fabricating systems or subsystems. The LSI is also responsible for defining and maintaining a growth strategy for integrating new technologies into the FCS brigade combat teams. Combined with a likely role in sustainment, the LSI will remain involved in the FCS program indefinitely.

Recently, the Under Secretary of Defense for Acquisition, Technology, and Logistics issued a directive to pursue alternate arrangements for any future FCS contracts. The Under Secretary found that the fixed fee was too high and the fee structure allows industry to receive most of the incentive fee dollars prior to demonstrating integrated FCS system-of-systems capability. The Under Secretary also directed that the Army conduct a risk-based assessment to examine contracting alternatives for FCS capability. This assessment is to evaluate opportunities for procurement breakout of the individual platforms/systems that comprise FCS and how the government's interests are served by contracting with the LSI as compared to contracting directly with the manufacturers of the items.

Conclusions

The 2009 milestone review is the most important decision on the Future Combat System since the program began in 2003. If the preliminary design reviews are successfully completed and critical technologies mature as planned in 2009, the FCS program will essentially be at a stage that statute and DOD policy would consider as being ready to *start* development. In this sense, the 2009 review will complete the evaluative process that began with the original 2003 milestone decision. Further, when considering that the current estimate for FCS ranges from $159 billion to $200 billion when

[22] GAO, *Defense Acquisitions: Role of Lead Systems Integrator on Future Combat Systems Program Poses Oversight Challenges*, GAO-07-380 (Washington, D.C.: June 6, 2007).

the potential increases to core program costs and estimated costs of spin outs are included, 90 percent or more of the investment in the program lies ahead. Even if a new, incremental approach to FCS is approved, a full milestone review that carries the responsibility of a go/no-go decision is still in order, along with the attendant reports and analyses that are required inputs. In the meantime, establishing a configuration steering board, as suggested in DOD policy, may help bridge the gaps between requirements and system designs and help in the timely completion of the FCS preliminary design reviews.

At this point, there are at least three programmatic directions, or some combination thereof, that DOD could take at the milestone review to shape investments in combat systems for the Army, each of which presents challenges. First, the FCS program as currently structured has significant risks and may not be executable within remaining resources. Second, although an incremental approach may improve the Army's prospects for fielding some capability, each increment must stand on its own and not be dependent on future increments. Third, spin outs to current forces currently rely on a rushed schedule that calls for making production decisions before production-representative prototypes have clearly demonstrated a useful military capability. The role of the LSI in the FCS production phase will be a factor that will have to be considered for any program that emerges from the milestone review.

There is no question that the Army needs to ensure its forces are well-equipped. The Army has vigorously pursued FCS as the solution, a concept and an approach that is unconventional, yet with many good features. The difficulties and redirections experienced by the program should be seen as revealing its immaturity, rather than as the basis for criticism. However, at this point, enough time and money have been expended that the program should be evaluated at the 2009 milestone review based on what it has shown, not on what it could show. The Army should not pursue FCS at any cost, nor should it settle for whatever the FCS program produces under fixed resources. Rather, the program direction taken after the milestone review must strike a balance between near-term and long-term needs, realistic funding expectations, and a sound plan for execution. Regarding execution, the review represents an opportunity to ensure that the emerging investment program be put on the soundest possible footing by applying the best standards available, like those contained in DOD's 2008 acquisition policy, and requiring clear demonstrations of the FCS concept and network before any commitment to production of core FCS systems.

Any decision the Army makes to change the FCS program is likely to lag behind the congressional schedule for authorizing and appropriating fiscal year 2010 funds. Because of this, Congress needs to preserve its options for ensuring it has adequate knowledge on which to base funding decisions. Specifically, it does not seem reasonable to expect Congress to provide full fiscal year 2010 funding for the program before the milestone review is held nor production funding before system designs are stable and validated in testing.

Matters for Congressional Consideration

The Congress should consider taking the following two actions:

- restricting the budget authority to be provided for FCS in fiscal year 2010 until DOD fully complies with the statutory FCS milestone review requirements and provides a complete budget justification package for any program that emerges, and
- not approving any production or long lead item funds for the core FCS program until the critical design review is satisfactorily completed and demonstrations using prototypes provide confidence that the FCS system-of-systems operating with the communications network will be able to meet its requirements.

Recommendations for Executive Action

We recommend that the Secretary of Defense

- ensure that the investment program that emerges from the 2009 milestone review be conformed with current DOD acquisition policy, particularly regarding technology maturity, critical design reviews, and demonstrating production-representative prototypes before making production commitments;
- direct the Secretary of the Army to convene, following the preliminary design reviews and in time to inform the 2009 FCS milestone review, an FCS Configuration Steering Board to provide assistance in formulating acceptable trade-offs to bridge the gaps between the FCS requirements and the system designs;
- ensure that if an incremental approach is selected for FCS, the first increments are justifiable on their own as worthwhile capabilities that are not dependent on future increments for their value, particularly regarding the order in which the information network and individual manned ground vehicles will be developed;
- ensure that FCS systems to be spun out to current forces have been successfully tested in production-representative form before they are approved for initial production; and

- reassess the appropriate role of the LSI in the FCS program, particularly regarding its involvement in production.

Agency Comments and Our Evaluation

DOD concurred with all our recommendations and provided comments on two. Regarding our recommendation on testing spin out systems, DOD commented that any production decision for FCS systems going to the current force will be informed by an operational assessment or user test of the systems. Although the Army plans to conduct such testing prior to the spin out low-rate initial production decision in late 2009, that testing will employ surrogate and non-production representative systems. We maintain that any systems planned for production should be production-representative and thoroughly tested in a realistic environment. DOD noted that such testing was more in line with what is required for the full-rate production decision versus the initial low-rate decision. The testing standards we apply reflect the best practice and DOD policy of having production-representative prototypes tested prior to a low-rate production decision. This approach demonstrates the prototypes' performance and reliability as well as manufacturing processes—in short, that the product is ready to be manufactured within cost, schedule, and quality goals. In fact, current DOD policy states that development "shall end when the system meets approved requirements and is demonstrated in its intended environment, using the selected production-representative article; manufacturing processes have been effectively demonstrated in a pilot line environment; industrial capabilities are reasonably available; and the system meets or exceeds exit criteria and [low-rate initial production] entrance requirements."

Regarding our recommendation about reassessing the role of the LSI, DOD stated that the FCS contractual arrangement is not an LSI contract as defined by law. According to the Duncan Hunter National Defense Authorization Act for Fiscal Year 2009, the FCS prime contractor "shall be considered to be a lead systems integrator until 45 days after the Secretary of the Army certifies in writing to the congressional defense committees that such contractor is no longer serving as the lead systems integrator."[23] Army officials have stated that they are unaware of the Army preparing any such certification for the defense committees. Regardless of how the prime contractor is characterized, it was originally envisioned by the Army as an LSI, and its unusually close relationship with the Army on the FCS program still warrants additional oversight.

[23] Pub. L. No. 110-417, § 112.

Regarding our matters for congressional consideration, DOD expressed concern over the impact to FCS acquisition execution with the fiscal year 2010 budget authority limitations that we suggested Congress consider. We believe a restriction is necessary as congressional committees will be asked to provide funds for fiscal year 2010 before the FCS milestone review, currently scheduled for July 30, 2009, is held. The review will lead to a decision on whether the program should continue as currently structured, continue in restructured form, or be terminated. The scope and significance of those decisions create the possibility that the Army's fiscal year 2010 budget plans for FCS could differ significantly from the request that Congress will consider. A restriction need not amount to a denial or reduction of funds, but rather creates an opportunity for Congress to review any change in Army plans before releasing funds for FCS for the entire fiscal year.

We received other technical comments from DOD, which have been addressed in the report, as appropriate.

We are sending copies of this report to the Secretary of Defense; the Secretary of the Army; and the Director, Office of Management and Budget. Copies will also be made available at no charge on the GAO Web site at http://www.gao.gov.

Please contact me on (202) 512-4841 if you or your staff has any questions concerning this report. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. The major contributors are listed in appendix VIII.

Paul L. Francis

Paul L. Francis
Director
Acquisition and Sourcing Management

List of Committees:

The Honorable Carl Levin
Chairman
The Honorable John McCain
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Daniel K. Inouye
Chairman
The Honorable Thad Cochran
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Ike Skelton
Chairman
The Honorable John M. McHugh
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable John P. Murtha, Jr.
Chairman
The Honorable C. W. (Bill) Young
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Scope and Methodology

To develop information on to what extent knowledge will likely be available to DOD and the Congress in the key areas of technology, design, demonstrations, network performance, and cost and affordability to support the 2009 milestone review, and the execution challenges that a post-milestone review FCS program presents to DOD and the Congress, 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 Secretary of Defense's Program Analysis and Evaluation; Director Defense Research and Engineering; the Joint Staff; Assistant Secretary of Defense (Networks and Information Integration); the Army's Training and Doctrine Command; the Director of Operational Test and Evaluation; the Future Force Integration Directorate; the Army Evaluation Task Force, the Army Test and Evaluation Command; the Director of the Combined Test Organization; the Program Manager, Future Combat System (Brigade Combat Team); and the Project Manager, Future Combat System Spin Out.

We reviewed relevant Army and DOD documents, including the *Future Combat System's Operational Requirements Document*, the *Acquisition Strategy Report*, the *Selected Acquisition Report*, critical technology assessments and technology risk mitigation plans, and spin out test results.

We attended system-level preliminary design reviews, board of directors reviews, and system demonstrations. 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 certify that officials from DOD and the Army have provided us access to sufficient information to make informed judgments on the matters in this report. We discussed the issues presented in this report with officials from the Army and the Secretary of Defense and made several changes as a result. We conducted this performance audit from March 2008 to March 2009 in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION
TECHNOLOGY
AND LOGISTICS

MAR - 3 2009

Mr. Paul L. Francis
Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Francis:

This is the Department of Defense (DoD) response to the GAO Draft Report, GAO-09-288, "DEFENSE ACQUISITIONS: Decisions Needed to Shape Army's Combat Systems for the Future," dated February 2, 2009 (GAO Code 120740).

The report recommends Congress (1) consider restricting the budget authority for Future Combat Systems (FCS) in Fiscal Year (FY) 2010 until the Department complies with statutory FCS review requirements and (2) not approve production or long lead item funds for the core FCS program until the critical design review is completed and demonstrations using prototypes provide confidence that FCS will meet its requirements. The Department is concerned with the impact to FCS acquisition execution with the FY2010 FCS budget authority limitations GAO is recommending to Congress. Also of note, GAO's recommended testing requirements in support of the low-rate initial production decision is more in line with the testing required for Initial Operational Test and Evaluation, which occurs with low-rate production assets and informs the full rate production decision.

The report recommends that the Secretary of Defense ensure the FCS program conforms to current defense acquisition policy, direct the Army to convene a Configuration Steering Board, ensure any increments of FCS capability are justifiable on their own, ensure any systems going to the current forces have been successfully tested, and reassess the involvement of the FCS contractor in production.

The Department concurs with the GAO recommendations and our comments are enclosed. It should be noted, the FCS contractual arrangement is not an LSI contract as defined by law. Detailed technical comments were provided separately.

Sincerely,

David G. Ahern
Director
Portfolio Systems Acquisition

Enclosure:
As stated

GAO DRAFT REPORT DATED FEBRUARY 2, 2009
GAO-09-288 (GAO CODE 120740)

"DEFENSE ACQUISITIONS: DECISIONS NEEDED TO SHAPE ARMY'S COMBAT SYSTEMS FOR THE FUTURE"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATION

RECOMMENDATION 1: The GAO recommended that the Secretary of Defense ensure that the investment program that emerges from the 2009 milestone review be conformed with current DoD acquisition policy, particularly regarding technology maturity, critical design reviews, and demonstrating production-representative prototypes before making production commitments.

DOD RESPONSE: Concur.

RECOMMENDATION 2: The GAO recommended that the Secretary of Defense direct the Secretary of the Army to convene, following the preliminary design reviews and in time to inform the 2009 Future Combat System (FCS) milestone review, an FCS Configuration Steering Board to provide assistance in formulating acceptable trade-offs to bridge the gaps between the FCS requirements and the system designs.

DOD RESPONSE: Concur.

RECOMMENDATION 3: The GAO recommended that the Secretary of Defense ensure that if an incremental approach is selected for FCS, the first increments are justifiable on their own as worthwhile capabilities that are not dependent on future increments for their value, particularly regarding the order in which the information network and individual manned ground vehicles will be developed.

DOD RESPONSE: Concur.

RECOMMENDATION 4: The GAO recommended that the Secretary of Defense ensure that FCS systems to be spun out to current forces have been successfully tested in production-representative form before they are approved for initial production.

DOD RESPONSE: Concur. Any Milestone C decisions on FCS systems going to the current force will be informed by an operational assessment or user test of the systems.

RECOMMENDATION 5: The GAO recommended that the Secretary of Defense reassess the appropriate role of the lead system integrator (LSI) in the FCS program, particularly regarding its involvement in production.

DOD RESPONSE: Concur. In November 2008, the USD(AT&L) directed the Secretary of the Army to examine contracting alternatives for procurement of FCS capability. The FCS contractual arrangement is not an LSI contract as defined by law.

Appendix III: Legislative Requirements for 2009 FCS Go/No-Go Review

Section 214 of Public Law 109-364 mandated that the Secretary of Defense perform a milestone (go/no-go) review of the Future Combat Systems acquisition program. The following depicts that legislation in its entirety as amended by section 211 of Public Law 110-417.

(a) MILESTONE REVIEW REQUIRED.—Not later than 120 days after the preliminary design review of the Future Combat Systems program is completed, the Secretary of Defense shall carry out a Defense Acquisition Board milestone review of the Future Combat Systems program. The milestone review shall include an assessment as to each of the following:

(1) Whether the warfighter's needs are valid and can be best met with the concept of the program.
(2) Whether the concept of the program can be developed and produced within existing resources.
(3) Whether the program should—

(A) continue as currently structured;
(B) continue in restructured form; or
(C) be terminated.

(b) DETERMINATIONS TO BE MADE IN ASSESSING WHETHER PROGRAM SHOULD CONTINUE.—In making the assessment required by subsection (a)(3), the Secretary shall make a determination with respect to each of the following:

(1) Whether each critical technology for the program is at least Technical Readiness Level 6.
(2) For each system and network component of the program, what the key design and technology risks are, based on System Functional Reviews, Preliminary Design Reviews, and Technical Readiness Levels.
(3) Whether actual demonstrations, rather than simulations, have shown that the concept of the program will work.
(4) Whether actual demonstrations, rather than simulations, have shown that the software for the program is on a path to achieve threshold requirements on cost and schedule.
(5) Whether the program's planned major communications network demonstrations are sufficiently complex and realistic to inform major program decision points.
(6) The extent to which Future Combat Systems manned ground vehicle survivability is likely to be reduced in a degraded Future Combat Systems communications network environment.

(7) The level of network degradation at which Future Combat Systems manned ground vehicle crew survivability is significantly reduced.
(8) The extent to which the Future Combat Systems communications network is capable of withstanding network attack, jamming, or other interference.
(9) What the cost estimate for the program is, including all spin outs, and an assessment of the confidence level for that estimate.
(10) What the affordability assessment for the program is, given projected Army budgets, based on the cost estimate referred to in paragraph (9).

(c) REPORT.—The Secretary shall submit to the congressional defense committees a report on the findings and conclusions of the milestone review required by subsection (a). The report shall include, and display, each of the assessments required by subsection (a) and each of the determinations required by subsection (b).

(d) RESTRICTION ON PROCUREMENT FUNDS EFFECTIVE FISCAL 2009.—

(1) IN GENERAL.—For fiscal years beginning with 2009, the Secretary may not obligate any funds for procurement for the Future Combat Systems program.
(2) EXCEPTIONS.—Paragraph (1) does not apply with respect to—

(A) the obligation of funds for costs attributable to an insertion of new technology (to include spin out systems) into the current force, if the insertion is approved by the Under Secretary of Defense for Acquisition, Technology, and Logistics; or
(B) the obligation of funds for the non-line-of-sight cannon system.

(3) TERMINATION.—The requirement of paragraph (1) terminates after the report required by subsection (c) is submitted.

Appendix IV: 2009 Defense Acquisition Board In-Process Review Criteria

Program Execution[1]

- Preliminary Design Reviews completed for System-of-Systems, Network, Manned, Unmanned, and Sensors/Munitions Family-of-Systems
- Platforms and Networks—Design, build, and test schedules are aligned and executable
- FCS/Joint Tactical Radio System/Warfighter Information Network-Tactical Programs development, build, and test schedules are aligned and executable
- Technology Readiness Level 6 achieved for threshold critical technologies

Unmanned Systems

- 36 Class I Unmanned Aerial Vehicles Block 0 operational with 2nd Brigade Combat Team, 25th Infantry Division
- 8 Class IV airframes (less payloads) built
- Unmanned Ground Vehicles and Autonomous Navigation System engineering technology demonstrators built
- 22 Small Unmanned Ground Vehicles, Block 1 Delivered to Army Evaluation Task Force

Manned Ground Vehicles

- Demonstrated Manned Ground Vehicle Common Chassis
- Demonstrations of Non-Line of Sight-Mortar and Mounted Combat System firing platforms
- 5 Non-Line of Sight-Cannon early prototypes built

Network

- 12 Engineering Development Model ground mobile radios and 40 Engineering Development Model handheld, manpack small form fit radios delivered to FCS and operational in an unclassified environment
- Demonstration of integrated sensor data feeds using Level 1 Fusion in an operational environment
- Integrated Computer Systems with cross domain demonstrated

[1]Future Combat Systems (FCS) Acquisition Decision Memorandum (ADM) for Secretary of the Army issued by The Under Secretary of Defense for Acquisition, Technology, and Logistics, Aug. 16, 2008.

- Software Build 1.0 Qualification Test complete
- Centralized Controller Spiral 1 prototype
- System-of-Systems Common Operation Environment Build 2 (Services or Air and Ground Network) Functional Qualification Test Complete

Test/Experimentation/Demonstration

- Demonstration of 16 Urban-Unattended Ground Sensors, 10 Tactical-Unattended Ground Sensors, 6 Non-Line of Sight-Launch System Container Launch Units, 4 Small Unmanned Ground Vehicles Block 1 and 6 Class I Unmanned Aerial Vehicles Block 0 with the Army Evaluation Task Force in an operational environment
- Ongoing Non Line of Sight Launch-System guided test vehicle flights
- Spin Out Pre-Limited user test completed
- Experiment 2.1/Joint Expeditionary Force Experiment 2008 and Experiment 2.2 completed
- Integrated Mission Testing 1 completed
- Software Build 2 Early Engineering Release completed
- System-of-System Simulation Framework maturation assessment completed

Appendix V: Other Related Legislation

Section 212 of Public Law 110-417 requires the Assistant Secretary of Defense (Networks and Information Integration) to report by September 30, 2009 on its analysis of FCS communications network and software. The specific issues to be addressed are listed below.

- An assessment of the vulnerability of the FCS communications network and software to enemy network attack, in particular the effect of the use of significant amounts of commercial software in FCS software.
- An assessment of the vulnerability of the FCS communications network to electronic warfare, jamming, and other potential enemy interference.
- An assessment of the vulnerability of the FCS communications network to adverse weather and complex terrain.
- An assessment of the FCS communication network's dependence on satellite communications support, and an assessment of the network's performance in the absence of assumed levels of satellite communications support.
- An assessment of the performance of the FCS communications network when operating in a degraded condition …and how such a degraded network environment would affect the performance of FCS brigades and the survivability of FCS Manned Ground Vehicles.
- An assessment, developed in coordination with the Director of Operational Test and Evaluation, of the adequacy of the FCS communications network testing schedule.
- An assessment, developed in coordination with Defense, Operational Test & Evaluation, of the synchronization of the funding, schedule, and technology maturity of the WIN-T and JTRS programs in relation to the FCS program, including any planned FCS spin outs.

Appendix VI: Technology Readiness Levels

Technology Readiness Levels (TRL) are measures pioneered by the National Aeronautics and Space Administration and adopted by DOD to determine whether technologies were sufficiently mature to be incorporated into a weapon system. Our prior work has found TRLs to be a valuable decision-making tool because they can presage the likely consequences of incorporating a technology at a given level of maturity into a product development. The maturity level of a technology can range from paper studies (TRL 1), to prototypes that can be tested in a realistic environment (TRL 7), to an actual system that has proven itself in mission operations (TRL 9). According to DOD acquisition policy, a technology should have been demonstrated in a relevant environment or, preferably, in an operational environment (TRL 7) to be considered mature enough to use for product development. Best practices of leading commercial firms and successful DOD programs have shown that critical technologies should be mature to at least a TRL 7 before the start of product development.

Table 3: TRL Descriptions

Technology readiness level	Description	Hardware and software	Demonstration environment
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	None (paper studies and analysis).	None.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis).	None.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of non-scale individual components (pieces of subsystem).	Lab.
4. Component and/or breadboard. Validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.	Low-fidelity breadboard. Integration of non-scale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab.

Technology readiness level	Description	Hardware and software	Demonstration environment
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory Integration of components.	High-fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size, weight, materials, etc.). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.	Prototype—Should be very close to form, fit, and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit, and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative operational environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight-qualified hardware.	Developmental test and evaluation in the actual system application.
9. Actual system "flight proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form.	Operational test and evaluation in operational mission conditions.

Source: GAO analysis of National Aeronautics and Space Administration data.

Appendix VII: FCS Critical Technology Ratings and Projections for Achieving TRL 6

FCS Critical Technologies			2007 TRL rating	2007 TRL 6 projection	2008 TRL rating	2008 TRL 6 projection
Joint interoperability		**Software programmable radio**				
	1	JTRS Ground Mobile Radio	6	N/A	6	N/A
	2	JTRS Handheld, manpack, small form fit	6	N/A	6	N/A
	3	WIN-T	5	2008	6	N/A
		Interface and Information Exchange				
	4	Army, Joint, multinational interface	6	N/A	6	N/A
	5	SOSCOE interoperability	5	2008	6	N/A
Networked battle command		**Security Systems and Algorithms**				
	6	Cross Domain Guarding Solution	6	N/A	6	N/A
	7	Intrusion detection--IP network	5	2008	6	N/A
	8	Intrusion detection--waveform	6	N/A	6	N/A
	9	**Mobile ad hoc networking protocols**	6	N/A	5	2009
	10	**Quality of service algorithms**	5	2008	6	N/A
	11	**Unmanned systems relay**	N/R	N/A	N/R	N/A
		Wideband waveforms				
	12	Wideband waveform--JTRS	6	N/A	5	2009
	13	Wideband waveform--SRW	6	N/A	6	N/A
	14	**Advanced man-machine interfaces**	6	N/A	6	N/A
	15	**Multi-Spectral sensors and seekers**	6	N/A	6	N/A
	16	**Decision aids/intelligent agents**	6	N/A	6	N/A
		Combat identification				
	17	Air (rotary wing/UAV)--to--ground	6	N/A	6	N/A
	18	Air (fixed wing)--to--ground (interim/robust solutions)	N/R	N/A	N/R	N/A
	19	Ground--to--ground (mounted)	6	N/A	6	N/A
	20	Ground--to--air (mounted)	N/R	N/A	N/R	N/A
	21	Ground--to--soldier	N/R	N/A	N/R	N/A
	22	**Rapid battlespace deconfliction**	5	2008	5	2009
		Sensor/data fusion and data compression algorithms				
	23	Distributed fusion management	5	2008	6	N/A
	24	Level 1 fusion engine	6	N/A	6	N/A
	25	Data compression algorithms	6	N/A	7	N/A
Networked lethality	26	**Dynamic sensor--shooter pairing algorithms and fire control**	6	N/A	6	N/A
		LOS/BLOS/NLOS precision munitions terminal guidance				
	27	PGMM precision munitions	N/R	N/A	N/R	N/A

FCS Critical Technologies			2007 TRL rating	2007 TRL 6 projection	2008 TRL rating	2008 TRL 6 projection
	28	MRM precision munitions	6	N/A	6	N/A
	29	Excalibur precision munitions	7	N/A	7	N/A
	30	NLOS-LS	6	N/A	6	N/A
		Aided/automatic target recognition				
	31	Aided target recognition for RSTA	5	2008	6	N/A
	32	NLOS-LS ATR for seekers	6	N/A	6	N/A
	33	**Recoil management and lightweight components**	6	N/A	6	N/A
	34	**Distributed collaboration of manned/unmanned platforms**	6	N/A	6	N/A
	35	**Rapid battle damage assessment**	N/R	N/A	N/R	N/A
Transportability						
Sustainability / reliability		**High-power density/fuel-efficient propulsion**				
	36	High-power density engine	6	N/A	6	N/A
	37	Fuel-efficient hybrid-electric engine	6	N/A	6	N/A
	38	**Embedded predictive logistics sensors and algorithms**	N/R	N/A	N/R	N/A
	39	**Water generation and purification**	N/R	N/A	N/R	N/A
	40	**Lightweight heavy fuel engine**	5	2008	5	2009
Training	41	**Computer generated forces**	6	N/A	6	N/A
	42	**Tactical engagement simulation**	6	N/A	6	N/A
Survivability		**Active protection system**				
	43	Active protection system	5	2008	6	N/A
	44	Threat warning sensor	4	2010	6	N/A
	45	**Signature management**	6	N/A	6	N/A
	46	**Lightweight hull and vehicle armor**	5	2008	6	N/A
	47	**Health monitoring and casualty care interventions**	7	N/A	8	N/A
	48	**Power distribution and control**	N/R	N/A	N/R	N/A
		Advanced countermine technology				
	49	Mine detection	6	N/A	6	N/A
	50	Mine neutralization	6	N/A	6	N/A
	51	Efficient resource allocation	N/R	N/A	N/R	N/A
	52	Protection	5	2008	6	N/A
	53	**High-density packaged power**	6	N/A	6	N/A
		Class 1 UAV propulsion technology				
	54	Ducted fan	6	N/A	6	N/A

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

Appendix VIII: GAO Contact and Staff Acknowledgments

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