United States General Accounting Office

GAO

Report to Congressional Committees

May 1995

COMANCHE HELICOPTER

Testing Needs to be Completed Prior to Production Decisions

GAO/NSIAD-95-112

GAO

United States
General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

B-259389

May 18, 1995

The Honorable Strom Thurmond
Chairman
The Honorable Sam Nunn
Ranking Minority Member
Committee on Armed Services
United States Senate

The Honorable Floyd Spence
Chairman
The Honorable Ronald Dellums
Ranking Minority Member
Committee on National Security
House of Representatives

This report presents the results of our review of the Department of the Army's Comanche helicopter program. Because this program is the centerpiece of Army aviation modernization efforts and faces major funding shortages and restructuring, we focused our review on cost and technical issues. Because of your expressed interest in the Comanche program, we believe the information in this report will be useful as you review the Department of Defense's (DOD) plans for the program.

Background

The Comanche program was established in 1983 to replace the Army's light helicopter fleet. The contractor team of Sikorsky Aircraft Corporation and Boeing Helicopter Company were expected to design a low-cost, lightweight, advanced technology helicopter capable of performing the primary missions of armed reconnaissance and attack. Critical to achieving these capabilities are the successful development of advanced technologies, including composite materials, advanced avionics and propulsion systems, and sophisticated software and hardware. The Army must meet ambitious maintainability goals in order to (1) realize significantly lower operating and support costs predicted for this program and (2) achieve a wartime operational availability for the Comanche of 6 hours per day.

In December 1994, the Secretary of Defense directed the Army to restructure the Comanche helicopter program as part of efforts to meet budgetary constraints. The Secretary's restructure decision reduced funding for the program from $4.2 billion to $2.2 billion for fiscal years

1996 through 2001. In addition to extending the development phase by 3 years, it also called for two flyable prototypes to be produced and the Comanche production decision to be deferred.

In response to the Secretary's decision, the Army proposed a program restructure that would allow it to acquire, within the Secretary's funding constraint, six aircraft in addition to the two prototypes by deferring developmental efforts to fiscal year 2002 and beyond. DOD approved the proposal in March 1995.

Results in Brief

Under the Army's restructured program, production decisions will be made before operational testing of the Comanche starts, thereby continuing the high degree of risks associated with concurrent development and production. However, the time provided by extending the development phase and the acquisition of the six additional aircraft under the restructure provides the Army with the opportunity to conduct operational testing before committing funds to any production decisions. Because of the Comanche program's high costs and technical risks, we believe the Army should complete operational testing before long-lead and low-rate initial production decisions are made, thereby significantly reducing the risks from the program.

The Comanche will be a much more expensive armed reconnaissance helicopter than the one originally justified to the Congress. The Comanche's program acquisition unit cost[1] has almost tripled in 10 years. It has increased from $12.1 million in 1985 to $34.4 million as of February 1995. Program acquisition unit cost increases occurred primarily because of program restructuring and a 74-percent decrease in the quantity of aircraft to be procured. Cost and program schedule will again be affected because of the decisions to restructure the program.

After a decade of developing the Comanche, the Army continues to experience technical problems. The Army is experiencing software development and testing problems associated with electronic systems that affect the performance of the Comanche. All key aircraft maintainability requirements for the Comanche may not be achievable. Therefore, the Comanche's ability to meet its wartime availability requirements and its objective of lower operating and support cost is questionable. On the positive side, the program is currently meeting its goals of reducing

[1]Throughout this report, both the total program acquisition costs and program acquisition unit costs are depicted in current dollars and include research, development, and acquisition costs but exclude military construction costs.

maintenance levels and keeping within acceptable limits of overall weight growth for the Comanche.

Restructuring Continues Risks

The Army's restructuring of the Comanche program continues risks (1) associated with making production decisions before knowing whether the aircraft will be able to perform as required and (2) of higher program costs.

Restructuring Continues Highly Concurrent Program

According to DOD's April 1990 guidelines for determining degrees of concurrency, a program with high concurrency typically proceeds into low-rate initial production before significant initial operational test and evaluation is completed. Regarding the need to keep concurrency low, the guidelines note that establishing programs with no concurrency, or a low degree of concurrency, avoids the risks that (1) production items have to be retrofitted to make them work properly and (2) system design will not be thoroughly tested. As we recently reported, aircraft systems, including the T-45A and C-17, that entered low-rate initial production before successfully completing initial operational testing and evaluation experienced significant and sometimes costly modifications to achieve satisfactory performance.[2] Under the Army's restructured program, operational testing will not begin until after the low-rate initial production decision is made, continuing the risks associated with the highly concurrent Comanche program.

In responding to the Secretary's restructure decision, the Army proposed, and was subsequently granted approval, to buy six "early operational capability" aircraft, in addition to the two prototypes that were to be acquired under the Secretary's decision. According to program officials, these aircraft are estimated to cost in excess of $300 million. The Army does not consider these aircraft as either prototype or low-rate initial production aircraft; however, program officials believe that when these aircraft are fielded, the Army will be able to better evaluate the Comanche's mission capability. The Army intends to fund these aircraft by deferring additional developmental efforts to fiscal years 2002 and beyond.

Under the Army's restructured program, operational testing will not begin until well after funds are committed to buy production aircraft. Armed reconnaissance and attack mission equipment packages are to be

[2]Weapons Acquisition: Low-Rate Initial Production Used to Buy Weapon Systems Prematurely (GAO/NSIAD-95-18, Nov. 1994).

integrated into the six early operational aircraft by fiscal year 2004. The Army plans to use these aircraft to start operational testing by about August 2005. However, long-lead production decisions are scheduled for November 2003, and low-rate initial production is planned to start in November 2004, about 9 months before operational testing begins.

According to DOD's guidelines, the amount of risk associated with concurrency can be limited by reducing production aircraft to the minimum necessary to perform initial operational testing. The Army maintains that under the stretched out program it can conduct initial operational testing with the six early operational aircraft. Because the restructure has provided the additional time and aircraft, the Army has an opportunity to significantly reduce or eliminate program concurrency and its associated risks by completing operational testing before committing funds to any production decisions.

Comanche Costs Continue to Increase

The Comanche was originally justified to the Congress as a relatively inexpensive aircraft. However, since 1985, the program has experienced significant increases in program acquisition unit cost. Funding reductions have caused the program to undergo significant restructuring, resulting in sharp decreases in planned acquisition quantities and lengthening of development schedules, thereby increasing Comanche program costs.

In 1985, the Comanche had estimated total program acquisition costs of about $61 billion for 5,023 aircraft (or $12.1 million per aircraft). In 1992, we reported that (1) as of October 1991, the program acquisition unit cost had increased to $27.4 million, (2) acquisition quantities had been reduced to 1,292 aircraft, and (3) future increases in cost per aircraft were likely.[3] As of February 1995, the Comanche's estimated program acquisition unit cost was $34.4 million per aircraft, a 185-percent increase from the 1985 estimate. The estimated total program acquisition cost for the planned acquisition of 1,292 aircraft is now more than $44 billion.

Both the Secretary's decision and the Army's restructure would extend the development program by about 3 years and, under either, increase the risk of higher total program cost and cost per aircraft. However, in reviewing the Army's restructure proposal, DOD noted some concern over Comanche program costs for fiscal year 2002 and beyond and the large increase in investment programs projected to occur about that time. We are also

[3]Comanche Helicopter: Program Needs Reassessment Due to Increased Unit Cost and Other Factors (GAO/NSIAD-92-204, May 27, 1992).

concerned that the Army's plan to defer additional developmental efforts to fiscal year 2002 and beyond may increase the risk that needed funds may not be available to perform the deferred developmental effort.

Technical Risks to Be Resolved

The Comanche program's uncertainties in software development and aircraft maintainability increase the risk that the aircraft will not perform successfully. We believe the restructuring provides additional time to resolve these issues before the decision to enter production is made.

Software Development Is at Risk

The Comanche will be the most computerized, software-intensive Army helicopter ever built. The Army estimates that about 1.4 million lines of code are required to perform and integrate mission critical functions. With additional ground support and training software to be developed, the total program will have more than 2.7 million lines of code. This compares to about 573,000 lines of code for the upgraded Apache attack helicopter with fire control radar. The Army estimates 95 percent of the Comanche's total software will be written in Ada, a DOD-developed programming language. The Army plans to demonstrate initial software performance with the mission equipment package, which includes the flight control system, during first flight of the Comanche, scheduled for November 1995.

The development and integration of on-board, embedded computer systems is a significant program objective. The Comanche's performance and capability depend heavily on these systems and efforts have been ongoing to solve the problems associated with these systems. Nevertheless, (1) software development problems still exist with the Ada compilation system, (2) delays in software development and testing are occurring, and (3) improvements are needed in configuration management. If these issues are not resolved, the aircraft's performance and capability will be degraded and first flight could be delayed.

Development Problems Remain Unresolved for the Ada Compilation System

Almost all of the Comanche software will be developed in the Ada programming language; however, software developers are not using the same version of the Ada compilation system. The Ada compilation system translates Ada code into machine language so that software can be used by the Comanche's computers. For example, it is being used to help develop software for use on the mission equipment package that is critical for first flight.

Subcontractors and the contractor team should be using the same, qualified version of this compilation system to ensure effective software integration. However, fixes to individual compiler software problems are not being shared with all developers; therefore, they are not using a common compilation system. These problems have already delayed qualification testing of the compilation system by 1 year.

The lack of a uniform, qualified compilation system among software developers could put first flight at risk, according to the Defense Plant Representative Office. Problems with software integration may show up once integration testing begins in the June to November 1995 time frame. If that occurs, there may not be time to fix problems prior to scheduled first flight.

Delays in Software Development and Testing

The program is experiencing high turnover of software engineers at one of the contractor team's facilities. In its December 1994, monthly assessment report, the Defense Plant Representative Office, which is responsible for contract oversight, observed that high turnover of software personnel was putting scheduled first flight at risk. Loss of key personnel has already contributed to schedule slippage in several critical software development areas. Software development for the following areas has been affected: the airborne engine monitoring system, aircraft systems management, control database, and crewstation interface management.

The contractor team has formulated a "get well" plan that is dependent on being able to hire additional personnel in these areas. However, hiring additional qualified personnel is difficult, according to the Defense Plant Representative Office, because employment would be short term.

The flight control system software verification testing is also being delayed. As of February 8, 1995, Boeing had conducted only 163 of approximately 500 tests originally planned to be completed by that date. The subcontractor responsible for developing this software has been late delivering software for testing and has provided faulty software to Boeing, according to the Defense Plant Representative Office. Boeing established a recovery plan for this area that would have resulted in a completion date in March 1995—about a 1-month delay from the original plan. However, in February 1995, the contractor revised the recovery plan to reflect a completion date of July 1995—a 5-month delay.

The flight control system is critical to first flight, according to the Defense Plant Representative Office. However, because of delays with verification

testing, the Defense Plant Representative Office is concerned that the remaining verification testing, as well as, the validation and formal qualification testing will not be completed in a timely manner. As a result, first flight may be delayed. Boeing is scheduled to complete these tests prior to first flight. According to the program office, Boeing's plan to complete the testing calls for it to be conducted concurrently. If major problems occur in any one of the testing phases, there may not be enough time to fix the problem and complete all testing before first flight.

Improvements in Configuration Management Are Needed

Configuration management is the discipline of applying technical and administrative direction and surveillance to (a) control the flow of information between organizations and activities within a project; (b) manage the ownership of, and changes to, controlled information; (c) ensure information consistency; and (d) enable product release, acceptance, and maintenance. The part of configuration management used to report software problems and changes among the contractor team and subcontractors has shortcomings that put software development at risk.

In its November 1994 monthly assessment report, the Defense Plant Representative Office observed that the lack of a common problem reporting system made proper handling of software related changes difficult. Furthermore, the report noted that this situation could adversely impact scheduled first flight of the Comanche. As of February 1995, the contractor team still did not have a common, automated database available to track problem change reports. Thus, the contractor team, as well as subcontractors, did not have visibility over changes made to software.

Key Maintainability Requirements at Risk

Maintainability requirements are important to achieving lower operating and support costs and wartime availability goals. However, these goals are at risk because key maintainability requirements such as direct maintenance man-hours per flight hour (MMH/FH), the mean time to repair (MTTR), and fault isolation may not be achievable. Individually, failure to meet these parameters may not be a significant problem; however, collectively they affect the ability of the Comanche to achieve lower operating and support cost and wartime availability objectives.

Key Maintenance Goal May Not Be Realistic

In March 1987, the Army established a 2.6 direct MMH/FH requirement for the Comanche. It represents the corrective and preventive maintenance per flight hour expected to be performed at the unit level. The Army formulated its planned wartime operating tempo for a Comanche battalion

based on 6 hours a day per aircraft, or 2,200 flying hours per year. It then determined the maintenance factor needed to support this operating tempo—2.6 MMH/FH. As the MMH/FH level increases, the number of maintainers needed to sustain the 2,200 wartime flying hour goal increases, as do operating and support costs. Conversely, if the Army could not increase the number of maintainers, the planned operating tempo would have to be reduced.

The reasonableness of the Comanche's 2.6 direct MMH/FH requirement has been debated for several years within the Army and DOD. Representatives from the program office; the Army Materiel Systems Analysis Activity, which independently evaluates program testing results; the Office of the Assistant Secretary of the Army for Research, Development, and Acquisition; and the Army Cost and Economic Analysis Center met on October 28, 1994, to discuss the direct MMH/FH goal for the Comanche program. They agreed that the 2.6-MMH/FH requirement was not a realistic, achievable goal. Consequently, Army officials reached consensus and agreed on 3.2 direct MMH/FH as the Army-wide position for this parameter. However, during these discussions, Army Materiel Systems Analysis Activity personnel noted that attaining a 3.2-MMH/FH goal represented a medium to high risk, while a 4.3-MMH/FH goal had a low to medium risk. Increasing the maintenance factor increased the number of maintainers needed and will increase estimated operating and support costs by about $800 million over a 20-year period.

The direct MMH/FH requirement does not represent the total maintenance burden for the Comanche because it does not include indirect maintenance time. The Army does not normally collect data on indirect maintenance time. According to the program office, its best estimate of indirect maintenance time, following Army guidance, is 2.5 MMH/FH, and this figure has been used for calculating manpower needs for crew chief personnel on the Comanche. Thus, the total maintenance burden assumed for the Comanche is currently 5.7 MMH/FH (3.2 direct MMH/FH plus 2.5 indirect MMH/FH).

Repair Requirement May Not Be Met

To minimize turnaround time for repairs at the unit and depot, the Army established MTTR requirements of 52 minutes for repairs at the unit level and up to 12 hours at the depot level for the Comanche. These requirements represents the average time expected to diagnose a fault, remove and repair an item, and perform an operational check and/or test flight. We determined that any increase in MTTR above 1 hour will begin to

impact the Army's wartime availability goal of 2,200 hours per year, unless additional maintenance personnel are available.

As of January 1995, the contractor team was estimating that the Army would achieve 59 minutes for unit level repairs. According to contractor team officials, the requirement was not being met because the cure time required for composite material used on the aircraft was greater than expected. The contractor team discussed changing the MTTR requirement to 1 hour; however, the program office believes the problem could be resolved and did not believe the specification should be changed. The contractor team has not yet developed MTTR estimates for depot-level repair.

Key Diagnostic System Requirement May Not Be Achieved

The Comanche's diagnostic system is required to correctly isolate failed mechanical and electrical components at least 80 percent of the time with a high degree of accuracy. A high level of accuracy is essential as it allows maintainers to isolate and fix problems at the unit level. If the fault isolation requirement is not met, the Comanche is unlikely to achieve its MTTR requirement, thereby adversely affecting the Army's ability to execute its maintenance concept and its wartime availability goals.

Contractor team officials stated the fault isolation requirement was very optimistic, and although they are striving to meet this requirement, it may eventually have to be changed. As of January 1995, the contractor team predicted the system could achieve an overall 69-percent fault isolation rate; however, this rate would not meet the specification for mechanical and electrical component fault isolation. There are design limitations on two components, according to the program office, and changes to bring these components into conformance with specifications would be costly and increase the weight of the aircraft. Therefore, as of January 1995, the contractor team and the program office have agreed not to take action on these components.

False Removal Rate Is High Risk

The Army established a requirement of a 1-percent false removal rate for the Comanche. A false removal occurs when a part removed from the aircraft shows no evidence of failure when tested. This requirement is dependent, to a large extent, on the success of the fault detection/isolation system in detecting and isolating failed components. Program personnel characterize the 1-percent requirement as stringent and one that will be challenging to achieve. An Army Materiel Systems Analysis Activity official believes some design improvements have occurred in this area, but the risk associated with achieving this requirement still remains high. If the

Comanche does not meet this requirement, estimated operating and support costs for the Comanche will be higher than previously predicted.

The Army has not had good experience in developing fault detection/isolation and false removal systems for other aircraft. In September 1990, we reported that the fault detection and isolation system on the Apache aircraft did not always accurately detect the component that caused a particular fault, and the system detected faults that did not actually exist about 40 percent of the time.[4] As a result, Apache maintainers had to perform additional work to locate failed components. Recently, through a reliability program, the false removal rate for the targeting and night vision systems on the Apache improved to about 10 to 15 percent, according to Army officials. This is still significantly higher than the 1-percent requirement established for the Comanche program.

Some Program Goals Are Currently Being Met

Although the program is experiencing technical problems, it is currently meeting its goals of reducing maintenance levels and keeping overall weight growth within acceptable limits for the Comanche.

The Army's maintenance concept for the Comanche program is predicated on two levels of maintenance—unit- and depot-level maintenance. This concept is important to achieving operating and support savings predicted for the program because it eliminates the intermediate level of maintenance. Unit-level maintenance entails removing and replacing components required to return the aircraft to a serviceable condition. Depot-level maintenance requires higher level maintenance skills and sophisticated capital equipment and facilities not found at the unit level. The Army traditionally uses a three-level maintenance concept that includes intermediate-level maintenance to handle component repairs. Intermediate-level maintenance is usually located close to the battalion. It is performed on components that cannot be easily repaired at the unit level and do not require the more sophisticated repairs done at the depot level.

As of January 1995, no Comanche component had been designated for repair at the intermediate level, according to the program office. Contractor team personnel are conducting repair level analysis on Comanche components to determine whether components should be repaired at unit, intermediate, or depot facilities, according to program

[4]Apache Helicopter: Serious Logistical Support Problems Must Be Solved to Realize Combat Potential (GAO/NSIAD-90-294, Sept. 28, 1990).

and contractor team officials. Any candidates identified for intermediate-level repair are reviewed for possible design changes that could allow maintenance at the unit or depot level. If economically feasible, the contractor team will make design changes to the component to preclude the need for intermediate-level repair.

As of February 7, 1995, the Comanche's empty weight increased from its original specification of 7,500 pounds to 7,883 pounds. Although the Comanche's weight continues to increase, it remains within the allowable design limit of 7,997 pounds. Weight increases affect vertical rate of climb performance on the Comanche. The Army established a limit of 500 feet-per-minute as the minimum acceptable vertical rate of climb performance.[5] If the Comanche's weight exceeds 8,231 pounds, the engine will have to be redesigned to produce enough power at 95 percent maximum rated engine power to sustain the minimum 500 feet-per-minute vertical rate of climb requirement.

Recommendation

We recommend that the Secretary of Defense require the Army to complete operational testing to validate the Comanche's operational effectiveness and suitability before committing any funds to acquire long-lead production items or enter low-rate initial production.

Agency Comments and Our Evaluation

DOD generally concurred with the findings and original recommendations in our draft report. In commenting on the draft report, DOD offered explanations about why the problems that we identified were occurring and what they were doing to fix those problems. DOD disagreed with the report's conclusion about false removals and stated that we had not presented any evidence that the Comanche's 1-percent false removal rate may not be achievable. We still believe that the false removal goal is high risk and adjusted the report to more clearly reflect our concern.

Regarding our draft report recommendation that DOD develop program fixes that achieve program goals and reduce the risks we identified, DOD concurred and noted that the approved restructuring will significantly reduce risk. DOD concurred with our other draft recommendation not to commit production funds to the program until performance and mission requirements are met and noted that the program would be reviewed by DOD before approving the Army's request to proceed to the engineering and

[5]At 95-percent maximum rated engine power.

manufacturing development phase—the Milestone II decision scheduled for October 2001.

Because DOD concurred in our draft report recommendations and is taking action on them, we are no longer including them in this report. However, our analysis of information on the restructuring obtained after we had submitted our draft report to DOD has further heightened our concerns about the risk of concurrency; therefore, we have revised the report and added a new recommendation. Under the stretched out, restructured Comanche program, operational testing is not even scheduled to begin until after the low-rate initial production decision is made. This approach continues the risks associated with making production decisions before knowing whether the aircraft will be able to perform as required.

Prior to the restructure, the Army planned to start operational testing with eight aircraft in May 2003. Under the restructured program, the Army plans to start operational testing with six helicopters by about August 2005. We believe that the stretched out time frame and the six aircraft acquired under the restructure provide sufficient time and aircraft to operationally test the Comanche prior to making any production decisions.

Additionally, because operational testing is not scheduled until about August 2005, DOD will not be in a position at Milestone II in October 2001 to adequately address whether the Comanche program is meeting its performance requirements. DOD's comments are presented in their entirety in appendix I, along with our evaluation.

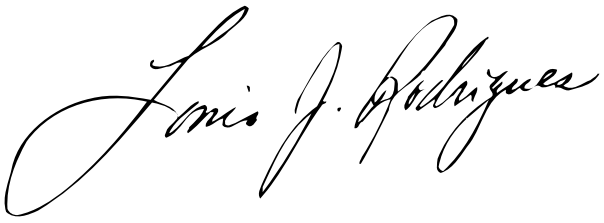
Scope and Methodology

To assess cost changes, software development, maintainability, and weight growth issues, we reviewed program documents and interviewed officials from the Department of the Army headquarters, Washington, D.C.; the Comanche Program Manager's Office, St. Louis, Missouri; the U.S. Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland; the Ada Validation Facility, Wright-Patterson Air Force Base, Ohio; and the Office of the Assistant Secretary of Defense for Program Analysis and Evaluation, Washington, D.C. We also reviewed program documents and interviewed contractor and Defense Plant Representative Office officials at the Boeing Helicopter Company, Philadelphia, Pennsylvania; the Sikorsky Aircraft Corporation, Stratford, Connecticut; and the Comanche Joint Program Office, Trumbull, Connecticut.

We conducted our review between August 1994 and February 1995 in accordance with generally accepted government auditing standards.

We are also sending copies of this report to the Chairmen and Ranking Minority Members of the Senate and House Committees on Appropriations, the Senate Committee on Governmental Affairs, and the House Committee on Government Reform and Oversight; the Director, Office of Management and Budget; and the Secretaries of Defense and the Army. We will also provide copies to others upon request.

This report was prepared under the direction of Thomas J. Schulz, Associate Director, Systems Development and Production Issues. Please contact Mr. Schulz at (202) 512-4841 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix II.



Louis J. Rodrigues
Director, Systems Development and
Production Issues

Contents

Abbreviations

DOD	Department of Defense
MTTR	mean time to repair
MMH/FH	maintenance man-hours per flight hour

Comments From the Department of Defense

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

OFFICE OF THE UNDER SECRETARY OF DEFENSE
ACQUISITION AND TECHNOLOGY

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

APR 2 0 1995

Mr. Henry L. Hinton, Jr.
Assistant Comptroller General
National Security and International
Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Hinton:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "COMANCHE HELICOPTER: Opportunity to Reassess Costs and Technical Risks dated March 6, 1995 (GAO Code 707084), OSD Case 9877. The Department partially concurs with the GAO draft report.

See comment 1.

While the DoD agrees that the unit cost of the Comanche has increased, the GAO discussion of unit cost is somewhat misleading since it does not clearly define the term "unit cost" or state whether unit costs are being measured in constant or current year dollars. The DoD maintains that Comanche unit flyaway cost should be measured in constant FY 1988 base-year dollars, since that basis provides a more accurate measure of relative cost increases over time.

See comment 2.

The DoD also agrees that the software intensive nature of the Comanche will require that progressive software development be monitored and demonstrated. The Department recently approved a restructured Comanche program that will provide for additional operational experience during development and addressed overall program risk. Under that approach, production and weapon systems integration will be deferred until additional operational results are available, thereby significantly reducing technical risk. The Defense Acquisition Board will review the program to ensure that performance and mission requirements are satisfied before Comanche enters the Engineering and Manufacturing Phase.

The detailed DoD comments on the report findings and recommendations are provided in the Enclosure. The Department appreciates the opportunity to comment on the draft report.

George R. Schneiter
Director
Strategic and Tactical Systems

Enclosure

**GAO DRAFT REPORT - DATED MARCH 6, 1995
(GAO CODE 707084) OSD CASE 9877**

"COMANCHE HELICOPTER: OPPORTUNITY TO REASSESS COSTS AND TECHNICAL RISKS"

DEPARTMENT OF DEFENSE COMMENTS

* * * * *

FINDINGS

- **FINDING A: Comanche Is Not a Low-Cost Aircraft.** The GAO reported that in 1985, the Comanche had estimated total program costs of about $61 billion for 5,023 aircraft (or $12.1 million per aircraft). The GAO observed that in 1992, (1) program cost per aircraft had increased to $27.4 million, (2) acquisition quantities had been reduced to 1,292 aircraft, and (3) future increases in program cost per aircraft were likely. The GAO determined that as of February 1995, the Comanche's estimated program cost was $34.4 million per aircraft, a 185-percent increase from the 1985 estimate. The GAO also determined that the estimated total program cost for the planned acquisition of 1,292 aircraft is now more than $44 billion.

  The GAO reported that in December 1994, the Secretary of Defense directed the Army to restructure the Comanche helicopter program as part of efforts to meet budgetary constraints. The GAO noted that the Secretary's decision (1) reduced funding for the program from $4.2 billion to $2.2 billion for FY 1996-FY 2001, (2) called for two flyable prototypes to be produced, and (3) deferred the Comanche production decision.

  The GAO reported that as an alternative to the Secretary's December 1994 restructuring decision, the Army is proposing to buy six "early operational capability" aircraft, in addition to the two prototypes, costing in excess of $300 million. The GAO noted that the Army does not consider those aircraft as either prototype or low-rate initial production aircraft; however, according to program officials when the aircraft are fielded, the Army will be able to better evaluate the Comanche's mission capability. The GAO further noted that an Army program official also indicated that the six aircraft can be acquired within the proposed $2.2 billion funding level by deferring additional developmental efforts.

  The GAO concluded that both the DoD and Army proposal will extend the development program by about three years and, under

Now on pp. 3-5.

either proposal, the overall cost of the program and cost per aircraft will likely increase. The GAO noted, however, that the DoD proposal provides an opportunity to reduce the risk that the Army will concurrently produce aircraft, while significant development efforts are ongoing. The GAO, nevertheless, pointed out that the Army proposal to defer additional developmental efforts to FY 2002 and beyond may increase the risk that needed funds may not be available then. The GAO noted that if that is the case, the Army may (1) further stretch out the program or (2) enter production before critical technology is fully developed. (pp. 2-7/GAO Draft Report)

See comment 1.

DOD RESPONSE: Partially concur. The DoD acknowledges that Comanche unit costs have increased. However, the GAO discussion of unit cost in the report is misleading, because it does not specifically define how "unit cost" is measured. There are many measures of unit cost, such as program acquisition unit cost, unit procurement cost, and average unit flyaway cost. It is unclear from the report which unit cost measure the GAO is using. In addition, the report does not recognize that the total production quantity and annual production rate reductions, along with changes in the fleet aircraft capability, have significantly increased unit cost by any measure. Since the mid-1980s, the total procurement quantity has been reduced from 5,023 aircraft to the 1,292 aircraft planned today; the annual production rate has been reduced from 480 aircraft per year to a maximum of 120 aircraft per year; and the utility version of the aircraft has been eliminated, leaving only the more complex and expensive reconnaissance/attack version.

It also appears the GAO used current year or then year dollars, which include the affects of inflation, to report the unit costs. Comanche funding was reduced in the FY 1993 and the FY 1996 DoD budgets, resulting in program delays and restructuring. Those delays contributed to increased cost when measured in current year dollars due to increased inflation effects. A more appropriate measure for comparing the relative increase in Comanche unit cost is average unit flyaway cost, expressed in constant year dollars. Prior to 1988, the program was in a conceptual stage, and the estimated flyaway cost fluctuated often, as design trades and user requirements were established. In 1988, Milestone I approval was granted, and the average unit flyaway cost was established at $7.5 million for a program with a total buy of 2,096 aircraft produced at a rate of 216 aircraft per year. The last average unit flyaway cost estimate, established by the Army in 1993, is $10.5 million for 1,292 aircraft purchased at a rate of 120 aircraft per year. Both estimates are in constant FY 1988 dollars, the program's base year.

The DoD also acknowledges that should additional Comanche development efforts deferred until FY 2002 will have to compete for funds with other DoD programs. However, this necessarily increase the risk of funds not being available. However, the DoD does not support the GAO's contention that the program will stretch or enter production before critical technology is fully developed. The restructured program will put six Early Operational Capability aircraft in the hands of operational troops, and will provide an opportunity to have real world experience fed back into the aircraft developmental process. The Department will also evaluate the full potential of Comanche in future joint operations. The aircraft will be configured with key technologies, such as a second-generation Forward Looking Infrared device, advanced aided target detection, and low observables, which are critical to the accomplishment of the Comanche's primary reconnaissance mission. In addition, the Defense Acquisition Board will review program status, acquisition strategy, risk, affordability, and demonstrated benefits of Comanche at Milestone II before approving the Army's request to proceed into the Engineering and Manufacturing Development Phase.

See pp. 11-12.

- **FINDING B: Software Development is at Risk.** The GAO reported that the Comanche will be the most computerized, software-intensive helicopter ever built. The GAO noted that the Army estimates that more than 1.3 million lines of code are required to perform and integrate mission critical functions. The GAO added that, with additional ground support and training software to be developed, the total program will have more than 2.7 million lines of code. The GAO added that the Army estimates 95 percent of the Comanche's total software will be written in Ada, a DoD-developed programming language. The GAO noted that the Army plans to demonstrate initial software performance with the mission equipment package, which includes the flight control system, during first flight of the Comanche, scheduled for November 1995. The GAO concluded that (1) software development problems still exist with the Ada compilation system, (2) delays in software development and integration are occurring, and (3) improvements are needed in configuration management. The GAO further concluded that if the issues are not resolved, the aircraft's performance and capability will be degraded. (pp. 7-8/GAO Draft Report)

Now on p. 5.

- **DOD Response:** Concur. The DoD acknowledges that a program that includes an estimated 2.7 million lines of code will in involve some degree of risk. However, the Army has recognized the risks and has developed software engineering management and risk management plans to address the specific risk areas involved.

- **FINDING C: Development Problems Remain Unresolved for the Ada Compilation System.** The GAO asserted that, although almost all of the Comanche software will be developed in the Ada programming language, software developers are not using the same version of the Ada compilation system. The GAO stated that subcontractors and the contractor team should be using the same qualified version of the compilation system to ensure effective software integration. The GAO asserted, however, that fixes to individual compiler software problems are not being shared with all developers; therefore, they are not using a common compilation system. The GAO asserted that those problems have already delayed qualification testing of the compilation system by 1 year.

  The GAO reported that the lack of a uniform, qualified compilation system among software developers, could put first flight at risk, according to the Defense Plant Representative Office (DPRO). The GAO added that problems with software integration may show up once integration testing begins in the June to November 1995 time frame; and if that occurs, there may not be time to fix problems prior to the scheduled first flight. (pp. 8-9/GAO Draft Report)

Now on pp. 5-6.

  DOD RESPONSE: Partially concur. Unnecessary risk is incurred by the program if the vendors and subcontractors use variant Ada compilation systems. That is not necessarily an uncommon practice in such a large scale effort, with multiple developers working simultaneously, for different families of tools (including compilers) to be utilized. However, contrary to the GAO assertion, common updates to the Ada Compilation System are provided to all software developers whose software is co-resident in the same computer. Software developers then transition to the updated compilation system over a period of time compatible with their ongoing development efforts. The DoD agrees that compilation system qualification is a year behind the original schedule. The delay resulted from a conscious Army decision to put a higher priority on software development support over Ada compilation. The management decision was caused by a congressional funding reduction of $60 million in the FY 1994 President's budget.

- **FINDING D: Delays in Software Development and Testing.** The GAO reported that the program is experiencing high turnover of software engineers at one of the contractor team's facilities. The GAO found that loss of key personnel has already contributed to schedule slippage in several critical software development areas, such as the airborne engine monitoring system, aircraft systems management, control database, and crewstation interface management. The GAO noted that the contractor team has formulated a "get well" plan that is dependent on being able to hire additional personnel in those

areas. The GAO commented, however, that hiring additional qualified personnel is difficult, according to the DPRO, because employment would be short term.

The GAO also found that the flight control system software verification testing is being delayed. The GAO noted that as of February 8, 1995, Boeing had conducted only 163 of approximately 500 tests originally planned to be completed by that date. The GAO observed that Boeing's latest recovery plan reflected a completion date of July 1995--a 5-month delay. The GAO noted that Boeing is scheduled to complete the tests prior to first flight. The GAO commented that according to the program office, Boeing's plan to complete the testing calls for it to be conducted concurrently. The GAO asserted that if major problems occur in any one of the testing phases, there may not be enough time to fix the problem and complete all testing before first flight. (pp. 9-11/GAO Draft Report)

Now on pp. 6-7.

DOD RESPONSE: Concur. Some delays have been experienced as a result of personnel losses; however, those personnel have been replaced with qualified and experienced personnel. A behind-schedule condition existed while the replacement personnel were hired. The program is currently addressing the behind-schedule condition by the use of overtime, and by implementing process improvements to meet the November 1995 first flight date.

- **FINDING E: Improvements in Configuration Management Are Needed.** The GAO concluded that the part of configuration management used to report software problems and changes among the contractor team and subcontractors has shortcomings that put software development at risk. The GAO noted that in the November 1994 monthly assessment report, the DPRO observed that the lack of a common problem reporting system made proper handling of software related changes difficult. The GAO also noted that the report indicated that the situation could adversely impact scheduled first flight of the Comanche. The GAO added that as of January 1995, the contractor team still did not have a common, automated database available to track problem change reports. The GAO concluded, therefore, that the contractor team, as well as subcontractors, did not have visibility over changes made to software. (pp. 11-12/GAO Draft Report)

Now on p. 7.

DOD RESPONSE: Concur. Configuration Management system improvements--addressing the common problem reporting system and common, automated database concerns raised by the GAO--are being implemented and should be in place by the end of 1995.

- **FINDING F: Key Maintenance Goal May Not Be Realistic.** The GAO pointed out that the reasonableness of the Comanche's 2.6 direct maintenance man-hours per flight hour (MMH/FH) requirement has been debated for several years within the Army and the DoD. The GAO noted that representatives from the program office, the Army Materiel Systems Analysis Activity, the Office of the Assistant Secretary of the Army for Research, Development, and Acquisition, and the Army Cost and Economic Analysis Center, met on October 28, 1994, and agreed that the 2.6 MMH/FH requirement was not a realistic, achievable goal. The GAO noted that, consequently, Army officials reached consensus and agreed on 3.2 direct MMH/FH. The GAO added that, however, during those discussions, Army Materiel Systems Analysis Activity personnel noted that attaining a 3.2 MMH/FH goal represented a medium to high risk, while a 4.3 MMH/FH goal had a low to medium risk.

  The GAO concluded that the direct MMH/FH requirement does not represent the total maintenance burden for the Comanche because it does not include indirect maintenance time. The GAO asserted that the Army does not normally collect data on indirect maintenance time. The GAO noted that according to the program office, its best estimate of indirect maintenance time, following Army guidance, is 2.5 MMH/FH, and that figure has been used for calculating manpower needs for crew chief personnel on the Comanche. The GAO indicated that, thus, the total maintenance burden assumed for the Comanche is currently 5.7 MMH/FH (3.2 direct MMH/FH plus 2.5 indirect MMH/FH). The GAO asserted that increasing the maintenance factor to 5.7 MMH/FH increased the number of maintainers needed and will increase estimated operating and support costs by about $800 million over a 20-year period. (pp. 12-14/GAO Draft Report)

  DOD RESPONSE: Partially concur. The DoD acknowledges that the Army decided to calculate maintenance manpower based on 3.2 maintenance man-hours per flight hour instead of the 2.6. However, it should be recognized that the program office has not changed the design requirement.

  Further, current Army budget and plans are based on a 3.2 direct maintenance man-hours per flight hour and 2.5 indirect maintenance man-hours per flight hour. Therefore, existing operating and support estimates take into account the higher direct maintenance man-hours per flight hour and would not need to be increased as stated by the GAO.

- **FINDING G: Repair Requirement May Not Be Met.** The GAO reported that to minimize turn-around time for repairs at the unit and depot, the Army established mean time to repair (MTTR) requirements of 52 minutes for repairs at the unit level and up to 12 hours at the depot level for the Comanche.

Now on pp. 7-8.

See comment 3.

The GAO noted that those requirements represent the average time expected to diagnose a fault, remove and repair an item, and perform an operational check and/or test flight. The GAO asserted that any increase in MTTR above 1.0 hours will begin to impact the Army wartime availability goal of 2,200 hours per year, unless additional maintenance personnel are available.

The GAO noted that as of January 1995, the contractor team was estimating that the Army would achieve 59 minutes for unit level repairs. The GAO commented that according to contractor team officials, the requirement was not being met, because the cure time required for composite material used on the aircraft was greater than expected. The GAO indicated that the program office felt the problem could be resolved and did not believe the specification should be changed. The GAO added that the contractor team has not yet developed MTTR estimates for depot-level repair. (pp. 12-14/GAO Draft Report)

Now on pp. 8-9.

DOD RESPONSE: Partially concur. The DoD concurs that any increase above 1.0 hour mean time to repair (MTTR) will impact operational availability. However, the Department does not agree with the GAO conclusion that the Comanche repair requirement of 1.0 hour may not be met. First, the Comanche prediction is meeting the 1.0 hour Operational Requirements Document (ORD) requirement. The shortfall is between the contractor prediction (0.98 hour) and the contractual specification (0.87 hour). Second, the contractor is actively addressing the shortfall. As noted by the GAO, composite materials cure time is a factor in meeting the repair requirement. Existing and emerging technologies and processes are being examined for systemic impacts in an effort to reduce cure times. Chemical, temperature, and magnetic-field-effect composite cure accelerators are among the technologies being explored.

See comment 3.

- **FINDING H: Key Diagnostic System Requirement May Not be Achieved.** The GAO reported that the Comanche's diagnostic system is required to correctly isolate failed mechanical and electrical components at least 80 percent of the time with a high degree of accuracy. The GAO noted that a high level of accuracy is essential as it allows maintainers to isolate and fix problems at the unit level. The GAO pointed out that, if the fault isolation requirement is not met, the Comanche is unlikely to achieve its MTTR requirement, thereby adversely affecting the Army's ability to execute its maintenance concept and its wartime availability goals. The GAO observed that the contractor team officials indicated the fault isolation requirement was very optimistic, and may eventually have to be changed. (pp. 15-16/GAO Draft Report)

Now on p. 9.

See comment 3.

DOD RESPONSE: Partially concur. Fault isolation is one of the key diagnostic system requirements. The DoD agrees that, if the fault isolation requirement is not met, the Comanche is unlikely to achieve its mean-time-to-repair requirement, thereby adversely affecting the Army ability to execute its two-level maintenance concept. However, achieving the Army wartime operational availability goals is not solely dependent on achieving the fault isolation requirement.

The Army recognizes that the key diagnostic system requirements are challenging and has established risk mitigation activities specifically intended to reduce the risk of not meeting diagnostic requirements. Diagnostics have been a key design area throughout the Comanche's development. The program office has included testability analysis, maintainability and logistics demonstrations, and separate diagnostic demonstrations to ensure the diagnostic requirements are met. Additionally, the Department has established an exit criterion on the successful completion of the electro-optical sensor system (EOSS) diagnostic demonstration before entering production. The EOSS system is considered the most complex and most representative subsystem of the complex Comanche design.

- **FINDING I: False Removal Rate Probably Not Achievable.** The GAO reported that the Army established a requirement of a 1-percent false removal rate for the Comanche. The GAO noted that the program personnel characterize the 1-percent requirement as stringent and one that will be challenging to achieve. The GAO commented that according to an Army Materiel Systems Analysis Activity official, some design improvements have occurred in this area, but the risk associated with achieving the requirement still remains high. The GAO concluded that if the Comanche does not meet the requirement, estimated operating and support costs for the Comanche will be higher than previously predicted. The GAO asserted that the Army has not had good experience in developing fault detection/isolation and false removal systems for other aircraft. (pp. 16-17/GAO Draft Report)

Now on pp. 9-10.

DOD RESPONSE: Nonconcur. The DoD nonconcurs that the false removal rate requirement is "probably" not achievable. Although the false removal rate requirement is stringent and the Army has not had good experience in the past with false removals on other aircraft, there is no current evidence or test data to suggest that the requirement is "probably" not achievable.

See comment 4.

The Army has established a number of risk mitigation activities to help meet the requirement. Additionally, a Portable Maintenance Aid Instrumentation Pack (PIP) is being

developed to test components on aircraft versus off the aircraft. The PIP addresses the historical problem of testing components off the aircraft and finding no evidence of failure (a false removal). The ability to test the component and the associated aircraft interfaces using the PIP will significantly reduce false removals and ensure the achievement of the false removal rate requirement.

- **FINDING J: Some Program Goals Are Currently Being Met.** The GAO reported that although the program is experiencing technical problems, it is currently meeting its goals of reducing maintenance levels and keeping overall weight growth within acceptable limits for the Comanche.

  The GAO pointed out that as of January 1995, no Comanche component had been designated for repair at the intermediate level, according to the program office. The GAO reported that contractor team personnel are conducting repair level analysis on Comanche components to determine whether components should be repaired at unit, intermediate, or depot facilities, according to program and contractor team officials. The GAO noted that any candidates identified for intermediate-level repair are reviewed for possible design changes that could allow maintenance at the unit or depot level. The GAO also noted that, if economically feasible, the contractor team will make design changes to the component to preclude the need for intermediate-level repair.

  The GAO reported that as of February 7, 1995, the Comanche's empty weight increased from its original specification of 7,500 pounds to 7,883 pounds. The GAO noted that, although the Comanche's weight continues to increase, it remains within the allowable design limit of 7,997 pounds. The GAO explained that weight increases affect vertical rate of climb performance on the Comanche. The GAO pointed out that the Army established a limit of 500 feet-per-minute as the minimum acceptable vertical rate of climb performance. The GAO asserted that if the Comanche's weight exceeds 8,231 pounds, the engine will have to be redesigned to produce enough power at 95 percent maximum rated engine power to sustain the minimum 500 feet-per-minute vertical rate of climb requirement. (pp. 17-19/GAO Draft Report)

  DOD RESPONSE: Concur. The DoD concurs that some program goals are currently being met. With specific regard to the Comanche weight requirement, the GAO is correct that the empty weight goal at Milestone I was 7,500 pounds. However, in 1993 the Comanche empty weight contract specification was changed to 7,765 pounds. That change was attributed to incorporating provisions for Longbow; the heavier, more powerful T800 growth

Now on pp. 10-11.

engine; and the redefinition of the empty weight calculation to include additional combat kits.

The February 7, 1995, empty weight estimate (7,883 pounds) referenced by the GAO is the current estimate measured against the contemporary 7,765-pound goal. The 7,997 pounds referenced by the GAO is the value specified in a design flexibility clause in the contract. That value allows the contractor to propose cost versus performance tradeoffs up to that limit. The 500 feet-per-minute vertical rate of climb goal cannot be met with Longbow installed if the empty weight of the Comanche exceeds 8,231 pounds.

* * * * *

RECOMMENDATIONS

- **RECOMMENDATION 1:** The GAO recommended that the Secretary of Defense assess the Comanche program to assure that the Army develops fixes that achieve program goals and reduce risk associated with the technical problems identified in this report and with the restructuring of the Comanche program. (pp. 19-20/GAO Draft Report)

Now on p. 12.

DOD Response: Concur. On March 21, the Department approved a restructured program which includes two prototypes and six Early Operational Capability aircraft in the hands of the troops for user evaluation. This approach defers production and weapon system integration, which will significantly reduce risk.

See pp. 11-12.

- **RECOMMENDATION 2:** The GAO recommended that the Secretary of Defense assess the Comanche program to assure that the program meets performance and mission requirements before any production funds are requested. (pp. 19-20/GAO Draft Report)

Now on p. 12.

DOD Response: Concur. As explained in the DoD response to Recommendation 1, the revised Comanche development program will provide an opportunity for additional operational experience during Comanche development. Overall program results will be considered by the Defense Acquisition Board at the Milestone II review for approval to proceed into the Engineering and Manufacturing Phase. The Milestone II review is currently projected for October 2001.

See pp. 11-12.

The following are GAO's comments on the Department of Defense's (DOD) letter dated April 20, 1995.

1. As DOD's comments note, there are many measures of unit cost, such as average unit flyaway cost, program acquisition unit cost, and unit procurement cost. We believe that the program unit cost that we used in the report—which the footnote in the report defines as total research, development, and acquisition costs in current dollars—is as valid as flyaway cost to portray program cost growth over time. We have adjusted the report to more clearly define the basis of the unit cost we use.

2. These comments are dealt with on pages 11 and 12 of the report and in our responses to the specific DOD comments that follow. Report material on costs and concurrency has been revised to reflect information obtained after our fieldwork had been concluded.

3. The report does not say that maintainability goals will never be met. We pointed out that some key maintainability requirements are not being met and, therefore, there is a risk that the Army may not achieve the lower operating and support costs and wartime availability goals that it has established for this program. We also said that individually, failure to meet these parameters may not be a significant problem; however, collectively they affect the ability of the Comanche to achieve the cost and availability goals. This point is clearly illustrated in DOD's comments on the failure of the fault isolation system. According to DOD, "Fault isolation is one of the key diagnostic system requirements. The DOD agrees that if the fault isolation requirement is not met, the Comanche is unlikely to achieve its mean-time-to-repair requirement, . . .".

4. We still believe that this goal is very aggressive. DOD acknowledges that this goal is stringent and the Army has not had good experience in the past with false removals on other aircraft. Additionally, as noted in the report, Army Materiel Systems Analysis Activity said the risk associated with achieving this requirement remains high. We changed the section heading to emphasize the high risk.

Major Contributors to This Report

National Security and International Affairs Division, Washington, D.C.	Robert J. Stolba
Accounting and Information Management Division	David Chao
Kansas City Regional Office	Gary L. Billen Robert D. Spence Lauri A. Bischof Michael W. Buell Karen A. Rieger

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20884-6015

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000 or by using fax number (301) 258-4066, or TDD (301) 413-0006.

Each day, GAO issues a list of newly available reports and testimony. To receive facsimile copies of the daily list or any list from the past 30 days, please call (301) 258-4097 using a touchtone phone. A recorded menu will provide information on how to obtain these lists.

United States
General Accounting Office
Washington, D.C. 20548-0001

Bulk Mail
Postage & Fees Paid
GAO
Permit No. G100

Official Business
Penalty for Private Use $300

Address Correction Requested