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Report to the Committee on Armed Services, U.S. Senate

May 2006

DEFENSE ACQUISITIONS

Better Acquisition Strategy Needed for Successful Development of the Army's Warrior Unmanned Aircraft System

GAO

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Better Acquisition Strategy Needed for Successful Development of the Army's Warrior Unmanned Aircraft System

Why GAO Did This Study

Through 2011, the Department of Defense (DOD) plans to spend $20 billion on unmanned aircraft systems, including the Army's "Warrior." Because of congressional concerns that some systems have been more costly and taken more time to produce than predicted, GAO reviewed the Warrior program. This report (1) describes the Army's requirements underlying its decision to acquire Warrior instead of existing systems such as the Air Force's Predator, and (2) assesses whether the Army has established a sound acquisition strategy for the Warrior program.

What GAO Recommends

GAO recommends the Secretary of the Army ensure that a sound, knowledge-based acquisition strategy guide the Warrior program. Specifically, GAO recommends that the Army not approve long-lead items for Warrior low-rate initial production until it can clearly demonstrate that the program's technologies are mature and its design stable. DOD states that delaying procurement of long-lead items will increase program costs and delay fielding of Warrior. GAO's past work shows that programs proceeding without needed knowledge on technologies and design ultimately take longer and cost more money.

www.gao.gov/cgi-bin/getrpt?GAO-06-593.

To view the full product, including the scope and methodology, click on the link above. For more information, contact John Hutton at (202) 512-7773 or huttonj@gao.gov.
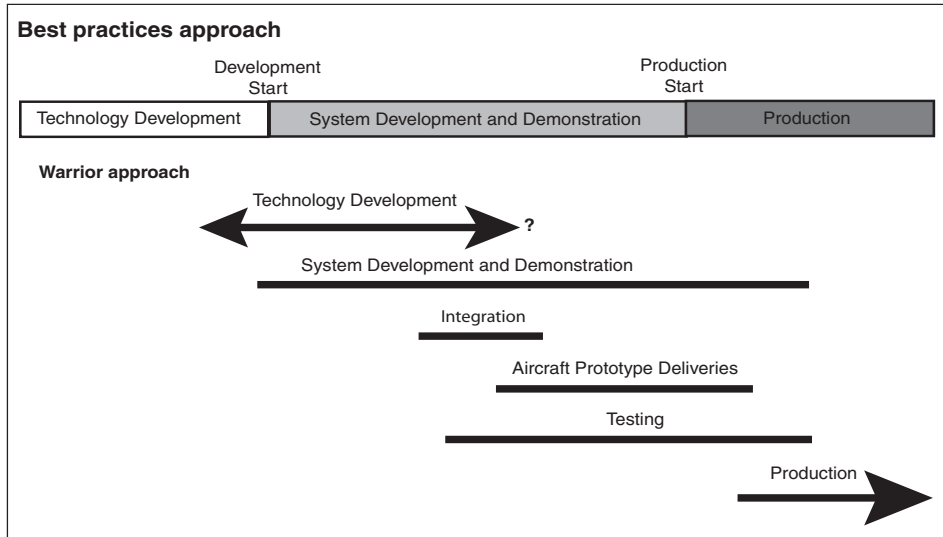
What GAO Found

The Army determined the Warrior is its best option for an unmanned aircraft system directly controlled by field commanders, compared with existing systems such as the Air Force's Predator A. The Army believes that using the Warrior will improve force capability through teaming with other Army assets; using common ground control equipment; and allowing soldiers in the field to operate it. Warrior's key technical features include a heavy fuel engine; automatic take-off and landing system; faster tactical common data link; ethernet; greater carrying capacity for weapons; and avionics with enhanced reliability. The Army projects that Warrior will offer some cost savings over Predator A.

In terms of technology maturity, design stability, and a realistic schedule, the Army has not yet established a sound, knowledge-based acquisition strategy for Warrior. Two of four of the Warrior's critical technologies were immature at the contract award for system development and demonstration and remain so in early 2006, and the mature technologies still have some risk associated with them because neither has previously been fully integrated onto an unmanned aircraft. The Warrior schedule allows 32 months from award of the development and demonstration contract to the initial production decision. Achieving this schedule will require concurrency of technology and product development, testing, and production. Once developmental aircraft are available for testing, the Army plans to fund procurement of long-lead items in August 2007. Experience shows that these concurrencies can result in design changes during production that can prevent delivery of a system within projected cost and schedule. The Warrior program faces these same risks.

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

Contents

Abbreviations

DOD	Department of Defense
SDD	System Development and Demonstration
TRL	Technology Readiness Level

United States Government Accountability Office
Washington, DC 20548

May 19, 2006

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

Unmanned aircraft systems[1] are being developed and fielded in growing numbers and the diversity of designs and applications is also increasing. Through 2011, the Department of Defense plans to spend $20 billion to develop, procure, and support a rapidly increasing inventory of such systems. Among the new developments is the Army's Extended Range Multi-Purpose Unmanned Aircraft System, also known as "Warrior." The Army intends for Warrior to fill what it terms a capability gap for an unmanned aircraft system at the division level. Warrior is being developed and produced by the contractor also involved in the Air Force's Predator A and Predator B unmanned aircraft systems. Warrior is to some degree similar to those systems, a fact recognized by the Air Force and Army. In January 2006, both services signed a memorandum of understanding that recognized that complementary/joint requirements exist between the Predator and Warrior systems, and they committed to reaching agreement on how to develop and use these capabilities.

Because of the growth in requirements and new technologies for unmanned aircraft systems and your concerns that some unmanned aircraft systems have not produced the expected cost and schedule outcomes, you asked us to review the Army's Warrior program. Specifically, this report (1) describes the Army's requirements underlying its decision to acquire Warrior instead of existing systems such as the Air Force's Predator; and (2) assesses whether the Army has established a sound acquisition strategy for the Warrior program.

To address the first objective, we reviewed Army requirements documents as well as compared key technical features of the planned Warrior and

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[1] Until recently, DOD referred to these aircraft as "unmanned aerial vehicles." "Unmanned aircraft" is consistent with the Federal Aviation Administration's classification and emphasizes other components of the aircraft system, such as payload, ground stations, and communications equipment.

GAO-06-593 Warrior Acquisition Strategy

Predator. We also reviewed the process the Army used to select the Warrior system. To address the second objective, we reviewed the Warrior acquisition strategy and evaluated it according to best practices criteria utilizing GAO's "Methodology for Assessing Risks on Major Weapons Systems Acquisition Programs." We also analyzed budget-related, programmatic, and planning information to determine the soundness of the Army's acquisition strategy. For both objectives, we interviewed Army officials and obtained information on Army requirements and acquisition strategy for Warrior. We also leveraged other recent GAO work on the Air Force's Predator system[2] and our overall body of work on best practices of leading companies. We conducted our review from September 2005 to April 2006 in accordance with generally accepted government auditing standards.

Results in Brief

The Army has determined that the Warrior is the best option available to meet its operational requirement, which requires an unmanned aircraft system dedicated to direct operational control by its field commanders. The Army believes that the Predator A is operationally and technically mismatched with its needs. The Army intends to use Warrior to enhance overall force capability by teaming it with other of its assets such as the Apache helicopter, using common ground control equipment to network with other unmanned aircraft systems, and allowing soldiers in the field to operate the aircraft. The Army expects Warrior to have several key technical features that the Army believes will better meet its operational needs, including a heavy fuel engine that uses a single Army-wide fuel, an automatic take-off and landing system to improve safety, a faster tactical common data link for interoperability with other Army assets, an ethernet for quicker communications within the Warrior system, greater carrying capacity for weapons, and avionics with enhanced reliability. The Army estimates that each Warrior aircraft and associated basic equipment will cost about $4.4 million, less than the aircraft and similar equipment for the Predator A at $4.8 million. While the Predator B system is expected to meet or exceed some of the Warrior's capabilities, it is estimated to cost $9 million for similar equipment.

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[2] GAO, *Unmanned Aircraft Systems: New DOD Programs Can Learn from Past Efforts to Craft Better and Less Risky Acquisition Strategies*, GAO-06-447 (Washington, D.C.: Mar. 15, 2006).

In terms of technology maturity, design stability, and a realistic schedule, the Army has not established a sound, knowledge-based acquisition strategy for Warrior that is consistent with best acquisition practices. The Army contracted for Warrior system development and demonstration in August 2005 even though two of four critical technologies were not mature. These two critical technologies still are not mature as of early 2006, and the two that are mature have some risk associated with them because neither has previously been fully integrated onto an unmanned aircraft. The Army does have backups in place for the two immature critical technologies, but use of these would result in a less capable system. It is uncertain if the Army will be able to complete maturation of technologies and achieve Warrior's overall design stability by the time of the planned design readiness review in July 2006. Overall, the Warrior schedule is very aggressive, with 32 months from the award of the development and demonstration contract to the initial production decision. Achieving this schedule will require concurrency of technology and product development, testing, and production. For example, the Army is establishing production capabilities while the first 17 developmental aircraft are being designed and fabricated. Within months of these aircraft becoming available for developmental testing, the Army plans to commit funding for procurement of long-lead items as early as August 2007. Experience shows that these concurrencies can result in design changes during production that can prevent delivery of a system within projected cost and schedule. The Warrior program faces these same risks.

We are recommending that the Secretary of the Army take action to ensure that a sound, knowledge-based acquisition strategy guides the future of the Warrior program. Specifically, we recommend that the Army not approve long-lead items for Warrior low-rate initial production until it can clearly demonstrate that the program is proceeding based on accumulated knowledge such as technology maturity and design stability.

DOD concurred with only one part of our recommendation and did not concur with the other two parts. DOD stated that delaying the procurement of long-lead items will increase program costs and delay fielding of Warrior. Our prior work shows that proceeding into the latter stages of acquisition without needed knowledge on technologies and design ultimately takes longer and costs individual programs more money.

Background

Currently, DOD has five major unmanned aircraft systems in use: the Air Force's Predator A and Global Hawk, the Marine Corps' Pioneer, and the Army's Hunter and Shadow. The services also have developmental efforts

underway, for example, the Air Force's Predator B, the Army and Navy's vertical take-off and landing system, and the Army's Warrior. Overall, DOD now has about 250 unmanned aircraft in inventory and plans to increase its inventory to 675 by 2010 and 1,400 by 2015.[3] The 2006 Quadrennial Defense Review reached a number of decisions that would further expand investments in unmanned systems, including accelerating production of Predator and Global Hawk. It also established a plan to develop a new land-based, long-strike capability by 2018 and set a goal that about 45 percent of the future long-range strike force be unmanned.

DOD expects unmanned aircraft systems to transform the battlespace with innovative tactics, techniques, and procedures as well as take on the so-called "dull, dirty, and dangerous missions" without putting pilots in harm's way. Potential missions for unmanned systems have expanded from the original focus on intelligence, surveillance, and reconnaissance to limited tactical strike capabilities. Projected plans call for unmanned aircraft systems to perform persistent ground attack, electronic warfare, and suppression of enemy air defenses.

Unmanned aircraft fly at altitudes ranging from below 10,000 feet up to 50,000 feet and are typically characterized by approximate altitude—"low altitude" if operating at 10,000 feet or less, "medium altitude" if flying above 10,000 but below 35,000 feet, and "high altitude" if operating above 35,000 feet. The Army's classifies Warrior as a medium-altitude system, in the same category as its Hunter system, its Warrior prototype known as I-GNAT, and the Air Force's Predator A. The Air Force's Predator B is expected to operate at both medium and high altitudes.

The Warrior as envisioned by the Army shares some similarities with the Air Force's Predator A and B models. First, all three systems share the same contractor, General Atomics. Second, Predator A and Warrior are expected to be somewhat similar in physical characteristics. In particular, the build of the main fuselage, the location of fuel bays, and design of the tailspar are alike. According to Army program officials, the Predator B and Warrior are expected to share the same flight controls and avionics. Predator A and Warrior are anticipated to perform some similar missions, including reconnaissance, surveillance, and target acquisition and attack.

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[3] These numbers are the larger systems and do not count numerous small and hand-launched systems used by ground forces.

The development of the Warrior program began in late 2001 when the Army started defining requirements for a successor to its Hunter system. In September 2004, the Army released a request for a "systems capabilities demonstration" so that companies could demonstrate the capabilities of their existing aircraft. In December 2004, the Army awarded demonstration contracts worth $250,000 each to two contractors, Northrup Grumman and General Atomics. Subsequently, the Army evaluated, among other things, the demonstrated capabilities of the competitors' existing aircraft in relation to Warrior technical requirements. The Army did not perform a formal analysis of the alternatives comparing expected capabilities of Warrior with current capabilities offered by existing systems; rather, its rationale was that the Warrior is needed near-term for commanders' missions and considered this competition to be a rigorous analysis of available alternatives.

Based on the competition, the Army concluded that General Atomics' proposal (based on Warrior) provided the best value solution. In August 2005, the Army awarded the system development and demonstration (SDD) contract to General Atomics. The contract is a cost plus incentive fee contract with an award fee feature. It has a base value of about $194 million, with approximately another $15 million available to the contractor in the form of incentive fees, and about an additional $12 million available as award fees. The time line in figure 1 illustrates the sequence of past and planned events for the Warrior program.

Figure 1: Time Line for Warrior Program

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

GAO-06-593 Warrior Acquisition Strategy
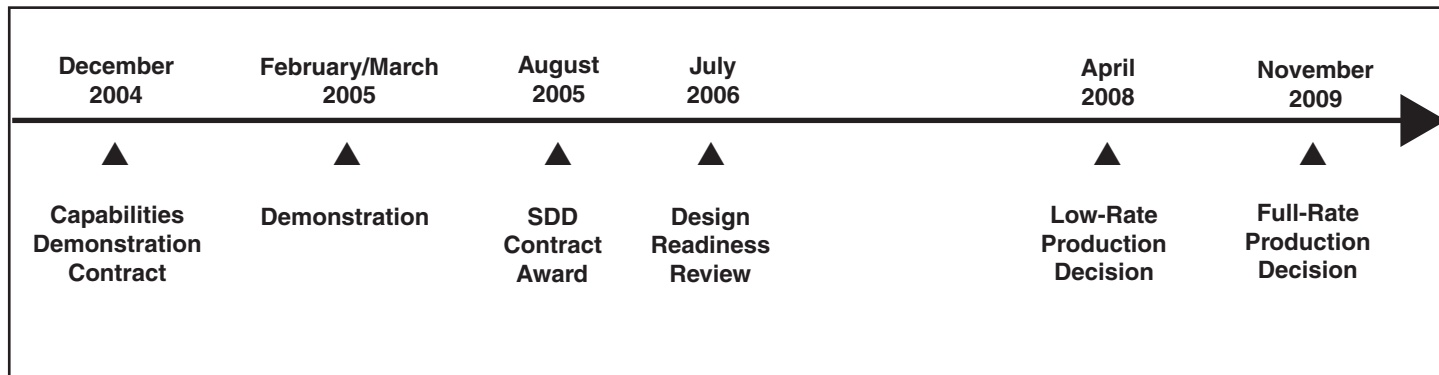
The Army plans for a full Warrior system to entail 12 aircraft as well as 5 ground control stations, 5 ground data terminals, 1 satellite communication ground data terminal, 12 air data terminals/air data relays, 6 airborne satellite communication terminals, 2 tactical automatic take-off and landing systems, 2 portable ground control stations, 2 portable ground data terminals and associated ground support equipment. The Army expects to buy 1 developmental system with 17 aircraft and 11 complete production systems with a total of 132 production aircraft through 2015. However, the Army has not yet decided on the number of systems it might buy beyond that date.

The Army is employing an evolutionary acquisition strategy to produce Warrior. The Army expects the current Warrior program of record to provide for immediate warfighting needs and plans to build on the capabilities of this increment as evolving technology allows.

Warrior Capability Is Targeted to Support Army Commanders' Needs

The Army has an operational requirement, approved by the Joint Requirements Oversight Council, for an unmanned aircraft system dedicated to direct operational control by Army field commanders. The Army has determined that the Warrior was the best option available to meet this operational requirement. Army program officials believe that the Predator is operationally and technically mismatched with Army needs. The Army expects Warrior to offer key technical features that will better meet Army operational needs than Predator A.

Army Operational Requirement Focuses on Control by Commanders in the Field

According to the Army, the Predator is operationally mismatched with its division-level needs. Army program officials noted that one of the Army's current operational difficulties with Predator is that frontline commanders cannot directly task the system for support during tactical engagements. Rather, Predator control is allocated to Theater and Joint Task Force Commands, and the system's mission is to satisfy strategic intelligence, reconnaissance, and surveillance needs as well as joint needs. Army programmatic and requirements documents maintain that Army division commanders in the field need direct control of a tactical unmanned aircraft asset capable of satisfying operational requirements for dedicated

intelligence, surveillance, and reconnaissance, communications relay, teaming with other Army assets, and target acquisition and attack.[4]

Army program officials also indicated that Predator's time is apportioned among various users, and the Army typically does not receive a large portion of that time. According to Warrior program documents, the Army has historically been able to draw only limited operational support from theater assets such as Predator. For example, a program office briefing noted that overall Iraq theater-level support was neither consistent nor responsive to Army needs, and that division level support was often denied or cancelled entirely. The briefing also said that the shortfall was expected to continue, even with the addition of more Predators and Global Hawks.

Army program officials also told us that they expect Warrior to enhance overall force capability in ways that Predator cannot. Specifically, the Army expects Warrior to support teaming with Army aviation assets and aid these assets in conducting missions that commanders were previously reluctant to task to manned platforms. Under this teaming concept, manned assets, including the Apache helicopter, Army Airspace Command and Control system, and Aerial Common Sensor, would work jointly with Warrior to enhance target acquisition and attack capabilities. The Army plans for the manned platforms to not only receive data and video communications from Warrior but also control its payloads and flight. The Army also plans to configure Warrior for interoperability with the Army One System Ground Control Station, an Army-wide common ground control network for unmanned aircraft systems. According to Army documents, Warrior's incorporation into this network will better support the Army ground commander by allowing control of Warrior aircraft to be handed off among ground stations, provide better battlefield coverage for Joint Forces, and ensure common operator training among unmanned aircraft systems, including the Army's Warrior, Shadow, and Hunter and Marine Corps' unmanned aircraft systems. Additionally, Army program officials pointed out that Warrior will be physically controlled by an enlisted soldier deployed in the theater where Warrior is being used. They contrast this with Predator, which is typically flown from a location within the continental United States by a pilot trained to fly manned aircraft.

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[4] The Army requirements document for Warrior was approved by the Joint Requirements Oversight Council in April 2005. The Council, among other responsibilities, conducts requirements analyses and validates mission needs and performance objectives and thresholds.

Army Expects Warrior to Address Operational Needs with Key Technical Features

The Army believes that the Warrior design will offer key technical features to address Army operational requirements and maintains that these features will better meet its operational needs than those found on Predator A. The technical features include:

- multi-role tactical common data link,
- ethernet,
- heavy fuel engine,
- automatic take-off and landing system,
- more weapons,
- interoperability with Army One System Ground Control Station, and
- dual-redundant avionics.

Table 1 shows the respective purpose of each technical feature, describes whether or not a particular feature is planned for Warrior and exists now on Predator A, and provides the Army's assessment of operational impact provided by each feature.

Table 1: Comparison of Warrior and Predator A Technical Features

Technical Feature	Purpose	Warrior	Predator A	Army's Assessment of Operational Impact
Tactical Common Data Link	• Communications between ground control station and aircraft • Interoperability with Army aviation platforms	Yes – digital Ku-band data link[a]	No – analog C-band data link	• Faster external data transmission • Improved control of aircraft • Teaming with Army aviation
Ethernet	• Real-time internal communications, including among avionics, payloads, weapons	Yes	No	• Faster internal data transmission
Heavy Fuel Engine	• Powers aircraft	Yes	No	• Single Army fuel on battlefield • Improved endurance and take-off weight
Automatic Take-off and Landing	• Launch and recovery	Yes	No - pilot using manual controls	• Safer • Reduced chance for operator error
Weapons	• Target attack	Yes – 4 Hellfire	Yes – 2 Hellfire	• Prosecute more targets
Dual-Redundant Avionics	• Improve airworthiness	Yes	No	• More reliable
Ground Control Station	• Control of unmanned aircraft system	Yes –common with other Army/Marine Corps systems	Yes – unique to Predator	• Single control of several unmanned aircraft systems • Broader battlefield coverage

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

[a]Ku-band and C-band are ranges of radio frequencies used in wireless communications.

A February 2006 Warrior program office comparison of costs for Warrior and Predator A projects that Warrior's unit cost will be $4.4 million for

each aircraft, including its sensors, satellite communications, and Hellfire launchers and associated electronics. The cost comparison indicates that Predator A's unit cost for the same elements is $4.8 million. Although the Air Force's Predator B is planned to be more capable than Warrior in such areas as physical size and payload and weapons capacity, the Warrior program office estimates that it will have a unit cost of $9.0 million—about double the anticipated cost for Warrior. The Army's cost estimates for the Warrior are, of course, predicated on Army plans for successful development and testing.

Warrior Acquisition Strategy Not Consistent with Best Practices

In terms of technology maturity, design stability, and a realistic schedule, the Army has not yet established a sound, knowledge-based acquisition strategy for Warrior that is consistent with best practices for successful acquisition. Warrior is expected to rely on critical technologies that were not mature at the time of the system development and demonstration contract award in August 2005 and were still not mature in March 2006. Furthermore, it appears that the Army may be unable to complete development of these technologies and achieve overall design stability by the time of the design readiness review scheduled for July 2006. Moreover, the Warrior schedule is very aggressive and overlaps technology development, product development, testing, and production. For example, the Army plans to consider awarding a contract for procurement of long-lead items at a time when it is still unclear if Warrior will be technologically mature and have a stable design. Such concurrency adds more risk, including the potential for costly design changes after production begins, to the already compressed schedule.

In the last several years, we have undertaken a best practices body of work on how leading developers in industry and government use a knowledge-based approach to develop high-quality products on time and within budget. A knowledge-based approach to product development employs a process wherein a high level of knowledge about critical facets of a product is achieved at key junctures known as "knowledge points."[5] This event-driven approach, where each point builds on knowledge

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[5] Best practices for successful product development include three knowledge points (KP). Knowledge Point 1 should occur at development start and is attained when a technologies and resources match requirements; KP 2 should occur at the mid-point between development and production and is attained when 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.

attained in the previous point, enables developers to be reasonably certain that their products are more likely to meet established cost, schedule, and performance baselines. A key to such successful product development is an acquisition strategy that matches requirements to resources and includes, among other elements, a high level of technology maturity in the product at the start of system development and demonstration, design maturity at the system's design readiness review usually held about half-way through the system's development phase, and adequate time to deliver the product.

Some Warrior Critical Technologies Have Yet to Reach Maturity

Achieving a high level of technology maturity at the start of system development is an important indicator that a match has been made between the customer's requirements and the product developer's resources in term of knowledge, money, and time. This means that the technologies needed to meet essential requirements—known as "critical technologies"—have been demonstrated to work in their intended environment. Our best practices work has shown that technology readiness levels (TRL) [6] can be used to assess the maturity of individual technologies and that a TRL of 7—demonstration of a technology in an operational environment—is the level that constitutes a low risk for starting a product development program.

As identified by the Army, the Warrior program contains four critical technologies: (1) ethernet, (2) multi-role tactical common data link, (3) heavy fuel engine, and (4) automatic take-off and landing system. Two of the four critical technologies—ethernet and data link—were not mature at the time the Army awarded the Warrior system development and demonstration contract in August 2005, and in early 2006 remain immature at TRLs of 4. Army program officials told us that they project the ethernet to be at TRL 6 and the data link at TRL 5 or 6 by the time of the design readiness review scheduled for July 2006. However, it is not certain that these two technologies will be as mature at design readiness review as the Army anticipates. Army program officials indicated that the data link hardware is still in development and expect its integration with other Warrior components to be a challenge. As such, they rated data link integration status as a moderate risk to the Warrior program. While they

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[6] Technology readiness levels characterize the readiness of technologies for hand-off to project implementers. Nine levels are defined, representing concepts from fundamental research level (TRL 1) through technologies fully qualified and demonstrated in flight (TRL 9).

stated that use of the ethernet has been demonstrated on Army helicopters and should not be a technical integration challenge, the officials also said that neither the ethernet nor specific data link technologies to be used on Warrior has been integrated previously onto an unmanned aircraft platform. Further, if the technologies are demonstrated at TRL 6 by design readiness review, they will meet DOD's standard for maturity (demonstration in a relevant environment) but not the best practices maturity standard of TRL 7 (demonstration in an operational environment).

The Army has technologies in place as backups for the data link and ethernet, but these technologies would result in a less capable system than the Army originally planned. According to Army program officials, there are several potential backups for the data link that could be used on the Warrior aircraft. Among the backups they cited is the same data link used on the Predator A–analog C-band. However, as we noted in a report last year, C-band is congested, suffers from resulting delays in data transmission and relay, and the Department of Defense has established a goal of moving Predator payloads from this data link.[7] Similarly, the other data link backups cited by the officials either had slower data transmission rates or also were not yet mature. Program officials indicated that the backup for the ethernet is normal ground station control of the on-board communication among such components as the payloads, avionics, and weapons. While they stated that there would be no major performance penalty if the backup was used, they did note that the ethernet would significantly improve ease of integrating payloads and of integrating with other Army assets that might need control of a Warrior payload to support missions.

The other two critical technologies, the automatic take-off and landing system and the heavy fuel engine, are mature at respective TRLs of 7 and 9. Nevertheless, some program risk is associated with these technologies as well. The contractor has never fielded an automatic take-off and landing component on an unmanned aircraft system. Army program officials told us that they are confident about the take-off and landing system because a similar landing system had been fielded on the Shadow unmanned aircraft, but they also indicated that the take-off component has not been fielded

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[7] GAO, *Unmanned Aircraft Systems: DOD Needs to More Effectively Promote Interoperability and Improve Performance Assessments*, GAO-06-49 (Washington, D.C.; Dec. 13, 2005).

on an unmanned aircraft. The officials also expressed confidence in the heavy fuel engine because it is certified by the U.S. Federal Aviation Administration and is in use on civilian manned aircraft. However, like the complete take-off and landing system, it has not previously been integrated onto an unmanned aircraft.

Warrior Design Stability Uncertain

Best practices for successful acquisition call for a program's design stability to be demonstrated by having at least 90 percent of engineering drawings completed and released to manufacturing at the time of the design readiness review. If a product's design is not stable as demonstrated by meeting this best practice, the product may not meet customer requirements and cost and schedule targets. For example, as we reported previously, the Army's Shadow unmanned aircraft system did not meet best practices criteria because it had only 67 percent of its design drawings completed when the system entered low-rate production. Subsequent testing revealed examples of design immaturity, especially relating to system reliability, and ultimately the Army delayed Shadow's full-rate production by about 6 months.[8]
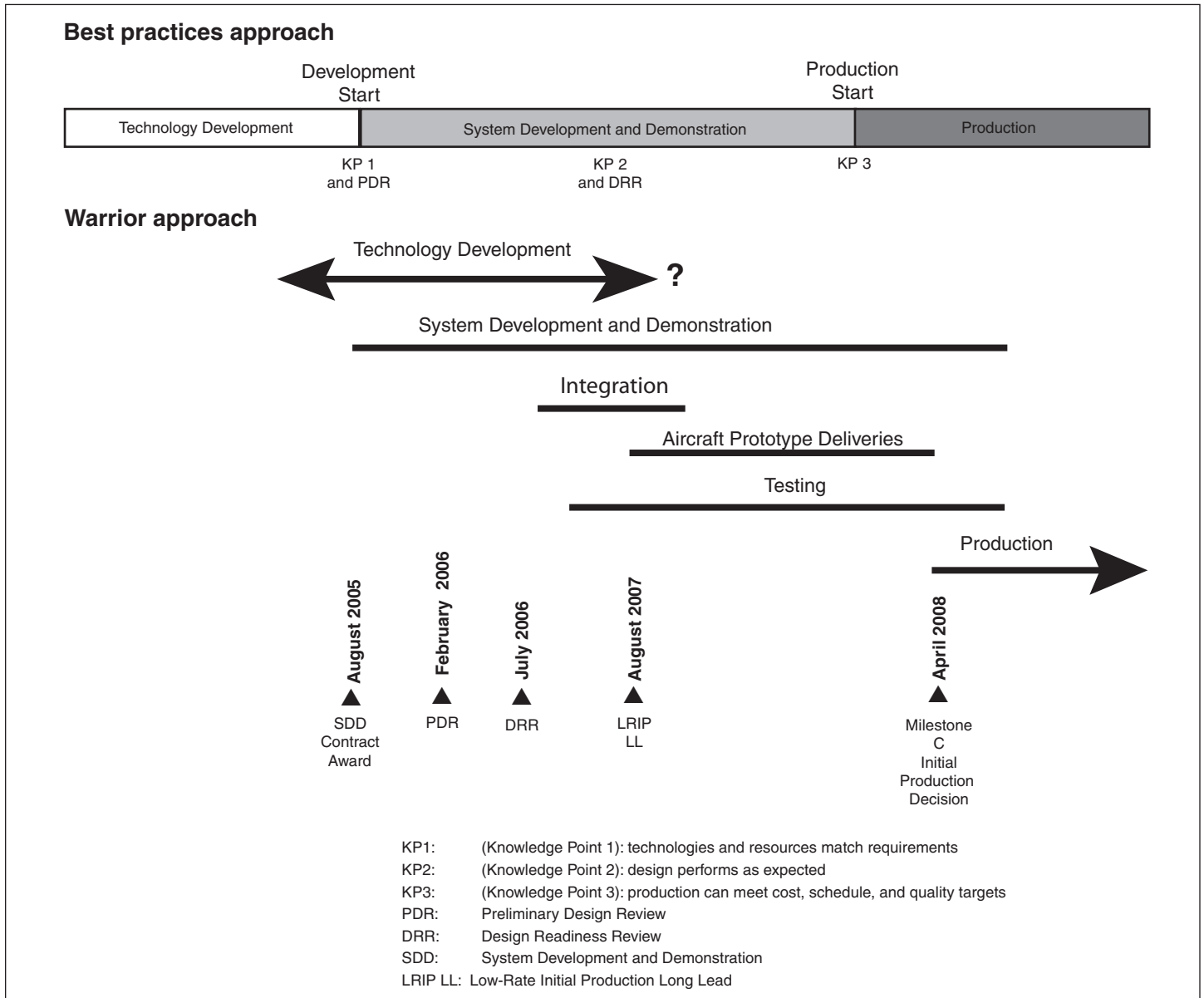
The Warrior program also faces increased risk if design drawings do not meet standards for best acquisition practices. The Warrior program office projects that Warrior's design will be stable and that 85 percent of drawings will have been completed and released to manufacturing by the time of the design readiness review in July 2006. However, it seems uncertain whether the Warrior program will meet this projection because percentages of drawings complete for some sub-components were still quite low in early 2006 and, in some cases, have declined since the system development and demonstration contract award. For example, according to an Army program official, the percentage of completed design drawings for the aircraft and ground control equipment dropped after contract award because the Army made modifications to the planned aircraft and also decided that it needed a larger transport vehicle for the Warrior's ground control equipment.

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[8] GAO, *Defense Acquisitions: Assessments of Major Weapon Programs*, GAO-04-248 (Washington, D.C.: Mar. 31, 2004).

Aggressive Schedule and Concurrent Activities Increase Program Risk

The Warrior program appears driven largely by schedule rather than the attainment of event-driven knowledge points that would separate technology development from product development. The latter approach is characteristic of both best practices and DOD's own acquisition policy. Warrior's schedule is compressed and aggressive and includes concurrency among technology development, product development, testing, and production. Concurrency—the overlapping of technology and product development, testing, and production schedules—is risky because it can lead to design changes that can be costly and delay delivery of a useable capability to the warfighter if testing shows design changes are necessary to achieve expected system performance. As shown in figure 2, the Warrior schedule overlaps technology development, product development, testing, and production.

Figure 2: Concurrency in Warrior's Technology Development, Product Development, Testing, and Production Compared to Best Practices Model

Best practices approach

Development Start

Production Start

| Technology Development | System Development and Demonstration | Production |

KP 1 and PDR

KP 2 and DRR

KP 3

Warrior approach

Technology Development

?

System Development and Demonstration

Integration

Aircraft Prototype Deliveries

Testing

Production

August 2005 — SDD Contract Award

February 2006 — PDR

July 2006 — DRR

August 2007 — LRIP LL

April 2008 — Milestone C Initial Production Decision

KP1: (Knowledge Point 1): technologies and resources match requirements
KP2: (Knowledge Point 2): design performs as expected
KP3: (Knowledge Point 3): production can meet cost, schedule, and quality targets
PDR: Preliminary Design Review
DRR: Design Readiness Review
SDD: System Development and Demonstration
LRIP LL: Low-Rate Initial Production Long Lead

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

The following examples highlight some of the concurrency issues within the Warrior program:

- Thirty-two months have been allotted from the system development and demonstration contract award in August 2005 to the low-rate production decision in April 2008. Out of that, 10 months—from July 2006 to May 2007—are set aside for integrating system components (including all four critical technologies) into the aircraft. Two of these technologies are not yet mature (as of early 2006); none of the specific technologies as planned to be used on Warrior have previously been fully integrated onto an unmanned aircraft. The Army plans to continue integration through May 2007 would seem to undermine the design stability expected to be achieved at the July 2006 design readiness review. Ideally, system integration is complete by that time.

- Delivery of 17 developmental aircraft is to take place within a 12-month period from April 2007 to April 2008, and the Army plans for them to undergo developmental testing as they are delivered. It is unclear whether all components will be fully integrated for this testing, but the results of some tests should be available when the Army considers approval of long-lead items for the first lot of low-rate initial production in August 2007. The Army is requesting about $31 million in fiscal 2007 to procure long-lead items, including items associated with the automatic take-off and landing system, heavy fuel engine assembly, and ground control. Prior to the planned approval of the first lot in fiscal 2008, the developmental aircraft will be evaluated in a limited user test.

The Warrior program office acknowledges that the schedule is high-risk. Additionally, according to Army program officials, both the program office and contractor recognize that there are areas of moderate to high risk within the program, including integration of the tactical common data link as well as timely availability of a modified Hellfire missile and synthetic aperture radar used for visibility in poor atmospheric conditions. Army program officials told us that they are trying to manage Warrior as more of a knowledge-based, event-driven rather than schedule-driven program. As an example, they stated that the contractor is currently building two off-contract aircraft to help mitigate risk by proving out design, development, and manufacturing. However, they also told us that these two aircraft would not include the tactical common data link, Hellfire missile, synthetic aperture radar, or satellite communications used for relay purposes. They noted that some of these items are still in development so are not expected to be available, but they do plan for the two aircraft to

have the ethernet, heavy fuel engine, and automatic take-off and landing system.

Conclusions

In concept, the Army has determined that the Warrior will meet its operational requirements better than available alternatives such as the Predator. In practice, however, the Warrior might very well encounter cost, schedule, and performance problems that would hinder it from attaining the Army's goals. Half of its critical technologies are not yet mature, and its design is not yet stable. Compounding this, its aggressive schedule features extensive concurrency among technology development and demonstration, design integration, system demonstration and test, and production, leaving little time to resolve technology maturity and design stability issues by testing. If the Warrior program continues forward prior to attaining adequate technology and design, it may well produce under-performing Warrior aircraft that will not meet program specifications. The program may then experience delays in schedule and increased costs.

The next key program event with significant financial implications is the scheduled approval of long-lead items for the initial lot of Warrior low-rate initial production in August 2007. That will be the first use of procurement funding for Warrior. We believe that is a key point at which the Army needs to demonstrate that the Warrior program is knowledge-based and better aligned to meet program goals within available resources than it currently appears.

Recommendations for Executive Action

We recommend that the Army not approve long-lead items for Warrior low-rate initial production until it can clearly demonstrate that the program is proceeding based on accumulated knowledge and not a predetermined schedule. In particular, we recommend that, prior to approving the Warrior long-lead items for low-rate initial production, the Secretary of the Army require that

- critical Warrior technologies are fully mature and demonstrated;
- Warrior design integration is complete and at least 90 percent of design drawings be completed and released to manufacturing; and
- fully-integrated Warrior developmental aircraft are fabricated and involved in development testing.

Agency Comments and Our Evaluation

DOD provided us with written comments on a draft of this report. The comments are reprinted in Appendix I. DOD concurred with one part of our recommendation but not with the other two parts. DOD also provided technical comments, which we incorporated where appropriate.

DOD concurred with the part of our recommendation that it should seek to have at least 90 percent of design drawings completed and released to manufacturing prior to procuring long-lead items for Warrior's low-rate initial production. However, DOD also said that the decision to procure long-lead items will not be based solely on the percentage of drawings completed, but also on the schedule impact of unreleased drawings.

DOD did not concur with the rest of our recommendation that, prior to approval of long-lead items for Warrior's low-rate initial production, the Secretary of the Army needed to ensure (a) critical Warrior technologies are fully mature and demonstrated and (b) fully-integrated Warrior developmental aircraft are fabricated and involved in development testing. Although DOD agreed that two critical technologies are less mature than the others within the Warrior system, it also stated that these technologies are at the correct levels to proceed with integration. However, the Warrior program is nearing the end of integration and is about to begin system demonstration, signified by the July 2006 design readiness review. In that review, the design is set to guide the building of developmental aircraft for testing. These developmental aircraft will be used to demonstrate the design in the latter half of System Development and Demonstration. While DOD stated that risk mitigation steps are in place, including possible use of back-up technologies, if either of the two critical technologies is not ready for integration, the decisions on whether to use back-up technologies in the design would ideally have been made by the design readiness review. Even if the two critical technologies mature by that point, they would still have to be integrated into the design, as would the back-up technologies if DOD chose to use those instead. To the extent that technology maturation and integration extend beyond the design readiness review, the program will incur the risk of integrating the design at the same time it is attempting to build developmental aircraft to demonstrate the design. Our recommendation to make the technology decision before committing to long-lead items provides a reasonable precaution against letting the technology risks proceed further into the demonstration of the developmental aircraft and into the purchase of production items. Making the technology decision as early as possible is particularly important given that the program schedule allows no more than a year to demonstrate the design with the developmental aircraft before committing to production. Our past work has shown that

increased costs and schedule slippages may accrue to programs that are still maturing technologies well into system development when they should be focused on stabilizing system design and preparing for production.

With regards to the part of our recommendation that fully integrated development aircraft are fabricated and involved in developmental testing prior to approval of long-lead items, DOD indicated that modeling and simulation, block upgrades, early operational deployments, and early testing will enable the Department to mitigate design and performance risks while remaining on schedule. While we agree that these activities help reduce risk, the most effective way to reduce risk is to verify the design through testing of fully-integrated developmental aircraft before committing to production. Our recommendation underscores the value of conducting such testing, which can still be done if technology decisions are made early.

Our work over the past several years has shown that a knowledge-based acquisition strategy consistent with best practices can lead to successful outcomes. Specifically, proceeding without mature technologies and a stable design can lead to costly design changes after production is underway and negatively impact funding in other Department programs, ultimately affecting DOD's ability to respond to other warfighter needs.

Scope and Methodology

To address the first objective, to identify the requirements that led to the Army's decision to acquire Warrior, we reviewed Army operational requirements, acquisition strategy, and other programmatic documents and briefings. We did not assess the validity of the Army's requirements for Warrior. We also reviewed the process the Army used in selecting Warrior. In comparing Warrior to existing unmanned systems in the inventory, we limited our review to comparable medium-altitude systems within the military services. To assess differences in operational capabilities for Warrior and Predator, we reviewed operations-related documents for Predator A and B. We also reviewed critical technologies as well as other key technical features of the respective systems that highlighted differences in Warrior and Predator A capabilities.

To address the second objective, whether the Army established a sound acquisition strategy for Warrior, we reviewed planning, budget, and programmatic documents. We also utilized GAO's "Methodology for Assessing Risks on Major Weapon System Programs" to assess the Army's acquisition strategy with respect to best practices criteria. The
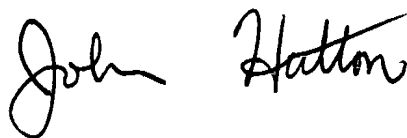
methodology is derived from the best practices and experiences of leading commercial firms and successful defense acquisition programs. We also used this methodology to review risks within the Warrior program, but we did not focus our assessment on all risk areas the Army and Warrior contractor identified within the program. Instead, we focused on those risk areas that seemed most critical to the overall soundness of the Army's acquisition strategy.

To achieve both objectives, we interviewed Army officials and obtained their views of the Army's requirements and soundness of the Army's acquisition strategy. We also incorporated information on Warrior from GAO's recent Assessments of Major Weapon Programs.[9]

We performed our review from September 2005 to April 2006 in accordance with generally accepted government auditing standards.

We are sending copies of this report to the Secretary of Defense, the Secretary of the Army, and the Secretary of the Air Force, and interested congressional committees. We will also make copies available to others upon request. Additionally, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

Should you or your staff have any questions on matters discussed in this report, please contact me on 202-512-7773. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Principal contributors to this report were William R. Graveline, Tana Davis, and Beverly Breen.

John Hutton
Acting Director, Acquisition and Sourcing Management

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

Appendix: Comments from the Department of Defense

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

ACQUISITION
TECHNOLOGY
AND LOGISTICS

MAY 1 2 2006

Mr. John Hutton
Acting Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Mr. Hutton:

This is the Department of Defense (DoD) response to the GAO draft report,
GAO Draft Report, GAO-06-593, "DEFENSE ACQUISITIONS: Better Acquisition
Strategy Needed for Successful Development of the Army's Warrior Unmanned Aircraft
System" dated April 18, 2006 (GAO Code120485)

The DoD non-concurs with parts a) and c) and concurs with part b) of the GAO
recommendation. The rationale for the DoD's position is enclosed.

The Department appreciates the opportunity to comment on the draft report. For
further questions concerning this report, please contact Dyke Weatherington, Deputy,
Unmanned Aircraft Systems Planning Task Force, 703-695-6188.

Sincerely,

Mark D. Schaeffer
Acting Director
Defense Systems

Enclosure:
As stated

GAO Draft Report Dated APRIL 18, 2006
GAO-06-593 (GAO CODE 120485)

"DEFENSE ACQUISITIONS: BETTER ACQUISITION
STRATEGY NEEDED FOR SUCCESSFUL DEVELOPMENT OF
THE ARMY'S WARRIOR UNMANNED AIRCRAFT SYSTEM"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION: The GAO recommended that prior to approving the Warrior
long-lead items for low-rate initial production the Secretary of Army require that:

a) critical Warrior technologies are fully mature and demonstrated;

b) Warrior design integration is complete and at least 90 percent of design
drawings be completed and released to manufacturing;

c) fully-integrated Warrior development aircraft are fabricated and involved in
development testing. (p. 17/GAO Draft Report)

DOD RESPONSE: The Department non-concurs with parts a) and c) and concurs with
part b) of the GAO recommendation. Rationale follows:

Part a) Non-concur. Risk mitigation steps are in place if one of the critical
technologies is not ready for full integration. Design steps are being taken to provide
the flexibility for integration of the desired critical technology, as well as mitigating
technology. By definition, System Development and Demonstration (SDD) consists of
two major efforts: 1) System Integration and 2) System Demonstration. System
Integration is the system design phase during which the chosen technologies and
subsystems are integrated into a detailed system design and the manufacturing processes
are developed. The Department concurs that the Multi Role-Tactical Common Data
Link (MR-TCDL) and Ethernet, at this point in time, are less mature than other
components/subsystems within the Warrior system. However, it is the Department's
position that these critical technologies are at the correct maturity levels to proceed with
the integration phase of SDD. If MR-TCDL is not ready for integration, TCDL will be
integrated. TCDL is currently being integrated and has gone through initial
demonstration testing with the Shadow UAS. Prototype versions of the TCDL have
been integrated into the Hunter UAS, as well as manned platforms, for early evaluation
in manned-unmanned teaming demonstrations. Ethernet is a proven technology, and
the contractor has integrated Ethernet into its UAS ground stations. If Ethernet is not
ready for integration into the Warrior, the 1553 Multiplex Data Bus will be integrated
which is a very mature component that is integrated within older variants of the
manufacturer's UAS's. MR-TCDL and Ethernet can be integrated later during Block
upgrades. The Technology Readiness Assessment Deskbook indicates Technology

Readiness Level (TRL) 6 is typical. However, it also indicates lower TRLs are adequate for critical technologies, if a planned and funded program is in place to mature the technology quickly or if a mature backup technology exists that meets the program requirements and schedule exits.

Less than 10% of the long lead items are directly tied to the critical technologies at a TRL of 6 or lower. The lack of long lead items for integration will result in a schedule slip that will increase program costs and further delay fielding this capability. The Department will weigh programmatic risk vs. fielding combat capability to the Global War on Terrorism to determine the most prudent course of action for long lead items. The Department plans to use block upgrades to provide capability sooner to the warfighter while further maturing the technology.

Part b) Concur. The Department will seek to obtain at least 90% engineering design drawings completed and released to manufacturing before purchasing long lead parts. However, the decision to procure long lead items will not be based solely on the percentage of engineering drawings completed. The Department will base this decision on what engineering design drawings are completed combined with the schedule impact of unreleased drawings.

The Warrior successfully completed its Systems Requirements Review and Preliminary Design Review, and all indications are that the Warrior design will be well within the mandated requirement by the Critical Design Review. In order to assure the program maintains schedule, several additional initiatives have been put in place to enhance monitoring and managing program and schedule risk. These initiatives include, but are not limited to, six Integration Product Teams that meet daily/weekly, regular program reviews, a Limited User Test, and an early Operational Test prior to low rate initial production. An award fee contract is also being used to incentivize the contractor to provide the desired performance within cost and schedule.

Part c) Non-concur. Modeling and simulation, block upgrades, early operational deployments, and early testing will enable the Department to mitigate design and performance risks while remaining on schedule.

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