United States General Accounting Office

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Report to the Chairman, Subcommittee on Projection Forces and Regional Defense, Committee on Armed Services, U.S. Senate

March 1991

MILITARY AIRLIFT

Cost and Complexity of the C-17 Aircraft Research and Development Program

143408

GAO United States
General Accounting Office
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National Security and
International Affairs Division

B-236066

March 19, 1991

The Honorable Edward M. Kennedy
Chairman, Subcommittee on Projection
Forces and Regional Defense
Committee on Armed Services
United States Senate

Dear Mr. Chairman:

As you requested, this report provides information on the cost and complexity of the C-17 aircraft research and development program.

We are sending copies of this report to the Chairmen, House and Senate Committees on Appropriations and on Armed Services; the Secretary of Defense; the Director, Office of Management and Budget; and other interested parties.

Please contact me on (202) 275-4268 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix II.

Sincerely yours,

Nancy R. Kingsbury

Nancy R. Kingsbury
Director
Air Force Issues

Executive Summary

Purpose

The Air Force is developing the C-17 aircraft to improve its long-range airlift capability. The September 1990 Air Force price estimate for the C-17 program was $31.2 billion, of which $5.5 billion was expected to be expended on research and development. The Chairman, Subcommittee on Projection Forces and Regional Defense, Senate Armed Services Committee, asked GAO to identify the cost elements of the C-17 research and development program and to provide information on the complexity of C-17 systems and structures.

Background

In 1981, the Department of Defense established a long-range, or intertheater, airlift goal of 66 million ton-miles per day. (A ton-mile refers to the airlift capacity needed to move one ton of cargo a distance of one mile.) The Air Force analyzed alternatives to reach this goal, which included buying additional C-5 aircraft or developing the C-17. The Air Force concluded that the C-17 was the cost-effective alternative, based on the following requirements: life-cycle costs, mission requirements, manpower levels, force stabilization, and force modernization. The C-17 is expected to account for 16 million ton-miles per day.

The Air Force awarded the C-17 contract to the Douglas Aircraft Company of the McDonnell Douglas Corporation in 1982. This is a single, fixed-price incentive contract for research and development and two production options. The contract has a single ceiling price of $6.6 billion, of which $4.9 billion has been allocated by the Air Force for the research and development effort. The allocated target price of the research and development portion of the program is $4.2 billion. This portion of the contract provides for the fabrication of a flyable test aircraft and two full-scale ground test airframes.

The C-17 is required to fly a 167,000-pound payload for 2,400 nautical miles and land on remote, austere runways as short as 2,700 feet. It is also designed with a capacity to fly under 800 feet 11 percent of the time. The C-17 has a crew of only three, consisting of two pilots and one loadmaster, which reduces life-cycle costs. In comparison, the C-5 and C-141 cargo aircraft have crews of five to seven each.

In an April 1990 statement before the House Armed Services Committee, the Secretary of Defense said that because of recent changes in the "strategic environment," the 66 million ton-miles per day airlift goal had changed. As a result, the Secretary concluded that only 120 C-17 aircraft were needed. Before the Secretary's statement, the Air Force had planned to purchase 210 aircraft.

There is disagreement between the Department of Defense and Douglas Aircraft about Douglas' ability to meet its contractual obligations at an amount less than or equal to the ceiling price of $6.6 billion. Douglas officials say that they can, but various DOD estimates show the ceiling being exceeded by at least $0.5 billion, and some estimates are significantly higher. Under the contract, Douglas is responsible for all costs above the ceiling price. There is also disagreement about the Air Force's use of an "allocated" ceiling for the research and development portion of the contract. Douglas has raised legal questions about this practice, which were unresolved as of February 1991.

Results in Brief

About half of the target price of the C-17 research and development contract is attributable to the design and development of the aircraft. No individual structure or system constituted a large portion of these costs. The other half is attributable to management costs such as overhead, and contractor's fee.

According to Air Force and contractor officials, the C-17 is a state-of-the-art transport aircraft that employs few technologies that have not been used on other Air Force or commercial aircraft. However, according to these officials, the integration of sophisticated technologies into a workable aircraft design is a major engineering and management task.

Principal Findings

Research and Development Cost Estimates

The September 1990 Air Force price estimate for C-17 research and development was $5.5 billion, of which $4.9 billion was attributable to the research and development portion of the contract. The difference is for the government's program costs, including management and testing costs. GAO examined contract prices based on the target price of $4.2 billion. This is the negotiated cost of the program based on the government's authorization of work to be performed by the contractor as well as the contractor's profit. About 51 percent of the target price is for costs directly associated with the design and development of the C-17 aircraft and includes engineering, manufacturing, and procurement. The remaining 49 percent is for overhead, general and administrative costs, and other negotiated costs, and the contractor's fee.

GAO analyzed the portion of the target price related specifically to the design and development of the aircraft, the total cost of which is $2.1 billion. Approximately 54 percent of this cost is for the design and development of the aircraft and construction of the development and test articles, known as air vehicle costs. Of this amount, the major cost components are the avionics system, the power system, structural analysis, systems engineering integration, and the wing. The remaining 46 percent of the design and development costs are for management, evaluation, and support equipment.

Complexity of the C-17 Aircraft

Although some of the individual structures and systems of the C-17 involve sophisticated technologies, few new technologies are used in the aircraft. The more sophisticated structures and systems on the C-17 include the wing, the landing gear area, the contour of the fuselage, and the use of new or composite materials in the airframe. According to program officials, the integration of these sophisticated technologies into a workable aircraft design is a major engineering and management task.

- The wing had to be specially designed to enable the aircraft to land on austere airfields with short runways and to withstand the added stress of flying at low altitudes and at high speeds.
- The landing gear area had to be strong enough to absorb the impact from a steep descent landing and redesigned to accommodate the auxiliary power unit, which was moved from the aft fuselage.
- The C-17 fuselage has complex contours to accommodate the landing gear, the various cargo payload requirements, and an inward-opening cargo door in the rear of the aircraft, making it more of a design problem.
- New or composite materials, such as aluminum lithium, have been used in several structures as a weight reduction measure.

Recommendations

In this report, GAO provides information on the cost and complexity of the C-17 aircraft research and development program. GAO makes no recommendations.

Agency Comments

The Department of Defense concurred with GAO's report. (See app. I.) The McDonnell Douglas Corporation found the report to be "thorough and succinct." Both provided suggested technical changes and updated information, which were incorporated where appropriate.

Contents

Abbreviations

DOD	Department of Defense
FSED	full-scale engineering development
GAO	General Accounting Office

Introduction

The Air Force is developing the C-17 aircraft to improve its long-range airlift capability. In April 1990, the Secretary of Defense informed the Congress that because of changes in the "strategic environment" the Department of Defense (DOD) would purchase one developmental aircraft and 120 production aircraft at an estimated price of $29.9 billion. The September 1990 Air Force estimate is $31.2 billion. The Air Force's updated estimate, due in April 1991, is expected to be higher than $31.2 billion. Previously, the Air Force planned to acquire one developmental aircraft and 210 production aircraft at an estimated cost of $41.8 billion. The C-17 is one of DOD's largest acquisition programs.

The Air Force Systems Command's Aeronautical Systems Division manages the development and acquisition of the C-17; and Douglas Aircraft Company, McDonnell Douglas Corporation (Douglas), is the prime contractor. The Military Airlift Command and the Air Force Reserves will operate the C-17.

Background

In 1981 DOD identified a need for additional long-range airlift capability and established a goal of being able to airlift 66 million ton-miles per day.[1] At that time the Air Force's long-range airlift capability was 29 million ton-miles per day. To improve this capability, the Air Force requested proposals from industry for either a new or an existing aircraft. The Air Force set minimum requirements for aircraft performance, but industry was given flexibility in how these requirements were to be met. The Air Force made life-cycle costs a determining factor in the final selection. Three proposals were submitted that met minimum requirements. The Air Force concluded that the C-17 was the cost-effective alternative, based on the life-cycle costs of the alternatives and how well each alternative met mission requirements and affected manpower levels, force stabilization, and force modernization.

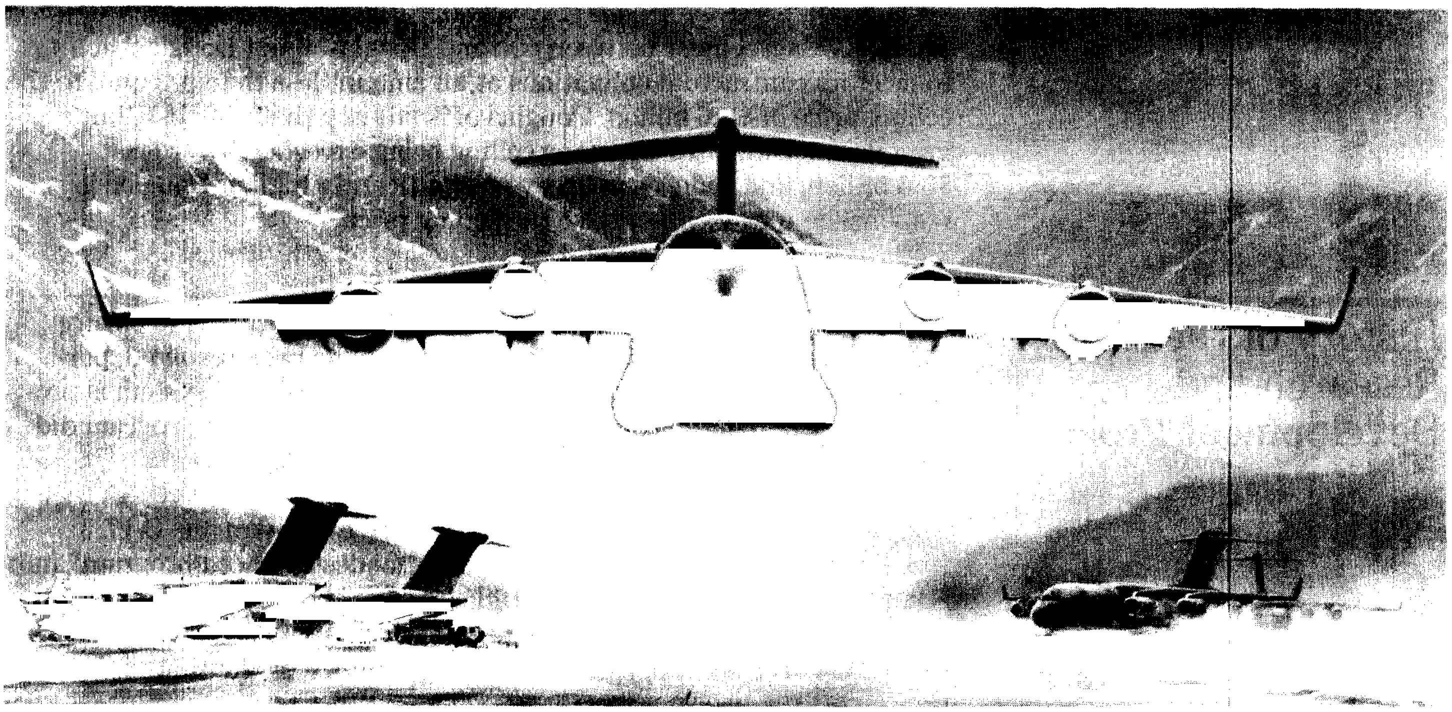
The Secretary of Defense, in an April 1990 statement before the House Armed Services Committee, said that the circumstances that led to the 66 million ton-miles per day goal had changed. (According to Air Force officials, the current airlift capability is about 48 million ton-miles per day.) He concluded that 120 C-17 aircraft would be needed rather than the 210 aircraft originally planned. The Secretary said that in making this decision, he considered several options involving other aircraft,

[1] Long-range airlift capability refers to the capability to airlift between theaters. A ton-mile refers to the airlift capacity needed to move 1 ton of cargo a distance of 1 mile. For example, the movement of 500 tons of cargo a distance of 2,000 miles equals 1 million ton-miles.

including the C-5 and C-141. He found that the C-17 offered the most capability at the lowest cost in every case and that it is the "best airlift option for all likely scenarios in all regions of the world."

The C-17 will be a four-engine, wide-body aircraft, designed to airlift substantial payloads over long ranges without refueling (see fig. 1.1). It is being developed to provide additional intertheater (from one theater of operation to another) and intratheater (operations within a theater) airlift capability. The C-17 is expected to provide an intertheater airlift capability of 16 million ton-miles per day.

Figure 1.1: C-17 Aircraft



Source: McDonnell Douglas Corporation

Contract Status

The C-17 research and development program is being conducted under a fixed-price incentive contract[2] with Douglas for full-scale engineering development (FSED) and two production options. The contract limits the government's liability (on the contract) to the ceiling price of $6.6 billion, of which $4.9 billion has been allocated by the Air Force to the FSED effort.[3] The principal products provided by the FSED portion of the contract are the fabrication of one flyable test aircraft and two full-scale ground test airframes. The production options provide for six aircraft. As of September 30, 1990, $6.2 billion has been obligated for this program and $4.5 has been expended. The flyable test aircraft, the two full-scale ground test airframes, and three production aircraft are in assembly, as of February 1991.

There is disagreement between DOD and Douglas about Douglas' ability to meet its contractual obligations at an amount less than or equal to the ceiling price of $6.6 billion. Douglas officials say that they can, but various DOD estimates show the ceiling being exceeded by at least $0.5 billion, and some estimates are significantly higher. Douglas is responsible for all costs above the ceiling price.

History of the Research and Development Program

The purpose of the FSED phase of the acquisition process is to ensure that the design is complete, major problems have been resolved, performance requirements have been met, and the designed system is producible. Although the contract was signed in 1982, a FSED program did not begin until the contract was restructured in 1985.

The 1985 contract restructure was necessary to convert the C-17 research and development effort from a "modestly paced program" into a FSED effort. Between 1982 and 1985, the Congress appropriated only enough funds for a low-scale engineering development effort. According to an Air Force official, this was due to continued evaluation of the military airlift requirement by DOD.

[2]A fixed-price incentive contract is a fixed-price contract that provides for adjusting profit and establishing the final contract price by application of a formula based on the relationship of total final negotiated cost to total target cost. Under this pricing arrangement, a target cost, target profit, price ceiling, and profit adjustment formula are negotiated. If the final cost is less than the target cost, application of the formula results in a final profit greater than the target profit. Conversely, if the final cost is more than the target cost, application of the formula results in a final profit less than the target profit.

[3]Many contracts have separate contractual ceilings for FSED and each production option. This contract does not, although the Air Force manages the contract through the use of "allocated ceilings." Douglas has raised legal questions about this practice, which were unresolved as of February 1991.

The estimated price of the FSED portion of the contract has increased from $3.4 billion at the time of the contract restructure in 1985 to approximately $4.9 billion in September 1990. This is equal to the FSED pro rata share of the total ceiling price. The government's program costs, including management and testing costs raises the total FSED program price to $5.5 billion. The causes for the increase include the following.

- In 1986, the Congress directed the Air Force to reallocate the tooling cost from the production account to the FSED account, an increase of $725 million.
- The Air Force was unable to fund the program to existing contract amounts, because the Congress had reduced funding to the program by $76 million during fiscal years 1985 and 1986. According to Air Force officials, this resulted in the restructure of the contract in January 1988 and an increase of $96.1 million. The contract restructure resulted in major schedule changes.
- Part of the remaining increase resulted from Douglas' underestimation of the resources that would be required to meet the contracted performance expectations.

Performance Requirements

The C-17 is expected to achieve a level of performance that distinguishes it from the other aircraft—the C-5, C-141, and C-130—in the airlift force. Following are some examples of expected performance and features of the C-17.

- The C-17 is expected to land on austere runways as small as 90 feet by 2,700 feet, maneuver on a taxiway 40 feet wide, and move in and out of parking areas as small as one-third of an acre. The aircraft's maneuverability will be enhanced with the capability of backing up a 2-percent grade fully loaded. At a maximum takeoff gross weight, the C-17 will require 7,600 feet of runway for takeoff. It will be able to use over 6,000 free world airfields, outside of the United States, that are too small for the C-141 and C-5.
- The C-17 is designed to have a total cargo volume of 20,900 cubic feet and a capability to satisfy several different cargo loading patterns. It will also have a maximum payload capacity of 172,200 pounds, which is twice that of a C-141, though only 66 percent of the maximum capacity of a C-5. Furthermore, the C-17 will be able to air-drop up to 110,000 pounds of equipment. 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 C-17 is expected to have a range of 2,300 nautical miles with a maximum payload, as compared to 1,970 nautical miles for the C-141 and 1,460 nautical miles for the C-5. The C-17 is under contract to carry a 167,000-pound payload a distance of 2,400 nautical miles. The aircraft is designed for a life of 30,000 flying hours, 11 percent of which are to be at altitudes under 800 feet. In order for it to land at small, austere airfields, the C-17 is designed to have a descent rate of 15 feet per second, compared to a more typical rate of 10 feet per second for transport aircraft.
- To reduce life-cycle costs, the C-17 will have a crew of three—a pilot, a copilot, and a loadmaster. In comparison, the C-5 and the C-141 have a crew of five to seven.

Objectives, Scope, and Methodology

Because of concern about the cost of the C-17 research and development program, the Chairman, Subcommittee on Projection Forces and Regional Defense, Senate Armed Services Committee, asked us to identify the cost elements of the research and development program and to provide information on the complexity of C-17 systems and structures.

We interviewed engineering, business management, and contract management officials from the Air Force Systems Command's Aeronautical Systems Division, C-17 System Program Office at Wright-Patterson Air Force Base, Ohio, and the Douglas Aircraft Company, McDonnell Douglas Corporation at Long Beach, California. We obtained information related to the complexity of the aircraft's design and the program's current cost. We did not examine the reasonableness of the future schedule of the C-17 research and development program, including the test program, and therefore did not assess the reasonableness of the government's and contractor's projection of the program's final research and development cost.

We spoke with government and contractor staff about various aspects of the C-17 design program. For example, we obtained information on (1) several components or aircraft sections and how they related to the missions for the aircraft, (2) the basis for the engineering design hours required for each of those sections, and (3) any changes in the approach to the design of the aircraft since 1981.

We examined contract records, and reviewed the government's cost estimates for the program for 1984, 1985, and 1988, the latter being the most recent estimate provided by the Air Force. In addition, we examined the Air Force Price Negotiation Memorandum for the 1981 and 1985 contract negotiations. The 1981 memorandum included the initial source selection negotiation and the 1985 memorandum was a contract renegotiation necessitated by a delay in the program. Our objectives were to determine (1) what the Air Force had used as the original justification for the cost of this program, (2) if government cost estimates and their justifications had changed, and (3) whether these changes were associated with the complexity of the C-17 system. We also examined the February 1987 and November 1989 contractor performance reports for the C-17 research and development program. We used this information to document the cost of the research and development program.

We conducted our review between December 1989 and February 1991 in accordance with generally accepted government auditing standards. We obtained comments on a draft of this report from DOD and Douglas, and they concurred with our findings.

Cost of the C-17 Research and Development Program

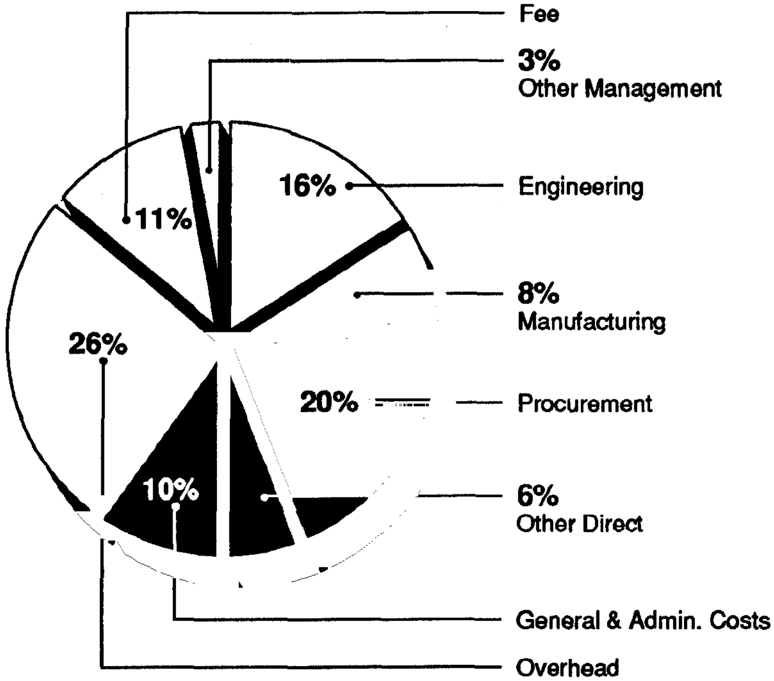
About half of the research and development contract target price represents engineering, procurement, manufacturing and other direct costs. The other half represents management costs such as overhead, and the contractor's fee.

About Half of Target Price Is for Design and Development Work

The target price allocated to the FSED portion of the contract by the Air Force is $4.2 billion. The target price is a negotiated cost, based on the government's authorization of work to be performed by the contractor, as well as the negotiated fee (contractor's profit).

The costs directly attributable to the design and development of the C-17 account for about 51 percent ($2.15 billion) of the target price (see fig. 2.1). These costs include engineering, manufacturing, procurement (materials), and other direct costs. Most of this work relates to the air vehicle, which includes the airframe, engines, and all other installed equipment. Other design and development is for testing and support equipment. Overhead costs, general and administrative costs, the contractor's fee (or profit), and other management costs (i.e., the cost of money and management reserve costs) are negotiated as part of most contracts and account for about 49 percent ($2.08 billion) of the target price.

Figure 2.1: Target Price by Expense Category



Direct costs total 51 percent and management costs and fee total 49 percent, but due to rounding, categories on this chart total 50 percent for direct costs and 50 percent for management costs and fee.

Engineering, manufacturing, and procurement costs account for 45 percent of the target price and 88 percent of the design and development costs. Douglas' estimate at completion, which is its estimate of the program's actual final cost, indicates continued increases in engineering, manufacturing, and procurement costs.

Engineering costs, which have increased 27 percent ($148 million) since 1987, are associated with design and general engineering, laboratory engineering, flight testing analysis, program control, and production support. These cost increases have been due primarily to the redesign of some structures. For example, the wing was redesigned as part of a weight reduction effort.

Manufacturing costs, which have increased 114 percent ($179 million) since 1987, are those for the fabrication, assembly, quality assurance, support, planning, and tooling of the prototype aircraft. The cost of the manufacture of tooling has almost tripled since 1987 and is primarily responsible for the overall increase in manufacturing costs since 1987.

There was a 6-percent decrease ($10 million) in manufacturing costs between 1985 and 1987 due to a decrease (27 percent) in the estimate of the in-house cost of fabrication and assembly of the test aircraft and other test articles.

Procurement costs increased 53 percent ($195 million) between 1985 and 1987 and 55 percent ($307 million) between 1987 and 1989. Procurement costs include the purchase of raw materials, tooling, engineering services, instrument and special equipment, and subcontract costs. The increase is attributable to instrument and special equipment costs and subcontract costs. Douglas officials said that the 48-percent increase between 1985 and 1989 in instrument and special equipment costs is due to additional scope and work requirements involving such items as avionics simulation hardware and software, the hydraulic system simulator, and the on-board inert gas generating system. They further stated that due to a decision to perform less manufacturing in-house than originally planned, there was an increase in subcontract costs from $1.1 million in 1985 to $413.0 million in 1989. This offset the decrease in in-house manufacturing fabrication and assembly costs.

Air Vehicle Is the Major Cost of Design and Development

To determine the costs of specific systems or structures related to the C-17 research and development effort, we analyzed the portion of the contract related specifically to the design and development of the aircraft, that is engineering, manufacturing, procurement, and other direct costs, and examined these costs along functional lines. These costs total $2.1 billion, of which almost $1.2 billion, or 54 percent, is for air vehicle costs. Project management, test and evaluation, peculiar support equipment, and other costs account for the remaining 46 percent. No single system or component accounts for a large portion of the total air vehicle cost. (See table 2.1.)

Table 2.1: Air Vehicle Target Cost by Structure and System

Dollars in millions

Structure/system	Cost	Percent
Avionics system	$130.1	11.2
Power system	119.4	10.2
Structural analysis	114.6	9.8
Systems engineering integration	114.1	9.8
Wing	104.5	9.0
Tail	82.3	7.1
Electronic flight control system	73.1	6.3
Control surfaces	34.9	3.0
Fuselage	34.1	2.9
Environmental systems	31.9	2.7
Landing gear	27.8	2.4
Electrical system	26.4	2.3
Mission equipment system	11.3	1.0
Other	10.8	0.9
Unallocated costs[a]	251.1	21.5
Total	**$1,166.3**	**100.0**

Note: Totals do not add due to rounding.

[a]Almost 84 percent of the unallocated costs are for air vehicle manufacturing. Douglas does not allocate these costs to specific structures or systems.

Information on the Complexity of C-17 Systems and Structures

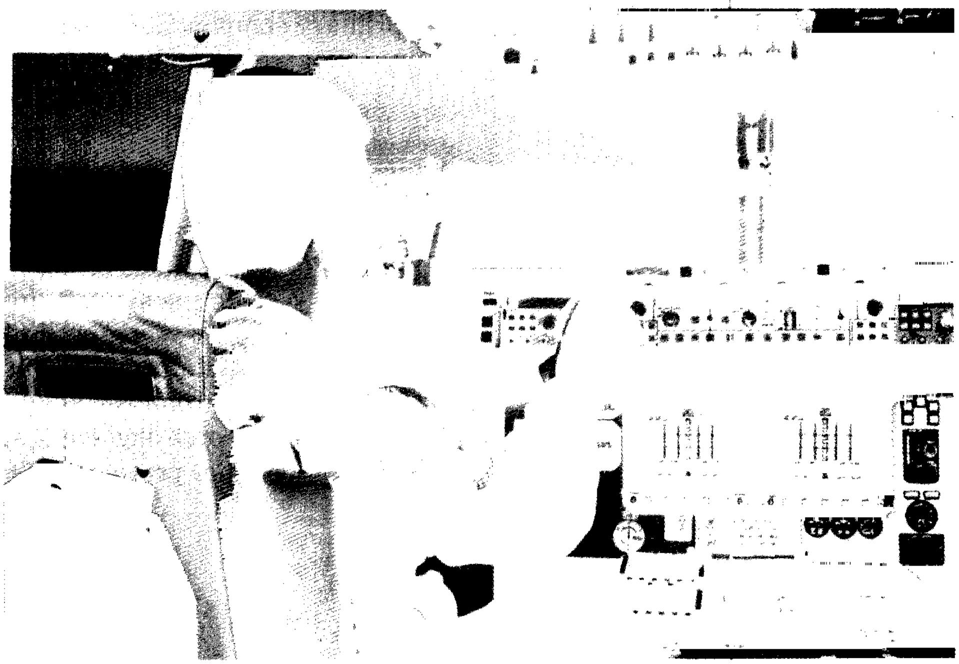
The C-17 aircraft research and development program was to use current, available, and proven technology to minimize development costs and to structure a low technical risk program. The individual structures and systems of the C-17 program are not considered to be complex, although some incorporate sophisticated technology. These include the wing, the landing gear area, the contour of the fuselage, and some new or composite materials in the airframe.

There is no simple measure of complexity. According to Air Force and Douglas engineers, the C-17 aircraft employs very little new technology and the program requirements have not changed much since the program's restructure in 1985. However, these engineers agree that the integration of sophisticated structures and systems into a workable aircraft design has required a great deal of engineering and management effort.

Avionics

The avionics suite includes the mission computer, two heads-up displays, and all other electronics for flight and other cathode ray tube technology needed for a two-pilot crew. The two-pilot crew is necessary to keep the aircraft's life-cycle costs low. The heads-up display is an arrangement of equipment that projects images into a pilot's line of sight. It uses cathode ray tube technology that converts electrical signals into a visible form. Figure 3.1 shows a mock-up of the C-17 cockpit, including the heads-up display (in front of the pilot) and cathode ray tube indicators (to the right of the pilot).

Figure 3.1: Mock-Up of the C-17 Cockpit



Source: McDonnell Douglas Corporation

The state-of-the-art technology associated with the avionics is not new and is used on other military aircraft, according to Air Force and Douglas officials. However, this is the first time that Douglas has undertaken avionics integration with components as complicated as those of the C-17's. The contractor's primary aircraft building experience is with commercial aircraft. The C-17 must perform more functions than commercial aircraft, resulting in more complicated avionics. Flying in formation, air-dropping cargo, landing with heavy loads on short runways, and flying at high speed at low altitudes potentially under hostile fire are some of the functions required of the C-17 but not of commercial aircraft.

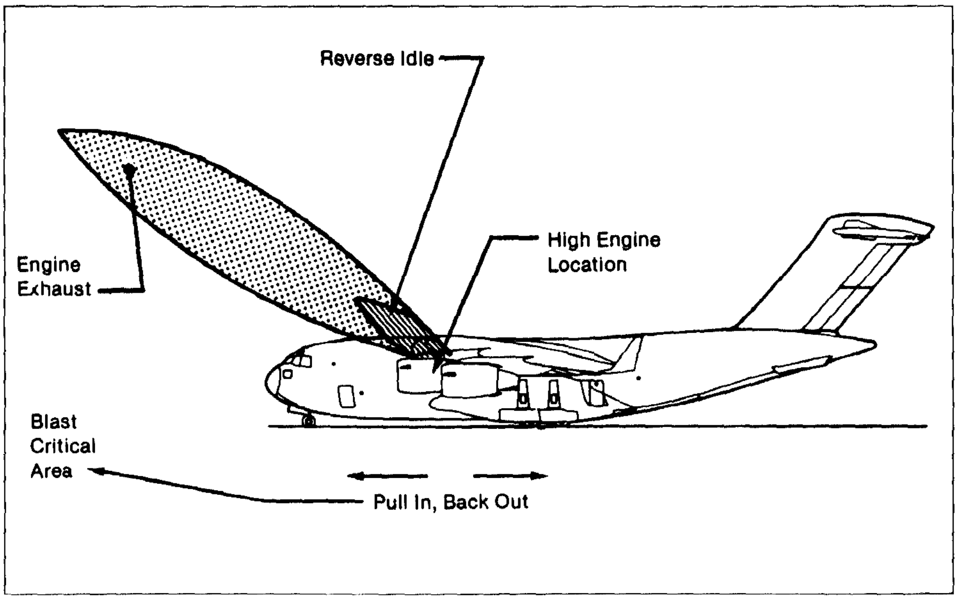
According to Douglas officials, some subcontractors underestimated the effort needed in avionics, which complicated the integration effort. For example, Douglas considered the majority of the bids submitted for the mission computer software to be underscoped. Douglas permitted all bidders to resubmit their bids. However, the subcontractor selected was unable to meet the contract requirements, and Douglas has taken over management of the mission computer software development. The mission computer software system involves about 495,000 lines of code.

Power System

The primary component of the power system consists of the four engines that were purchased from a subcontractor. Air Force engineers said that the C-17 power system is similar to that of other aircraft and is not complex.

A unique feature is the engines' thrust reversers, which are able to reverse both the fan and core thrust and enable the aircraft to back up a 2-percent slope. They also direct the flow of air up and allow ground personnel access to the aircraft area while engines are in reverse. (See fig. 3.2.) The thrust reversers employ cascades, or flow diverters, that are usually made of aluminum, but because they are in a high temperature, high-load environment, they are made of titanium. According to Douglas and Air Force engineers, similar thrust reversers were used on the YC-15, an earlier prototype aircraft.

Figure 3.2: C-17 Thrust Reverser Operations



Source: McDonnell Douglas Corporation

Systems Engineering Integration

Integration involves the design, development, and production of mating surfaces, structures, equipment, parts, and materials required to assemble aircraft components into larger structures and systems. This task includes activities such as the determination of overall design characteristics, quality planning and control, and inspection.

The integration of electrical, electronic, and mechanical systems for the C-17 has required a great deal of engineering effort, according to Air Force and Douglas engineers. Air Force officials said that the amount of effort needed for integration was not surprising because the C-17 is a new design that incorporates mature technology used on other aircraft. One official said that designing the C-17 is a major engineering and management task and is thus an expensive undertaking.

Wing

The wing design enables the aircraft to land on austere airfields with short runways. The 7.8-foot height of the wing provides clearance over brush or other obstacles during taxiing and landing. Winglets made of composite material enable the C-17 to have a shortened wing for maneuvering, while providing the necessary wing length to maintain flying efficiency.

To meet low-level flying requirements, the original wing had to be redesigned so that it could withstand the added stress of flying at low altitudes and at high speeds for 11 percent of the time. According to Douglas officials, additional unanticipated redesign work on the wing, including incorporation of aluminum lithium (a recently developed material), is due to a weight reduction program.

Tail Section

Portions of the T-shaped tail section of the aircraft were redesigned four times as a result of the weight reduction program. However, Air Force officials said the tail section is not complex.

Flight Control System

The flight control system and flight control computer direct and control the movement of the aircraft. The original mechanical system designed for the C-17 was replaced by a digital "fly-by-wire" system in 1987. This electronic system is necessary for the aircraft to meet the low-level flying requirement and to make the steep approach needed for landing on austere, short runways. Without such a system, the aircraft may enter an unsafe flight condition during takeoff and landing. The electronic system is quadruple redundant and has a mechanical backup, which is unique to the C-17.

The electronic flight control system has experienced software development and integration problems. For example, the original subcontractor was replaced in 1989 after failing to meet critical milestones. However, Air Force and contractor officials say that the new subcontractor is on schedule, as of January 1991.

Fuselage

The fuselage, or body of an aircraft, must be designed to accommodate all the aircraft's equipment and systems. The C-17's fuselage has complex contours to accommodate the landing gear, cargo payload requirements, and a single inward-opening cargo door located in the rear of the aircraft. Each of these items makes the fuselage more of a design problem.

Both the fuselage and landing gear had to be strengthened to absorb the impact from a steep descent landing. Also, the auxiliary power unit was moved from the aft fuselage into the main landing gear opening, to achieve better weight distribution. These changes complicated engineering design.

The C-17 cargo area is designed to meet several cargo payload requirements. The height of the cargo area is 13.5 feet, which is high enough to accommodate an AH-64 helicopter. The width of the area is 18 feet, designed to accommodate two 5-ton vans. This design has contributed to the shape of the fuselage.

The rear cargo door also serves as a ramp. When the cargo door is opened and closed for airdrops, pressure must be maintained inside the aircraft. The entire fuselage is pressurized to a bulkhead located behind the cargo door, eliminating the need for secondary pressure boundaries. The ramp can be moved to a position level with the floor for airdrop missions or to the ground for cargo loading. During flight, it can support vehicles or loads on pallets.

Electrical System

The electrical system includes electromechanical installation, electrical wiring installation, wire design, the electrical power system and electrical subgroups. The system requires a great deal of integration related to items such as an on-board inert gas generating system, an explosive system for the emergency exit, loadmaster items, and survivability measures.

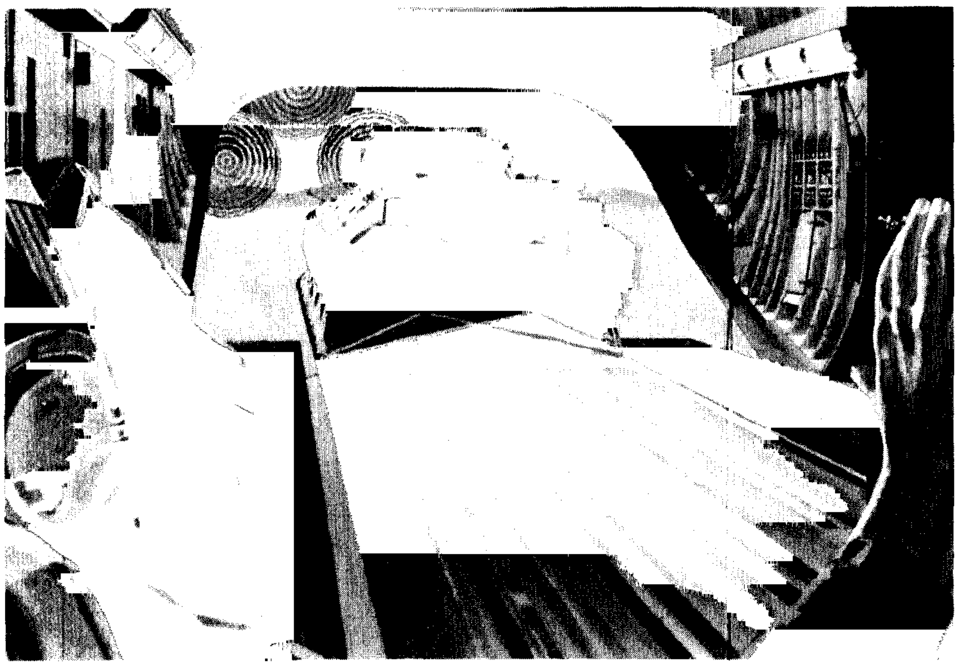
The electrical system is not complex but, according to agency officials, additional design effort has been required because the amount of design work was originally underestimated by Douglas. Several changes were made to this system because of the weight reduction program. The cockpit also had to be redesigned to provide additional clearance for the heads-up display.

Mission Equipment System

The mission equipment system is not complex. It involves operational functions such as carrying troops and moving and air-dropping cargo. Development of the system includes designing the life support system, life raft ejection system, the seating configuration for the pilots, and designing the cockpit to meet the needs of pilots, for example, easy access to the controls.

The logistical and air delivery rails, rollers, and other components of the cargo delivery system are part of the mission equipment system. For the C-17, these components are located in the floor instead of on the floor, which is more common. This unique system is self-sufficient and does not have to be stored off the aircraft. One loadmaster can operate this integrated system, whereas it takes three or more loadmasters to operate the traditional system located on the floor, such as those on the C-130 and the C-5. Figure 3.3 shows the rollers and rails embedded in the floor of a drawing of the C-17.

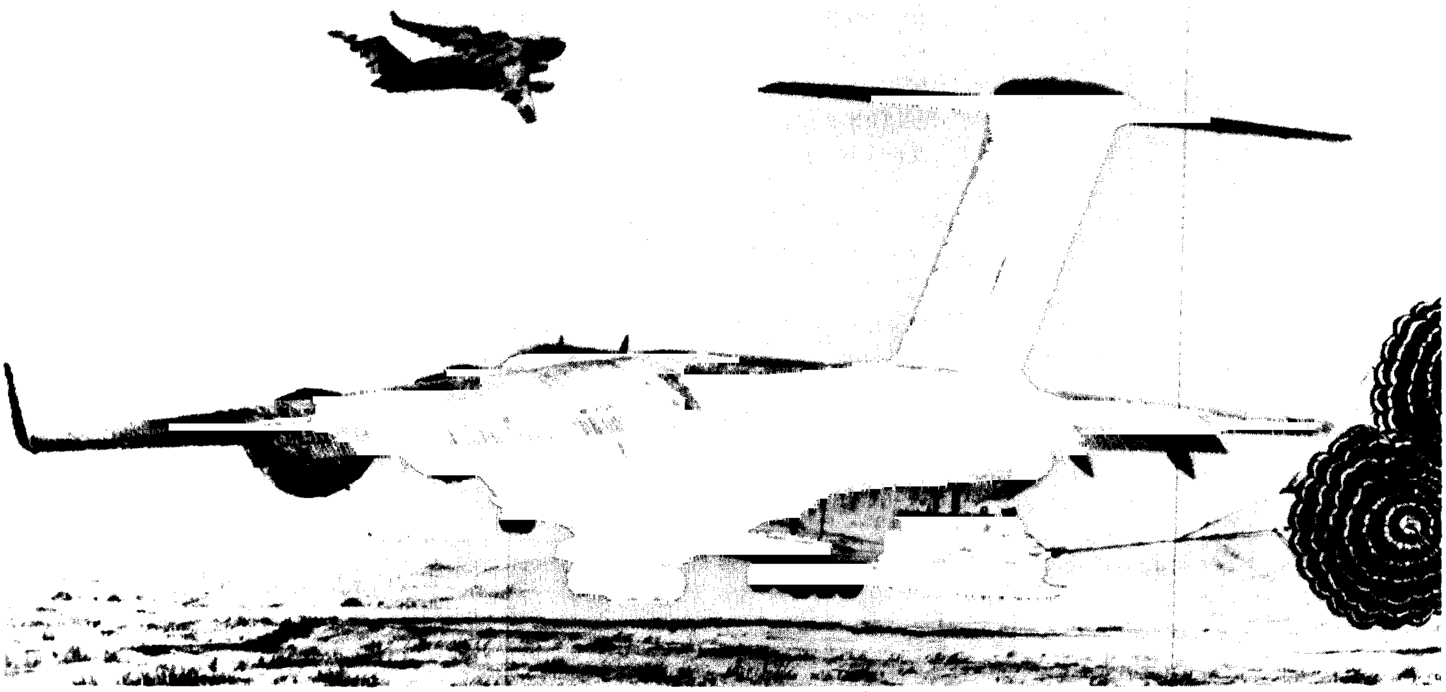
Figure 3.3: The C-17 Cargo Delivery System



Source: McDonnell Douglas Corporation

The aircraft has a low altitude parachute extraction system similar to that on the C-130. However, the C-17 system is integrated to incorporate technology developed over the past few decades. (See fig. 3.4.)

Figure 3.4: Low Altitude Parachute Extraction System



Source: McDonnell Douglas Corporation

Comments From the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
WASHINGTON, DC 20301

ACQUISITION

28 DEC 1990

Ms. Nancy Kingsbury
Director, Air Force Issues
National Security and
International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Ms. Kingsbury:

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "MILITARY AIRLIFT: Data on the Cost and Complexity of the C-17 Aircraft Research and Development Program," dated November 6, 1990 (GAO Code 392529), OSD Case 8535.

The DoD has reviewed the report and concurs with the report findings. The information on the costs of the C-17 research and development program are accurate as of the time the report was written. However, the Air Force and the Office of the Secretary of Defense have continued to monitor contractor performance, and the program's costs were revised in the certification letter provided to the Congress by the Deputy Under Secretary of Defense for Acquisition on December 13, 1990.

Additional technical comments were provided separately. The Department appreciates the opportunity to review the report in draft form.

Sincerely,

John D. Christie
Director, Acquisition Policy
and Program Integration

The following is GAO's comment on the Department of Defense's letter dated December 28, 1990.

GAO Comment

1. DOD officials told us that the cost estimate in the December 13, 1990, certification letter is based on a procurement schedule that is in the process of revision. As a result, and as we note in Chapter 1, DOD officials expect costs to further increase, but are unable to say by how much.

Major Contributors to This Report

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