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THE C-17: COSTS AND ALTERNATIVES

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NOTES

Numbers in the text and tables may not add to totals because of rounding.

Unless otherwise stated, costs in this paper are expressed in current dollars.

PREFACE

This paper was prepared at the request of the Chairman of the Senate Committee on the Budget. The paper analyzes cost growth, schedule delays, and problems with technical performance that have plagued the C-17 program over the past several years. It also discusses the Administration's April 1993 plan, two alternatives that buy fewer C-17s, and two alternatives that cancel the C-17 and substitute purchases or modifications of other aircraft. The options are intended to illustrate possible alternatives to the C-17 program and do not constitute a recommendation by the Congressional Budget Office (CBO) for reduced spending.

William Myers and Victoria Fraider of CBO's Budget Analysis Division prepared this analysis under the general supervision of Michael A. Miller, C. G. Nuckols, and Paul N. Van de Water. Sherry Snyder edited the paper. Janice M. Johnson prepared it for publication.

Robert D. Reischauer
Director

August 1993

SUMMARY

The C-17 is an airlift aircraft that is designed to carry all types of cargo over intercontinental distances without refueling. It has features that other airlift aircraft do not provide, and the Air Force intends to use the C-17 to augment its fleet of C-141s and C-130s.

The C-17 program has had problems almost since its development phase began in 1981. It has had difficulty meeting the three major criteria against which all acquisition programs are judged--cost, schedule, and technical performance. For example, estimates of the program's costs have grown by nearly $19 billion, or 47 percent, since its inception, excluding the effects of changes in both quantity and expected inflation. And future cost growth may be even greater. Acquisition costs for the program are expected to total about $40 billion, which is close to the original estimate, but that amount will pay for 120 aircraft instead of the original goal of 210. In addition, the program schedule has slipped so that production will end in 2001 instead of 1998 as originally planned.

Finally, the C-17's performance has fallen short of original goals. The C-17 was originally designed to carry 172,200 pounds over 2,400 nautical miles without refueling. The goal was first reduced to 167,000 pounds because of design changes that the Department of Defense (DoD) required. The Air Force reduced its goal to 160,000 pounds based on the C-17's performance, and the current estimate of performance is 154,300 pounds at 2,400 miles, but this estimate may be lowered further if other problems cause still more design changes.

There are many options for meeting the needs for military airlift. This paper presents estimates of the Administration's April 1993 plan to buy 120 C-17s and estimates of four alternatives:

- Option 1: Buy 60 C-17s at reduced production rates.
- Option 2: Buy 30 C-17s at reduced production rates.
- Option 3: Buy 20 C-17s, restart the C-5B assembly line, and modify the wings on C-141s.
- Option 4: Buy 20 C-17s, restart the C-5B assembly line, and purchase new commercial airlift aircraft.

Because the cost estimates rely on estimates by the Administration and the contractors that may prove too optimistic, the Congressional Budget Office's estimates may measure relative costs better than absolute costs.

The four options affect airlift capacity in two ways. Relative to the April plan, Options 1 and 2 would cut costs by 50 percent to 75 percent but would reduce overall capacity by 15 percent to 25 percent because they would cut the C-17 program without replacing the lost capacity. In contrast, Options 3 and 4 both provide more capacity than the April plan at an estimated cost saving of 10 percent to 20 percent. Option 4 provides the most airlift capacity by adding to and then replacing the capacity of the C-141 fleet.

The Congress faces many issues in making decisions about strategic airlift. Proponents of the C-17 believe that it is uniquely capable of meeting current U.S. airlift needs. Opponents argue that the program cannot meet its goals, that its capability is excessive, and that proven aircraft could provide all or most of the C-17's capability at a cheaper price. From a purely budgetary standpoint, canceling the C-17 program after producing only 30 aircraft would yield the largest savings but the lowest airlift capacity and the highest cost per million ton-miles per day of all the options. Also, if decisionmakers believe that the Air Force needs more airlift capability, then any savings from buying fewer C-17s may have to be spent on other airlift alternatives. Each of the alternatives, including the Administration's April 1993 plan, has advantages and limitations that should be considered before developing any options for the C-17 program.

THE C-17 PROGRAM

Airlift aircraft provide the United States with a capability to rapidly deliver, reinforce, and sustain combat forces worldwide. The aircraft are also used for humanitarian missions such as Operation Restore Hope in Somalia. The current active and reserve airlift fleet consists of C-130, C-141, KC-10, and C-5 aircraft. These military planes are supplemented with commercial cargo aircraft that form a mobilization reserve--the Civil Reserve Air Fleet (CRAF). Participating commercial carriers have committed a total of 515 aircraft to transport troops and cargo. According to the Air Force, the CRAF transported nearly two-thirds of the troops and one-quarter of the cargo to the Middle East during Desert Shield/Desert Storm. Two of the commercial aircraft included in the program are the McDonnell Douglas DC-10 and the Boeing 747. Appendix A contains a brief description of the military and commercial aircraft that are discussed in this paper.

The McDonnell Douglas C-17 Globemaster III aircraft is intended to augment C-141 and C-130 aircraft and is expected to last for the next 20 to 30 years. The plane is designed to carry all types of cargo (including outsized cargo such as helicopters, large trucks, and even M-1 tanks and Bradley

fighting vehicles) over long distances without refueling. Because one C-17 can carry either one M-1 tank or two Bradley fighting vehicles at a time, it is unlikely that the C-17 fleet would ever be used to move an entire division of tanks or fighting vehicles. The C-17 can land on small airfields in remote areas--a capability that is provided now by C-130 aircraft but not by C-141s or C-5s.

The C-17 also has capabilities that are not available in any other airlift aircraft and are some of the key reasons cited by the Department of Defense for purchasing the C-17. These features include the ability to back up and make tight turns, thereby reducing the amount of ramp parking space needed, without its jet exhaust interfering with other aircraft; cargo door, ramp airdrop, and cargo restraint systems that can be operated by one person and permit rapid unloading without special equipment; improved instrument displays that the two-person cockpit crew can easily read; and built-in test equipment and modern avionics gear that are readily accessible to maintenance personnel.

Because the current airlift fleet is aging and because its mission requires capabilities that existing aircraft do not offer, the Department of Defense has developed the C-17. Through 1993, the Congress has approved $5.3 billion for research, development, test, and evaluation (RDT&E) and $7.5 billion for procuring 20 C-17s and providing advance procurement funds for 1994. The Administration requested $180 million for RDT&E and about $2.4 billion to buy six more aircraft in 1994 and advance procurement for eight aircraft in 1995.

The C-17 has had a long and troubled history that includes schedule delays, design problems, test failures, and cost growth. The RDT&E program began in 1981, and purchases of the first two aircraft were authorized in 1988. The original plan for the C-17 was to buy 210 aircraft by 1998, but DoD reduced its planned quantity to 120 aircraft in 1990. The Administration's April 1993 plan is to complete the purchase of 120 aircraft in 2001--three years later than the original plan and with 43 percent fewer aircraft. The Administration estimates that this plan would cost $39.5 billion--nearly as much as the original estimate for 210 aircraft.

The Under Secretary of Defense for Acquisition, John Deutch, testified before Congress that the C-17 still had problems and that he had serious concerns about cost growth, schedule delays, and technical problems.[1]

1. Statement of John Deutch, Under Secretary of Defense for Acquisition, before the Subcommittees on Military Acquisition and on Oversight and Investigations, House Committee on Armed Services, May 11, 1993.

Accordingly, he is conducting analyses of the C-17's cost, the effectiveness of its operation, its affordability, and its requirements. He has also established a high-level review of all aspects of the C-17. In August, the Defense Acquisition Board (DAB) is scheduled to review the C-17 program and consider alternatives such as terminating or restructuring the program or continuing to work out the problems. The next three sections discuss subjects of special interest to Congressional oversight committees and DoD program managers--the cost, schedule, and technical performance of the C-17.

Cost Growth

Cost estimates for the C-17 have increased $18.7 billion, or 47 percent, from the original plan if one excludes cost changes caused by updated assumptions about inflation and the number of aircraft to be purchased (see Table 1 and Figure 1). Since last year's defense budget, costs have risen $5 billion, or 14 percent. Of course, these estimates are subject to change as DoD reviews the C-17 program.

Cost increases commonly occur in weapons programs, and the C-17's problems might be considered in that context. A recent study found that the costs for 22 systems increased by 50 percent on average--roughly the same as for the C-17.[2] However, the study did not include any airlift aircraft. The C-5A program, another airlifter, also experienced cost growth. On the one hand, costs for the C-5A program increased only 43 percent after adjusting for inflation and quantity changes. On the other hand, the C-5A suffered from a serious design problem and required a separate wing modification program, which brought total cost growth to 76 percent.

The results of the Congressional Budget Office's (CBO's) analysis of cost growth are tentative for several reasons. First, CBO has excluded two causes of cost growth that are clearly not influenced by program management--updated assumptions about inflation and changes in quantity. Although these causes are not the only sources of cost growth that are beyond the control of program managers, they are the only sources that can be easily culled from the available data. Second, CBO and other defense analysts have pointed out many weaknesses in the main data source, the Selected Acquisition Report (SAR).[3] For example, because the costs reported in the

2. See Paul G. Hough, *Pitfalls in Calculating Cost Growth from Selected Acquisition Reports*, RAND, N-3136-AF (Santa Monica: RAND Corporation, 1992).

3. Ibid.

TABLE 1. C-17 COST GROWTH ADJUSTED FOR INFLATION AND CHANGES IN QUANTITY (Costs in billions of current dollars)

SAR Date	Procurement Quantity	Total Cost Estimate	Total Annual Cost Changes	Inflation and Quantity Changes	Cost Growth			
					Annual[a]		Cumulative[a]	
					Billions of Current Dollars	Percent	Billions of Current Dollars	Percent
1983[b]	210	39.8	0	0	0	0	0	0
1984	210	37.9	-1.9	-0.2	-1.7	-4	-1.7	-4
1985	210	34.5	-3.4	-5.1	1.8	5	0.1	c
1986	210	35.4	0.9	-0.6	1.5	4	1.6	4
1987	210	35.7	0.3	0.1	0.2	1	1.8	4
1988	210	37.5	1.8	-0.5	2.3	6	4.1	10
1989	210	41.8	4.4	2.9	1.5	4	5.5	14
1990	120	35.3	-6.5	-13.4	6.9	16	12.4	31
1991	120	35.8	0.5	-0.8	1.3	4	13.7	34
1992	120	39.5	3.7	-1.3	5.0	14	18.7	47
Total	n.a.	n.a.	-0.3	-19.0	18.7	n.a.	n.a.	n.a.

SOURCE: Congressional Budget Office based on Department of Defense, Selected Acquisition Reports dated December 31 each year and provided to the Congress 60 days after the annual budget submission.

NOTES: Annual cost growth is measured from the estimate one year earlier; cumulative cost growth is measured from the December 1983 estimate.

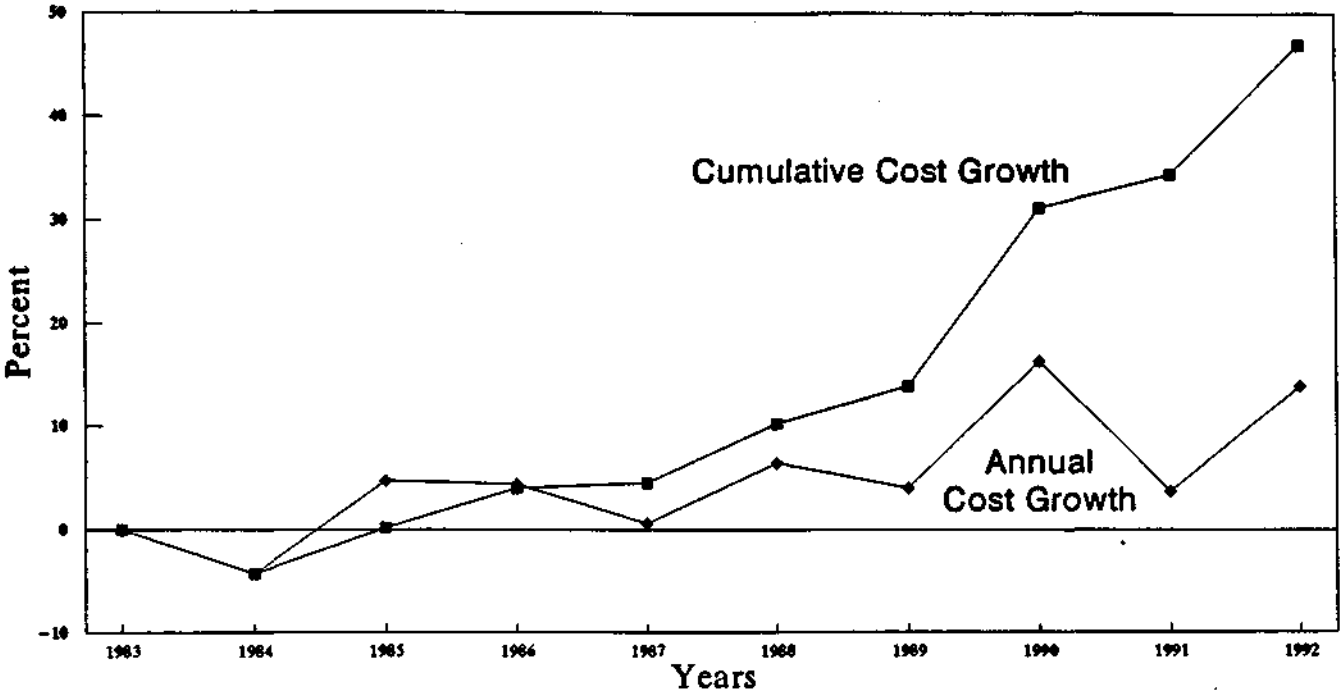
SAR = Selected Acquisition Report; n.a. = not applicable.

a. Excludes cost changes caused by updated inflation assumptions and procurement quantities--two causes of cost growth that are not influenced by program management.

b. First SAR submitted to the Congress.

c. Less than 0.5 percent.

FIGURE 1. C-17 COST GROWTH ADJUSTED FOR INFLATION AND CHANGES IN QUANTITY



SOURCE: Congressional Budget Office using data from Department of Defense, Selected Acquisition Reports dated December 31 each year and provided to the Congress 60 days after the annual budget submission.

C-17 SAR include DoD's projections of future costs, the accuracy of those projections will not be known until all of the aircraft have been produced and delivered. Only 6 of the 120 C-17s have been delivered to date. Third, the most recent SAR indicates that the Administration expects costs to grow further.[4] Finally, several factors have complicated program management and contributed to cost growth; they are discussed below.

Although the C-17 program began development in 1981, the full-scale development contract was not made final until December 1985. In 1985, DoD's contracting philosophy was to award fixed-price contracts for development programs in order to limit the government's liability for cost overruns. The program manager's latest estimate is that full-scale development will exceed the ceiling price by about $1.1 billion, or 22 percent. In addition, the program manager expects the costs of the first two production lots to exceed targets by about 20 percent and 13 percent, respectively, which will result in contract overruns totaling nearly $290 million. This situation provides the incentive for the contractor to file claims against the government for anything that the contractor believes was requested by the government but was not included in the contract's statement of work. McDonnell Douglas has reportedly filed claims totaling $425 million and may file additional claims totaling as much as $1 billion. Under Secretary Deutch has asked McDonnell Douglas to submit the total value of the claims by August 1, 1993, for the DAB review.

The C-17 started production when so-called concurrency was in vogue. A concurrent program is one in which development and testing overlap production--a "buy-before-you-fly" philosophy that was designed to compress the time needed to acquire weapons. This kind of program contributes to cost growth when problems are discovered during testing and changes have to be made to weapons that are already in production. The C-17 has experienced such problems. For example, only 20 percent of the planned research (measured by outlays) had been completed when production began in 1988. At that time, RDT&E funding was planned to overlap 7 of the 11 years that weapons would be built.

In April 1990, DoD announced the results of its Major Aircraft Review and reduced the planned purchase to 120 aircraft (from 210). DoD also reduced its 1991 procurement request from six to two aircraft to allow for

4. The SAR of December 1993 states "Incorporation of new inflation rates causes potential program unexecutability in FY 94 and out years. Results of this assessment will be incorporated in future documentation as necessary." CBO interprets these statements to mean that the program is underpriced and that future estimates will show higher costs.

additional flight-testing before requesting increased production in 1992. By the time DoD's 1991 appropriation request was being considered by the Congress in October 1990, the program was behind schedule, and none of the 1990 funds had been obligated. In addition, the 10 aircraft that the Congress had previously authorized were not scheduled to be delivered until the end of 1992. Based on these considerations, the Congress did not authorize any new purchases in 1991 but provided funding to protect the production base from a break in the production line and a subsequent layoff of workers. The Air Force reacted to this production "skip year" and the plan for fewer aircraft by restructuring the program and further stretching out production. These program changes increased the estimate of total costs by nearly $7 billion--a 16 percent increase, after adjusting for inflation and the change in quantity, from the estimate made one year earlier.

It is always difficult to fix blame when a program has had as many problems as the C-17. Nevertheless, the Pentagon's Inspector General found that several Air Force officials failed to make accurate and timely reports or to respond properly to the C-17's deteriorating cost and schedule delays.[5] Accordingly, Secretary of Defense Les Aspin dismissed the former program manager, a general, from a command position and disciplined two other generals and one high-level civilian. Some of the C-17's problems may therefore be ameliorated by sounder management.

The General Accounting Office recently testified that reduced orders for McDonnell Douglas commercial aircraft have caused disruptions in the C-17 assembly line.[6] A labor contract allows senior workers on commercial projects to "bump" or displace workers with less seniority on the C-17 production line. This situation was confirmed by the testimony of the Under Secretary of Defense for Acquisition. Labor bumping results in significant disruptions and higher costs because the workers have to be retrained on the C-17 assembly line and are usually paid higher hourly wages. One-third of the C-17 assembly work force was reportedly displaced in 1992. This labor bumping may have affected the contractor's ability to meet planned delivery schedules.

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5. See Department of Defense, Office of Inspector General, *Government Actions Concerning McDonnell Douglas Corporation Financial Condition During 1990* (January 1993).

6. Statement on the status of the C-17 development program by Frank C. Conahan, Assistant Comptroller General, National Security and International Affairs Division, before the Subcommittees on Military Acquisition and on Oversight and Investigations, House Committee on Armed Services, March 10, 1993.

Schedule Delays

One measure of schedule performance is whether the contractor is delivering aircraft on time. According to the latest SAR, the contractor is behind schedule on only one of the six planned deliveries. Press reports indicate, however, that the sixth aircraft was delivered on June 11, 1993. Another measure of schedule performance is to determine how well the program is meeting key milestones in the schedule. A comparison of the program manager's current estimate in the SAR with the production estimate from 1989 reveals that the program has completed or is projected to complete 50 percent of selected major milestones on or ahead of schedule and 50 percent behind schedule (see Table 2).

Looking at which individual milestones are behind schedule provides further insight into problems with the schedule. For example, developmental test and evaluation and initial operational test and evaluation (IOT&E) are scheduled to finish in September 1994 and June 1994--15 months and 12 months behind schedule, respectively. Nevertheless, the SAR indicates that the Air Force will revise the time span needed to complete IOT&E, and press reports indicate that the time span is likely to be lengthened, not shortened. Completion of these test milestones is critical because problems discovered during testing have to be corrected and the changes have to be integrated into aircraft that are either being manufactured or have already been delivered. Delays in completing test milestones also contribute to delays in the production program. For example, delivery of the 12th aircraft to the first squadron (so-called initial operational capability) is 18 months behind schedule. Also, the Air Force estimates that approval of full-rate production (Milestone IIIB) is 22 months behind schedule.

The program is also having difficulty meeting the revised dates contained in the latest approved program (see Table 2). The reasons cited by the Air Force for slips in completing the milestones include late aircraft deliveries, reorganization of the assembly line, restructuring of the program, revised schedules, deferral of manufacturing work, faulty aircraft systems, and the inefficiency of flight tests. In addition, the C-17 program has encountered several performance or technical problems that have contributed to these schedule delays.

TABLE 2. STATUS OF SELECTED C-17 SCHEDULE MILESTONES AS OF DECEMBER 31, 1992

Milestone	Production Estimate[a] (PdE)	Approved Program[b] (AP)	Current Estimate[c] (CE)	Months Ahead (-) or Behind Schedule: CE Minus PdE	Months Ahead (-) or Behind Schedule: CE Minus AP
Source Selection Decision	Aug. 81	n.a.	Aug. 81	0	n.a.
Contract Award	July 82	n.a.	July 82	0	n.a.
Start Full-Scale Engineering Development	Feb. 85	n.a.	Feb. 85	0	n.a.
Milestone II (Engineering and manufacturing development approval)	Nov. 87	Feb. 85	Feb. 85	-33	0
First Full-Funded Production Lot	Jan. 88	Jan. 88	Jan. 88	0	0
Milestone IIIA (Low-rate production approval)	Nov. 87	Jan. 89	Jan. 89	14	0
Low-Rate Initial Production	n.a.	Jan. 89	Jan. 89	n.a.	0
First Flight	June 91	n.a.	Sept. 91	3	n.a.
Initial Operational Capability (Delivery of 12th aircraft)	June 93	Sept. 94	Dec. 94	18	3
Developmental Test and Evaluation					
Start	n.a.	June 91	Sept. 91	n.a.	3
Complete	June 93	Aug. 93	Sept. 94	15	13
Initial Operational Test and Evaluation					
Start	n.a.	Jan. 93	Jan. 94	n.a.	12
Complete	June 93	Aug. 93	June 94	12	10
Milestone IIIB (Full-rate production approval)	Sept. 93	TBD	July 95	22	TBD
Full Operational Capability (All primary aircraft delivered and operating)	Sept. 01	Sept. 01	July 01	-2	-2

SOURCE: Congressional Budget Office based on Department of Defense, Selected Acquisition Reports.

NOTES: n.a. = not applicable; TBD = to be determined.

a. The production estimate, dated May 1989, is the first updated estimate after Milestone IIIA was approved and given to the Congress in the September 1990 Selected Acquisition Report.

b. The approved program, dated February 1992, reflects the latest approved acquisition baseline.

c. The current estimate, dated December 1992, is the latest forecast.

Performance Issues

Meeting major performance characteristics is essential for the C-17 to accomplish its mission and stay within cost and schedule guidelines. On the one hand, the C-17 has encountered many technical problems that could result in higher production and operating costs, lower performance, and more schedule delays. On the other hand, technical problems should be expected because of the high level of concurrency involved in this program. The manufacturer and the Air Force are working to resolve these problems.

Increases in weight are a common problem for new military hardware, and the C-17 is no exception. For example, corrections to structural deficiencies of the wings are likely to increase the weight of the C-17. Portions of the C-17's wings--the flaps and slats--are subjected to extreme heat from the engines. During testing, the engines' heat buckled and weakened these parts. To correct this problem, McDonnell Douglas is changing some of the material for these components from aluminum to titanium. According to McDonnell Douglas, the redesigned flaps and slats are expected to add approximately 870 pounds to the C-17's weight. In October 1992, both wings of a C-17 aircraft buckled during a static test after applying 124 percent of the maximum operating weight. Specifications call for the airframe to withstand loads of up to 150 percent. The wing modification to correct this test failure is expected to add another 650 to 750 pounds. These weight increases will probably increase production costs, add to estimated operating costs, and affect the plane's range and payload capability.

The C-17 is having difficulty meeting its performance requirements for range and payload. In December 1983, the Air Force planned for the C-17 to carry cargo (payload) weighing 172,200 pounds over a distance of 2,400 nautical miles (range) without refueling. Since then, the Air Force has lowered the goal for payload to 167,006 pounds to accommodate design changes it had made, but the Air Force also has indicated that it would accept a goal of 160,000 pounds. Thus far, flight-testing and mathematical modeling have indicated that the maximum payload at 2,400 nautical miles is 154,322 pounds. However, this estimate does not reflect the added weight to correct the structural deficiencies in the wings. In other words, after easing the performance requirements, the planes that have been delivered do not meet the specifications. Range and payload performance are important when comparing the C-17's planned capability with alternatives such as the C-5B, C-141, or commercial aircraft that have a proven capability.

Many factors contribute to calculations of range and payload including the weight of the plane with fuel and cargo when it takes off, wind resistance or drag, engine performance, the desired distance or range, and how the plane is flown. Moreover, these factors influence each other. For example, increases in the plane's weight to correct the deficiencies in the wings affect the weight of the cargo it can carry, fuel consumption, or range. The Air Force is attempting to meet its current objective by adding 5,000 pounds to the limit on the plane's takeoff weight so that it can carry more fuel to increase its range; by making aerodynamic changes to the plane to lower the amount of drag and therefore lower fuel consumption; by improving fuel consumption to increase the range; by reducing the aircraft's weight to increase range and payload; and by changing the way range and payload performance is measured to approximate actual operations. If these initiatives are not successful, the Air Force may have to ease the contract specifications further and accept a plane that is not as capable as was planned.

Recently, the main landing gear of the C-17 has been experiencing some problems. Cracks in one pivot point (the trunnion) on the landing gear and failure of another have caused the test aircraft to be grounded several times. McDonnell Douglas personnel indicate that the failures of the landing gears were caused by removing shock-absorbing "shimmy dampeners" that are not required by the contract specifications. According to the contractor, no further problems have been encountered since they reinstalled the shimmy dampeners and replaced damaged parts.

The costs to operate and maintain the C-17 may be higher than expected. For example, the C-17 engine is not meeting contract specifications for fuel efficiency. In addition, forecasts of the number of maintenance hours per flying hour have increased from 14.6 hours when production approval was first sought to the current 16.3 hours, a 12 percent increase. Moreover, further increases may be likely because the Air Force appears to be willing to accept 18.6 maintenance hours per flying hour. The Air Force indicates that actual maintenance hours per flying hour for the C-5B are much higher than those for the C-17, averaging about 29 hours per flying hour for the past three years. As of March 1993, the C-17's demonstrated performance, after flying 50 hours, is 47 maintenance hours per flying hour. Nonetheless, maintenance hours typically are high in the beginning of a program and then fall as problems are worked out and experience is gained.

Although the C-17 has experienced many problems, most analysts agree that the United States needs more airlift capability to support the current war-fighting scenarios and to provide humanitarian assistance. Cost growth, schedule delays, and technical problems coupled with a declining defense

budget, however, have caused the C-17 to be the subject of intense scrutiny by both DoD and the Congress. Congressional staff have asked many questions about the C-17. Will it perform as advertised? Can the contractor meet revised delivery schedules? Will DoD and the Congress commit to buy an airlifter that the Administration currently estimates will cost nearly $330 million each?[7] Will the Air Force land such an expensive airlifter near the battlefield?

THE ADMINISTRATION'S APRIL 1993 PLAN AND FOUR ALTERNATIVES

As the Congress has pondered these questions, it has considered alternatives to the C-17 program put forth by the Air Force. The Chairman of the Senate Committee on the Budget asked CBO to prepare cost estimates for four alternatives to the Administration's April plan. The alternatives, which were specified in a letter to CBO dated July 15, 1993, include two alternatives that buy fewer C-17s and two alternatives that cancel the C-17 and substitute purchases or modifications of other aircraft. These options are far-reaching but are hardly the only airlift options.

The base case for this analysis is the plan contained in the Air Force's justification books that support the Administration's April budget. This plan is under review and may change as early as August 1993. Nevertheless, it represents a useful benchmark for measuring alternatives. The April plan would buy 120 C-17s and would construct facilities at four main operating bases and one depot facility.[8] The plan would provide 102 primary aircraft for 8 squadrons, 8 trainers, and 10 backup aircraft. CBO assumes that funds would be appropriated to procure the aircraft and that programmed deliveries would be made on time. Consequently, the entire fleet would be operational in 2003.

The first alternative to the April plan would reduce total procurement to 60 aircraft, thereby providing the Air Force with 51 primary aircraft for 3 squadrons, 4 trainers, and 5 backup aircraft. The production rate for 1995 would be the minimum sustaining rate of 6 units, compared with 8 in the

7. This estimate is based on the Administration's total estimate of funding for development, procurement, and military construction, and production of 120 aircraft.

8. Selected Acquisition Report for the C-17 Program, dated December 31, 1992, and submitted to the Congress on June 7, 1993, in support of the 1994 budget.

April plan. Furthermore, the production rate would reach only 10 units in 1997 and 1998 compared with 15 for the plan. The lower production rate should give the contractor ample time to finish testing before increasing the production rate. Because fewer aircraft would be bought, deliveries would be completed in 2000--three years sooner than planned.

Option 2 further reduces the C-17 program by stopping purchases after 30 aircraft. In addition to the 20 aircraft already purchased by the Air Force, 6 aircraft would be purchased in 1994 and the final 4 would be bought in 1995. Thus, the force structure would contain 26 primary aircraft for 2 squadrons, 2 trainers, and 2 backup aircraft. These forces would be operational in 1997 barring any schedule delays.

The third option would not buy any more than the 20 C-17s already funded through 1993. Thus, the Air Force would have 17 primary aircraft for 1 squadron, 1 trainer, and 2 backup aircraft. To satisfy the need for airlift resources, the option calls for the purchase of 61 C-5Bs and a service life extension program (SLEP) for 178 C-141s. The C-141 SLEP is designed to correct the cracks in the wings and at the cockpit posts that have restricted the C-141s' operations. The manufacturer estimates that the SLEP would extend the service life of the C-141 airframe from 45,000 to 85,000 hours; DoD estimates that 60,000 hours could be achieved. The purchase of 61 C-5Bs would replace the 100 C-17s that would not be acquired. CBO calculated this number strictly on the amount of payload the C-5B could carry (261,000 pounds) at 2,400 nautical miles without refueling. The C-17's goal for range and payload is 160,000 pounds at 2,400 nautical miles without refueling. In other words, the option does not reflect other operational considerations such as the size of the landing field or the ability to deliver cargo directly to small airfields. All remaining C-141s in the fleet in 2000 would undergo the SLEP. Final deliveries for each aircraft would be as follows: C-17s in 1995, C-5Bs in 2002, and C-141s in 2002.

Option 4 is similar to Option 3 in that it terminates the C-17 program after 1993, providing the Air Force with 20 aircraft by 1995. Also, it would procure the same number of new C-5Bs, with final delivery by 2002. To replace the 178 aging C-141s, Option 4 would buy 60 commercial aircraft capable of serving airlift needs--the Boeing 747-400F aircraft. CBO calculated the number of 747s based on the number of ton-miles per day the 747 would provide. Final delivery of the commercial airlifters would occur in 2000. The Boeing 747 aircraft is not the only commercial freighter that could be bought, so this option is merely illustrative. Indeed, press reports indicate that the Air Force is considering several commercial alternatives including purchases of used aircraft.

In summary, the April plan would buy 120 C-17s, and the four options would cut this program back by at least half. Options 1 and 2 would reduce the number of C-17s to be acquired--to 60 and 30 aircraft, respectively--without compensating for the relative loss of airlift capability. Options 3 and 4 would require the Department of Defense to buy no more than the 20 C-17s that have been authorized to date. Options 3 and 4, however, would address the loss of airlift capacity by purchasing 61 more C-5Bs. In addition, Option 3 would extend the service life of 178 C-141s, and Option 4 would provide comparable capability with 60 new commercial Boeing 747 cargo aircraft instead.

Airlift Capacity and Costs Under the Administration's April 1993 Plan

Military commanders need the ability to transport troops and equipment between and within theaters of operations. A key component of this ability is the military airlift under the command of the Air Force's Air Mobility Command. The Air Force currently employs four types of aircraft to handle intertheater airlift--the KC-10, the Civil Reserve Air Fleet, the C-5 (A and B models), and the C-141. The C-17 is expected to augment this force in the future. Because each aircraft can carry different payloads, this section describes how overall capacity would be affected by the options.

Airlift capability is commonly measured by the amount of cargo (weight) that can be shipped a certain distance (miles) per day. Hence, aircraft are compared in terms of how many millions of ton-miles per day (MTM/D) they can deliver. For example, DoD allots 23 of its KC-10s to transport about 0.110 MTM/D each. Thus, the KC-10 fleet provides approximately 3 MTM/D and is expected to do so beyond 2010. Many variables are blended into this measure including cargo capacity, range, and rate of use. Many variables are left out, however, including capacity for cargo that is especially large by volume (outsized) and the ability to land, taxi, and take off from small airfields.

The Civil Reserve Air Fleet comprises commercial aircraft that are owned and operated by airlines but that are available to the Air Force in time of need. CRAF is segmented into stages according to need and priority; it provides 10.0 MTM/D in conditions that are short of a national emergency (Stage II) and 17.5 MTM/D in a national emergency (Stage III). CBO's analysis of capacity does not include CRAF Stage III because it would be used in only extreme circumstances and its activation would most likely have a severe economic impact on civilian airlines.

The fleet of C-5s includes both A and B models. The last A model was built in 1973, and the last B model was produced in 1989. The average capacity of all C-5s is 0.151 MTM/D. Thus, the estimated capacity of the C-5 fleet is 16 MTM/D provided by 109 aircraft. The Air Force expects to maintain this level of capacity through at least 2010, when the older C-5As will begin to be retired or will require a service life extension program. Each C-5B is expected to provide 0.171 MTM/D.

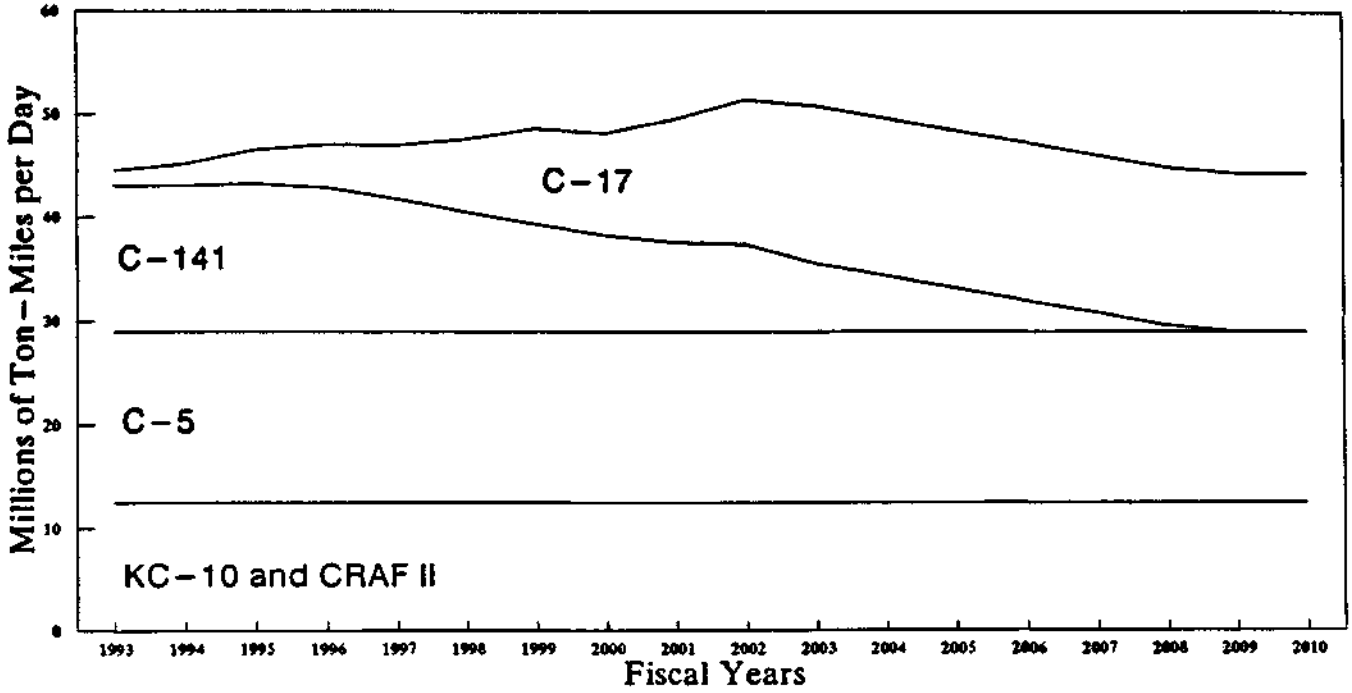
The C-141 Starlifter has been the workhorse of the airlift fleet. The current fleet of C-141s (a little over 200 aircraft) provides about 14 MTM/D of capacity. As the aircraft come to the end of their service life, they are scheduled to be retired. By about 2009, the entire fleet would be retired. Therefore, the Air Force would have to forgo the capacity the Starlifters provide or obtain it from another source.

The first C-17 was delivered to an operational squadron on June 14, 1993. As additional planes are delivered, the amount of capacity provided by the C-17 will increase. Each aircraft is expected to provide 0.150 MTM/D. Thus, upon final delivery in 2003, the fleet of C-17s planned by DoD would provide approximately 15 MTM/D of airlift capacity.

In sum, the April plan provides for 45 MTM/D in 1993 and would replace the aging C-141 by completing the C-17 program (see Figure 2). KC-10s and CRAF provide 13 MTM/D and will continue to do so through 2010. C-5s and C-141s provide 30 MTM/D until 1997 when the C-141s start retiring, and the C-17s are eventually expected to provide 15 MTM/D. The amount of capacity grows until 2002, reaching 52 MTM/D as the number of C-17s increases. By 2009, however, the capacity drops to 44 MTM/D as the C-141s reach retirement.

The total cost of the April plan to buy 120 C-17s has three components--procurement; research, development, test, and evaluation; and military construction (see Table 3). Funding already committed (the sunk costs) for the 20 aircraft purchased to date is estimated to be about $13 billion. To complete the program, the Administration estimates that it will need approximately $26.5 billion more that would be spent through 2003. The majority of these future costs will be for procurement, although RDT&E costs will be incurred through 1999, and military construction costs continue through 2000. The cost estimates in this paper are stated in current dollars, include amounts for facilities as necessary, and are based on data from the Department of Defense and weapons manufacturers. (Table B-1 contains CBO's estimates in 1994 dollars.) Operation and support (O&S) costs, however, are not included in the analysis.

FIGURE 2. THE CONTRIBUTION OF EACH TYPE OF AIRCRAFT TO AIRLIFT CAPACITY UNDER THE ADMINISTRATION'S APRIL 1993 PLAN
(At the end of the fiscal year)



SOURCE: Congressional Budget Office based on estimates by the Administration.

NOTES: The Administration's April 1993 plan would buy 120 C-17s.

CRAF II = Civil Reserve Air Fleet, Stage II (used in conditions short of a national emergency).

TABLE 3. ESTIMATED COSTS OF STRATEGIC AIRLIFT OPTIONS
(By fiscal year, costs in millions of current dollars)

Category	1993 and Before (Sunk Costs)	1994	1995	1996	1997	1998	1999	2000 and Beyond	Total Excluding Sunk Costs	Average Unit Costs[a]
Administration's April 1993 Plan: Buy 120 C-17s										
Quantity	20	6	8	12	15	15	16	28	100	n.a.
Cost										
Procurement	7,482	2,400	3,200	3,800	3,500	3,100	3,900	6,100	26,000	260
RDT&E	5,324	180	87	23	8	6	5	0	309	n.a.
MilCon	147	15	50	44	0	45	12	13	179	n.a.
Total	12,953	2,595	3,337	3,867	3,508	3,151	3,917	6,113	26,488	265
Option 1: Buy 60 C-17s at Reduced Production Rates										
Quantity	20	6	6	8	10	10	0	0	40	n.a.
Cost										
Procurement	7,482	2,400	2,600	2,800	2,600	2,400	200	200	13,200	330
RDT&E	5,324	180	87	23	8	11	0	0	309	n.a.
MilCon	147	15	50	44	0	0	0	0	109	n.a.
Total	12,953	2,595	2,737	2,867	2,608	2,411	200	200	13,618	340
Option 2: Buy 30 C-17s at Reduced Production Rates										
Quantity	20	6	4	0	0	0	0	0	10	n.a.
Cost										
Procurement	7,482	2,400	1,900	200	100	100	0	0	4,700	470
RDT&E	5,324	180	127	0	0	0	0	0	307	n.a.
MilCon	147	15	50	44	0	0	0	0	109	n.a.
Total	12,953	2,595	2,077	244	100	100	0	0	5,116	512

(Continued)

TABLE 3. CONTINUED

Category	1993 and Before (Sunk Costs)	1994	1995	1996	1997	1998	1999	2000 and Beyond	Total Excluding Sunk Costs	Average Unit Costs[a]
Option 3: Buy No More C-17s, Buy C-5s, and Extend the Service Life of the C-141s										
C-17 Quantity	20	0	0	0	0	0	0	0	0	n.a.
C-17 Cost										
Procurement	7,482	190	130	50	20	0	0	0	390	n.a.
RDT&E	5,324	304	0	0	0	0	0	0	304	n.a.
MilCon	147	106	0	0	0	0	0	0	106	n.a.
Subtotal	12,953	600	130	50	20	0	0	0	800	n.a.
C-5 Quantity	0	0	6	8	12	12	12	11	61	n.a.
C-5 Procurement Cost	0	1,100	2,100	2,100	2,600	2,400	2,300	1,900	14,500	238
C-141 SLEP Quantity	0	0	0	10	24	36	36	72	178	n.a.
C-141 SLEP Procurement Cost	0	230	330	700	900	1,000	900	1,180	5,240	29
Total Cost of Option 3	12,953	1,930	2,560	2,850	3,520	3,400	3,200	3,080	20,540	n.a.
Option 4: Buy No More C-17s; Buy C-5s and 747s										
C-17 Quantity	20	0	0	0	0	0	0	0	0	n.a.
C-17 Cost										
Procurement	7,482	190	130	50	20	0	0	0	390	n.a.
RDT&E	5,324	304	0	0	0	0	0	0	304	n.a.
MilCon	147	106	0	0	0	0	0	0	106	n.a.
Subtotal	12,953	600	130	50	20	0	0	0	800	n.a.
C-5 Quantity	0	0	6	8	12	12	12	11	61	n.a.
C-5 Procurement Cost	0	1,100	2,100	2,100	2,600	2,400	2,300	1,900	14,500	238
747 Quantity	0	3	6	12	13	13	13	0	60	n.a.
747 Procurement Cost	0	1,000	1,000	1,700	1,800	1,500	1,000	400	8,400	140
Total Cost of Option 4	12,953	2,700	3,230	3,850	4,420	3,900	3,300	2,300	23,700	n.a.

SOURCE: Congressional Budget Office based on estimates by the Administration and the contractors.

NOTES: n.a. = not applicable; RDT&E = research, development, test, and evaluation; MilCon = military construction; SLEP = service life extension program.

a. Exclude sunk costs.

Omitting O&S costs could put the C-17 at a disadvantage in cost comparisons with the alternatives. DoD favors buying the C-17 largely because its O&S costs are supposed to be so much lower than those of other airlifters. Indeed, the costs to operate the C-17 may be lower than other alternatives for several reasons. For example, the C-17 would have a crew of 3 people compared with a crew of 10 for the C-141 and 8 for the C-5.[9] Based on engineering estimates and contractual warranties, the Air Force anticipates that the C-17 will require fewer maintenance personnel than its alternatives and that its engines will be more fuel efficient. All of these factors should theoretically result in lower O&S costs. Table B-2 contains estimates of O&S costs that were made by DoD and the contractor.

But the problems of increasing weight, range, payload, and fuel consumption, and the potential increases in maintenance hours noted earlier, are indications that the C-17's O&S costs may be higher than expected. Despite these problems, the Air Force lowered its O&S estimate by about 7 percent from the estimate of a year earlier. This analysis omits O&S costs because of the inherent difficulties in estimating them for a new system, such as the C-17, that faces performance problems. Also, any optimism built into engineering estimates may contrast too sharply with known O&S costs for the alternatives. Nevertheless, the potential difference in O&S costs should be kept in mind along with qualitative characteristics when comparing alternatives.[10]

Airlift Capacity and Costs Under Four Options

Because CBO relied on estimates by the Administration and the contractors that may be too optimistic, the CBO estimates may measure relative costs better than absolute costs. For example, the latest DoD report on the C-17 indicates that the cost of the program may exceed current estimates. Consequently, the costs of Options 1 and 2 may also be underpriced. Option 3, however, may cost more if the Air Force seeks improvements over the B model of the C-5 or requires new engines for the C-141. Option 4 may be similarly underpriced.

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9. The crew sizes for the C-141 and C-5 are from the Air Force's Systematic Approach to Better Long-Range Estimating (SABLE) model, Version 93-1, October 1992. These crew sizes may not be the same as the actual crews that are employed by the Air Mobility Command.

10. For a discussion of relative O&S costs before the C-17 encountered performance problems, see Congressional Budget Office, "Improving Strategic Mobility: The C-17 Program and Alternatives," CBO Paper (September 1986), pp. 18-21.

Option 1: Buy Only 60 C-17 Aircraft at Reduced Production Rates. Because the Air Force would purchase fewer planes under Option 1, the capacity provided in that option after 2000 would be far less than that provided by the April plan. Maximum capacity of 47 MTM/D would be achieved in 1996 and maintained through 1999 (see Figure 3). After that, capacity would steadily decline through the end of the projection period--reaching 37 MTM/D in 2009 (or 7 MTM/D less than the April plan) when the remainder of the C-141 fleet is retired.

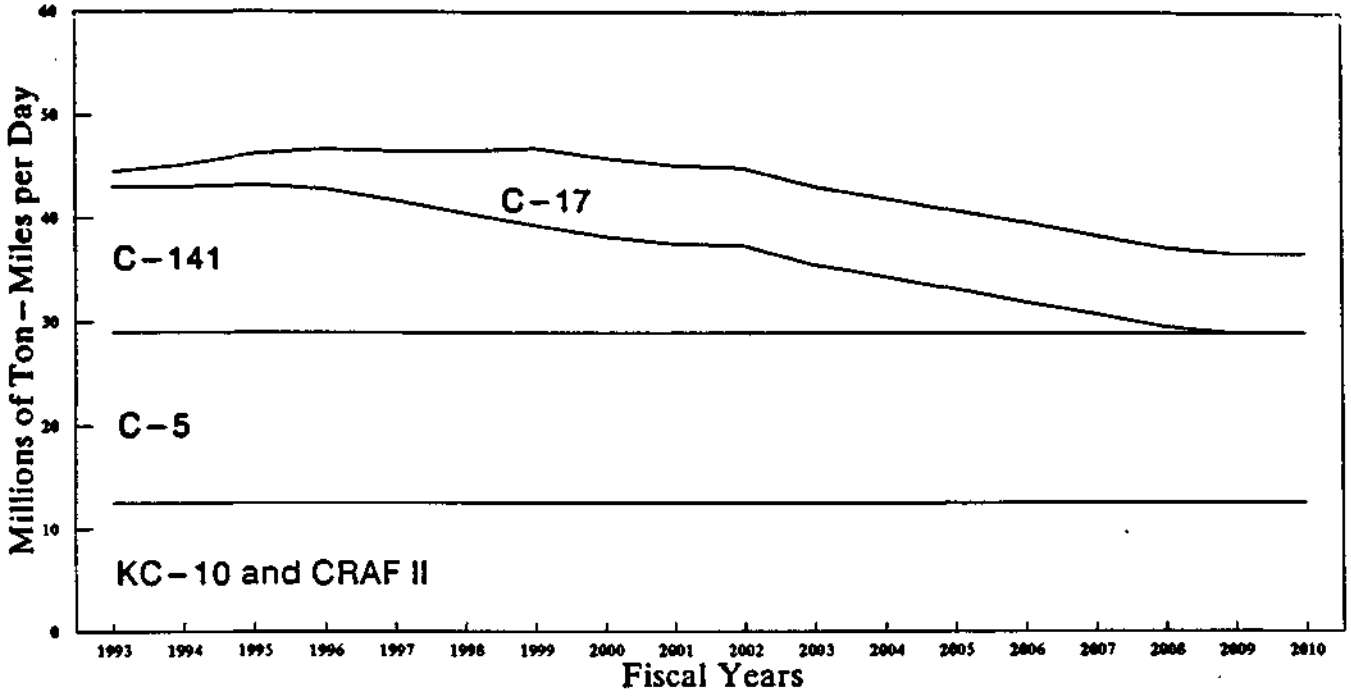
Total costs for this option are based on buying 60 C-17s at reduced production rates; compared with DoD's plan, it saves about $12.9 billion because it calls for 60 fewer aircraft, even though these aircraft would be bought at relatively less efficient production rates. As stated previously, the total cost for the 20 aircraft before the end of 1993 is about $13 billion. The additional 40 aircraft would cost approximately $13.6 billion, with the bulk of the expense incurred by 1999.

Option 2: Buy 30 C-17 Aircraft at Reduced Production Rates. Option 2 provides even less capacity than Option 1 because it would buy only 30 C-17s and would still retire C-141s. Maximum capacity of 47 MTM/D would be reached in 1996 (see Figure 4). Capacity would begin to decline immediately and would reach a low of 33 MTM/D in 2009, compared with 44 MTM/D under the April plan. In effect, the daily capacity in Option 2 for 2009 and beyond would be 75 percent of that in the April plan.

The cost of the additional 10 aircraft is estimated to be about $5.1 billion (see Table 3). Thus, the option would save about $21.4 billion relative to the April plan. The last of the 30 C-17s would be delivered in 1997.

Option 3: Buy No More C-17s, Buy C-5Bs, and Extend the Service Life of C-141s. Option 3 terminates the C-17 program after 20 aircraft. Thus, from 1993 through 2010, the C-17 fleet never contributes more than 3 MTM/D, as shown in Figure 5. Nevertheless, the purchase and delivery of 61 C-5Bs would provide the additional capacity of 0.171 MTM/D for each of the 52 aircraft available at any one time. Upon completion of delivery in 2002, the C-5 fleet would provide about 25 MTM/D through 2010. Also, the service life extension program for the C-141s would stabilize the contribution of that aircraft at 10 MTM/D from 1999 through 2010. Compared with the Administration's April plan, Option 3 would provide slightly less capacity in 2002 and 2003 but more capacity during the years 2005 through 2010.

FIGURE 3. ESTIMATED CONTRIBUTION OF EACH TYPE OF AIRCRAFT TO AIRLIFT CAPACITY UNDER OPTION 1 (At the end of the fiscal year)

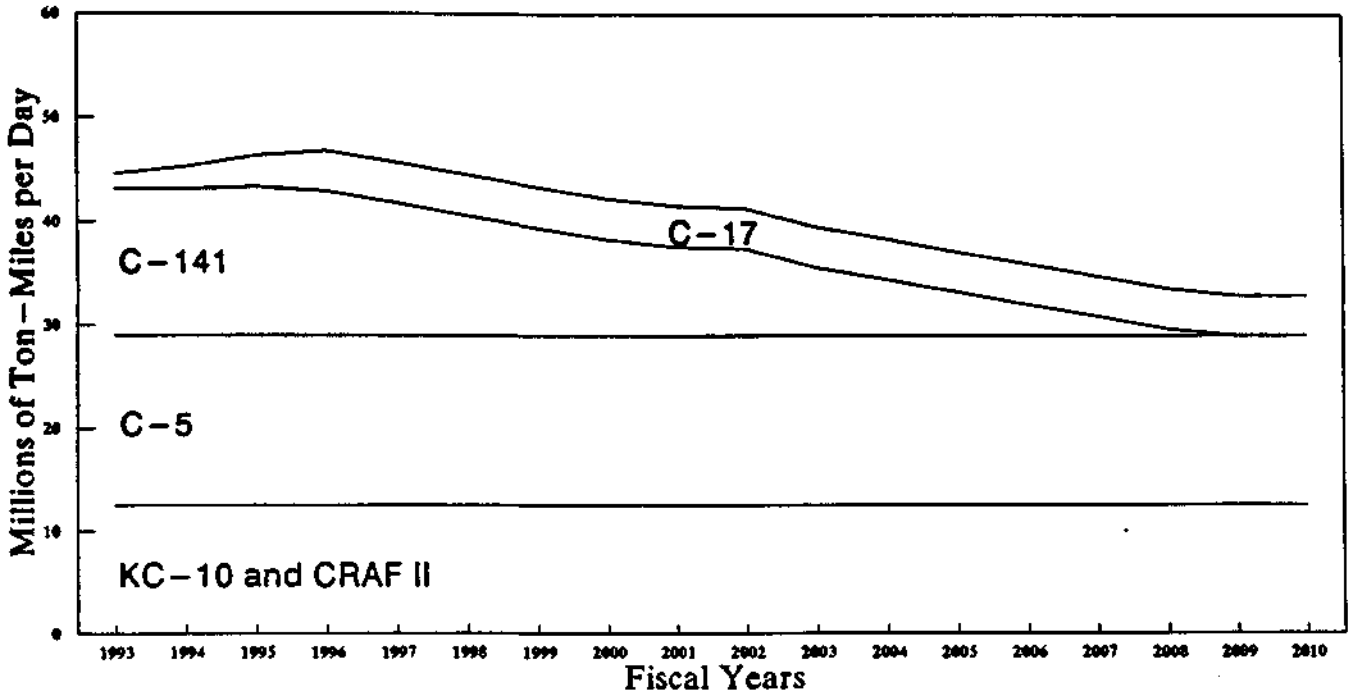


SOURCE: Congressional Budget Office based on estimates by the Administration.

NOTES: Option 1 would buy 60 C-17s at reduced production rates.

CRAF II = Civil Reserve Air Fleet, Stage II (used in conditions short of a national emergency).

FIGURE 4. ESTIMATED CONTRIBUTION OF EACH TYPE OF AIRCRAFT TO AIRLIFT CAPACITY UNDER OPTION 2 (At the end of the fiscal year)

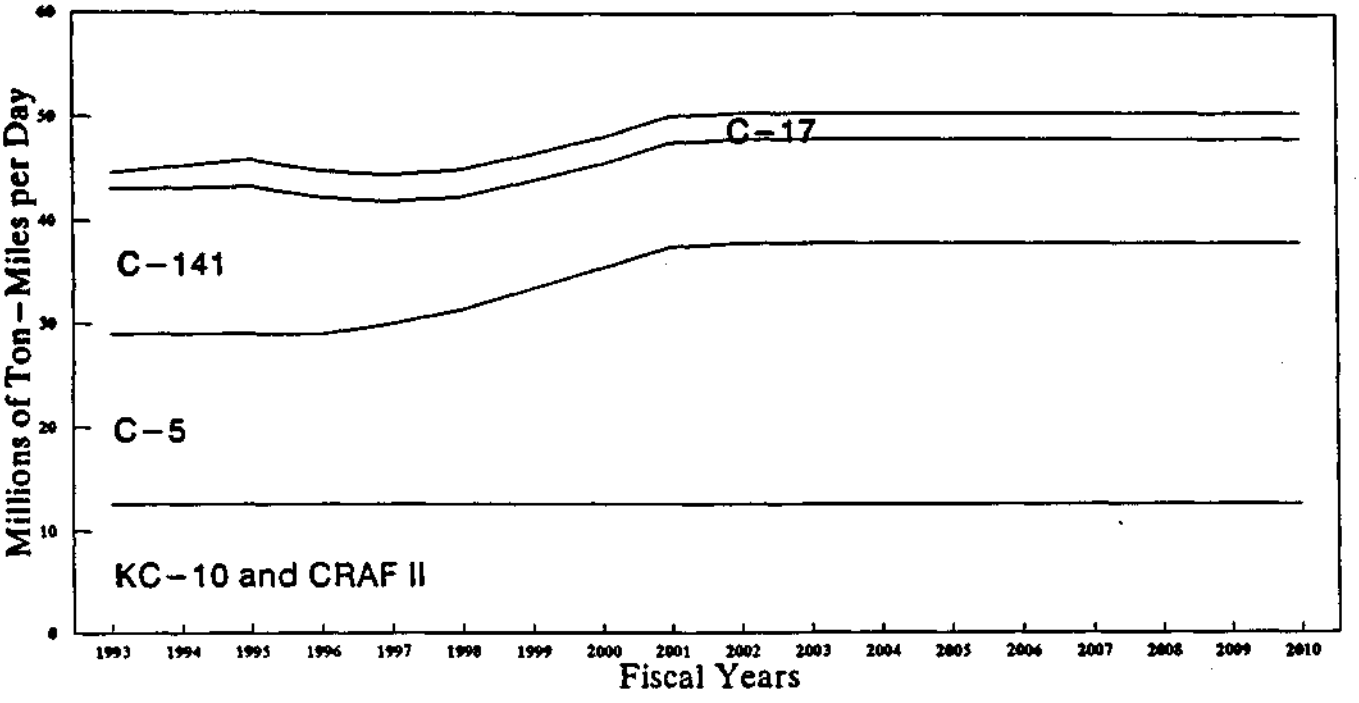


SOURCE: Congressional Budget Office based on estimates by the Administration.

NOTES: Option 2 would buy 30 C-17s at reduced production rates.

CRAF II = Civil Reserve Air Fleet, Stage II (used in conditions short of a national emergency).

FIGURE 5. ESTIMATED CONTRIBUTION OF EACH TYPE OF AIRCRAFT TO AIRLIFT CAPACITY UNDER OPTION 3 (At the end of the fiscal year)



SOURCE: Congressional Budget Office based on estimates by the Administration.

NOTES: Option 3 would buy no more C-17s, buy C-5s, and extend the service life of C-141s.

CRAF II = Civil Reserve Air Fleet, Stage II (used in conditions short of a national emergency).

The total cost for Option 3 has three major components--the savings from ending the C-17 program, the costs of buying more C-5Bs, and the costs of the C-141 SLEP. Ending the C-17 program would save about $25.7 billion. That amount does not include any termination costs for cutting the program, because the necessary data are not available.) Purchasing an additional 61 C-5Bs would cost about $14.5 billion. Because C-5s are already in the fleet, CBO assumed that the Air Force would not need military construction funding for additional hangars or maintenance facilities.[11] Finally, the SLEP for the 178 C-141s would cost approximately $5.2 billion. Costs for the SLEP could be higher if DoD seeks certain upgrades. For example, DoD could require new engines at an added cost of $5.2 billion, or hush kits costing $0.6 billion could be provided to reduce engine noise. (See Table B-3 for the estimates of these upgrades.) The total cost to complete Option 3, therefore, would be about $20.5 billion--or about $6 billion less than the April plan (see Table 3).

Option 4: Buy No More C-17s; Buy C-5Bs and Boeing 747-400Fs. Option 4 is the same as Option 3 except that it would purchase commercial airlifters instead of extending the service life of the C-141. The effect of terminating the C-17 program limits the capacity to 3 MTM/D through 2010. As shown in Figure 6, the procurement of 60 commercial 747s would greatly increase capacity. Because C-141s would still be available through 2008, overall peak capacity would be achieved in 2002 at 59 MTM/D and then would steadily decline to 50 MTM/D in 2009. Compared with the April plan, Option 4 would provide more capacity beginning in 1997. From 1998 through 2010, Option 4's capacity would be at least 6 MTM/D higher than that of the April plan.

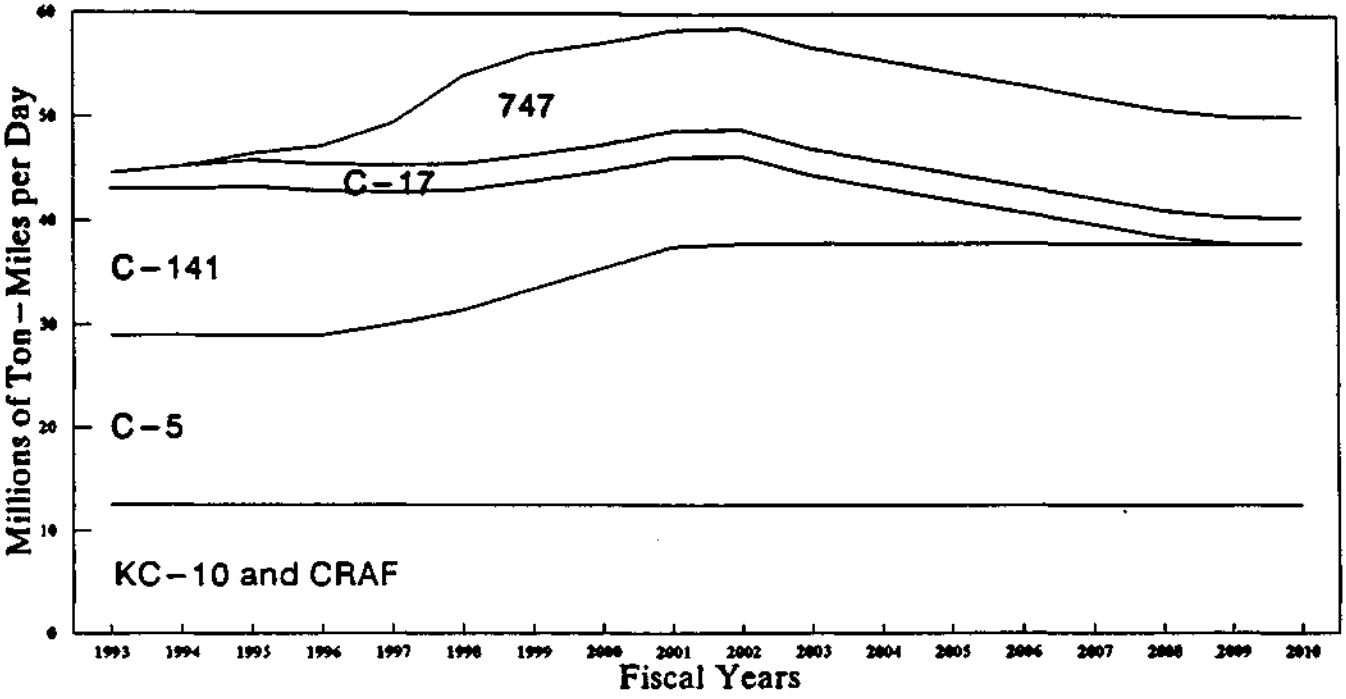
The first two of the three cost components for Option 4 are identical to those of Option 3. Purchasing 60 Boeing 747-400F aircraft to be used as military aircraft instead of the C-141 SLEP would cost approximately $3.2 billion more. Thus, the total cost to complete Option 4 would be about $23.7 billion--or about $2.8 billion less than the April plan (see Table 3).

How Much Capacity Is Needed?

According to DoD, there is no established goal for airlift capacity. However, a recent DoD study indicates that the department was considering a level

11. If additional maintenance facilities and hangars are needed, the added costs should be no more than $300 million to $500 million.

FIGURE 6. ESTIMATED CONTRIBUTION OF EACH TYPE OF AIRCRAFT TO AIRLIFT CAPACITY UNDER OPTION 4 (At the end of the fiscal year)



SOURCE: Congressional Budget Office based on estimates by the Administration.

NOTES: Option 4 would buy no more C-17s but would buy C-5s and 747s.

CRAF II = Civil Reserve Air Fleet, Stage II (used in conditions short of a national emergency).

of about 50 MTM/D (excluding CRAF Stage III, a national emergency).[12] The April plan would fall short of 50 MTM/D in every year except the four-year period 2001 through 2004 (see Figure 7). Options 1 and 2 would fall short of 50 MTM/D over the entire period, and Options 3 and 4 would meet or exceed that amount in most years.

Another way of determining the needed capacity is to look at the capacity that was used in the Persian Gulf War. Airlift requirements for Operations Desert Shield and Desert Storm reached 17 MTM/D during the peak period and represented the highest demand for airlift in history. For comparison, the 1973 airlift to Israel during the Arab-Israeli War required 4.4 MTM/D, the 1989 Operation Just Cause to Panama needed 2.0 MTM/D, and the Berlin Airlift took 1.7 MTM/D.[13] The April plan and all of the options exceed the peak demand during Desert Shield/Desert Storm by a factor of at least two over the period 1993 through 2010 (see Figure 7).

It appears that the military could theoretically carry out the airlift component of Desert Shield/Desert Storm with the lower capacities provided by Options 1 and 2, but these capacity figures could be misleading. Although the entire airlift fleet worked steadily throughout the nine-month deployment during Desert Shield/Desert Storm, there were two peak periods--during the initial response and again after the order for a second stage of deployments (a surge that lasted throughout Desert Storm). Such surges in demand required more crews and aircraft to be available. For example, although other airlift commitments were curtailed, the C-5s and C-141s often ran short of crews, particularly in the early days of the crisis before the reserve crews were activated.[14] Also, according to the Air Force, some noncritical maintenance actions were deferred in order to keep sufficient numbers of aircraft available. Thus, although the military had 45 MTM/D available, it apparently took some extreme measures to carry out Desert Shield/Desert Storm. In the Gulf War, the military had ample time (about five months) to deliver supplies and equipment before the conflict started, but the next deployment might not allow as much time. Therefore, using the rate for the Gulf War may not reflect the capacity required for a rapid deployment or account for any ongoing humanitarian missions.

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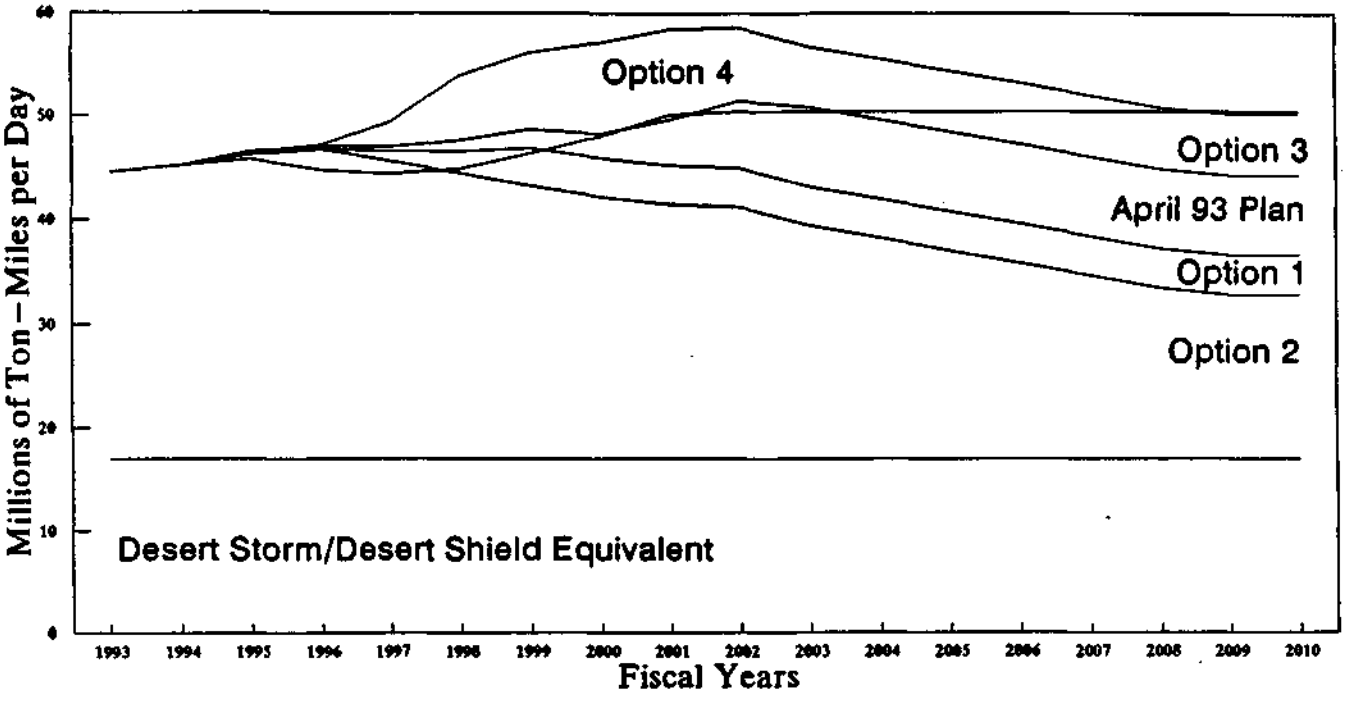
12. See Peter Grier, "The Ton-Mile Gap," *Air Force Magazine* (November 1992); and Joint Chiefs of Staff, *Mobility Requirements Study* (January 23, 1992).

13. Thomas A. Keany and Eliot A. Cohen, *Gulf War Airpower Survey Summary Report* (Washington, D.C.: Government Printing Office, 1993), Chapter 7, p. 3.

14. Ibid., pp. 4-5.

FIGURE 7. AIRLIFT CAPACITY UNDER THE ADMINISTRATION'S APRIL 1993 PLAN AND FOUR OPTIONS (At the end of the fiscal year)



SOURCE: Congressional Budget Office based on estimates by the Administration.

NOTES: The Administration's April 1993 plan would buy 120 C-17s.
Option 1 would buy 60 C-17s at reduced production rates.
Option 2 would buy 30 C-17s at reduced production rates.
Option 3 would buy no more C-17s, buy C-5s, and extend the service life of C-141s.
Option 4 would buy no more C-17s but would buy C-5s and 747s.

Press reports indicate that DoD is considering at least two different warfighting strategies. One would have U.S. forces fighting a war in one theater while holding an enemy at bay in another theater until the first conflict ended, the so-called win-hold-win strategy. Another strategy would have U.S. forces involved in simultaneous conflicts in two different theaters. It is plausible that these strategies would require airlift capacity significantly higher than that of Desert Shield/Desert Storm because at least one rapid deployment might be required to a new front, possibly in a different theater of operations. Therefore, pending the results of DoD's Bottom-Up Review, one cannot easily quantify the airlift requirements. At best, one can conclude that the need is greater than during the peak period of Desert Shield/Desert Storm.

RELATIVE ADVANTAGES AND DISADVANTAGES

A ranking of the alternatives could be driven by many considerations including estimated costs to complete each option, marginal or added capacity provided by each option, and the options' acquisition cost per MTM/D. Table 4 shows values for these variables over two time periods--an annual average from 1994 through 2010, and an annual average once all the planes have been delivered. The option that could save the most money relative to the April plan, Option 2, would result in the highest cost per additional MTM/D--nearly $5,120 million. The April plan would cost roughly $3,310 million per MTM/D, and Option 1 would cost about $3,405 million per MTM/D. The lowest cost per MTM/D is Option 4 at about $1,580 million, and Option 3 would cost nearly $1,870 million per MTM/D. But if one compares the total capacity each option would provide at completion of the program, the lowest cost option is Option 3 at $1,080 million per MTM/D; Option 4 would cost about $1,250 million per MTM/D (see Table 4). Of course, there are many other issues for the Congress to consider besides cost.

The April Plan

The April plan to buy 120 C-17s has distinct advantages. By keeping the production rates low through 1995, the contractor should have the time to complete the flight-test program and fix any problems before full-rate production begins. Also, the C-17 provides needed capacity and can perform the additional intratheater mission. The specifications for the program could be cut back, and the aircraft could still outperform other alternatives. For example, the aircraft can perform airdrops of troops and equipment as well as transport outsized cargo; however, the C-141 cannot haul outsized cargo,

TABLE 4. ESTIMATED COSTS PER MILLION TON-MILES PER DAY FOR STRATEGIC AIRLIFT OPTIONS
(Costs in millions of current dollars)

Category	Total Cost for 1994 and Beyond	Average Added Capacity (1994-2010) MTM/D	Average Added Capacity (1994-2010) Cost Per MTM/D	Added Capacity at Completion MTM/D	Added Capacity at Completion Cost Per MTM/D
Administration's April 1993 Plan:					
Buy 120 C-17s	26,488	8	3,311	12	2,207
Option 1: Buy 60 C-17s at Reduced Production Rates	13,618	4	3,405	5	2,724
Option 2: Buy 30 C-17s at Reduced Production Rates	5,116	1	5,116	1	5,116
Option 3: Buy No More C-17s, Buy C-5s, and Extend the Service Life of the C-141s					
Buy 20 C-17s	800[a]	0	n.a.	0	n.a.
Buy 61 C-5Bs	14,500	7	2,071	9	1,611
SLEP 178 C-141s	5,240	4	1,310	10	524
Total	20,540	11	1,867	19	1,081
Option 4: Buy No More C-17s; Buy C-5s and 747s					
Buy 20 C-17s	800[a]	0	n.a.	0	n.a.
Buy 61 C-5Bs	14,500	7	2,071	9	1,611
Buy 60 747s	8,400	8	1,050	10	840
Total	23,700	15	1,580	19	1,247

SOURCE: Congressional Budget Office based on estimates by the Administration and the contractors.

NOTES: Estimates were rounded to the nearest whole number.
MTM/D = million ton-miles per day; SLEP = service life extension program; n.a. = not applicable.

a. Estimated costs are for research and development, construction of facilities, spare parts, and support equipment to complete the C-17 program.

and the 747s cannot perform airdrops. Also, the C-141 and the 747 aircraft cannot land or maneuver on small airfields.

The limitations of the C-17 program are all related to the risk that it will not meet specifications or cost projections. First, costs will most likely increase, based on information in the most recent Selected Acquisition Report (December 31, 1992). The slowdown in the flight-test program and repairs to the slats and wings would probably add to the overall cost and could reduce the payload capacity. Second, flight-testing and production are behind schedule now, and production could fall further behind if turnover of the work force continues. Third, since the RDT&E and production overlap, additional problems may arise that will require adjustments in the schedule and repair costs. Finally, the aircraft, with its additional weight, is not able to perform to contract specifications. Although these specifications could be eased, that might lower the airlift capacity provided by the C-17s.

Option 1

The main advantage to Option 1 is the budgetary savings; otherwise, the advantages of Option 1 are basically the same as for the April plan. The contractor and the government would have two more years to finish testing and fix problems before increasing the production rate. Also, if the program "turns the corner," there is time for the Congress and DoD to consider follow-on procurement.

The same potential risks that apply to the April plan apply to Option 1. In addition, the smaller, less capable fleet under Option 1 may not meet airlift needs, although other alternatives could make up the shortfall. Furthermore, the 60 aircraft would have higher procurement unit costs, for two reasons: the fixed costs of plant and equipment would be spread over fewer production units, and the beneficial learning-curve effects of high-rate production would not be realized. Finally, no RDT&E savings would occur because the development cost must be paid no matter how many planes are produced.

Option 2

The smaller procurement of 30 aircraft under Option 2 has the same advantages as the April plan and Option 1. In addition, unlike Options 3 and 4, it would gradually shut down the manufacturer's plant, which might give employees time to find new jobs between now and 1997. The limitations

would be greater under Option 2, however, because it would provide even less airlift capacity.

Option 3

Option 3 has many advantages including greater capacity than the April plan in the years beyond 2004. It minimizes risk because the aircraft being purchased (C-5Bs) do not require extensive development and testing and provide the capability to transport all types of cargo. According to the manufacturer, the C-141 SLEP should increase the life of the airframe from 45,000 to 85,000 hours, although DoD estimates that the SLEP will provide only 60,000 hours. The C-141 SLEP should, according to DoD, maintain the existing C-141 capacity for at least another 10 to 15 years. Indeed, the manufacturer avers that the SLEP would extend the life of the C-141 by as much as 25 years. Furthermore, the approximately $6 billion in savings compared with the Administration's plan could be used to buy additional airlift or sealift capability or to reduce the deficit.

Limitations of Option 3 include uncertainty about the costs to extend the service life of an old aircraft, the C-141. The SLEP program would probably cost more than anticipated because of so-called over-and-above work. Any time a plane is taken apart, additional funding may be required to correct unexpected problems such as corrosion, cracks, or broken parts. Reportedly, one C-141 has been torn down, and the cracks in the wing "weep holes" were more severe than anticipated; however, it may be inappropriate to project the experience with one aircraft to the entire fleet. Even if no unexpected problems develop, costs for the SLEP could be higher if DoD seeks to improve the aircraft. For example, new engines could be required at added costs of $5.2 billion, or hush kits costing $0.6 billion could be provided to reduce engine noise (see Table B-3). Also, the C-141 SLEP is an interim measure that, according to DoD, may extend the plane's useful life 10 to 15 years, but eventually it would be replaced by a new aircraft, perhaps as early as 2015.

DoD seldom buys exactly the same plane when it reopens an assembly line. Indeed, the Air Force bought 50 C-5Bs (not C-5As) when it decided to increase its airlift capability. Thus, the Air Force could opt to purchase an improved version of the C-5B that would include current technology and would probably have higher costs than are reflected in Option 3. The Air Force may have to increase existing maintenance facilities and hangars to accommodate additional C-5 aircraft, increasing military construction costs by

$300 million to $500 million. Moreover, the Air Force avers that it would need one C-5B for every C-17 that would not be bought. If that is true, 100 C-5Bs would cost about $20.4 billion, or about $5.9 billion more than CBO's estimate for Option 3; Option 3 would then cost about the same as the April plan. Finally, the April plan for the C-17 may be superior to Option 3 if the program can overcome current performance problems to realize the savings in O&S costs projected by the Air Force.

Option 3 does not provide the C-17's unique capabilities that are key reasons cited by the Air Force for purchasing that aircraft. Furthermore, Option 3 presumes that there would be adequate airfields and facilities to transfer cargo from larger intercontinental aircraft to C-130s. There may be delays or bottlenecks involved in such transfers--obstacles that the C-17 was designed to overcome.

The Air Force argues that the rate of use planned for the C-17 does not reflect the entire mission profile and capabilities of the aircraft. For example, the rate does not include such factors as the aircraft's small size, its ability to land and maneuver on short runways, and ease of unloading cargo. And some people argue that C-5Bs cannot perform missions close to the battlefield--the intratheater mission--so C-130 aircraft that are planned to be retired may be retained in the fleet longer if fewer C-17s are bought. If that is true, the savings for Option 3 would be reduced by the costs to operate 85 C-130 aircraft. According to Air Force estimates, operating one C-130 aircraft costs about $4 million in 1994 dollars, or about $340 million a year for all 85. It is doubtful, however, that a high-value target like the C-17 or the C-5 would ever be sent to the forward edge of a battlefield. Thus, C-130s may have to be retained in the fleet and used for the intratheater mission, whether C-17s or C-5Bs are purchased or not.

Option 4

Options 3 and 4 share some advantages and disadvantages. By 2010, Option 4 would provide the same capacity based on ton-miles per day as Option 3. In addition, DoD would be buying proven aircraft.

Option 4 provides approximately $2.8 billion of savings compared with the April plan. However, modifications to the 747s, such as adding the ability to unload cargo easily, may be necessary and thus reduce savings. Also, questions about future maintenance and support costs may arise. For example, the Air Force could either take advantage of the contractor's spare

parts system and maintenance capabilities or establish its own in-house capability, which may not be as cost-effective.

Also, recent press reports indicate that Boeing has proposed a major modification to the entire commercial fleet of 747s as a precaution against in-flight separation of the engines from the wings--a condition that may have contributed to two fatal accidents. Nevertheless, lower O&S costs for the C-17 could give it a decisive cost advantage over Option 4 if, despite evidence to the contrary, Air Force estimates hold up.

APPENDIX A: DESCRIPTIONS OF AIRLIFT AIRCRAFT

The Department of Defense uses different types of aircraft to transport troops and cargo. The choice of aircraft depends on such factors as the characteristics of the cargo and the distance to be covered. This appendix describes the various aircraft and their capabilities.

Lockheed C-130 Hercules. The C-130 had its first flight in 1955. Since then, more than 2,000 have been built for the United States and other nations. Four models (C-130A/B/E/H) were produced to perform the standard transport role. Roughly 500 aircraft are used in the airlift role today. The Air Force is still buying C-130Hs. The plane is a four-engine, turbo-propeller-driven aircraft that was designed primarily to carry either small payloads (weighing from 25,000 to 43,000 pounds) or troops over short to intermediate distances. The plane can operate on short paved or unpaved runways. It can air-drop troops or bulk cargo, can use its low-altitude parachute extraction system to deliver its cargo without landing, or can land and deliver its cargo without having to come to a full stop. Thus, the C-130 is best suited for its tactical role within a theater rather than between theaters over intercontinental routes.

Lockheed C-141 Starlifter. The C-141 is a four-engine, long-range aircraft that was built between 1963 and 1968. From the mid-1970s to the early 1980s, the C-141 "stretch program" extended the length of the fuselage by about 23 feet and added aerial refueling capability to the entire fleet. The massive movement of troops and equipment to the Persian Gulf during Desert Shield/Desert Storm relied heavily on the capabilities of the C-141 fleet. However, the planes are currently operating under flight restrictions that have been imposed because of fatigue cracks and corrosion, most notably in the wings and at the cockpit posts. The commander of the Air Mobility Command restricted the C-141s' payload weight, aerial refueling, and altitude because of these deficiencies. Unless the problems are corrected, the Air Force may have to retire the C-141 sooner than originally planned. The C-141 can carry a variety of bulk cargo and oversized cargo, such as towed howitzers or small trucks, but cannot carry "outsized" cargo that is large by volume such as helicopters or tanks. It can unload supplies and equipment quickly through a back door and can air-drop cargo or troops, but it cannot land on short or unpaved runways.

McDonnell Douglas KC-10 Extender. The KC-10 is a military version of the commercial DC-10. It is a three-engine, wide-bodied transport that can be operated as a tanker for aerial refueling or as a cargo aircraft or that can combine both missions. The KC-10 made its first flight in 1980, and 60 aircraft were built between 1979 and 1990. The plane can carry bulk cargo and some oversized cargo but cannot carry outsized equipment. Special equipment is required to unload the KC-10 because the cargo door is high on

the side of the aircraft. By combining both its tanker and cargo capabilities, the KC-10 can refuel aircraft in transit while carrying a limited amount of supplies and equipment to sustain short-term combat operations. With its capability, the KC-10 supports fighter deployments, strategic airlift, strategic reconnaissance, and conventional operations. It can land only on paved runways.

Lockheed C-5 Galaxy. The C-5 is the largest aircraft operated by the Air Mobility Command. The prototype first flew in 1968, and by 1973 the Air Force had taken delivery of 81 C-5As. Between 1982 and 1987, the C-5A required a major modification to extend the life of its wings. The Air Force bought 50 C-5B aircraft between 1983 and 1987 that included improvements such as stronger wings (equivalent to the C-5A's upgraded wings), updated avionics, color weather radar, and new engines. The C-5Bs can carry passengers and all types of cargo, including outsized equipment, and can perform airdrops. In addition to being able to back up on a 1 percent grade, the aircraft can be lowered to truck-bed height or ground level for ease of unloading cargo.[1] Both models of the C-5 were designed to land on and take off from unpaved airfields, although the Air Force does not use this capability. The C-5s hauled nearly 42 percent of all the cargo that was flown to the Persian Gulf during Operations Desert Shield and Desert Storm.

Boeing 747-400F. The 747 is a four-engine wide-bodied commercial airlifter that is nearly as big as the C-5B. Although the first plane of this series (400F) was flown in 1988 and entered service in 1989, earlier versions of the 747s have been flown by commercial airlines for several years. Indeed, the 747 is based on Boeing's entry in the original design competition that resulted in the Air Force's buying the C-5s. Cargo can be unloaded from the nose of the plane and from the rear door using special equipment. The 747s are best suited for transporting troops or bulk and oversized cargo over long distances to main operating bases that have paved runways.

1. The Air Force states that it does not routinely back up the C-5 because of the aircraft's size (about as big as a football field). According to the Air Force, this procedure is used only in emergencies.

APPENDIX B: OTHER COST ESTIMATES

The tables in this appendix provide additional cost estimates that can used to supplement the text.

Table B-1 contains estimates of the Administration's April 1993 plan and the four alternatives in constant 1994 dollars. (Table 3 presented the estimates in current dollars.) Because the duration of spending varies among the alternatives, these estimates exclude the impact of assumptions about future inflation.

Table B-2 contains the Administration's and contractors' estimates of operating and support (O&S) costs. The Department of Defense favors buying the C-17 primarily because its O&S costs are supposed to be lower than those of other alternatives. However, the problems noted in the text (increases in its weight, range, payload, and fuel consumption and potential increases in maintenance hours) are indications that the C-17's O&S costs may be higher than expected. (Nonetheless, the Air Force's most recent O&S estimate is about 7 percent lower than the previous year's estimate.) The Congressional Budget Office's (CBO's) analysis omits O&S costs because of the difficulties estimating them for a new system like the C-17 that faces performance problems. Also, any optimism reflected in the engineering estimates may contrast too sharply with the known O&S costs for the alternatives. Nevertheless, a potential difference in O&S costs should be kept in mind along with qualitative characteristics when comparing alternatives.

Table B-3 contains CBO's estimates of possible improvements that could be made to the C-141's engines. In addition to the service life extension program for the C-141's wings, the Air Force may want to put new engines in the C-141s. These new engines would reduce noise and improve fuel efficiency. The cost to provide each of 178 aircraft with four new engines and one spare would be approximately $5.2 billion (see the top panel of Table B-3). Alternatively, if the Air Force wanted to bring the C-141's noise level down to one that was acceptable at overseas commercial airports, a "hush kit" modification would be sufficient. The primary change would involve the installation of sound-absorbing material in the engine housing (nacelle). The cost for developing, purchasing, and installing the hush kits for 178 C-141s would be about $625 million (see the bottom panel of Table B-3).

TABLE B-1. ESTIMATED COSTS OF STRATEGIC AIRLIFT OPTIONS
(By fiscal year, costs in millions of 1994 dollars)

Category	1993 and Before (Sunk Costs)	1994	1995	1996	1997	1998	1999	2000 and Beyond	Total Excluding Sunk Costs	Average Unit Costs[a]
Administration's April 1993 Plan: Buy 120 C-17s										
Quantity	20	6	8	12	15	15	16	28	100	n.a.
Cost										
Procurement	8,063	2,400	3,130	3,637	3,278	2,841	3,497	5,295	24,078	241
RDT&E	6,210	180	85	22	7	5	4	0	304	n.a.
MilCon	155	15	49	42	0	41	11	12	170	n.a.
Total	14,428	2,595	3,264	3,701	3,285	2,888	3,512	5,307	24,552	246
Option 1: Buy 60 C-17s at Reduced Production Rates										
Quantity	20	6	6	8	10	10	0	0	40	n.a.
Cost										
Procurement	8,063	2,400	2,543	2,680	2,435	2,199	179	188	12,624	316
RDT&E	6,210	180	85	22	7	10	0	0	304	n.a.
MilCon	155	15	49	42	0	0	0	0	106	n.a.
Total	14,428	2,595	2,677	2,744	2,442	2,209	179	188	13,034	326
Option 2: Buy 30 C-17s at Reduced Production Rates										
Quantity	20	6	4	0	0	0	0	0	10	n.a.
Cost										
Procurement	8,063	2,400	1,859	191	94	92	0	0	4,636	464
RDT&E	6,210	180	124	0	0	0	0	0	304	n.a.
MilCon	155	15	49	42	0	0	0	0	106	n.a.
Total	14,428	2,595	2,031	233	94	92	0	0	5,046	505
Option 3: Buy No More C-17s, Buy C-5s, and Extend the Service Life of the C-141s										
C-17 Quantity	20	0	0	0	0	0	0	0	0	n.a.
C-17 Cost										
Procurement	8,063	190	127	48	19	0	0	0	384	n.a.
RDT&E	6,210	304	0	0	0	0	0	0	304	n.a.
MilCon	155	106	0	0	0	0	0	0	106	n.a.
Subtotal	14,428	600	127	48	19	0	0	0	794	n.a.
C-5 Quantity	0	0	6	8	12	12	12	11	61	n.a.
C-5 Procurement Cost	0	1,100	2,054	2,010	2,435	2,199	2,062	1,667	13,527	222

(Continued)

TABLE B-1. CONTINUED

Category	1993 and Before (Sunk Costs)	1994	1995	1996	1997	1998	1999	2000 and Beyond	Total Excluding Sunk Costs	Average Unit Costs[a]
					Option 3 (Continued)					
C-141 SLEP Quantity	0	0	0	10	24	36	36	72	178	n.a.
C-141 SLEP Procurement Cost	0	230	323	670	843	916	807	1,025	4,814	27
Total Cost of Option 3	14,428	1,930	2,504	2,728	3,297	3,115	2,869	2,692	19,135	n.a.
					Option 4: Buy No More C-17s; Buy C-5s and 747s					
C-17 Quantity	20	0	0	0	0	0	0	0	0	n.a.
C-17 Cost										
Procurement	8,063	190	127	48	19	0	0	0	384	n.a.
RDT&E	6,210	304	0	0	0	0	0	0	304	n.a.
MilCon	155	106	0	0	0	0	0	0	106	n.a.
Total	14,428	600	127	48	19	0	0	0	794	n.a.
C-5 Quantity	0	0	6	8	12	12	12	11	61	n.a.
C-5 Procurement Cost	0	1,100	2,054	2,010	2,435	2,199	2,062	1,667	13,527	222
747 Quantity	0	3	6	12	13	13	13	0	60	n.a.
747 Procurement Cost	0	1,000	978	1,627	1,686	1,375	897	276	7,839	131
Total Cost of Option 4	14,428	2,700	3,159	3,685	4,140	3,574	2,959	1,943	22,160	n.a.

SOURCE: Congressional Budget Office based on estimates by the Administration and the contractors.

NOTES: n.a. = not applicable; RDT&E = research, development, test, and evaluation; MilCon = military construction; SLEP = service life extension program.

a. Exclude sunk costs.

TABLE B-2. ESTIMATED ANNUAL OPERATING AND SUPPORT COSTS FOR SELECTED AIRLIFT AIRCRAFT

Type of Aircraft	Number and Type of Crew per Aircraft	Number of Aircraft in a Squadron	Flying Hours per Aircraft	Cost per Aircraft (Millions of 1994 dollars)	Cost per Flying Hour (Thousands of 1994 dollars)
C-5A	1.8 Active Crews	18	620	8.9	14.3
C-5B	1.8 Active Crews	18	620	7.8	12.5
C-17	3.0 Active and 2.0 Reserve Crews	13	1,432	11.1	7.8
C-141	1.9 Active Crews	18	1,178	7.1	6.0
747	2.0 Active Crews	18	900	5.9	6.6

SOURCE: Congressional Budget Office compilation of estimates from the Air Force's Systematic Approach to Better Long-Range Estimating (SABLE) model, Version 93-1, October 1992; Department of Defense, Selected Acquisition Report for the C-17 dated December 31, 1992; and an estimate by the contractor.

NOTE: Operating and support (O&S) cost estimates are based on many factors, such as the number of crews per aircraft, the type of crew per aircraft (active, reserve, or both), the number of aircraft per squadron, and the number of flying hours per aircraft. Based on the available data, CBO is unable to calculate an O&S cost per aircraft that considers all of these factors uniformly for all aircraft. Also, these estimates do not equal budgeted amounts because they are based on mathematical models that approximate long-run costs.

TABLE B-3. ESTIMATED COSTS OF POSSIBLE ENGINE UPGRADES FOR THE C-141's SERVICE LIFE EXTENSION PROGRAM (By fiscal year, costs in millions of current dollars)

Category	1995	1996	1997	1998	1999	2000 Through 2002	Total
New Engines for the C-141s							
Numbers of Aircraft	0	10	24	36	36	72	178
Cost[a]							
Procurement	0	270	660	1,000	1,030	2,120	5,080
RDT&E	0	0	110	0	0	0	110
Total	0	270	770	1,000	1,030	2,120	5,190
Installation of Hush Kits on Current C-141 Engines							
Numbers of Aircraft	0	10	24	36	36	72	178
Cost[b]							
Procurement	0	30	80	120	120	260	610
RDT&E	15	0	0	0	0	0	15
Total	15	30	80	120	120	260	625

SOURCE: Congressional Budget Office based on estimates by the Administration and the contractor.

NOTE: RDT&E = research, development, test, and evaluation.

a. Estimates include the costs of four engines and one spare engine per plane.
b. Estimates include the costs of four hush kits and one spare hush kit per plane.