Chapter 3

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Almost all commercial all-cargo aircraft currently in the fleet are derivatives or conversions of passenger aircraft. Some civilian and military planners, as well as some all-cargo operators, have argued that the growth of the industry has been hampered by the lack of aircraft optimized to fulfill cargo carrying requirements.

Three alternative approaches to the development of future all-cargo aircraft have been identified:

1. as a derivative of a new or existing passenger or military airplane;
2. development of a dedicated civilian cargo aircraft designed without regard for either passenger or military requirements; and
3. development of a joint civil-military air cargo plane that would satisfy both commercial and military requirements.

Each of these alternatives will be discussed in turn.

FREIGHTERS DERIVED FROM PASSENGER AIRCRAFT

In 1963, freighter service was available only with propeller aircraft: about 75 percent piston aircraft (primarily the DC-7) and 25 percent turboprops (such as the CL-44). By 1970, almost 98 percent of scheduled freighter service was offered with jet aircraft: 55 percent with the B-707-300 B/C, 22 percent with the DC-8-63F, 11 percent with the DC-8-50F, and 10 percent with the B-727-1OO C/QC.

The fleet average operating cost declined from $0.30 per revenue ton-mile in 1963 to $0.16 in 1967 and then began to increase, reaching $0.27 in 1977 (current dollars). Total operating costs have been steadily rising since 1973 because of general inflation as well as the abrupt increase in the price of fuel. Although the introduction of the B-747 in domestic service did produce lower cost freighter service, the small number of B-747s relative to the B-707s and DC-8s has not yet changed the fleet average cost curve. B-747s have found much greater use in international cargo operations than they have in domestic operations.

Both the B-707 and the DC-8 were designed as passenger aircraft, with the fuselage cross-section being determined by the requirements of six-abreast seating and the width of the aisle. Both aircraft could carry 13 pallets of 88 by 125 inches, the standard units at that time.

The B-747 freighter comes closest to being a dedicated or uncompromised freighter design for commercial operations. When Boeing lost the competition for the military cargo C-5A contract to Lockheed in *1965*, Boeing took its assembled C-5A design team, added personnel from their commercial program, and set out to design an aircraft to meet the perceived needs of the rapidly growing commercial market. The resulting B-747 was designed as a passenger plane. However, because it appeared at that time that a supersonic transport (SST) would be a strong competitor, the 747 was also designed to be an efficient freighter in the event that the SST took over the passenger market.

The 747 was designed to hold two *8* by 8 ft containers abreast. This was the origin of the wide body, which at the time had little to do with passenger appeal.[1] The requirement that cargo be loaded through the nose of the aircraft forced the cockpit to be placed at the upper

[1] John E. Steiner, *Jet Aviation Development: One Company's Perspective*, prepared by Boeing Commercial Aircraft Co. (Washington, D. C.: National Air and Space Museum, Smithsonian Institution, October 1979), pp. 15-18.

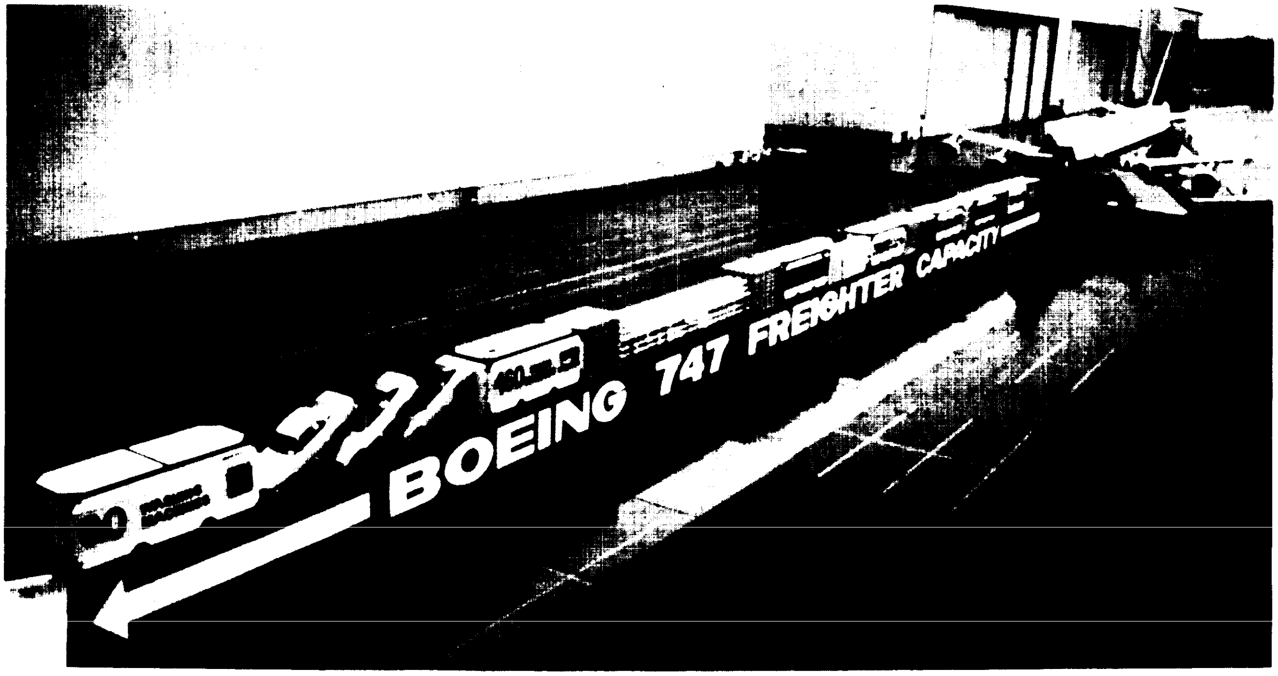

Photo credit: Boeing Aircraft Co.

Cargo capacity of Boeing's 747

deck. Aerodynamic considerations required the designers to allow a door height of only 8 feet, 2 inches—resulting in only a 2-inch clearance for containers.

Because the SST did not materialize as a competitor, the first 747 freighter was not delivered until 1972, more than 2 years later than the first passenger version. Since then, however, progress has been rapid, with a total of 129,747 freighters delivered by December 1980.[2]

Manufacturers are currently considering a number of variations on their existing aircraft. In the large-payload category, Boeing is considering stretching its B-747-200F up to 50 ft, resulting in *30* percent additional containerized volume. In the medium-payload category-derivative aircraft would include the L-1011-500F, the DC-1 OF, and the B767F. Douglas' DC-1OF could be stretched and offered in a "combi" version. Boeing's B-707-320C could conceivably be stretched. Finally, Boeing is planning a freighter version of the *B-767* aircraft.[3]

For the light-payload category of freighters—under 60,000 lb—Lockheed is considering marketing a potential derivative of its Hercules L-1OO, Dash sO. Current proposals include a stretch of up to 45 ft over the basic model, which would provide capability for transporting up to eight 8 by 8 by 10 ft containers with payload ranging from 54,000 to 72,000 lb. This aircraft could replace the B-707-320C and the DC-8F on a number of routes and also have the capability (because of being able to handle the 8 by 8 ft containers) to be an intermodal feeder freighter for carriers using the B-747F. Other advantages include lower fuel cost and straight-in, straight-out loading. The Dash *so* would be appropriate for short- to medium-range hauls—l,400 statute miles with a payload of *66,000* lb and 1,960 miles with a payload of 50,000 lb. Derivatives of the present B-727 and B-737 may also be possible.[4]

[2]Boeing Aircraft Co., telephone interview, July 14, 1981.

[3]Steiner, op. cit., 167-168.

[4]Ibid.

ADVANTAGES AND DISADVANTAGES OF DERIVATIVE AIRCRAFT

Existing air cargo derivatives of passenger airplanes have proven very satisfactory. For example, the B-747-200F has proven to be the large payload workhorse of the air cargo fleet and could continue unmodified for a number of years.

Any derivative freighter has the advantage of having most of its development costs already charged against the sale of its passenger counterpart. In addition, the financial arrangements for purchasing the airplane have already been established and there is a relatively short lead time before production (as compared to all new aircraft).

A major disadvantage of existing air cargo aircraft is that they represent 1960's technology and that, therefore, their direct operating costs are higher than what might be achieved with present technology. Additionally, since they generally have not been designed specifically for air cargo, loading and unloading can present problems; the aircraft may be pressurized more than necessary, and there may be equipment built in for passenger safety that is unneeded for cargo.

DEDICATED AIR FREIGHTERS

A dedicated commercial air freighter is an airplane which has been designed from the ground up as a freighter, with no constraints imposed by either passenger or military requirements. Over the years, there has been a debate concerning the cost effectiveness of such an airplane, with some all-cargo carriers claiming that they could consistently earn a profit if they had such an aircraft. To help resolve this controversy, the National Aeronautics and Space Administration (NASA) selected two contractors, Douglas Aircraft Co. and Lockheed-Georgia Co., to independently evaluate the feasibility of producing such a freighter by **1990.** This was done as part of the Cargo/Logistics Airlift Systems Study (CLASS). '

Douglas made several forecasts of the future fleet composition given various developments. Their analysis indicated that two new cargo aircraft could be *derived* from existing wide body aircraft using 1980 technology. These aircraft could be commercially viable and could become operational in 1985. Results suggested a preference for a short- and a long-range version, each with a payload of about 330,000 lb. [G] At comparable payloads, these cargo aircraft were estimated to provide a 20 percent reduction in trip cost and a 15 percent decrease in aircraft price compared to current wide bodies in inflated *1984* dollars, ' Douglas estimated there could be **400** such derivatives produced by 1998.[8]

A long- and a short-range *dedicated* freighter were then hypothesized to be introduced in 1994 using 1990 technology (an unrealistically short development time according to some experts). The *1990* technology assumed was derived from NASA's Aircraft Energy Efficiency (ACEE) program, which seeks to develop a variety of technologies leading to fuel savings and lower operating costs for future passenger aircraft. Some of the new technologies include: 1) composite materials, which reduce weights and provide higher strengths; 2) active controls, which provide automatic response to flight and gust conditions; and 3) advanced engine technology, with higher thrust to weight ratios and better specific fuel consumption.

'See: McDonnell Douglas Corp., Douglas Aircraft Co., *Cargo Logistics Airlift Systems Study (CLASS)*, 4 vols,, prepared by R. J. Burby and W. H. Kuhlman, under NASA contract No. NASl-14948 (Hampton, Va.: Langley Research Center, National Aeronautics and Space Administration, October 1978). (Hereafter cited as "Douglas, *CLASS.") See* also: Lockheed-Georgia Co., *Cargo 'Logistics Airlift Systems Study (CLASS) 2 vols.*, prepared by J. M. Norman, R. D. Henderson, F. C. Macey, and R. P. Tuttle, under NASA contract No. NASA-14967 (Hampton, Va.: Langley Research Center, National Aeronautics and Space Administration, November 1978). (Hereafter cited as "Lockheed, *CLASS.")*

'Douglas, *CLASS Volume -? Future Requirements of Dedicated Freighter Aircraft to Year 2008* pp. xxiv-xxv.

'Ibid., p. xxv.

'Ibid., p. xxvii.

In order to achieve a manufacturer's return on investment (ROI) of 15 percent while maximizing the airlines' ROI, it was determined that the long-range dedicated aircraft should have a payload of 150,000 lb, and the short-range, a payload of 100,000 lb. The airline ROI was relatively insensitive to payload in the cases assumed, however, because the payload could be increased to *330,000* lb for the long-range and 220,000 lb for the short-range with only a l-percent decrease of airline ROI.[9] Such dedicated freighters could reduce aircraft operating costs per trip (direct operating cost—DOC—less depreciation and insurance) by an estimated 43 percent below current wide bodies.[10] In combination with other improvements, such as containerization and mechanized terminals, shippers could gradually achieve overall savings of roughly *20* percent over the 1978-2000 period. '

'Ibid., pp. xxxiv-xxxv.

'"Ibid., p. xxix.

''Allen H. Whitehead, Jr., and William H. Kuhlman, "Demand for Large Freighter Aircraft as Projected in the NASA *Cargo/ Logistics Airlift Systems Studies,* " NASA Technical Memorandum 80074 (Hampton, Va.: Langley Research Center, National Aeronautics and Space Administration, April 1979), p. 6.

Lockheed calculated the payload which maximized air carrier profits assuming no constraint on manufacturer's ROI. For *1990* this was estimated to be *330,000* lb, as compared to **225,000** lb for the current **747-200F** freighter. It was estimated there would be a demand for 270 such airplanes in 1990 and over 480 in 2000. Air cargo rate reductions of up to 45 percent were estimated to be possible. These estimates, however, not only assume concomitant improvements in terminal operations, but also postulate an increase in air cargo demand of over *250* percent in response to the 45 percent rate decrease. In addition, the phase-out of all other aircraft is assumed. [1]2

Thus, while there appears to be some uncertainty about the optimum payload for a dedicated air freighter, Douglas and Lockheed agree that substantial cost savings and rate reductions could result. These findings, however, are extremely sensitive to assumptions about fuel and labor costs and, most particularly, to growth in demand for air cargo services. Further, it ignores the competitive situation brought about by the lower capital costs of future derivative air cargo aircraft.

"Lockheed, *CLASS Executive Summary,* pp. 27-32.

ADVANTAGES AND DISADVANTAGES OF A DEDICATED AIR FREIGHTER

In summary, the advantage of the dedicated air freighter is that it can be designed very specifically for air freight demand, providing the type of loading and unloading, flooring, fuselage configuration, pressurization, etc., which is optimal for its contents. Furthermore, given that it is unlikely to be built before the 1990's, it can make full use of NASA's ACEE results, with the potential of significantly lowering operating costs and fuel usage.

A major disadvantage of the dedicated air freighter would be that the estimated $2 billion to *$2.5* billion development cost (1976 dollars) would have to be absorbed solely by the sales of that airplane. [1]3 Such a high overhead raises the price of the airplane and its DOC (because of depreciation and insurance costs) and increases the financial risks to investors, especially since it would be competing with derivatives which have much smaller development costs per unit and which themselves have incorporated some of the cost-reducing technology.

A 1979 NASA analysis suggests that the significantly lower purchase price for the deriva-

"U.S. National Defense Transportation Association, Military Airlift Committee, *An Executive Report on the Potential for a Joint Commercial Military Air Cargo System Development* (Washington, D. C.: Apr. 29, 1977), p. 47. (Hereafter cited as "NDTA, *Executive Report.")*

tives would overshadow the economic benefits of the dedicated aircraft.[14] Apparently having come to the same conclusion, manufacturers are reluctant to undertake development of a dedicated air freighter unless there is some way to reduce the risk.

Some planners have spoken of a passenger derivative of the dedicated air freighter as one means of reducing risk. Since all-cargo airplanes form a very small percent of the carrier fleet, this would be an extreme example of the tail wagging the dog. It is much more likely that an all-cargo airplane would be derived from a passenger airplane which incorporates all ACEE technological improvements. However, assuming favorable growth in air cargo, there is increasing incentive for aircraft designers to take cargo needs into account when designing new passenger aircraft.

[14] William D. Conner, and John C. Vaughn, III, "Multi-role Cargo Aircraft Options and Configurations," NASA Technical Memorandum 80177 (Hampton, Va.: Langley Research Center, National Aeronautics and Space Administration, October 1979), p. 3.

A JOINT MILITARY-CIVIL CARGO AIRPLANE

The Department of Defense (DOD) perceives a shortfall in military airlift capability which will gradually worsen as the Army moves toward the use of larger and heavier vehicles. DOD wants the capability to react more quickly to overseas emergencies and to move equipment from one battle zone to another as needed.

There are several alternatives for making up the described shortfall in airlift capacity. One option would be to purchase an aircraft designed exclusively to meet military needs. The cost of procuring 200 such vehicles with a payload of 350,000 lb was estimated in 1977 to be in the range of $12 billion in 1976 dollars (about $60 million per aircraft).[15]

An alternative, longer range option is a joint military-civil airlift vehicle, which would be produced in two versions—a military version and a civilian version. Originally designed as the C-XX, it has recently been renamed the Advanced Technology Civil Military Aircraft (ACMA). The civilian version would include a reinforced floor and other special features so that it could serve as part of the Civil Reserve Air Fleet (CRAF). This could also reduce the number of required military ACMAS. The Military Airlift Command has also considered the feasibility of a commercial passenger version in order to increase the number built, and thereby reduce unit costs.

The 1977 Executive Report of the Military Airlift Committee of the National Defense Transportation Association estimated it would still cost over $11 billion to produce 200 ACMAs, despite some cost savings achieved through design compromises to meet civilian needs. However, they estimated that 80 percent of the 200 airplanes could be purchased by the commercial air carriers at a cost of $50 million each, or a price subsidy of $7 million apiece (1976 dollars) to cover decreased payload and increased operating cost. The cost to the military was estimated to total approximately $3 billion, a savings of some $9 billion over the cost of procuring 200 aircraft that might lie idle much of the time waiting for a crisis to develop.[16]

The Air Force has funded Boeing, Lockheed, and Douglas to look more closely at airplane designs and to anticipate the penalties to be incurred by a joint design. Douglas developed a design for a 200,00()-lb" payload aircraft with a conversion kit to convert a CRAF airplane for military use. The lower recommended payload was based on the contractor's estimate of the best commercial market. The conversion kit includes a heavy military floor for installation on

[15] NDTA, *Executive Report*, pp. 14, 20.

[16] Ibid., pp. 61-62.

top of the original floor as well as extra floor bracing, a front drive-in ramp, and landing gear conversion components that provide kneeling capability.[17] The conversion was estimated to take about *24* hours to complete.[18]

The civilian version of the ACMA aircraft would weigh approximately *6,500* lb more than a fully dedicated commercial freighter. The ACMAs purchased by the military would weigh approximately 6,8oo lb less than those civil reserve aircraft brought up to military standards through the kit modification approach.[19] Thus, this ACMA concept involves a weight penalty for both its civil and military applications. However, advanced technology could greatly reduce airplane size and weight compared to current technology. It has been estimated that operating weight and takeoff gross weight of a dedicated ACMA freighter would be only 65 percent and 76 percent of the corresponding weights for a current technology freighter having the same payload, range, cruise speed, and field length.[20]

Lockheed's ACMA design was considerably larger, having a payload in the range of 400,000 lb.[21] The contractor estimated a 34-percent reduction in DOC over the B-747, at a range of 3,5oo nautical miles, and a 5&percent decrease in fuel consumption.[22]

One question to be answered if an ACMA were to be developed is what organization would be responsible for its production. This is a major problem, because accommodating a wide variety of potential commercial customers, each with their own views, is inconsistent with traditional military purchase procedures. Previous attempts at interagency cooperative development of a joint military/civil cargo aircraft have not been successful. The Air Force's C-141 is a primary example of such a developmental effort; there appeared in the beginning to be enough commonality of military/civil aircraft requirements to justify a cooperative effort. The Federal Aviation Administration consulted with prospective commercial users of the aircraft and worked closely with the Air Force in certificating the plane for civil air operations. Nevertheless, only the military purchased the aircraft.[23] While there is general agreement that a joint effort makes sense, there is great skepticism on the commercial side that it would work to their advantage in practice.

A recent development could have a significant impact on the ACMA program. The Air Force has been directed to cancel its existing program to develop a tactical airlifter and to plan a new strategic airlifter, the CX, having some tactical capability. The emphasis is on developing an aircraft which will be in operation earlier than the ACMA. A CX task force is currently working to determine the specifications of the airplane. It seems likely that a CX would be a derivative of an existing aircraft. The effects of the CX program on the proposed ACMA program are uncertain at present, and would not be clarified until the CX is better defined. If the CX program is implemented, the most likely effect would be to delay consideration of the ACMA.[24]

“E. A. Barber, R. J. Marhefka, and D. G. Blattner, “Prospects for Commercial Commonality in Military Transport, ” presented at AIAA Aircraft Systems and Technology Meeting, Aug. 21-23, 1978, p. 10.

[18]Ibid., p. 10.

“Ibid., p. 11.

‘“ Ibid., pp. 11-21.

[21]W. T. Mikolowky, et al., Lockheed Aircraft Co., “Identifying Desirable Designs Features for the C-XX Aircraft: A Systems Approach,” presented at the AIAA Aircraft Systems and Technology Meeting, Aug. 20-22, 1979, p. 4.

“Ibid., p. 9.

[23]D H Reeher, *Survey of institutional Mechanisms Within the Federal Government for Cooperative Development of Military/Civilian Transport Aircraft* (Arlington, Va.: Analytic Services, Inc., April 1972), p. 4.

*'Ibid.

ADVANTAGES AND DISADVANTAGES OF JOINT DEVELOPMENT

One advantage of a joint development is that the development costs would be shared by the civil and military sectors, and the number of airplanes required by the military could be decreased by the number of CRAF airplanes purchased by air carriers and available to the military in case of emergency.

There are a number of potential disadvantages, including the constraints imposed by joint development, the penalties that would be incurred by both civil and military airplanes, and the difficulty in finding an organizational structure that permits their reconciliation. Certain features suitable to a military aircraft would have to be discarded, for example, because they are incompatible with a civil freighter. Also, each airplane would have to carry some weight which it would not carry if it were independently designed. This penalty weight reduces the payload and the profitability of the commercial version. MAC proposes to compensate for this through either a transfer payment at purchase, or an operating penalty compensation payment, or both.

Perhaps most important, it is not clear that there will be a sufficient market for the civil version or that it will be cost competitive with derivatives of future passenger aircraft. Finally, the advent of the CX program renders the timing of the ACMA program uncertain. The future of the ACMA program cannot be addressed until the details of the CX program have been agreed on.