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The Honorable Sam Nunn
Chairman, Committee on Armed Services
United States Senate

The Honorable Daniel K. Inouye
Chairman, Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Les Aspin
Chairman, Committee on Armed Services
House of Representatives

The Honorable John P. Murtha
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

This report provides information on the Air Force's progress in developing and acquiring the C-17 airlift aircraft. We found that the C-17 program faces significant schedule, cost, and performance challenges. We concluded that it is unlikely that the aircraft's planned first flight date of August 1990 will be met.

On August 4, 1989, as this report was going into printing, the C-17 Program Director informed us that, as a result of continuing problems documented by a recent program review, he intends to recommend that the planned first flight date be extended to December 1990. He also told us that meeting the December 1990 date still depends on the contractor's ability to effectively address existing assembly and avionics development problems. We will continue to evaluate Air Force and contractor progress in resolving these and other potential problems facing the C-17 program.

We are sending copies of this report to the Ranking Minority Member of your committees; other appropriate congressional committees; the Secretaries of Defense and the Air Force; the Director, Office of Management and Budget; and other interested parties.

This report was prepared under the direction of Harry R. Finley, Director, Air Force Issues. Other major contributors are listed in appendix II.

Frank C. Conahan
Assistant Comptroller General

Executive Summary

Purpose

The Air Force plans to buy 1 development aircraft and 210 C-17 production aircraft at an estimated cost of $37.5 billion, making this acquisition program one of the Department of Defense's (DOD) largest. The C-17 is intended to provide additional long-range airlift capability, modernize the airlift fleet, and improve U.S. capability to rapidly project, reinforce, and sustain combat forces worldwide.

To provide the Congress with information on the program's overall status, GAO reviewed the Air Force's progress in meeting C-17 program schedule, cost, and performance goals.

Background

In 1981 DOD identified a need for additional long-range airlift capability. In 1983 the Air Force bought 50 additional C-5 and 44 KC-10 aircraft to increase its near-term airlift capability, and it analyzed alternatives to solve its long-term airlift capability shortfall. These alternatives were to buy additional C-5s or develop the C-17 aircraft. The Air Force concluded that the C-17 was the cost-effective alternative.

The C-17 program is currently in full-scale development and transitioning to concurrent development and low-rate initial production. The Air Force planned concurrency into the C-17 program; the full-scale development and low-rate initial production phases will overlap between fiscal years 1988 and 1992.

Results in Brief

The Air Force's acquisition strategy for the C-17 program is based on a DOD goal to achieve an airlift capability of 66 million ton-miles per day by the year 2000. The program's schedule and planned procurement rates have been established to meet this goal. First flight is currently planned for August 1990, initial operational capability is estimated for September 1992, and a peak procurement rate of 29 aircraft per year is planned to begin in fiscal year 1993.

As the C-17 transitions from development to concurrent development and low-rate initial production, the program faces significant schedule, cost, and performance challenges. Delays in the avionics development and aircraft assembly schedules have made it unlikely that the C-17's first flight date will be met. This, in turn, will delay the start of the flight test program. Estimated program acquisition costs are increasing, but the extent of estimated cost growth will not be known until estimates can be made based on actual cost data from the manufacture of the development and first production aircraft. C-17 costs reported to the

Congress do not include costs associated with defensive systems planned for the aircraft. In addition, Douglas Aircraft Company and the Air Force are working to control the C-17's weight growth before it degrades requirements for aircraft range and payload.

It is important for the Air Force to meet these challenges because significant schedule slips or degradation in aircraft performance will reduce the C-17's expected contribution to the readiness of U.S. forces.

Principal Findings

Schedule

According to the C-17 Program Office, the C-17 program has experienced several setbacks due to reduced program funding in fiscal years 1986 and 1987. The start of fabrication and assembly of the development aircraft were delayed 9 months, from December 1987 to August 1988; the aircraft's scheduled first flight was delayed 6 months, from February 1990 to August 1990; and the planned initial operational capability date was pushed back 5 months, from April 1992 to September 1992.

It is unlikely that the Air Force will meet its planned August 1990 first flight date for the C-17 because (1) the assembly schedule for the development aircraft has a high degree of risk, since a major portion of the planned schedule was compressed from 329 to 258 days, (2) projected late deliveries of tooling and parts will delay the joining of major aircraft sections, and (3) subcontractor development of key avionics systems—the mission computer software and electronic flight control system—is behind schedule. The compressed assembly schedule must be met and the avionics development problems must be resolved to complete assembly of the development aircraft by January 1990, as currently planned, and permit sufficient testing before the first flight. According to the C-17 Program Office, assembly and avionics development problems could delay the first flight by up to an additional 4 months, which, in turn, will delay the start of the flight test program.

The Air Force must resolve the current assembly and avionics development problems and manage the program's concurrent schedule to avoid further delays, which would increase the risk that key milestones, such as initial operational capability, the operational readiness evaluation, and the full-rate production decision, would not be met.

The risk associated with achieving the first flight milestone on time is a major concern to the Air Force. The Air Force has assigned a high degree of risk to Douglas' ability to complete assembly of the development aircraft on time. Program assessments by the Air Force and the Office of the Secretary of Defense concluded that the existing assembly and avionics development problems have put the first flight milestone in jeopardy.

Cost

When full-scale development of the C-17 began in 1985, DOD estimated the program acquisition costs at $34.5 billion. DOD currently estimates that the C-17 program will cost $37.5 billion, an increase of $3 billion. In December 1988 the C-17 Program Director estimated that program acquisition cost would be $36.1 billion and established initiatives to keep procurement costs lower than DOD's estimate. The reason for the difference in total estimated program acquisition cost was primarily due to DOD's higher estimated procurement costs.

In January 1989 the Defense Acquisition Board limited full funding approval to 4 aircraft in fiscal year 1989 and 6 aircraft in fiscal year 1990. It also approved procurement funding for long-lead items and material for 10 aircraft in fiscal year 1991. Funding approval was limited primarily so an interim review can be conducted after the initial flights of the development and first production aircraft, but also because of the differences in procurement cost estimates. The Air Force had also requested full funding for 10 aircraft in fiscal year 1991 and for 20 aircraft in fiscal year 1992, and long-lead procurement funds for 29 aircraft in fiscal year 1993 and for full-rate tooling. However, the Board concluded that additional funding approval should be based on initial flight test results as well as more mature cost estimates, including actual cost data from initial production.

Additional costs of at least $437 million, depending on the number of C-17s to be equipped, can be expected when defensive systems are included in the estimates.

Performance

Although performance projections by Douglas show that the C-17's design will meet approved requirements for payload, range, and reliability, maintainability, and availability, actual performance will be demonstrated during flight testing, scheduled to begin in 1990, and the subsequent operational readiness evaluation.

The C-17's projected weight has increased and reached the maximum allowable to meet current performance requirements for payload and range. The Air Force and Douglas face the challenge of controlling further weight growth before it degrades requirements for aircraft range and payload.

The Air Force plans to improve the C-17's survivability by installing defensive systems to detect and counter combat threats. The Air Force also plans to conduct live fire tests on a production representative section of the aircraft's wing to determine the C-17's vulnerability to combat damage. Office of the Secretary of Defense officials expressed concern that the Air Force's plan did not address the vulnerability of the overall system to potential threats. The Air Force is working with these officials to ensure that its live fire test strategy is consistent with DOD guidelines and public law.

Recommendations

This report provides GAO's analysis of the status of the C-17 program in meeting schedule, cost, and performance goals. It contains no recommendations.

Agency Comments

DOD concurred with GAO's report. It provided suggested technical changes and updated information, which were incorporated where appropriate.

On August 4, 1989, the C-17 Program Director informed GAO that, as a result of continuing problems documented by a recent program review, he intends to recommend that the planned first flight date be extended to December 1990. He also told GAO that meeting the December 1990 date still depends on the contractor's ability to effectively address existing assembly and avionics development problems. GAO will continue to evaluate Air Force and contractor progress in resolving these and other potential problems facing the C-17 program.

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Abbreviations

DOD	Department of Defense
GAO	General Accounting Office
IOC	initial operational capability
MAC	Military Airlift Command
OSD	Office of the Secretary of Defense

Introduction

The Air Force is developing the C-17 aircraft to meet a shortfall in long-range airlift capability. It plans to acquire 1 development aircraft and 210 production aircraft at an estimated cost of $37.5 billion adjusted for inflation (referred to as then-year dollars), or about $177.5 million per aircraft.

The Congress has paid close attention to the development of the C-17. In response to past congressional requests, we reviewed[1] the Air Force's analysis supporting its decision to acquire the C-17, the competition held for producing C-17 wing components, and the C-17's program status relative to its authorized milestones. The Senate Committee on Armed Services has also expressed concern as to whether C-17 production goals are attainable, given projections of defense spending levels. As a result, the Secretary of Defense was requested to examine and report on alternative production rates and related procurement costs, including options for multiyear procurement, for the C-17 by January 1, 1989. The Department of Defense submitted its report to the Congress in May 1989. The report examines production rates of 12, 24, 29 and 36 aircraft per year and presents unit cost estimates for each alternative. It also presents cost estimates under both annual and multiyear procurement strategies for the three higher production rate alternatives. The report concludes that (1) the higher production rates successively reduce the unit cost of the aircraft by both decreasing the overall production period, and by increased manufacturing efficiency, and (2) multiyear procurement reduces the cost further by permitting economical order quantities for materials and equipment.

The C-17 is one of the DOD's largest acquisition programs. We conducted this review to provide the Congress with information on the Air Force's progress in meeting C-17 program schedule, cost, and performance goals.

[1] Military Airlift: Air Force Analysis Supports Acquisition of C-17 Aircraft (GAO/NSIAD-87-97, Mar. 20, 1987).

Military Airlift: C-17 Wing Competition Fair, but Savings Lower Than Air Force Estimates (GAO/NSIAD-88-3, Nov. 13, 1987).

DOD Acquisition Programs: Status of Selected Systems (GAO/NSIAD-88-160, June 30, 1988).

Figure 1.1: C-17 Aircraft

The C-17's projected ability to airlift the full range of military cargo directly into small, austere airfields distinguishes it from the other aircraft in the airlift force, such as the C-5, C-141, and C-130. The Air Force stated that it will routinely use the C-17 for direct deliveries, including deliveries to potentially hostile areas. This use is key to achieving the full potential benefits from the C-17.

The Air Force's Aeronautical Systems Division, Air Force Systems Command, manages the development and acquisition of the C-17. Douglas

Aircraft Company, McDonnell Douglas Corporation, is the prime contractor. The Military Airlift Command (MAC), the Air Force Reserves, and the Air National Guard will operate the C-17.

Program Status

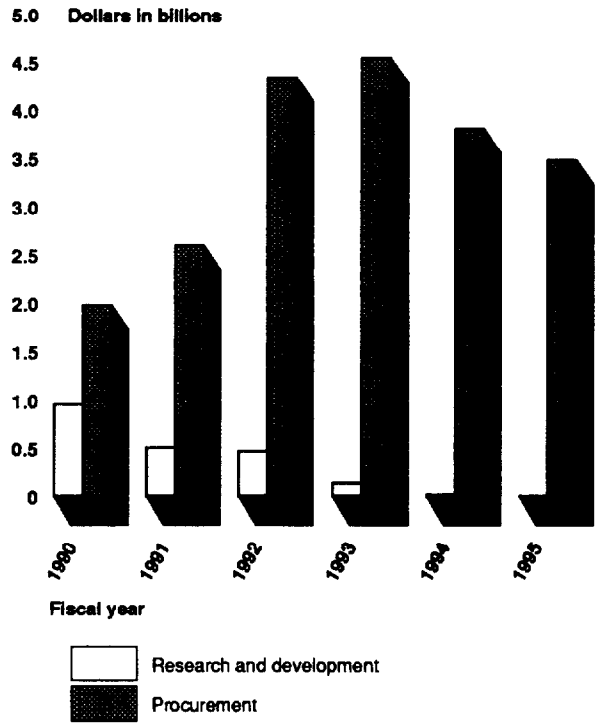
The Air Force plans to acquire 210 C-17 aircraft through fiscal year 1998. These aircraft will be assigned to MAC, Air Force Reserve, and Air National Guard units; 180 will be used for operational missions, 12 for training, and 18 for backup.

The C-17 program is currently in full-scale development and transitioning to concurrent development and low-rate initial production. Full-scale development, which began in 1985 under a fixed-price incentive (firm target) contract with Douglas, provides for the fabrication of one flyable test (development) aircraft and two full-scale, ground test units for structural and durability testing.

As of February 1989, the contract target price for full-scale development amounted to $4.2 billion. The contract also includes two options for production aircraft. In January 1988 the Air Force exercised the first option for two production aircraft at a cost of $604 million and plans to exercise the second option for four aircraft in fiscal year 1989.

Assembly of the development aircraft began in August 1988. The Defense Acquisition Board made the low-rate initial production decision in January 1989. The Board approved full funding for 4 aircraft in fiscal year 1989, 6 aircraft in fiscal year 1990, and long-lead items and material for 10 aircraft in fiscal year 1991. The full-rate production decision is scheduled for March 1993, after which an annual peak procurement rate of 29 aircraft is planned to achieve the goal of being able to airlift 66 million ton-miles per day by the year 2000. Over the next 6 years, DOD will be requesting about $22.8 billion to acquire the C-17. Figure 1.2 shows the C-17 program's projected funding levels.

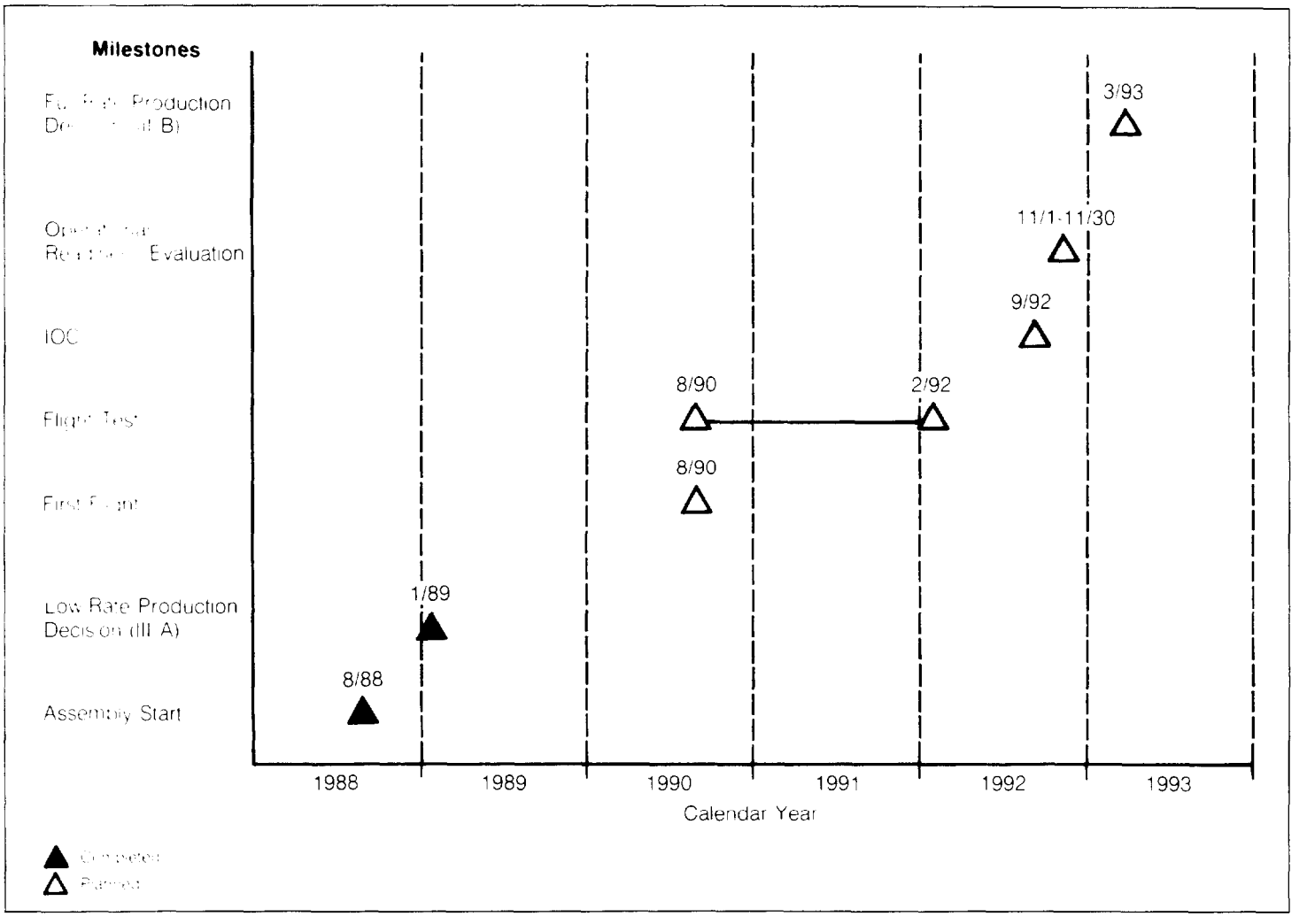
Figure 1.2: C-17 Program Funding by Fiscal Year



The C-17's first flight is planned for August 1990. A combined development test and evaluation and initial operational test and evaluation flight test program is scheduled to be completed by February 1992. Initial operational capability (IOC)—the delivery of the initial squadron of 12 aircraft to MAC with sufficient facilities, spares, support equipment, technical orders, and trained personnel for effective mission performance—is estimated for September 1992. IOC will be declared when the Commander-in-Chief, MAC, determines that the initial squadron is trained and supportable.

The Air Force planned concurrency into the C-17 program. The full-scale development and low-rate initial production phases of the program will overlap between fiscal years 1988 and 1992 when the flight test program is scheduled for completion. Figure 1.3 shows the program's current key milestones.

Figure 1.3: C-17 Program Milestone Dates



Objective, Scope, and Methodology

Our objective was to evaluate the C-17 program to provide the Congress with information on the Air Force's progress in meeting C-17 program schedule, cost, and performance goals.

We examined acquisition and test plans and schedules, cost reports, program assessments, the C-17 contract, regulations and other appropriate documentation prepared by the Office of the Secretary of Defense (OSD), the Air Force, and Douglas. We discussed the program with responsible DOD, Air Force, and Douglas officials. We did our work primarily at the C-17 System Program Office, Aeronautical Systems Division, Wright-

Patterson Air Force Base, Dayton, Ohio; and the Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach, California.

We conducted our review from April 1988 through April 1989 in accordance with generally accepted government auditing standards. DOD provided suggested technical changes and updated information on a draft of this report, which were incorporated in the report where appropriate.

C-17 Transitioning to Production With Increased Schedule Risk

The C-17 program has experienced delays in the start of fabrication and assembly of the first aircraft and delays in the aircraft's scheduled first flight and planned IOC date. Presently, the program is experiencing assembly and avionics development problems that, according to the program office, will delay first flight by up to an additional 4 months. This, in turn, will delay the start of the flight test program. The Air Force must resolve the current assembly and avionics development problems and manage the program's concurrency to avoid further delays, which would increase the risk that key milestones, such as IOC, the operational readiness evaluation, and the full-rate production decision, would not be met.

Program Schedule Changes to Date

The Air Force's acquisition strategy for the C-17 program is based on a DOD goal to achieve an airlift capability of 66 million ton-miles per day by the year 2000. The program's schedule and planned procurement rates have been established to accomplish this goal. First flight is currently planned for August 1990, IOC for an initial squadron of 12 aircraft is currently scheduled for September 1992, and a peak procurement rate of 29 aircraft per year is planned to begin in fiscal year 1993.

Key program milestones have changed, as shown in table 2.1, since full-scale development was approved in 1985.

Table 2.1: Changes in Key C-17 Milestones

	Milestone dates		Change
	Dec. 1985	Dec. 1988	(months)
Start of assembly	Dec. 1987	Aug. 1988	9
Low-rate production decision	Sep. 1986	Jan. 1989	28
First flight	Feb. 1990	Aug. 1990	6
IOC	Apr. 1992	Sep. 1992	5
Full-rate production decision	Aug. 1991	Mar. 1993	19

According to the program office, congressionally reduced program funding in fiscal years 1986 and 1987 caused a restructuring of the prime contract. As a result, the program incurred a 9-month delay in the start of fabrication and assembly of the development aircraft, a 6-month delay in expected first flight, and a 5-month delay in planned IOC.

Although the start of fabrication and assembly of the development aircraft was delayed 9 months, its planned first flight date was delayed only 6 months, compressing the time between the start of assembly and

planned first flight by 3 months. The 5-month delay in planned IOC maintains the Air Force's goal, established in 1983, of achieving IOC in fiscal year 1992.

The Air Force delayed the low-rate and full-rate production decision milestones to obtain additional information on C-17 technical and production readiness. It delayed the low-rate production decision, which was made in January 1989, twice until the results of the critical design review became available. The results of the third production readiness review were also available by then. The Air Force also moved the full-rate production decision to October 1992, after the initial operational test and evaluation is completed. In January 1989 the Defense Acquisition Board further delayed the full-rate production decision to March 1993 to consider the operational readiness evaluation results on aircraft reliability, maintainability, and availability.

Challenge in Meeting First Flight

It is unlikely that the Air Force will meet its planned August 1990 first flight date for the C-17 because (1) the compressed assembly schedule for the development aircraft has a high degree of risk,[3] (2) projected late deliveries of tooling and parts will delay joining of major aircraft sections, and (3) subcontractor development of key avionics systems, that is, the mission computer software and electronic flight control system, is behind schedule. The compressed assembly schedule must be met and the avionics development problems resolved to complete development aircraft assembly by January 1990, as currently planned, and permit sufficient testing before first flight.

The risk associated with achieving the first flight milestone is a major concern to OSD and the program office. Production readiness assessments by the Air Force and OSD concluded that existing assembly and avionics development problems have put the first flight milestone in jeopardy.

Compressed Development Aircraft Assembly Schedule

Douglas began assembling the development aircraft in August 1988. However, to make up for delivery delays of material, tooling, parts, and components and complete assembly by January 1990, it compressed a major portion of the aircraft assembly schedule, requiring its labor force to operate at high efficiency levels. For example, Douglas reduced the

[3]The Air Force defines a high degree of risk as the likelihood that a major, serious disruption of schedule will occur even with high contractor management attention and close government surveillance.

time to complete 17 of 19 assembly activities, which decreased the planned assembly time for these activities from 329 to 258 days, or about 14 workweeks.

According to the program office, before the assembly schedule was revised, a delay in the scheduled joining of the wing and fuselage was projected, which made the remainder of the assembly schedule unrealistic. Specifically, a 3-month slip in the date for joining of the wing and fuselage had been projected because of anticipated delays in receiving wing components. Under the revised assembly schedule, the planned date for joining the wing and fuselage would slip only 7 weeks, from early June to late July 1989. As of April 1989, Douglas projections showed that continued late deliveries of tooling and parts would delay the joining of major sections of the aircraft. As a result, the joining of the wing and fuselage would probably slip to November 1989, according to the C-17 Program Director.

Officials from Douglas and the program office agree that compressing the assembly schedule was necessary to achieve the August 1990 first flight date. According to the program office, further schedule compression would be an unacceptable solution to additional assembly problems. If the revised assembly schedule becomes unachievable, Douglas could add a third work shift and a weekend work shift, rather than compressing the schedule even further.

According to the program office, although Douglas' revised assembly schedule has a high degree of risk, it is achievable. To meet the revised schedule, the program office believes Douglas must operate at a labor efficiency level higher than it has ever recorded on any first aircraft. To achieve the necessary efficiency, Douglas said it will use more automation on the C-17 than it has used before in aircraft assembly. In addition, multidisciplined production teams will assemble specific portions of the aircraft and provide on-site resolution of assembly problems.

Avionics Development Delays

Subcontractors have fallen behind schedule in developing the C-17's mission computer software and electronic flight control system hardware and software. As a result, Douglas extended the completion dates for the mission computer software and is revising the schedule for the electronic flight control system. The Air Force and Douglas determined that complete mission computer software will not be ready for the currently scheduled first flight. However, the program office said that the

the pilot/co-pilot displays in the development aircraft mission computer/electronic display system.

Electronic Flight Control System

Development of the C-17's electronic flight control system has also fallen behind schedule. The electronic flight control system directs and controls the movement of the aircraft. The current plan is to have complete hardware and software for the electronic flight control system available for the development aircraft's first flight.

In 1987 Douglas revised the development schedule for the flight control system primarily to account for a design change made as a result of wind tunnel tests. These tests revealed the possibility that the C-17 could incur a deep-stall condition from which it might not recover as it approaches its landing. According to Douglas, the problem is common to other aircraft with high T-shaped tail structures, such as the C-5, C-141, and DC-9.

Douglas changed the flight control system so that it now automatically limits the angle at which the aircraft may be flown when making a landing approach. This reduces the potential for the pilot to stall the aircraft inadvertently. When this change was made, the subcontractor's schedule for development was about 2 months behind. The change caused the delivery schedule for the first development hardware and software to be delayed about 1 year, from April 1988 to May 1989.

Since the decision to redesign the flight control system, the subcontractor's development effort has proceeded more slowly than expected. For example, during 1988 the development effort fell from an estimated 4 to 16 weeks behind schedule. In December 1988 Douglas determined that the May 1989 delivery date for the initial hardware unit and software package could not be met. Douglas and its subcontractor subsequently decided that the first hardware unit could be completed in January 1990 and agreed to delay the first delivery of hardware and software until March 1990, or about 10 months late.

Air Force Assessment of Program Risk

In August 1988 the Air Force completed the critical design review and third production readiness review of the C-17's development. The critical design review evaluated the C-17's overall design to determine whether it met specifications before it was committed to production. The production readiness review, the third of six scheduled reviews, evaluated the program to verify that it is ready to transition from development to production without serious problems.

The Air Force concluded that there was a high degree of risk that Douglas would not be able to complete development aircraft assembly on time. The C-17 Program Director stated that there was a low degree of risk[4] with technical development of the avionics systems, but a high degree of risk with completing the development of mission computer software and avionics integration on schedule. The Program Director also concluded that there was a medium, but increasing, degree of risk[5] associated with completing the electronic flight control system development on schedule.

In April 1989 the Program Director said that, due to an expected delay in the date for joining the wing and fuselage (from July 1989 to November 1989), the most probable date for the development aircraft's first flight will be some time in late November or early December 1990. The start of the flight test program would be delayed accordingly. The program office is evaluating the impact of such a delay on the program's flight test schedule and currently believes that planned schedule contingencies in fiscal year 1992 will minimize any impact. In addition, Douglas is evaluating the impact of the recent slips in the mission computer software and electronic flight control system schedules on the development aircraft's first flight.

The Program Director's concern over development and integration of avionics systems is shared by the Air Force Operational Test and Evaluation Center, which is responsible for conducting independent operational tests of weapon systems. In preparation for the C-17's low-rate production review, the Center conducted an early operational assessment of the C-17. In its September 1988 report, the Center expressed concern over the adverse impact that delays in mission computer software and electronic flight control system development could have on initial operational test and evaluation. The report stated

"A major risk to the conduct of IOT&E [initial operational test and evaluation] on a properly configured aircraft is software development/avionics integration. The C-17 mission computer [MC] software development is behind schedule.....Because the MC is the focal point of the aircraft's avionics system, delays in MC software development will impact the time schedule required for avionics system integration testing. Also, the electronic flight control system [EFCS] has been redesigned.... This has slipped EFCS integration testing 12 months, placing it close to first flight.

[4]The Air Force defines a low degree of risk as low potential for disrupting schedule, increasing cost, and/or degrading performance.

[5]The Air Force defines medium degree of risk as the potential that some significant disruption of schedule will occur.

OSD Assessment of Schedule Risk

In November 1988 the Office of the Secretary of Defense made several assessments of the C-17 program to prepare for the low-rate production decision. In a November 4, 1988, assessment of the C-17 program, the Defense Product Engineering Services Office, Defense Logistics Agency, stated that the C-17 program is achievable and that no basis exists to warrant a change in program direction. However, the assessment also concluded that it is "highly improbable" that assembly of the development aircraft would be completed in January 1990 and first flight would occur in August 1990. The report stated

"The problems currently being experienced with design release, tool design, subcontractor procurement, early fabrication of tooling and piece-parts seem to be too much of a barrier to overcome and still build and assemble an aircraft in the remaining fourteen months. The normal time span for fabrication and assembly of an airframe on a mature aircraft program is usually about twenty four months. The C-17, for all intents and purposes, is still in the design phase.... There is a high probability of schedule slippage...."

Also, in a November 10, 1988, assessment, the Office of the Deputy Director for Test and Evaluation, OSD, concluded that "...the scope and progress of the... electronic flight control system and mission computer software development may cause a delay in first flight." The report added that "...the two critical systems...to first flight are the electronic flight control system and the mission computer. Both system schedules are slipping...and their availability for the August 1990 first flight date is at risk." The degree of risk that the systems would not be delivered on schedule was judged to be "medium to high."

Relationship of Flight Test Program to Other Key Milestones

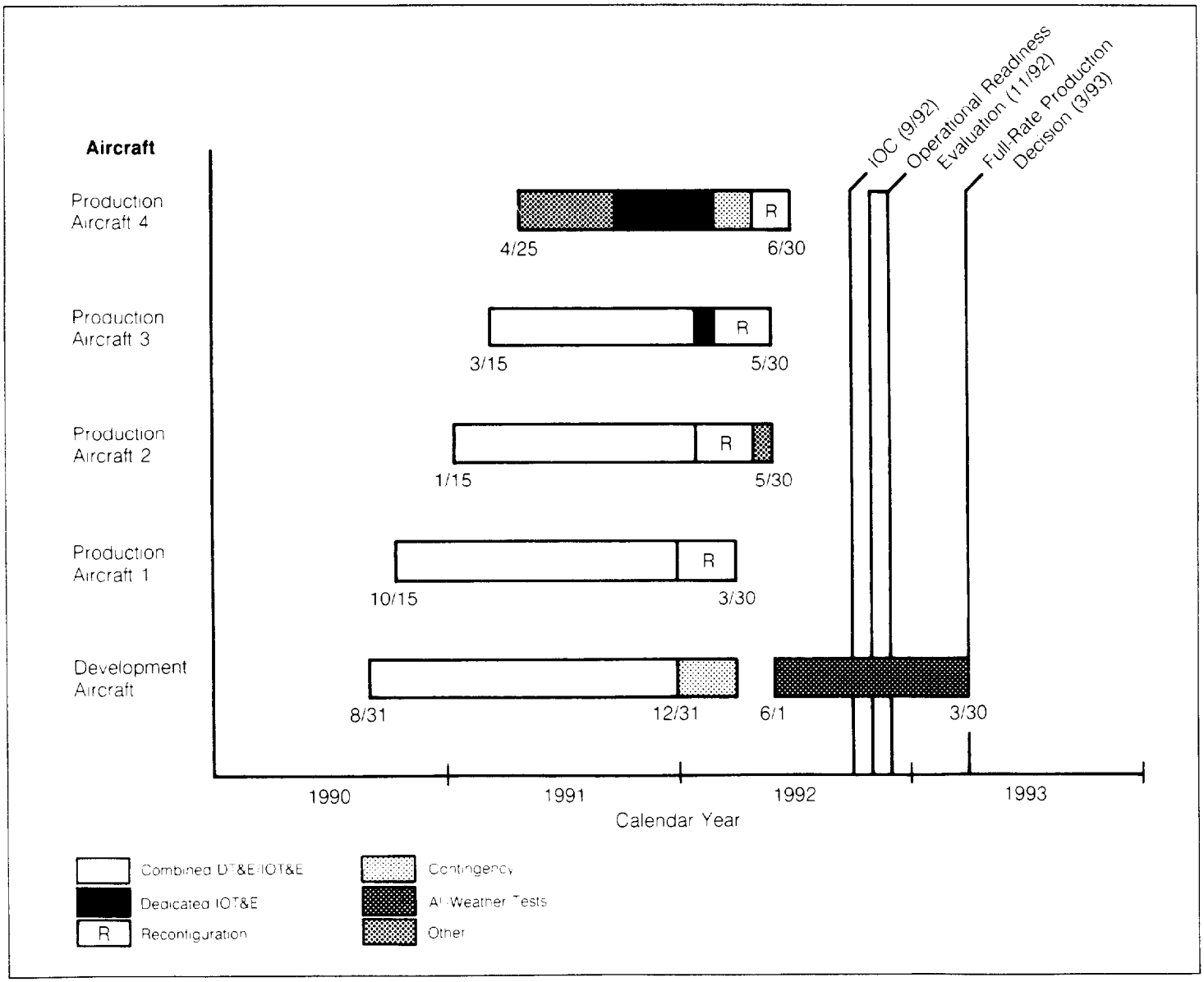
The Air Force needs to complete initial operational flight testing without lengthy delays if the C-17 is to meet the September 1992 IOC date. In addition, the operational readiness evaluation,[6] conducted shortly after IOC, must be completed and initial operational test and evaluation results must be available before a full-rate production decision, scheduled for March 1993,[7] can be made.

[6]The operational readiness evaluation is a series of operational flights by the initial squadron that are designed to determine if the C-17 has achieved its reliability, maintainability , and availability requirements.

[7]DOD and Air Force regulations require that initial operational test and evaluation must be completed before the full-rate production decision. The Air Force Operational Test and Evaluation Center is required to analyze and report on the test results, and OSD's Director of Operational Test and Evaluation is required to submit a report to the Congress on the adequacy of the testing and the operational effectiveness and suitability of the weapon system.

As previously discussed, the program already faces a delay of up to 4 months in the first flight of the development aircraft. The program office is assessing the impact of the delay on the flight test program. Figure 2.1 shows the C-17's flight test schedule and key milestone dates.

Figure 2.1: C-17 Development and Initial Operational Flight Testing



Note: DT&E stands for development test and evaluation; IOT&E stands for initial operational test and evaluation.

IOC depends on the timely transfer of the production aircraft used in the flight test program to the initial squadron. As shown in figure 2.1, flight testing will be accomplished using the development and first four production aircraft. A portion of the flight test program is dedicated solely to initial operational test and evaluation, using primarily the fourth production aircraft. That portion will begin after specific flight test tasks are accomplished by the earlier test aircraft. After flight testing, the four production aircraft will be reconfigured to the final production specifications[8] and assigned to MAC for initial squadron operations before IOC.

The C-17's flight test program provides about 7 months between the end of dedicated initial operational test and evaluation flight testing and IOC. As figure 2.1 shows, each production aircraft is scheduled to complete flight testing and reconfiguration to production specifications at different times. For example, the first production aircraft is scheduled to complete reconfiguration about 6 months before IOC; however, each subsequent aircraft will have less than 6 months to complete reconfiguration. Although all four production aircraft are necessary for initial squadron operations, the fourth production aircraft will only have about 3 months after reconfiguration for initial squadron flight operations before IOC. Consequently, the timely completion of flight testing, particularly initial operational test and evaluation with the fourth production aircraft, will ultimately determine whether a fiscal year 1992 IOC can be achieved.

A delay in IOC would delay the start of the operational readiness evaluation and potentially cause a delay in the full-rate production decision. The evaluation is scheduled to start about 30 days after IOC is declared and will last 30 days. The Defense Acquisition Board moved the full-rate production decision to March 1993 to have the evaluation results available for its review.

The program office currently has 3 months between the end of the operational readiness evaluation and the full-rate production decision to analyze the evaluation results and prepare for the full-rate production review. According to the C-17 Program Director, the program office needs a minimum of 2 months to prepare for the full-rate production review. Therefore, if more than a 1-month slip in the evaluation occurred, the full-rate production decision would also slip.

[8]The test equipment will be removed from the four production aircraft, and will be changed to meet the final production configuration, planned for the fifth production aircraft.

As noted previously, the program office is assessing the impact of the potential slip (up to 4 months) in the first flight of on the flight test program. The Program Director believes that the flight test schedule allows enough margin that, if the development aircraft's first flight is delayed up to 4 months, from August to December 1990, the start of the operational readiness evaluation would not be affected. He also believes that, in a worst case, start of the evaluation would slip 1 month to December 1992; however, the slippage would not delay the March 1993 full-rate production review because it still provides the minimum 2 months needed to prepare for the Defense Acquisition Board's review.

Risk Associated With Program Concurrency

To meet IOC, the Air Force established an acquisition plan with overlapping development and low-rate initial production activities. The overlap between development and production—referred to as concurrency—can be an effective technique to expedite fielding weapon systems. However, concurrency must be well planned and managed, or it can cause schedule, cost, and performance problems.

The potential problems associated with concurrency have also been recognized by the Congressional Budget Office and the program office. In an August 1988 study on concurrent weapons development and production, the Congressional Budget Office stated that

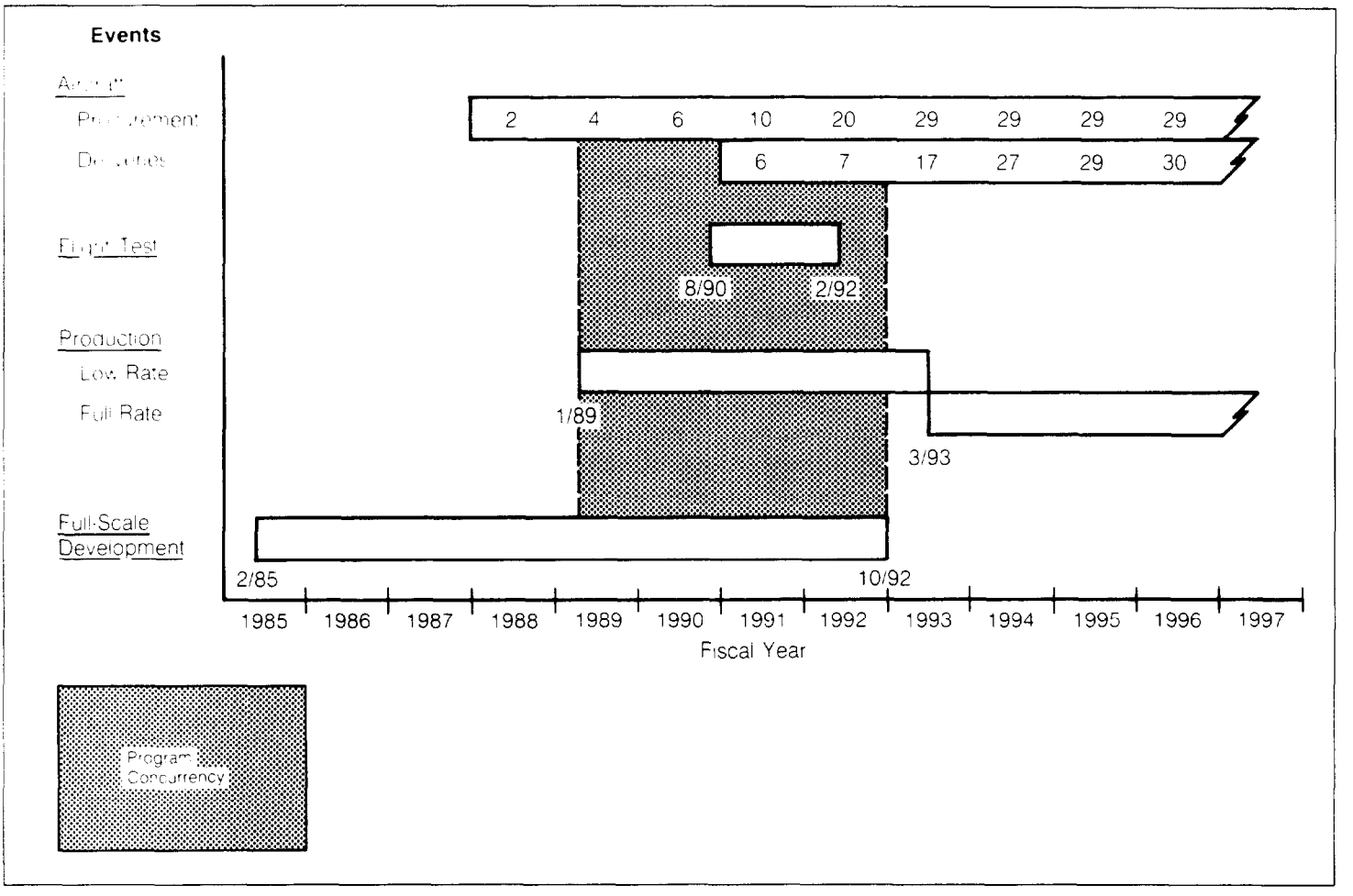
"If problems are discovered during development and testing that require major design changes, it may be necessary to stop production while the changes are incorporated into weapons already produced. Such disruptions mean delay...a process that is often expensive and time consuming."

The program office also acknowledged in its original acquisition plan that concurrent full-scale engineering development and production introduced schedule and cost risks. For example, the plan stated that

"...with concurrent FSED [full-scale development] and production, problems may be discovered only after a substantial commitment has been made to production, resulting in unfavorable cost and/or technical impact.... Concurrent test and production will make it more difficult to economically incorporate necessary changes into production aircraft...."

Figure 2.2 shows the concurrency in the C-17 program.

Figure 2.2: C-17 Program Concurrency



Note: Procurement ends in fiscal year 1998; full-rate production and deliveries end in fiscal year 2000.

The C-17 acquisition strategy provided for low-rate initial production to be approved about 4 years before full-scale development is to be completed in October 1992. In addition, the combined development and initial operational flight test program will begin with the scheduled August 1990 first flight of the development aircraft and end in February 1992.

Before the scheduled first flight of the development aircraft in August 1990, 12 production aircraft are planned to be on contract. By the end of the flight test program 9 production aircraft are planned to have been delivered, and assembly of the 18th aircraft is scheduled to have begun.

The program has experienced several delays since full-scale development began in 1985. Now, as the program transitions to low-rate initial production, the Air Force is faced with an increasing risk that current key milestones will not occur on schedule. The Air Force will have difficulty meeting its planned August 1990 first flight date for the C-17 because (1) a major portion of the assembly schedule for the development aircraft was compressed and has a high degree of risk, (2) projected late deliveries of tooling and parts will delay joining of major aircraft sections, and (3) subcontractor development of the mission computer software and electronic flight control system is behind schedule. These assembly and avionics development problems will delay the development aircraft's first flight up to 4 months and, therefore, the start of the flight test program.

Although the program office maintains that the potential first flight delay will not affect other program milestones and that the degree of concurrency in the program is acceptable, the Air Force must resolve the current assembly and avionics development problems and manage the program's concurrent schedule to avoid further delays, which would increase the risk that key milestones, such as IOC, the operational readiness evaluation, and the full-rate production decision, would not be met.

On August 4, 1989, the C-17 Program Director informed us that, as a result of continuing problems documented by a recent program review, he intends to recommend that the planned first flight date be extended to December 1990. He also told us that meeting the December 1990 date still depends on the contractor's ability to effectively address existing assembly and avionics development problems. We will continue to evaluate Air Force and contractor progress in resolving these and other potential problems facing the C-17 program.

C-17 Program Cost Estimates Increasing

In 1985 DOD estimated the program costs for the C-17 at $34.5 billion (then-year dollars). Current estimates of C-17 program costs total $37.5 billion, an increase of $3 billion. The Air Force estimates that full-scale development could exceed contract target cost by about $755 million, of which $604 million would be absorbed by the government.

Cost Growth During Full-Scale Development

DOD estimates that the C-17 program acquisition costs have increased by about $3 billion since full-scale development began in 1985. Table 3.1 compares estimated program acquisition costs in 1985 and 1988 based on Selected Acquisition Reports provided to the Congress.

Table 3.1: DOD C-17 Program Acquisition Cost Estimates

(Then-year dollars in millions)

Item	1985 Estimate	1988 Estimate	Net cost increase
Research and development	$4,053.4	$5,361.3	$1,307.9
Procurement	30,239.7	31,787.4	1,547.7
Construction	192.3	305.9	113.6
Total	**$34,485.4**	**$37,454.6**	**$2,969.2**
Program acquisition unit cost[a]	$163.4	$177.5	$14.1

[a]Program acquisition unit cost is the sum of research and development, procurement, and construction costs divided by 211 aircraft (210 production aircraft and 1 flyable development aircraft).

As shown in table 3.1, cost increases of $1.3 billion and $1.5 billion for research and development and procurement, respectively, accounted for almost all of the net increase in program acquisition costs.

A major portion of the increase in research and development costs was due to shifting $725 million in initial tooling costs from the procurement account, which, according to DOD, resulted from congressional direction. Other increases were due to revised projections of engineering man-hours, schedule revisions resulting from budget cuts and other funding constraints, and revised estimates of other contract costs by the program office in 1987 and 1988.

As a result of these increases, full-scale development could exceed contract target cost by approximately $755 million. In accordance with the cost-sharing provisions of the contract, the government would absorb 80 percent, or $604 million, of the estimated cost increase. The contract's $4.2 billion target price for full-scale development would therefore be exceeded by that amount, bringing the estimated price at completion to $4.8 billion, or $100 million less than the ceiling price of $4.9 billion,

which is the maximum amount the government will pay for this portion of the contract.

About $900 million of the net procurement cost increase was due to the Air Force's redefinition of initial spares. The cost for these spares was previously accounted for as replenishment spares and included as an element of operations and support costs. Other increases in procurement costs were due to higher estimates of aircraft manufacturing hours and other recurring airframe and avionics costs. These increases in procurement costs were partly off-set by shifting initial tooling to research and development, a decrease in projected inflation rates in future years, and an anticipated savings from multiyear procurement contracting in fiscal years 1993 through 1996 of approximately $932 million.

In December 1988 the C-17 Program Director estimated that C-17 program acquisition costs would be $36.1 billion, or about $1.4 billion less than DOD's current Selected Acquisition Report estimate. The program office has established cost avoidance initiatives to keep program costs lower than DOD's estimate. According to OSD and the program office, the difference in total estimated program acquisition cost was primarily due to OSD's position that higher procurement costs would be incurred to manufacture the aircraft. The difference may not be reconciled until actual cost data are available from the production of the development and first production aircraft.

In January 1989 the Defense Acquisition Board limited full funding approval to 4 aircraft in fiscal year 1989, and 6 aircraft in fiscal year 1990 and provided long-lead procurement funds for 10 aircraft in fiscal year 1991. Funding approval was limited primarily so an interim review can be conducted after initial flight tests, but also because of differences in procurement cost estimates between DOD and the program office. The Air Force had also requested full funding for 10 aircraft in fiscal year 1991 and for 20 aircraft in fiscal year 1992. In addition, it asked for long-lead procurement funds for 29 aircraft in fiscal year 1993 and for full-rate tooling. The Board concluded that additional funding approval should be based on initial flight test results as well as more mature cost estimates, including actual costs. Consequently, the Board directed that an interim program review be held in October 1990, subsequent to the scheduled delivery and first flights of the development and first production aircraft, to have cost data from actual manufacturing experience.

Cost Will Increase for Defensive Systems

Current program acquisition cost estimates reported to the Congress do not include costs for defensive systems that the Air Force plans to develop for the C-17. Space, weight, and power provisions for defensive systems are included in the C-17's design. However, costs for defensive systems have not been included in DOD's program acquisition cost estimates to date because no decision had been made to include the systems in the program. In January 1989 the Defense Acquisition Board directed the Air Force to include defensive systems costs in the program. In July 1987 MAC completed a study of defensive system options and recommended an initial system consisting of missile and radar warning receivers and flare and chaff[9] dispensers costing an estimated $616.8 million for development and procurement of these items for 180 operational aircraft. Follow-on options included in the study would cost at least an additional $450 million. According to OSD, the Air Force currently is evaluating plans to acquire the initial defensive option for either 106 or 210 aircraft. The cost to develop and install defensive systems in 106 aircraft is estimated to be $437 million. However, the 74 operational aircraft assigned to the Air National Guard, Air Force Reserve, and one active MAC squadron and 30 backup and training aircraft would not be retrofitted. According to OSD, the cost estimate for developing and installing defensive systems in 210 aircraft is currently being developed.

Conclusions

As the program transitions to low-rate initial production, estimated program acquisition costs are increasing, but the extent of cost growth will not be known until estimates can be made based on actual cost data. DOD estimated that acquisition costs for the C-17 program will total $37.5 billion, an increase of $3 billion since full-scale development began in 1985. On the other hand, the C-17 Program Director estimated that total program acquisition costs would be $36.1 billion. However, neither estimate includes the costs for defensive systems, which the Air Force plans to develop for the C-17.

OSD limited procurement funding for low-rate initial production through fiscal year 1991, although the Air Force had requested funding approval through fiscal year 1993, primarily so an interim review could be conducted after initial flight tests but also because of the different cost estimates. The difference in acquisition cost estimates between DOD and the

[9]Flares are used to counter infrared homing missiles. Flares are ejected from the aircraft to create an infrared energy source greater than that radiated by the aircrafts's engines, causing an infrared threat to track the flare rather than the aircraft. Chaff is aluminum-coated nylon or fiberglass material ejected from the aircraft to create multiple targets or a large area of solid radar images that confuse and mislead radar operators.

Program Director was primarily due to DOD's higher estimated procurement costs. DOD has stated that an interim program review in October 1990 is a prerequisite for additional funding approval. This review will provide initial flight test results as well as cost estimates based on actual cost data from the production of the development and first production aircraft.

C-17 Performance Projections and Planned Enhancements

Even though performance projections by Douglas and the Air Force show that the C-17's design will meet approved requirements for payload, range, and reliability, maintainability, and availability, actual performance will be demonstrated during flight testing, scheduled to begin in 1990, and the subsequent operational readiness evaluation.

The C-17's projected weight has grown and has reached the maximum allowable to meet performance requirements for payload and range. The Air Force and Douglas face the challenge of controlling further weight growth.

The Air Force plans to improve the C-17's survivability by installing defensive systems in the aircraft to detect and counter combat threats. The Air Force also plans to conduct live fire tests on a production representative section of the aircraft's wing to determine the C-17's vulnerability to combat damage.

Increases in Aircraft Weight Could Degrade Performance

According to Douglas and the program office, several factors such as fuel efficiency, engine thrust, and aerodynamic characteristics affect aircraft performance. Aircraft weight is also a principal factor determining whether the aircraft can meet payload, range, and takeoff/landing performance requirements. As the C-17's design has matured, the projected weight for the final production configuration aircraft has increased from a July 1982 estimate of about 236,633 pounds to an April 1989 estimate of 269,363 pounds.

Air Force analyses show that the C-17's performance begins to be adversely affected at a weight of approximately 269,300 pounds. For example, at that weight the C-17 will be able to carry about 167,000 pounds over a distance of 2,400 nautical miles, as currently required to meet the aircraft's maximum payload mission. However, as the aircraft's weight exceeds 269,300 pounds, the analyses show that the C-17's maximum payload range will drop below the 2,400 nautical mile requirement, or its payload carrying capability will decrease. If the aircraft's weight continues to grow further, other mission range or payload requirements would begin to be adversely affected.

According to the C-17 Program Director, if the aircraft weighed 269,300 pounds, it would actually be able to fly 2,475 nautical miles, not 2,400 nautical miles. This is because Douglas' range calculations, made in accordance with the contract, use a flight profile that does not include a normal descent from cruising altitude, which would likely be used.

The Air Force and Douglas have been controlling the C-17's projected weight since 1986 through a working group established to review the progress of Douglas' weight control program. According to Douglas, without its weight control program, the aircraft's projected weight would have reached 289,000 pounds. In January 1989 the Defense Acquisition Board expressed concern over the aircraft's weight growth. It directed the Air Force to report to the Board's Conventional Systems Committee on potential solutions for achieving current performance requirements if the projected weight of the C-17 increases above 269,300 pounds. Douglas has the flexibility to design the aircraft to meet performance requirements. According to OSD, Douglas is pursuing alternatives, including weight reduction, to meet C-17 performance requirements.

Flight Testing Will Demonstrate Performance

Actual C-17 aircraft performance will be demonstrated during flight testing, scheduled to begin in August 1990. Flight testing will consist of a combined development test and evaluation and initial operational test and evaluation flight test program, and a follow-on operational test and evaluation. In addition, MAC will conduct an operational readiness evaluation subsequent to the flight test program. The results of initial operational test and evaluation and the operational readiness evaluation will be used to make the full-rate production decision, scheduled for March 1993.

The development test and evaluation will evaluate the engineering design, verify that specifications have been met, demonstrate system performance, and ensure that critical issues have been resolved to permit a full-rate production decision. The initial operational test and evaluation will evaluate the C-17's operational effectiveness and suitability in an operational environment. Specifically, it will evaluate small, austere airfield operations, airdrops, air refueling, formation and low-level operations, and strategic missions. It will also evaluate the impact of C-17 operational characteristics, such as low-level flying and navigation accuracy, on survivability.

MAC will then conduct a follow-on operational test and evaluation for approximately 1 year. During this period MAC will collect reliability, maintainability, and availability data; identify deficiencies; evaluate modifications to the aircraft and support equipment; and develop and refine tactics and training criteria.

Requirements for reliability, maintainability, and availability ensure that a system is operationally ready, will successfully perform assigned functions, and can be economically operated and maintained. The program office plans to track C-17 reliability, maintainability, and availability performance starting with its first flight. The subsequent operational readiness evaluation will determine if the C-17 meets the contractual reliability, maintainability, and availability requirements.

Current projections show that reliability, maintainability, and availability requirements will be met or exceeded. For example, regarding the C-17's reliability, the contract requires a 93-percent probability that the system would complete a scheduled mission without an equipment failure or performance degradation, resulting in an abort or mission deviation. As of October 1988, the Air Force estimated this probability to be 94 percent.

The operational readiness evaluation will be a series of operational flights over a 30-day period that are designed to represent the C-17's peacetime and wartime missions. The initial squadron (12 aircraft) will be used to make this evaluation, which will be conducted by MAC and is scheduled to begin approximately 30 days after IOC. Data from approximately 1,600 to 1,800 hours of flying time will be analyzed to predict fleet reliability, maintainability, and availability. Under the warranty provisions of the research and development contract, Douglas is required to bring the system up to the required levels of performance if the results show that the reliability, maintainability, and availability requirements have not been met.

Plans to Enhance C-17 Capability

The Air Force plans to increase C-17 survivability by installing defensive systems in the aircraft. The Air Force is also planning to perform live fire tests[10] on a production representative section of the C-17's wing leading edge to determine the aircraft's vulnerability to specific types of munitions.

Survivability

The C-17 is being designed to operate in a medium-threat environment, characterized by small arms, light anti-aircraft artillery, shoulder fired weapons, and various other weapons. MAC has recommended that a missile warning radar, radar warning receiver, and a flare/chaff dispenser

[10]These are tests that involves the firing of live munitions at targets to examine personnel casualty, vulnerability, and/or lethality issues.

the vulnerability of the C-17's fuel system, the potential for uncontrollable fires caused by damaged engines, the effects of a weakened wing caused by damage to major wing components, and the damage to composite structures caused by ballistic impact.

The program office has responded to these suggestions and is working with OSD to develop a C-17 live fire test strategy that is consistent with DOD guidelines and public law.

Conclusions

An assessment of the C-17's performance will have to await the results of flight testing, scheduled to begin in 1990, and the subsequent operational readiness evaluation. Current performance projections show that the C-17's design will meet approved requirements for payload, range, and reliability, maintainability, and availability. However, concern exists within the program over growth in the aircraft's weight and the Air Force and Douglas face the challenge of controlling further weight growth to avoid degradation in range or payload performance.

The Air Force plans to improve the C-17's survivability by installing defensive systems in the aircraft to detect and counter combat threats. It also plans to conduct live fire tests on a production representative section of the aircraft's wing to determine the C-17's vulnerability to combat damage. The program office is working with OSD officials to ensure that its live fire test strategy is consistent with applicable guidelines and public law.

Comments From the Department of Defense

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

WASHINGTON, DC 20301-3010

20 JUN 1989

Mr. Frank C. Conahan
Assistant Comptroller General
National Security and
International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Conahan:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) Draft Report, "MILITARY AIRLIFT: C-17 Aircraft Transitioning To Production With Increasing Risks," dated May 11, 1989, (GAO Code 392372/OSD Case 7992).

The DoD concurs with the draft report. Suggested technical changes and updating information to the draft report have been separately provided. The Department appreciates the opportunity to comment on the draft report.

Sincerely,

Robert C. Duncan

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