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Cargo/Logistics Airlift System Study (CLASS)

Executive Summary

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INTRODUCTION

The one central question that attracts widespread interest is the question of the characteristics of the demand for air cargo both today and in the future. Of main interest is the quantity, i.e., "what is the size of the demand now and how large will the demand be in the future?" Following this, the items of major interest are the qualities that characterize the demand: transit time, frequency of service, safety, and those features that make air cargo profitable to the user. This report, based on work sponsored by NASA, addresses both of these basic air cargo questions: the size and the characteristics of the air cargo demand.

BACKGROUND

Lockheed has a fundamental interest in air cargo and always attempts to identify new trends and customer needs that are not being fully satisfied. In the late 1960's, working with shippers and airlines, Lockheed identified what was considered to be a significant future market resulting from more efficient and lower-cost air cargo transportation. Door-to-door service of large-volume shipments and reduced cargo handling were basic requirements. This system has not been realized for several reasons. One of these was the introduction of the widebody passenger aircraft. With this potential increase in belly hold lift, cargo agents began searching for ways to fill those bellies. It was found once again that the containers are too small for volume shipments, the passenger aircraft leave at the wrong time, and handling costs are still high. Finally, the airlines tried reducing the rates to near truck rates. But again, this did not substantially increase demand. These results have led to the belief in some quarters that reduced rates will not generate more demand; in other words air freight demand is inelastic to price.

Most shipping agents know that the belly capacity is only a by-product of airline passenger service whose total capacity is actually small compared with the demand he and his competitors could place on it. He also knows the law of supply and demand would come into effect about the time he is committed to extensive use of air transportation, hence increasing prices. While the shipper is interested in low rates, he will buy only long-term dedicated service capability, not a by-product. Lockheed's interest in finding ways to define this requirement more clearly led to the DOT-sponsored, industry-funded INTACT program, a prototype test of an intermodal air cargo system. The continued interest in the shipping community in the potential of intermodal air cargo operations, and the desire of NASA to identify the technology needed, led to the NASA-sponsored Cargo/Logistics Airlift System Study (CLASS). Thus, CLASS is the latest step in a series of tests and investigations that have a common theorem: dedicated air cargo operations, service, and equipment that meet the shipper's needs will create much higher demand than a by-product of passenger operations or operation of passenger aircraft modified for cargo.

The CLASS contract included the following tasks:

- o An analysis of the current air cargo system.
- o A case study of the users' need for a dedicated advanced air cargo system in 1990, including shippers, consignees, and surface transportation modes.
- o A 1990 air cargo demand forecast based on the results of the case studies.
- o An analysis of the advanced air cargo system using the 1990 demand forecast.
- o A comparison of the current and advanced air cargo systems.

The following sections summarize the findings of these tasks.

ANALYSIS OF CURRENT AIR CARGO SYSTEM

The current air cargo network is represented primarily by a system of scheduled trunk airlines, shown in Figure 1, which spans the majority of the world in mixed forms. The most common form, the belly holds of passenger aircraft, offers a widespread service for certain types of cargo. Another form, the modified freighter aircraft, appears less frequently although its geographical coverage is still quite substantial. Even with this type of total air cargo coverage, large differences have been noted in market penetration between areas and in routes, as well as in types of aircraft.

Because of air transportation's reputation for being a fast, high-cost, emergency mode of transportation, airfreight qualities are characterized by small size, high value, low density and perishability. This results in air transportation achieving only a miniscule penetration even among non-bulk commodities, although the relative values of the commodities are high compared to other non-bulk commodities.

The commodity characteristics also cause airfreight rates to be more expensive than those of other freight transportation modes. Except possibly at the minimum shipment size level and on certain U.S. domestic routes where surface less-than-truck-load rates have been employed for belly cargo, airfreight is almost always higher. In fact airfreight rates, including pick-up and delivery charges, are usually two to four times those of truck or

	ALL-CARGO SERVICE		COMBINATION
	SCHEDULED	NON-SCHEDULED	SCHEDULED
U. S. DOMESTIC			
11 TRUNKS	7	7	11
2 ALL-CARGO	2	2	-
20 LOCAL SERVICE AND OTHER	3	2	20
4 SUPPLEMENTAL	-	4	-
U. S. INTERNATIONAL			
10 TRUNKS	6	7	10
3 ALL-CARGO	3	3	-
6 SUPPLEMENTAL	-	6	-
NON-U. S. INTERNATIONAL (FREE WORLD)			
4 NORTH AMERICAN (NON-U. S.)	1	1	4
47 LATIN AND CARIBBEAN	12	17	46
41 EUROPEAN	26	21	39
15 MIDDLE EAST	4	4	14
32 AFRICAN	3	6	30
27 ASIAN AND PACIFIC	5	5	27

FIGURE 1. FREE WORLD AIR FREIGHT AIRLINES

rail as shown in Figure 2. On the other hand, air transportation has superior service over truck, rail, and ocean modes. This is found in both transit time and quality of handling, reflecting lower loss and damage claims. These advantages are more prominent for smaller shipment sizes, since surface modes are usually oriented toward larger volume shipments.

Cargo handling is another factor affecting air mode rates today. There are systems ranging from the sophisticated to systems based primarily on manual labor with little mechanical assistance. Indications are that the amount of air cargo business today simply does not justify an investment in costly facilities. In fact, the trend is toward the simpler loading system, except in cases where high volume and efficiency warrant automation to reduce indirect operating costs. An example of the latter is the Frankfurt airport, where the majority of the airfreight can be handled through a common facility. An example emphasizing the simplest system possible is Federal Express in Memphis, which operates a high-volume system using large amounts of manual labor in combination with a conveyor system.

The use of unit loading devices (ULD's) or containers is an attempt to simplify handling costs. Most carriers operating 737/DC-9 or larger freighters use some sort of container or contoured pallet for aircraft loading. However, a problem lies in the variety of types, along with the inconsistency of the handling interface throughout the entire system. Few, if any, air containers are considered intermodal with surface modes. As shown in Figure 3, only the 8 x 8 x 10 or 20-foot (2.4 x 2.4 x 3 or 6-meter) containers used on the Boeing 747 main deck bear any resemblance to containers used in surface shipping.

Recent events may change the present air cargo situation. On the domestic side, the scene has been set for removal of some important economic regulatory controls concerning route and price structure. This casts some uncertainty on the air cargo industry, and the outcome may be difficult to predict. On the international scene, air cargo service seems to be influenced increasingly by governmental interference in routes, schedules, and rates. Also important are the developing regulations on noise, smoke, etc. which sometime present obstacles to the air cargo system such as curfews and forced aircraft retirement schedules. These outside forces will have a significant impact on the air cargo industry into the future.

ADVANCED AIR CARGO SYSTEM CASE STUDIES

A 1990 Transportation Scenario and Advanced Intermodal Air Cargo System Concept booklet was used along with a questionnaire booklet to conduct Case Studies of leading companies in their fields. The questionnaire booklet contained questions on today's cargo system and future needs, along with a

	AIR	RAIL	TRUCK
SERVICE FACTORS			
Line Haul Time	1-2 days	5 days	6-8 days
Pick-up/Delivery (Total)	1-2 days	1-2 days	1-2 days
Carrier Scheduled Services Per Week	10(1)	7	UNK
Use of Containers	As noted(2)	Trailer (TOFC)	No
Door-To-Door Service	No	Yes (siding)	Yes
RATES PER POUND			
1. Non-Addictive Drugs			
500#	\$0.4745(4)	\$ -	\$0.1536
3,000#	0.3928(2)(5)	\$ -	\$0.1244
20,000#	\$0.2750(2)(6)	\$0.0766(3)	\$0.0885
2. Leather Luggage/Suitcases			
500#	\$0.4745(4)	\$ -	\$0.2569
3,000#	0.3928(2)(5)	\$ -	\$0.2038
20,000#	\$0.2750(2)(6)	\$0.0766(3)	\$0.1309

(1) Freighter services only for air carrier

(2) Container rate

(3) Rate for 30,000 lb trailer

(4) Pick-up & delivery charges of \$0.1115 to be added

(5) Pick-up & delivery charges of \$0.0710 to be added

(6) Pick-up & delivery charges of \$0.0388 to be added

FIGURE 2. COMPARISON OF TRANSPORTATION MODES - NEW YORK TO SAN FRANCISCO

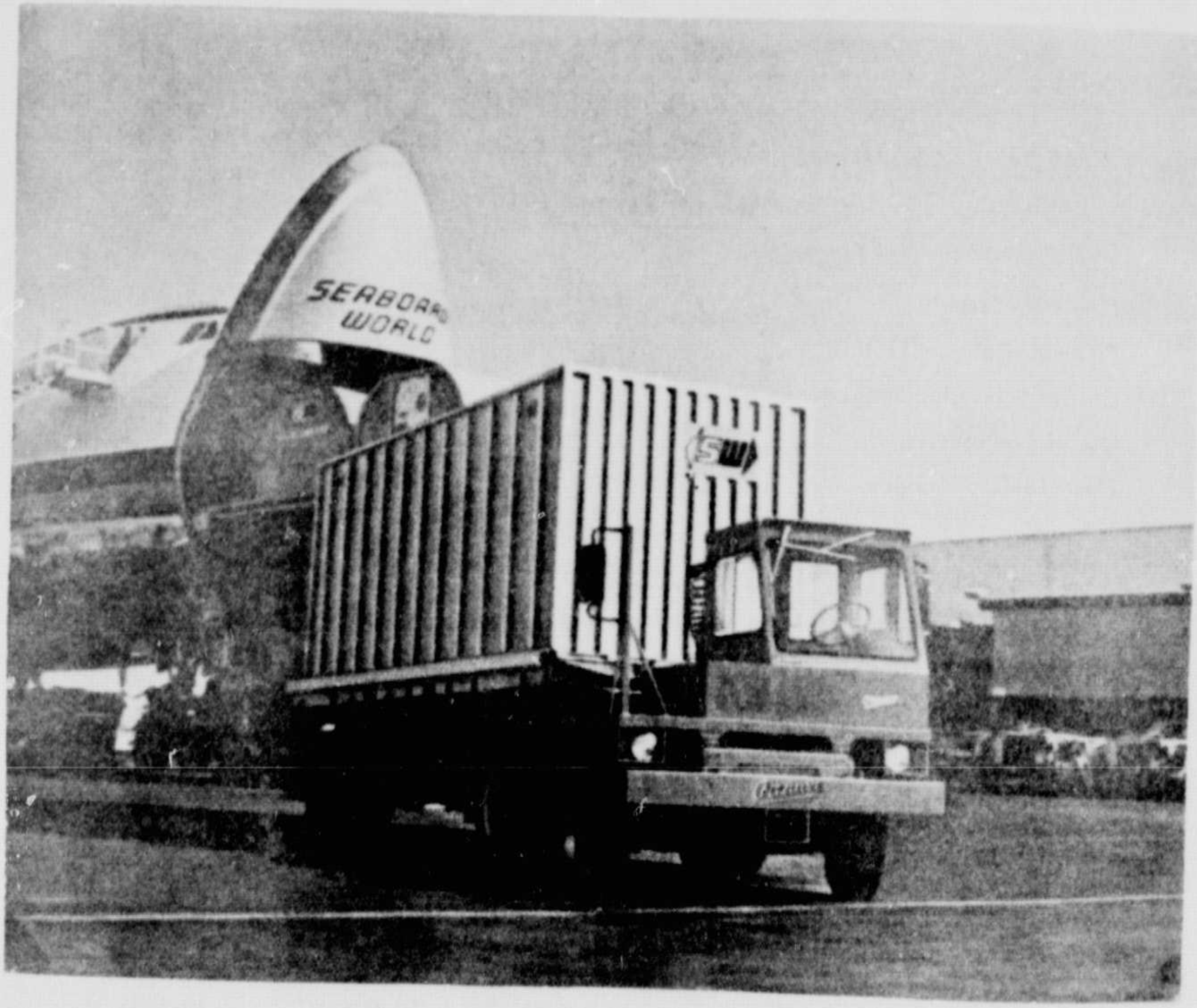

FIGURE 3. M-2 (8 x 8 x 20') CONTAINER/747F INTERFACE

space for comments and answers. The following assumptions were made in the concept booklet :

- o The Advanced Air Cargo System (AACS) will use an advanced-technology air freighter optimized for cargo carriage.
- o The AACS will provide coordinated door-to-door intermodal service in which the motor industry will perform connecting services between the air mode and shippers/consignees as well as connecting services with rail and water modes.
- o A single waybill will be used; single point of responsibility will be used; single point of responsibility will be assumed.
- o The cumulative effect of direct cost savings related to application of advanced design concepts, indirect cost savings for intermodal, containerized operations, and shared costs through the Civil Reserve Air Fleet Program is to offer the potential for significant reductions from current air freight rates.

The concept description and the questionnaire were provided to U.S. and European and Japanese companies. Sixty-two U.S. and eighteen overseas companies, shown in Figures 4 and 5, responded. As a follow-up action, a 2-to 4-hour interview was held with each company to cover any unanswered questions or to expand upon answers of particular interest. The companies were selected because of their prominence in industry groups, along with the broad spectrum of products and services covered, as shown in Figure 6. All are extensive users of current surface and airfreight transportation systems. With this cross-section of companies, a thorough knowledge of the shortcomings and capabilities of the system should emerge.

One aspect of the Case Studies involved air freight decision criteria. Questions were asked concerning the reasons why shippers would use the AACS. Figure 7 illustrates the results of this evaluation. The rankings received by each factor are indicated by the relative heights of the six bars. First-place rankings were assigned a value of 100, second place 80, and so on down to zero for sixth place. The composite ranking for each factor is underlined above the histogram. As shown transit time is seen to be more important, followed by competitive rate. This is not surprising, since most of today's airfreight service is used for exactly these reasons. However, the current use of air cargo is influenced little by modest changes in airfreight rate.

A further analysis was made between rates and service, a function of transit time. The analysis included 81 different commodities with a separate importance ranking from 0 to 100 given to freight rate and service for each commodity. The values were then compared, resulting in Figure 8. Twenty-two percent of the commodities were ranked equal in importance, as indicated by the shaded bar in the middle. The percentages of commodities for which rate

UNITED-STATES BASED

Allis Chalmers Corporation
Aluminum Company of America
AMF, Incorporated
Baxter Travenol Laboratories
Bechtel Corporation
Black & Decker Mfg., Co.
Bud Antle, Inc.
J. I. Case Company
Caterpillar Tractor Co.
Celanese Corporation
Clark Equipment Co.
D.A.B. Industries, Inc.
E. I. DuPont De Nemours & Co.
Eastm n Kodak Co.
Eaton Corporation
Ex-Cell-O Corporation
The R. T. French Company
Food Fair Stores, Inc.
Ford Motor Company
General Motors Corporation
Gold Kist, Inc.
The Goodyear Tire & Rubber Co.
Grower-Shipper Vegetable Association
Harnischfeger Corporation
Hercules, Inc.
International Business Machines
Jantzen, Inc.
Main Rubber International
McCormick & Co., Inc.
Monfort of Colorado
J. C. Penney Co., Inc.
RAC Corporation
Safeway Stores, Inc.
Samsonite
Scott Paper Company
Texas Instruments, Inc.
Westinghouse Electric Corp.
Whirlpool Corporation

EUROPEAN BASED

British Airways
CFM International
EMI Limited
ICI Overseas Freight
Philips
Plessey Co., Ltd
Regie Renault
Thompson-CSF

JAPANESE BASED

Canon, Inc.
Fujitsu Limited
C. Itoh & Co., Ltd.
Japan Air Lines
Matsushita Electrical Industrial Co. Ltd.
Nissan Motor Co., Ltd.
Sharp Corporation
Sony Corporation
Tohto Suisan K. K.

FIGURE 4. CASE STUDY SHIPPERS AND CONSIGNEES

Motor Carriers - General Freight

- Arkansas - Best Freight
- BN Transport, Inc.
- Chippewa Motor Freight, Inc.
- Consolidated Freightways Corp.
- Courier-Newsom Express, Inc.
- The Davidson Transfer & Storage Co.
- Gateway Transportation Co., Inc
- IML Freight, Inc.
- Neuendorf Transportation Co.
- Overnite Transportation Co.
- Pacific Intermountain Express Co.
- Rio Grande Motor Way, Inc.
- Shay's Service, Inc.
- United Parcel Service
- Wilson Trucking Corporation
- Yellow Freight System

Motor Carriers - Special Commodities

- A. J. Metler Hauling & Rigging, Inc.

Motor Carriers - Household Goods

- Allied Van Lines
- North American Van Lines

Airfreight Forwarders

- Emery Air Freight Corp.

Railroads

- Burlington Northern, Inc.
- Southern Railway System

Ocean Carriers

- Sea-Land Service, Inc.
- United States Lines, Inc.

Airlines

- British Airways*
- Japan Air Lines*

* All other carriers U. S. based.

FIGURE 5. CASE STUDY CARRIERS

PRODUCTS

Aircraft Engines
Computers
Electronic Components
Household Appliances
- Kitchen Equipment
- Laundry Equipment
- Radio & Television
- Recorders

Industrial Instrumentation
Lighting Equipment
Food Products Machinery
Construction Equipment
Power Tools
Office Machines
Marine Food Products
Motor Vehicles
Motor Vehicle Parts
Office Machines
- Calculators
- Copiers

Optical Products
Photographic Equipment
Telecommunications Equipment
Home Laundry Equipment
Motor Vehicles
Auto/Truck Parts
Engine Bearings
Tires
Fresh Produce
Lettuce
Fresh Poultry
Fresh Meat
Perishable Foodstuffs
Spices
Synthetic Textile Fiber
Wearing Apparel
Photographic Products
Pigments
Intravenous Solutions
Luggage
Coiled Aluminum Sheet
Electrical Motors
Electronic Components

SERVICES

Air Carrier
Freight Forwarder
Trading Company

FIGURE 6. CASE STUDY PRODUCTS AND SERVICES

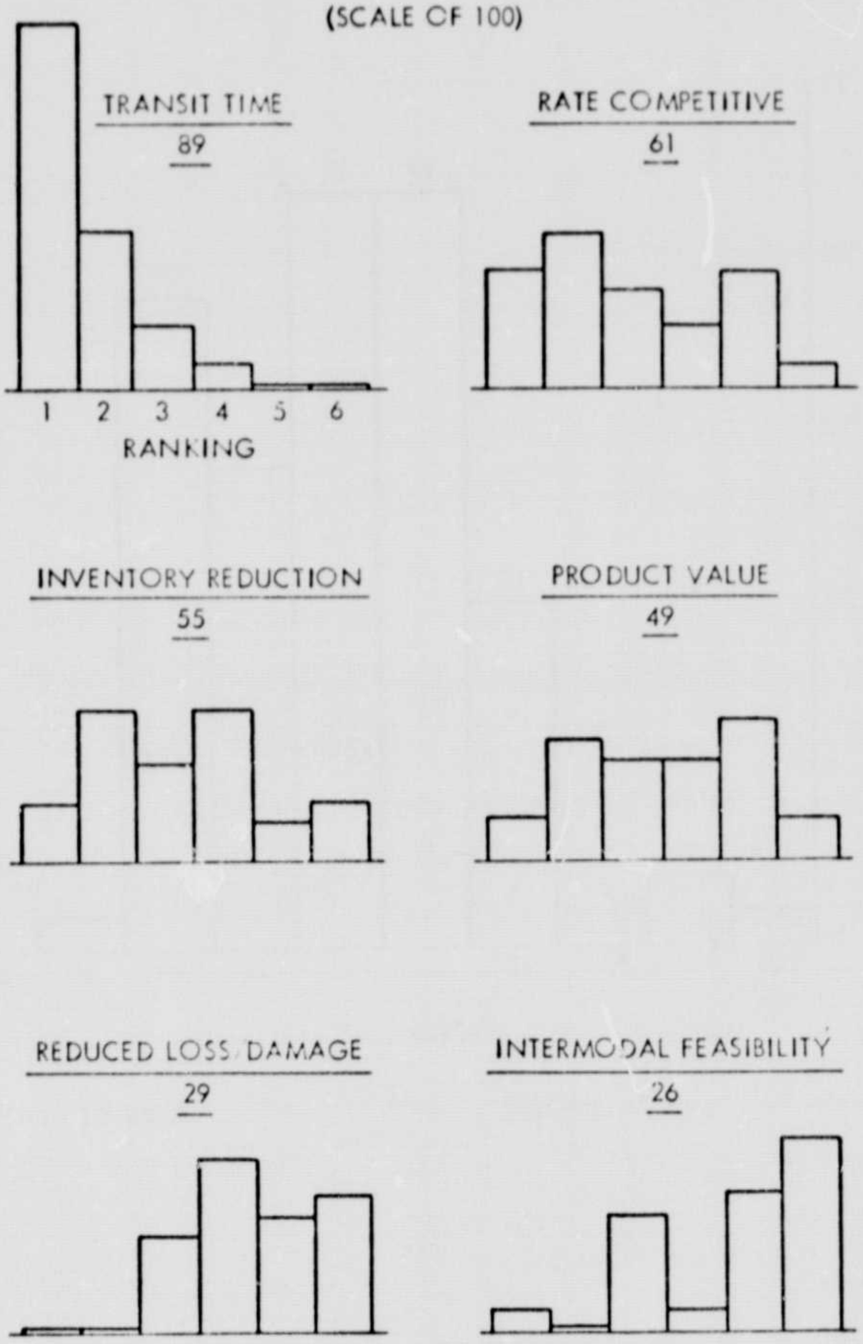

FIGURE 7. AIR FREIGHT DECISION CRITERIA

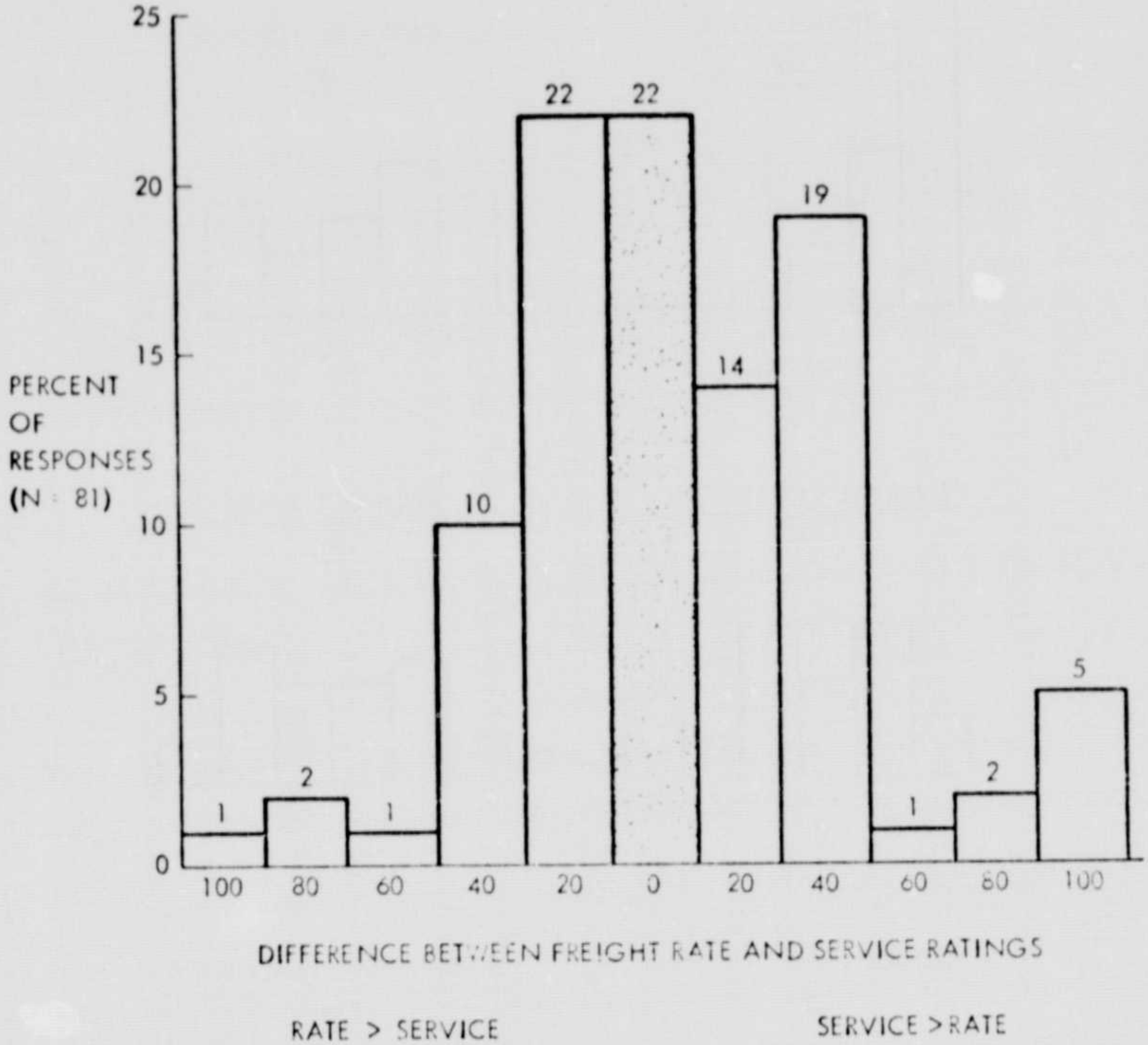

FIGURE 8. REASONS FOR INCREASED AIR SHIPMENT WITH AACS

was more important than service are shown to the left. On the right, service was more important than rate.

Another analysis was made to explore the relationship between the usage of the AACS and a 45 percent reduction in today's airfreight rates. With the assumption that the AACS would result in a reduction in airfreight rates, companies questioned responded with a favorable prediction of increased air freight usage for both international and domestic shipments. This prediction may be examined more closely in Figure 9, where it is shown that 78 percent of North American operations, along with 88 percent of operations for the rest of the world predict occasional to regular routine use. The remaining companies estimate no use or emergency use of the AACS. Comparing the data in another analysis, Figures 10 and 11 result. Figure 10 shows an 8 to 1 increase in demand if the AACS were available with rates at a level 45 percent below those for today's conventional airfreight. When the company responses were weighted by the company's annual sales, the demand increase for North America operations was 12 to 1, as shown in Figure 11.

Also analyzed was the future airfreight potential for the large group of manufactured products covered by the 1972 Transportation Census. In 1972 the actual air penetration amounted to only 0.06 percent by weight. From the Case Study input it was found that, if the AACS had been operational in 1972, the air penetration would have been 0.66 percent, or 11 times greater. This would have amounted to almost 9.7 million tons (8.73 million metric tons) in 1972. This trend also holds true for motor carriers participating in the study. Motor carriers estimated that the 11 percent of their freight, which moves over 800 miles (1288 km), would have used the AACS as a substitute service if it had been operational in 1976. When extrapolated to 1990 this penetration would have resulted in over 5.7 million tons annually (5.13 million metric tons). Similar figures for ocean carriers potential use of AACS were 5.6 percent, and 4.4 million tons (3.96 million metric tons) in 1990. The major reason for this was the cargo rate reductions envisioned by the AACS. Also, the demand can be separated into two categories: the high-value products which already have high air penetration, and a group of lower-values products which now move by air only on an emergency basis. The latter group, including office machines, household appliances, repair parts, and marine food products, can be expected to move by AACS in tonnages 16 to 24 times as great as are currently moving by air.

From international Case Studies of European and Japanese companies, most European companies interviewed were found to export 10 to 20 percent of their product by air today with 25 to 30 percent of those shipments by charter. If today's air freight rates were reduced by 45 percent, these companies estimate they would increase their total exports to 55 to 80 percent by air. This means a regular routine use of air freight as opposed to today's occasional emergency use. Estimated future export market growth varied from 6 to 15 percent through 1990 for the companies surveyed in Europe. Case Studies of Japanese companies indicated that they currently export 10 to 30 percent of their commodities by air. With a 45 percent reduction in today's air freight rates, these companies estimated that their exports by air freight would

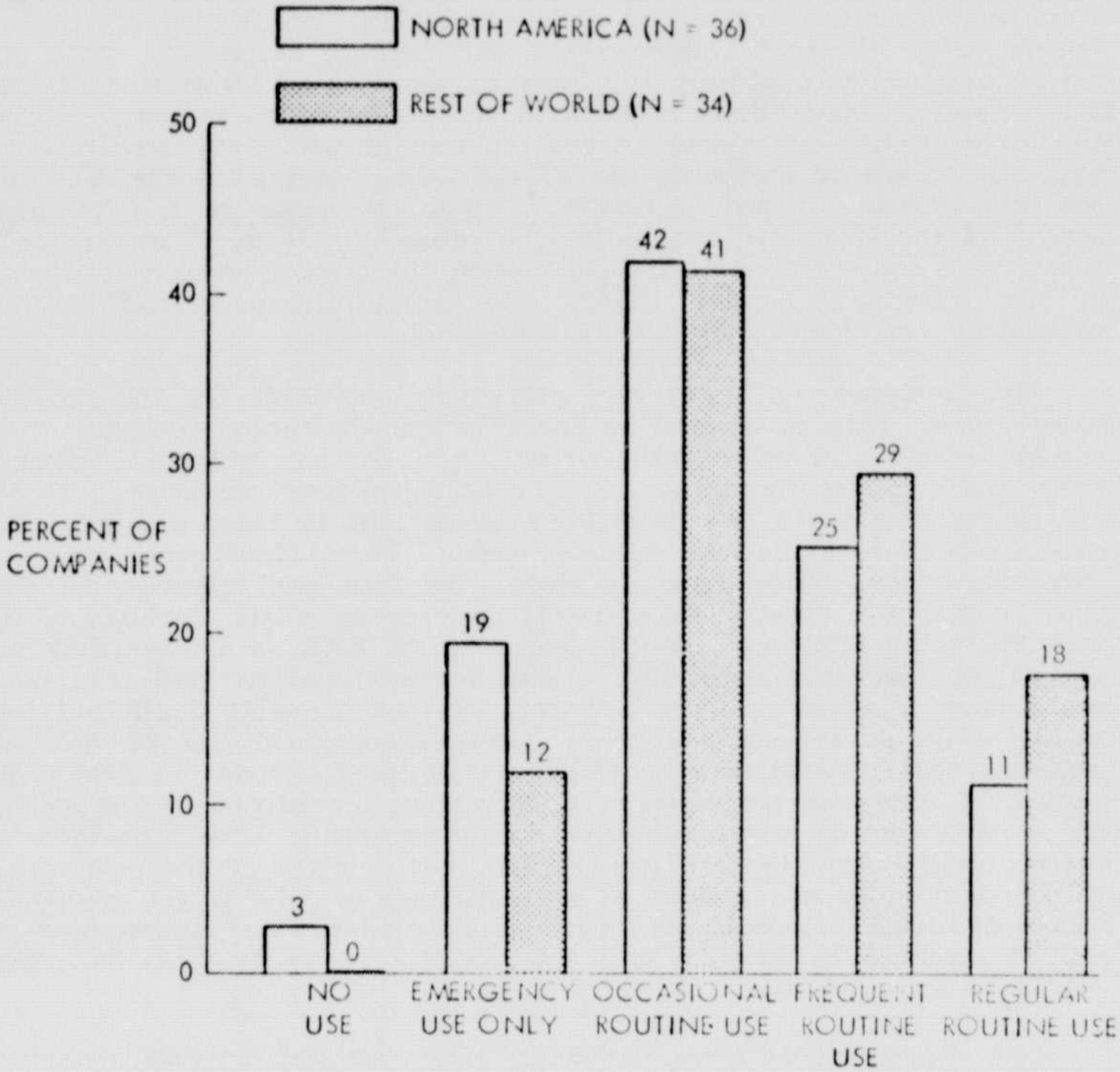

FIGURE 9. PROBABLE USAGE OF ADVANCED AIR CARGO SYSTEM

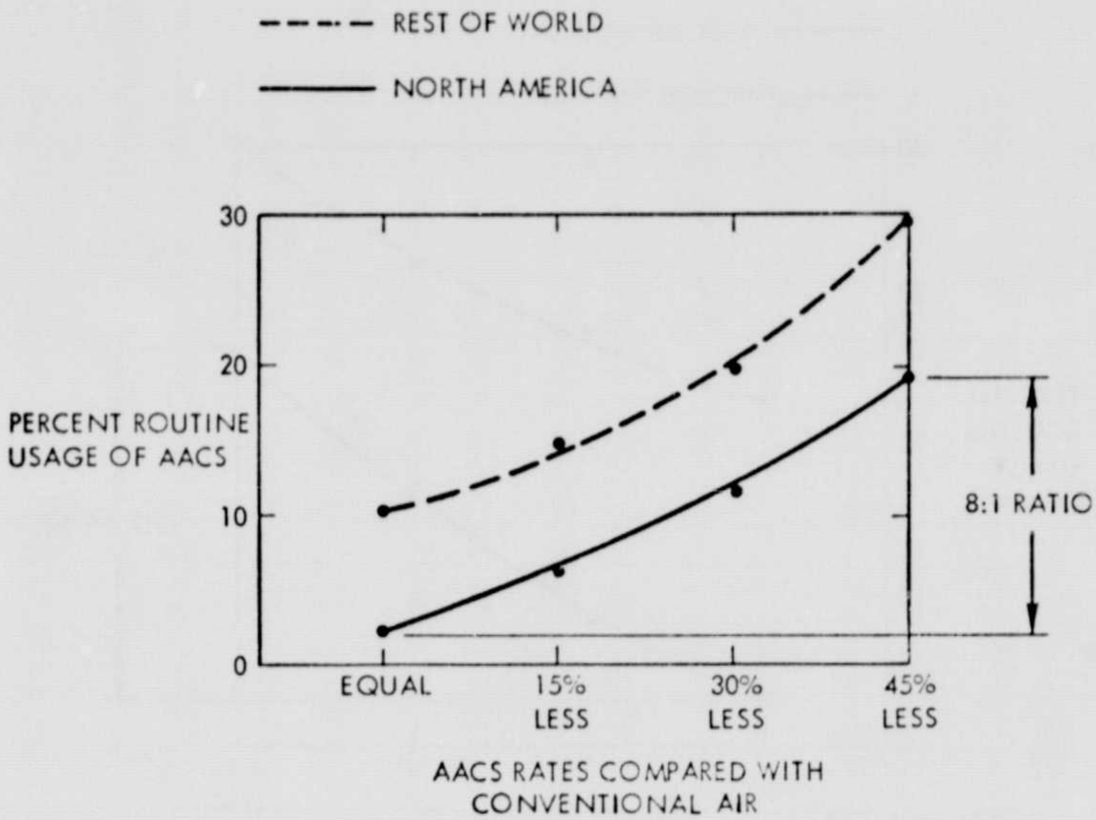

FIGURE 10. PROBABLE ROUTINE USAGE OF ADVANCED AIR CARGO SYSTEM BY U. S. COMPANIES

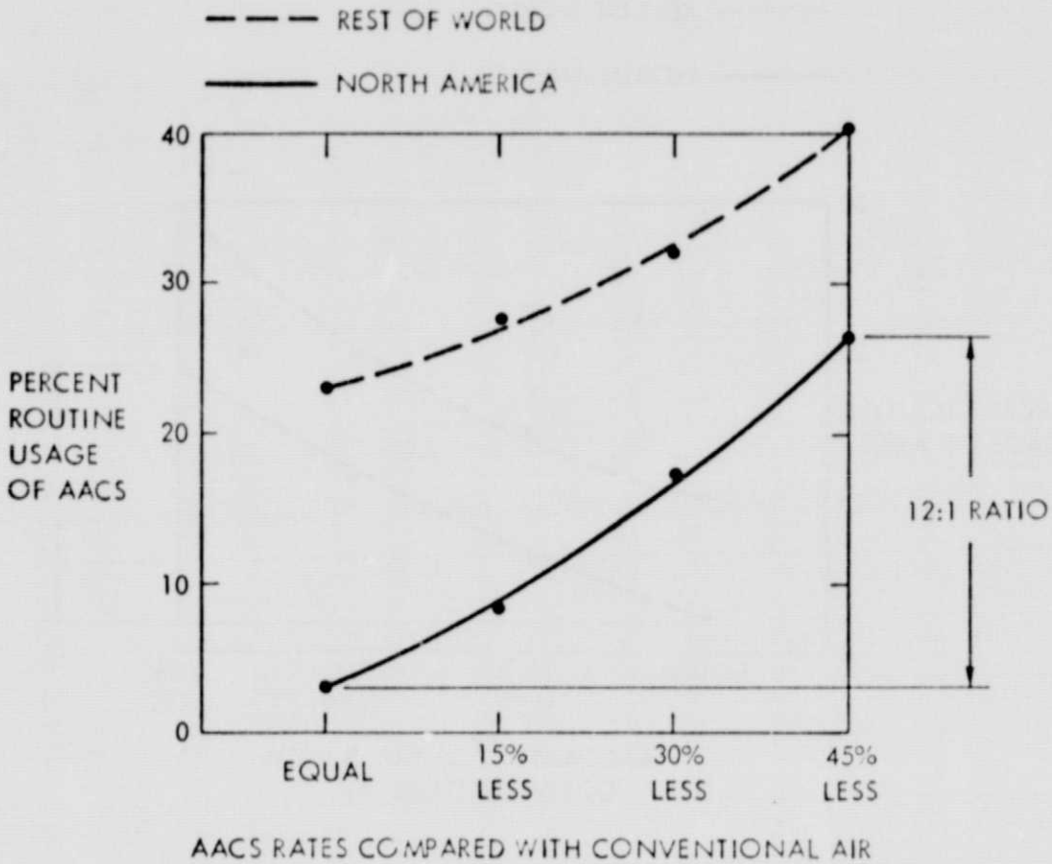

FIGURE 11. PROBABLE ROUTINE USAGE OF ADVANCED AIR CARGO SYSTEM WITH VALUES WEIGHTED BY ANNUAL SALES

increase to 35 to 75 percent. The official air cargo forecast from Japan's Ministry of Transport projects a growth in exports of over 15 percent per year from 1978 to 1988, with a 16 percent per year growth in imports.

Other important factors found in the Case Studies were a need for some type of door-to-door intermodal capability in the system along with through rates, and a master waybill. The need for this appeared stronger on the international market than the U.S. domestic market. If this type of system, the AACS, were available many new markets would be open. Among these are U.S. to Europe, Asia, and the Mideast shipments of fresh produce, fresh meat, canned food, and drinks; U.S. to China, and Southeast Asia in pharmaceuticals and wearing apparel; U.S. to South America in machinery components; and U.S. to foreign in foodstuffs.

The Case Study participants expressed their dissatisfaction with present air containers. Complaints were strong concerning small size, shape, and incompatibility with existing ground transportation equipment and manufacturer/shipper facility. Concensus was expressed for large containers, larger than the M-2 container, of greater than 8-foot (2.4-meter) heights, and sizes up to "larger than today's highway limits." Compatibility with ground transportation systems and shipper facilities was expected.

As an indication of the desire for an AACS, participants responses concerning the timing of the need for AACS are shown in Figure 12. Over one-fifth of the companies state an immediate need, one-half would like to have the AACS by 1985, and over four-fifths want it by 1990.

ADVANCED AIR CARGO SYSTEM DEMAND FORECAST

A market demand forecast for the Advanced Air Cargo System was made from the data collected in the Case Studies, along with information from previously derived industry forecasts and data. The derived forecasts represent an aggregation of commodities and trade routes to provide the total demand forecast. The results of the forecast are in two parts, U.S. Domestic and Free-World International.

In analyzing the U.S. Domestic results, a number of forecasts were used. Using the Department of Transportation forecast, "Trends and Choices," the total All Modes forecast was derived as shown by the upper line in Figure 13. According to this analysis, the total cargo transported for all commodities, all modes, over all distances will amount to 8 billion tons (7.2 billion metric tons) in 1990. In Figure 14, a belly forecast from the Air Transport Association's (ATA) publication of January 1978 shows an air cargo belly forecast amounting to 6 million tons (5.4 million metric tons) for 1990 in the bottom line. To achieve this, the ATA belly cargo forecast requires a doubling of belly hold load factor by 1990. Also in Figure 14 is the AACS Case Study forecast of air cargo demand which shows a 1972 demand of 9.7

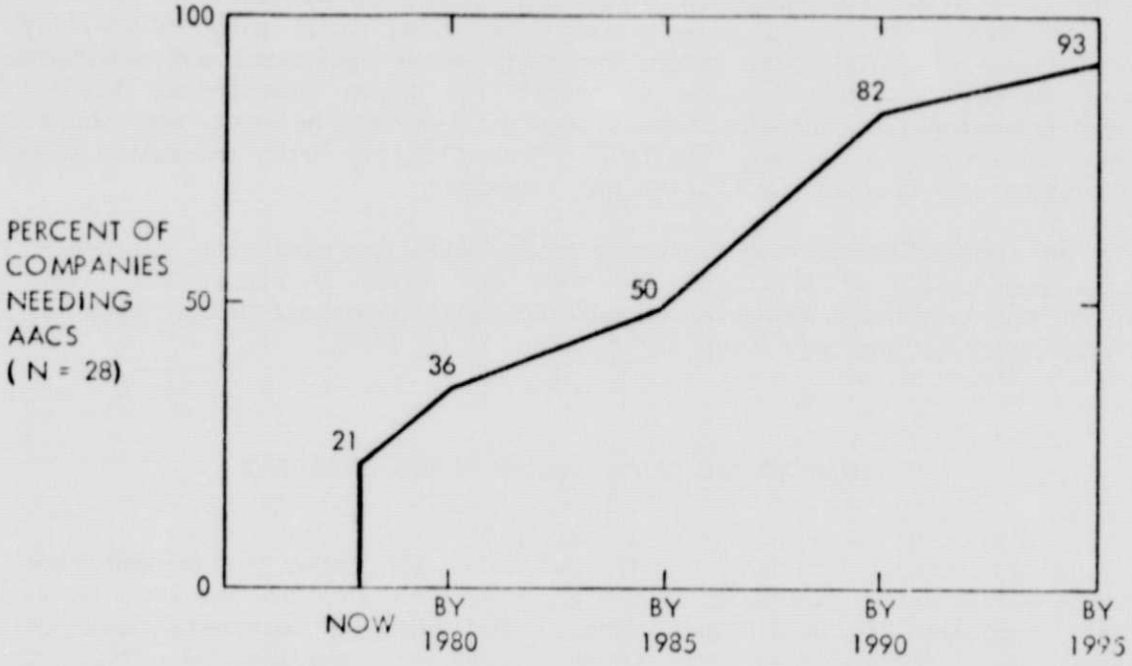

FIGURE 12. TIMING OF NEED FOR AACS

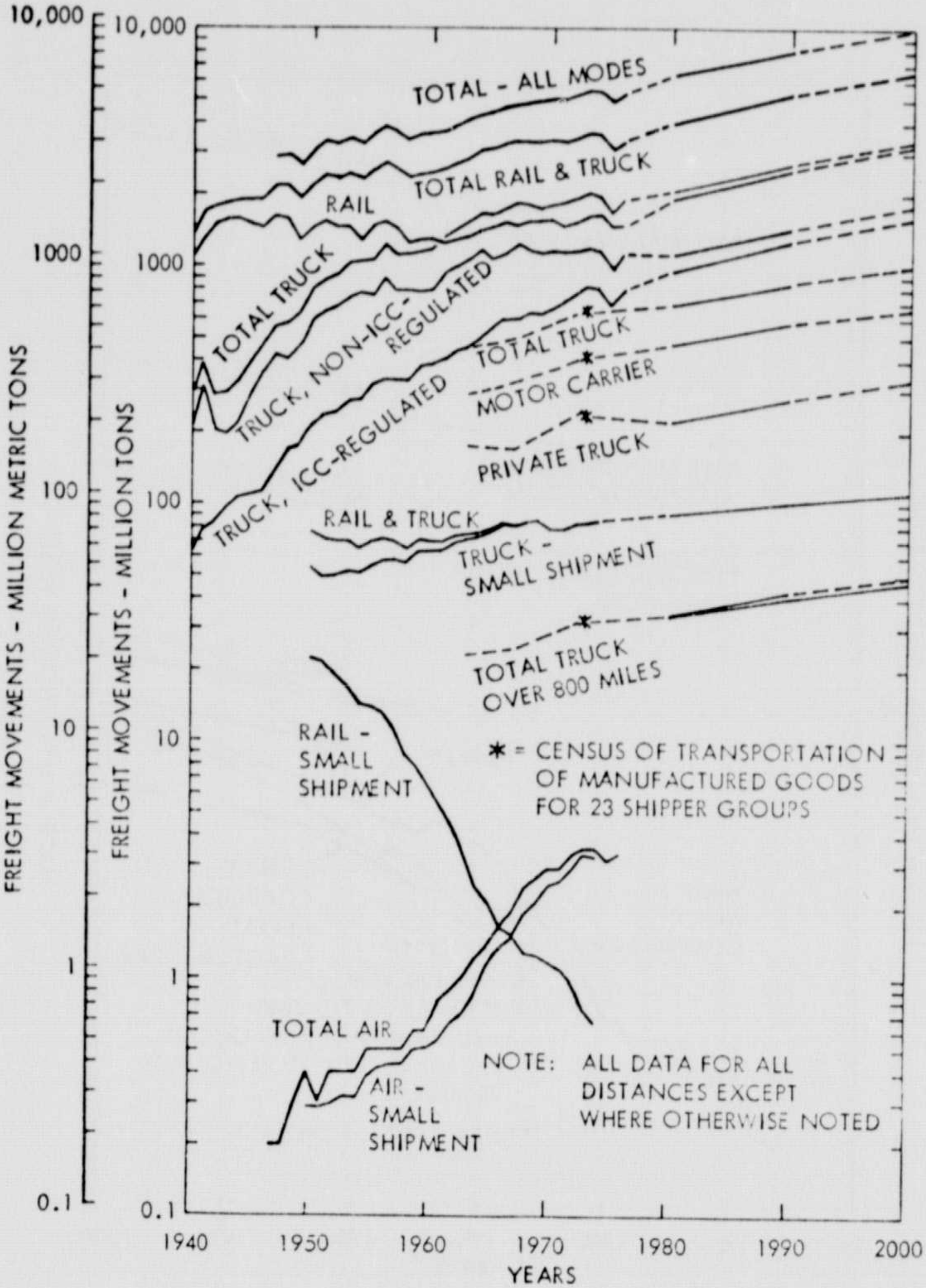

FIGURE 13. U. S. DOMESTIC FREIGHT MOVEMENTS IN TONS - VERSUS YEARS

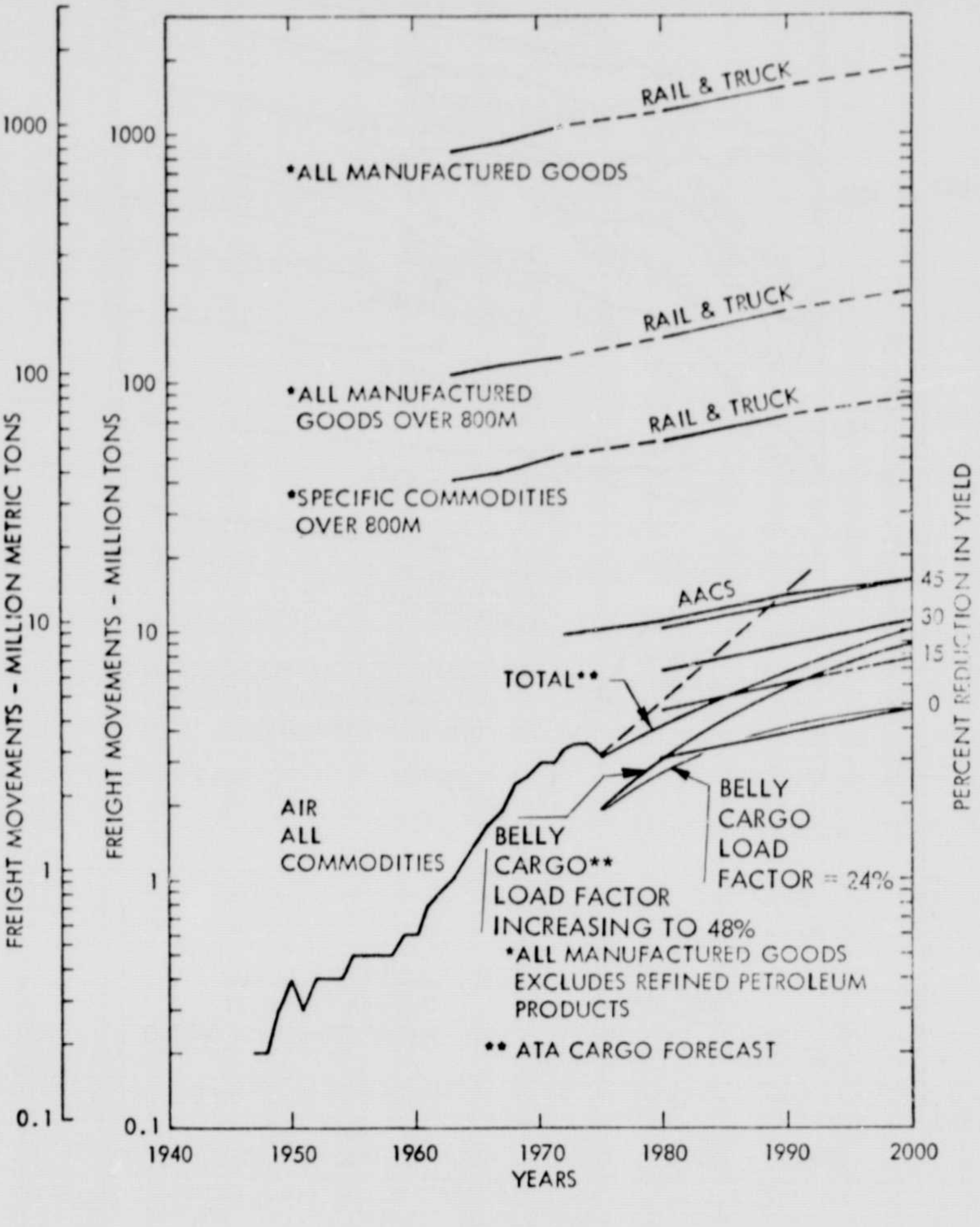

FIGURE 14. U. S. DOMESTIC MANUFACTURED GOODS MOVEMENT IN TONS VERSUS YEARS

million tons (8.73 million metric tons) and a 1990 demand of 14 million tons (12.6 million metric tons). This forecast was made using correlation analysis with the 1972 Census of Transportation, along with the Case Studies , at a 45 percent rate reduction. The analysis leads to a penetration of the Advanced Air Cargo System potential market demand of 19 percent, which when the AACS is fully operable, is postulated to remain constant. The AACS potential market is defined as the manufactured goods moving by truck or rail more than 800 miles (1288 km) and generating revenues more than 3 cents per ton mile (4.32 cents per metric ton km). The assumption made here is that if an AACS were introduced during or before 1990 this system would replace the present-day all-cargo system. Therefore, the cargo demand forecast by ATA as all-cargo, would be available to the new AACS.

Examining the growth of the advanced air cargo system more carefully it is seen that with the AACS in operation the total air cargo market demand would grow to 14 million tons (12.6 million metric tons) by 1990. The market demand available to the AACS in 1990 is the difference between 14 million tons (12.6 million metric tons) and the ATA belly forecast of 6 million tons (5.4 million metric tons), or 8 million tons (7.2 million metric tons). The forecast is based on the total transportation demand, which is in turn based on the forecasted growth of the U.S. economy and represents the domestic low market demand forecast. Another issue to consider beside the economy is the ATA belly forecast, which is predicted to double by the year 2000 without the AACS. The effect of the existence of the AACS on belly loads was not evaluated. However, if belly load factors do not double, but remain the same, then an additional 3 million tons (2.7 million metric tons) would be available for the advanced system. This is a 40 percent increase over the 8 million tons (7.2 million metric tons) discussed previously or a total of 11.2 million tons (10.0 million metric tons) and represents the high domestic market demand forecast. The upper and lower boundaries of the domestic forecast are summarized below.

Domestic Air Cargo Demand

	1980		1990		2000	
	Million Tons	Million Metric Tons	Million Tons	Million Metric Tons	Million Tons	Million Metric Tons
Lower Boundary	8	7.2	8	7.2	7	6.3
Upper Boundry	8.2	7.4	10	9	11.2	10

The factor of air penetration, as influenced by yield, was also examined. Air cargo yield, which is the resulting revenue per ton mile representing the averaging of rates, has declined from 65 cents per ton mile (1976 dollars) (93.6 cents per metric ton km) in 1947 to 32 cents per ton mile (46 cents per metric ton km) in 1976. It was postulated by Boeing that airlines could remain profitable in the future with improved equipment if yield in current dollars remained constant. So with 5 percent per year inflation the constant dollar yield would continue to decline at 5 percent per year. Also established was the fact that as the constant dollar yield declined, air penetration increased. Using this relationship Figure 14 shows the potential growth of freight movements for 0 to 45 percent reduction in yield. Each yield reduction line represents a constant line of air penetration. Thus the growth over time is related to the overall growth in transportation demand. The point at which each yield reduction line crosses the dashed line indicates the timing when the reduction in yield might be achieved based on historical trend of yield and demand.

From Figure 14, three things are apparent. The first is that in order that the ATA belly forecast be achieved, a 15 percent reduction in yield by 1991 is required. The second is that the dotted line extending from the air cargo historical data represents the projected timing in the reductions in yield for the system and shows that by extrapolating from previous trends, the demand of 14 million tons (12.6 million metric tons) is feasible by 1988. Finally, at a 45 percent reduction in rate or yield, a very close correlation is seen between the airfreight market projected for the AACS by the Case Study results, and the airfreight market projected on the basis of historical rate elasticity trend data. These are characteristics of the U.S. domestic analysis.

Another set of data was necessary to derive the Free World International Forecast. The Free World demand for the AACS was derived through analysis of Organization for Economic Cooperation and Development (OECD) foreign trade data. The demand forecast also incorporated input from the Maritime Administration's (MarAd) long-term forecast, along with analysis of Department of Commerce (DOC) total U.S. Foreign trade data. The basic data were broken up into major world regions in order to simplify it from the individual trade flows of trading partners. The commodity data were also aggregated to simplify output to the 3-digit level of commodity classifications, from 4- and 5-digit levels. At the 3-digit level there were 180 commodity descriptions. The commodities were grouped into bulk and non-bulk commodities based on current seaborne levels of containerization found in analysis of U.S. international trade flows by the Maritime Administration. These OECD data, reduced to 6000 time series, and were forecasted to the year 2000 based on regression of the historical trends of 1961 through 1975. This resulted in a 3.0 percent-per-year growth rate in seaborne containerized trade. By applying the U.S. Flag Carrier Case Study results of 5.6 percent penetration of seaborne containerized trade to this OECD data forecast, the low forecast for the AACS is obtained.

The growth rates from MarAd long-term seaborne trade forecast were used to establish an AACS high forecast through the year 2000. The MarAd long-term forecast shows a total of 745 million tons (671 million metric tons) in 1990 and 916 million tons (824 million metric tons) in the year 2000 for U.S. seaborne imports. For seaborne exports, the forecast shows 459 million tons (413 million metric tons) in 1990 and 675 million tons (608 million metric tons) in the year 2000. Of these, the combined air-penetrable imports and exports amounted to 2.8 percent in 1975, 3.4 percent in 1990, and 4.2 percent in the year 2000. This results in an overall growth rate of 5.0 percent per year for the total air penetrable tonnage. This higher growth rate of 5 percent per year was applied to the last historical data point for the OECD data, 1975. The high forecast was combined with the 10 percent penetration of seaborne containerized trade obtained from the International Case Studies to obtain the high forecast for the AACS.

A separate and independently developed Lockheed forecast of ICAO carrier air cargo is introduced for comparative purposes with the conventional forecast derived from the OECD data incorporating air penetration data from U.S. Department of Commerce Foreign Trade Data.

The results of these forecasts are shown in Figure 15, where a conventional air cargo forecast has been established by the lower curve of the graph through the year 2000. There are no data available from either IATA or the OECD forecast that would identify what percentage of current conventional air cargo goes in the bellies of passenger aircraft or by all-cargo aircraft. The lower solid curve represents the conventional air cargo system and assumes today's type of operation with derivative aircraft, e.g. 747F's, functioning during the post-1990 period. Therefore, the AACS generated air cargo demand is in addition to the conventional air cargo forecast. The conventional forecast was derived from OECD Data incorporating air penetration data from Department of Commerce U.S. Foreign Trade data. No analysis was made to determine to what extent the AACS would penetrate the current conventional air cargo market. The solid middle curve derived from OECD Series C data, represents a growth rate of approximately 3 percent per year. These curves reflect a 5.6 percent penetration of the seaborne containerized tonnage established through the Case Studies as the low demand forecase for the AACS. Figure 15 shows a 4-million ton (3.6-million metric ton) increase in demand for the AACS low forecast over the conventional forecast for 1990 and a 5.2-million ton (4.7-million metric ton) increase by the year 2000. The solid upper curve is based on a 5 percent growth rate derived from the MarAd long-term forecast and represents a 10 percent average seaborne penetration as indicated by the International Case Studies. Here an increase in demand of 9.7 million tons (8.7 million metric tons) is projected for the AACS high over the conventional forecast for 1990 and a 15-million ton (13.5-million metric ton) increase by 2000. These increases in demand are in all cases in addition to the growth of current conventional air cargo. The dashed lines represent the ICAO carriers overall traffic forecast, with the lower ICAO curve (labeled belly) representing the total traffic carried in passenger related operations, and the area between these two representing the traffic for all-cargo operations. The results suggest that a pent-up demand currently exists for the AACS operation and is forecast to continue through the late 1980's for the low AACS demand and through the early 1990's, with the high AACS demand. After this period, the AACS demand would appear to challenge the all-cargo traffic share forecast for ICAO carriers. However, based on the results of the Case Studies, the AACS and its resulting economics will be needed to provide the required capa-

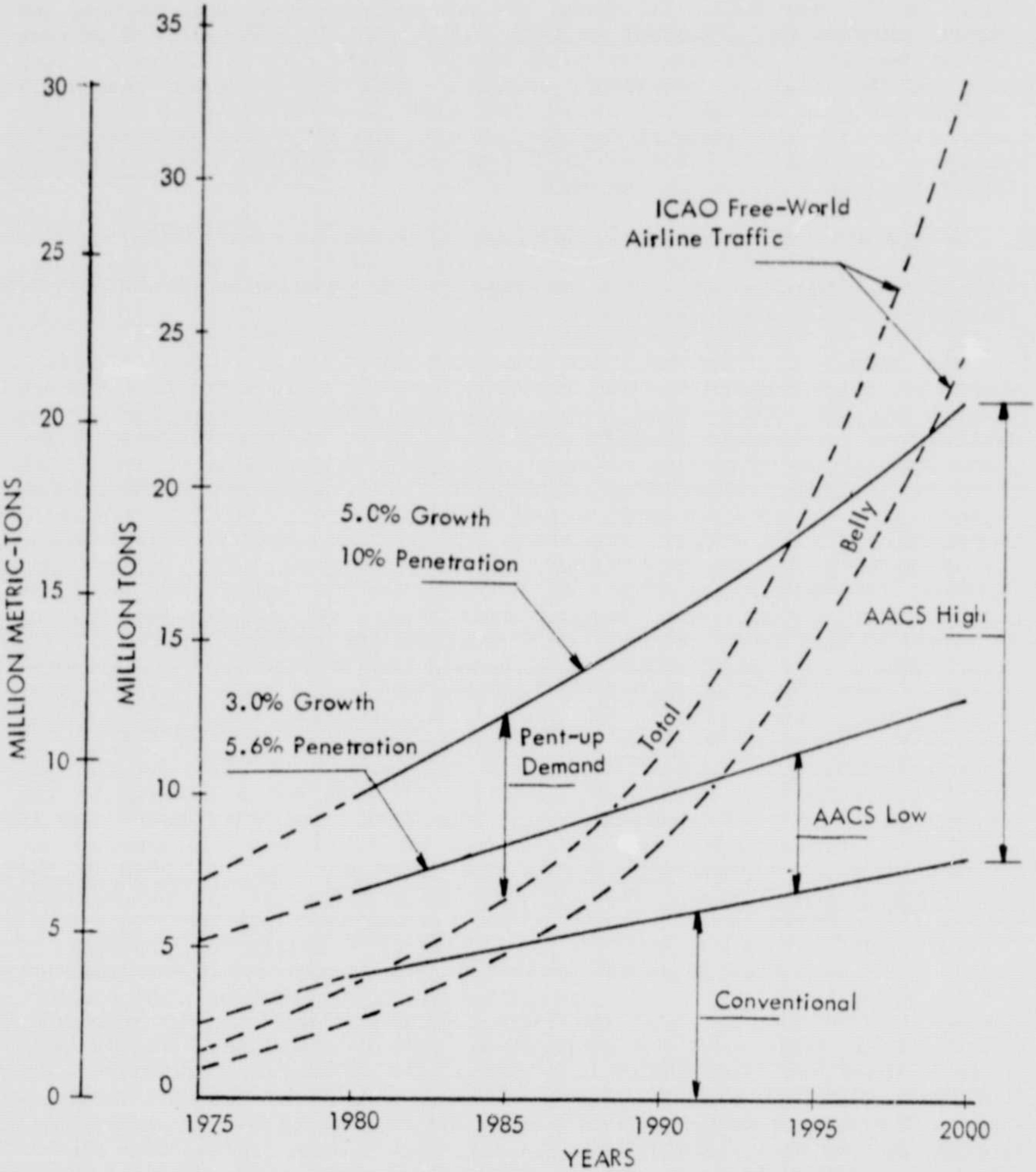

FIGURE 15. FREE-WORLD AIR CARGO DEMAND

city. The upper and lower boundaries of the free-world air cargo demand forecast are summarized below.

Free-World Air Cargo Demand

	1980		1990		2000	
	Million Tons	Million Metric Tons	Million Tons	Million Metric Tons	Million Tons	Million Metric Tons
Lower Boundary	2.8	2.5	4.0	3.6	5.2	4.6
Upper Boundary	5.8	5.2	9.7	8.7	14.9	13.4

AIR CARGO SYSTEMS ANALYSIS

The relationships between air cargo volume and air cargo rates, cost of operations, service frequencies, and operator profitability were investigated. These factors are interdependent, and a closed-loop analysis system consisting of a set of computer programs, shown in Figure 16, was used to control the variables systematically. The analytical model characterizes one day's operation of a representative air cargo airline. It provides a solution from which the optimum operating characteristics (those that maximize airline operator earnings) can be identified. The results are presented as trends and sensitivities over a range of values or between boundaries.

Future air cargo rate reductions of up to 45 percent projected by NASA are predicated on advanced technology aircraft with lower direct operating costs, intermodal operations resulting in reduced indirect operating cost, and less handling cost associated with larger shipment sizes inherent in intermodal, large-volume operations.

Based on the projected price-demand relationship derived from the Case Studies, airline operator's marginal earnings remain positive with rate reductions up to 45 percent. As shown in Figure 17, total earnings as a function of air cargo volume, or demand, were obtained from the composite runs for four sets of conditions: 1977 air cargo rates and three reductions (-15, -30, and -45 percent) shown by the straight lines.

On each earnings line we identified the potential volume of cargo corresponding to the price-elasticity of demand. In other words, for each price, 1977 rates, -15, -30, and -45 percent from 1977 rates, there is a specific potential volume of cargo demand. The curve that connects these four points is the airlines total earnings with increasing volume. The slope of this

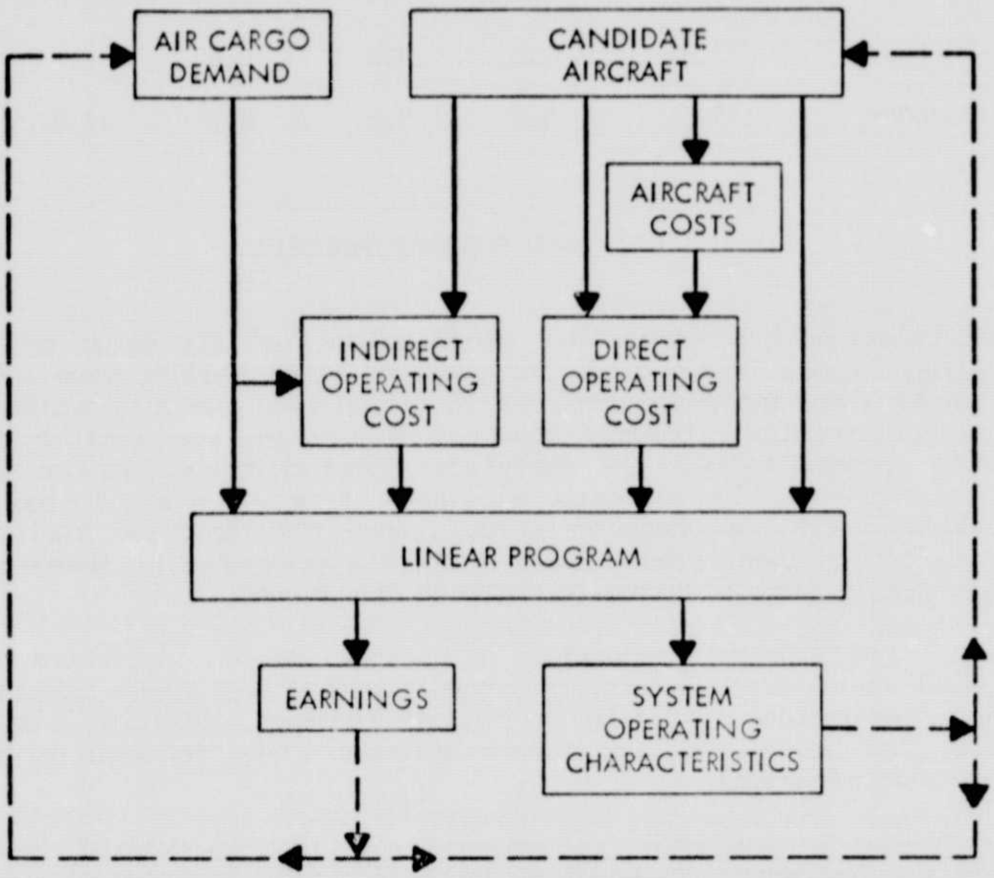

FIGURE 16. AIR CARGO ANALYSIS SYSTEM

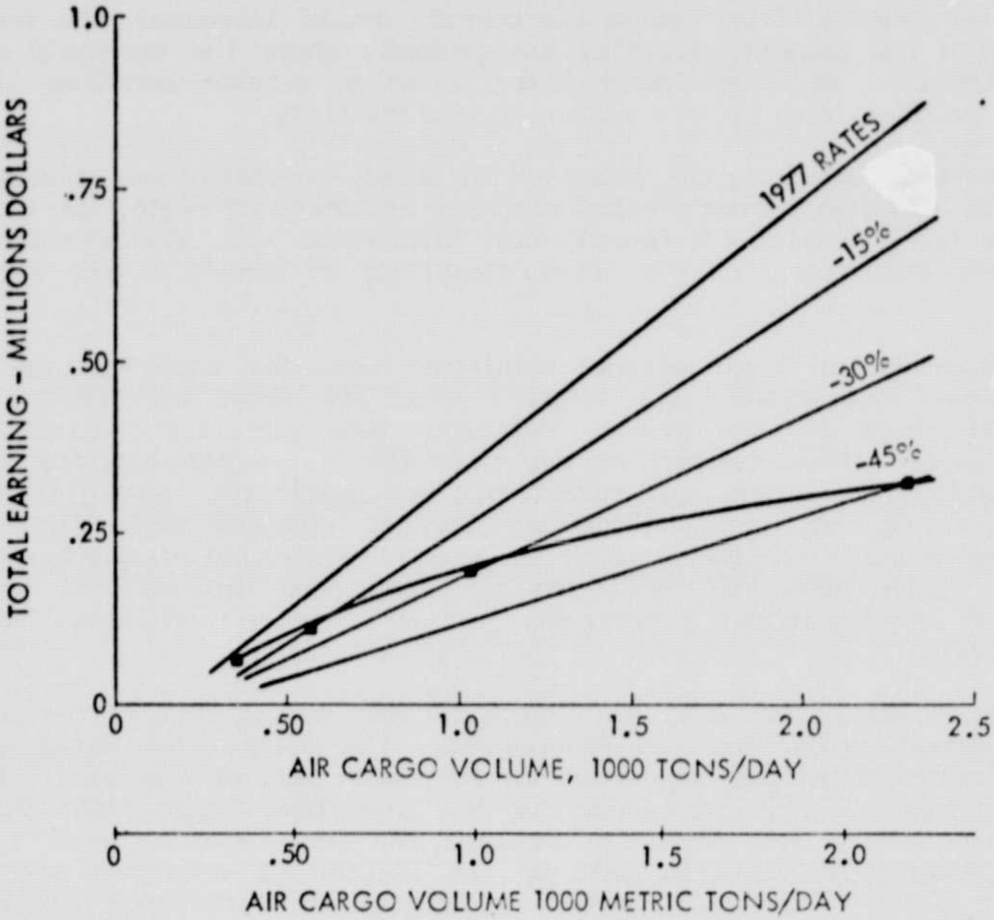

FIGURE 17. TOTAL EARNINGS-REPRESENTATIVE AIRLINE

curve is the marginal earnings or marginal profitability, i.e., how much profit was provided by the last ton of cargo. At some point, increased volume will not produce increased earnings; the marginal profitability at that point is zero. Beyond that point, operating cost would have to be reduced to retain positive marginal profitability.

Increased frequency of service to satisfy service sensitive demand reduces potential profitability, but as the overall demand increases, the frequencies, even with the largest aircraft, are probably above the threshold of service requirements. Efficient scheduling can solve service-sensitive, low-volume market problems with minimum effect on profitability.

Figure 18 indicates the reduction in direct operating cost associated with advanced technology aircraft and with the economies of scale, the two combined provide the potential for overall cost reductions that are commensurate with the rate reductions in the price elasticity of demand of the forecast for 1990.

Comparison of total airport-to-airport cost for three options involving technology, operations, and shipment size are shown in Figure 19, where aircraft costs are the direct operating costs plus all indirect operating costs except those related to cargo handling: cargo traffice servicing, reservations and sales, and advertising and publicity. Moving from the left to the center bar reflects the benefits of advanced technology and large shipment sizes, and indicates a 15 percent reduction in airport-to-airport costs. Going from the middle to the right-hand bar reflects the further benefits of intermodal operations, and indicates an additional 18 percent reductions.

Airport-to-airport costs in Figure 19 are used to develop the comparative door-to-door costs shown in Figure 20. The airport-to-airport costs are converted to costs per ton, shown on the lower part of each bar in Figure 20. Pick-up and delivery costs and, for the intermodal Truck Load (TL) option, container costs, are added to complete the door-to-door costs. The total door-to-door cost benefits felt by the shipper or consignee are about 15 percent savings due to advanced technology and increased shipment size, another 21 percent due to intermodality, and another 25 percent if he can ship in truck load lots.

The computer model (linear program) determines the optimum fleet mix that produces maximum operator earnings. The fleet mix is then used to determine the projected quantity of aircraft required. The aircraft fleet for optimum <u>domestic</u> operations indicate a requirement for about 65 new 330,000-pound (150,000 kg) payload intermodal freighters by 1990 for the upper boundary of the domestic forecast.

The upper boundary of the <u>international</u> air cargo demand forecast results in requirements for over 200 similar 330,000 pound (150,000 kg) payload aircraft. Thus, the combined requirements for a basic aircraft of this size including both domestic and international versions in 1990 could be over 270. By the year 2000, the requirement for this size aircraft exceeds 480.

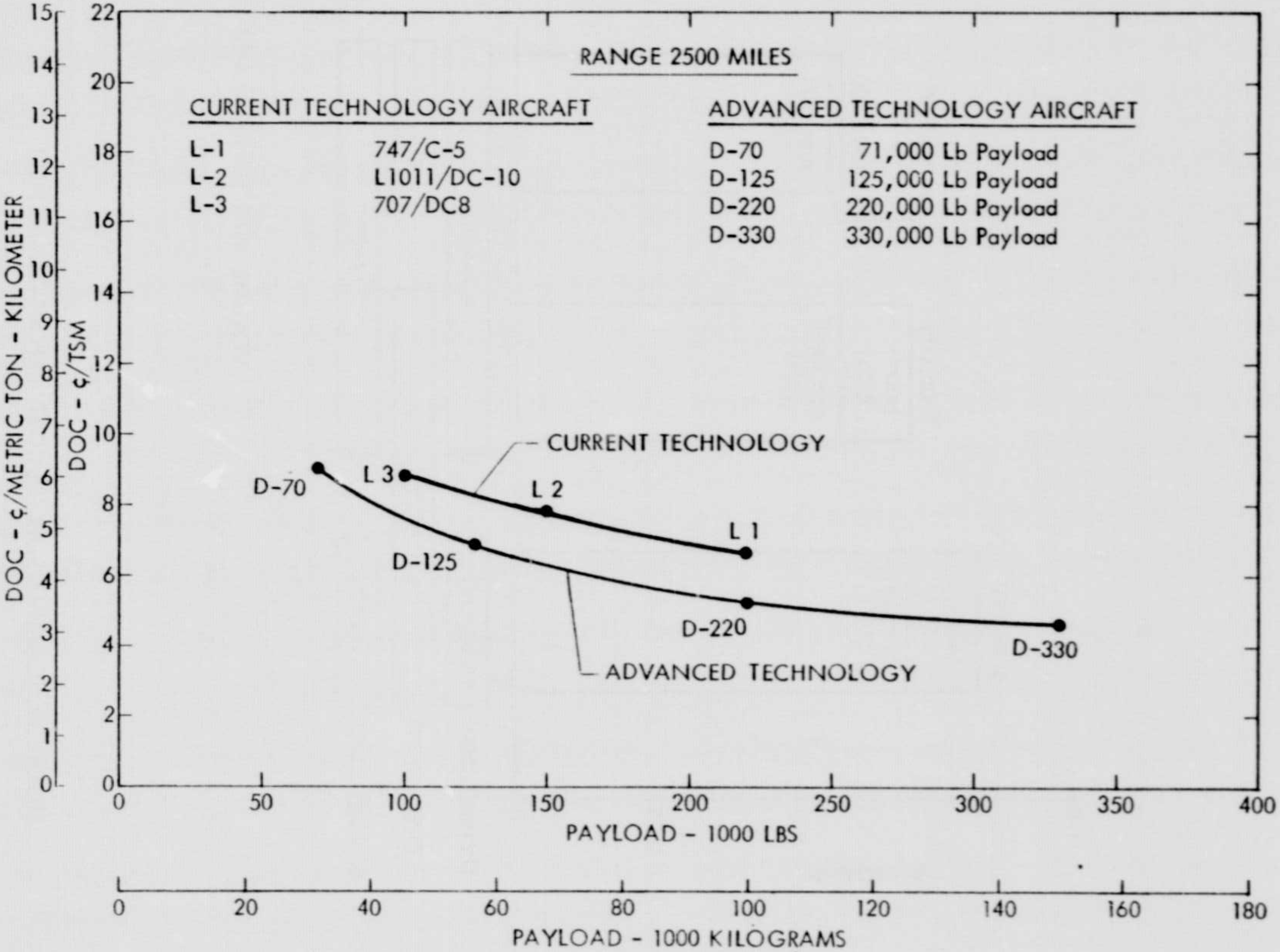

FIGURE 18. TECHNOLOGY COMPARISON DOC

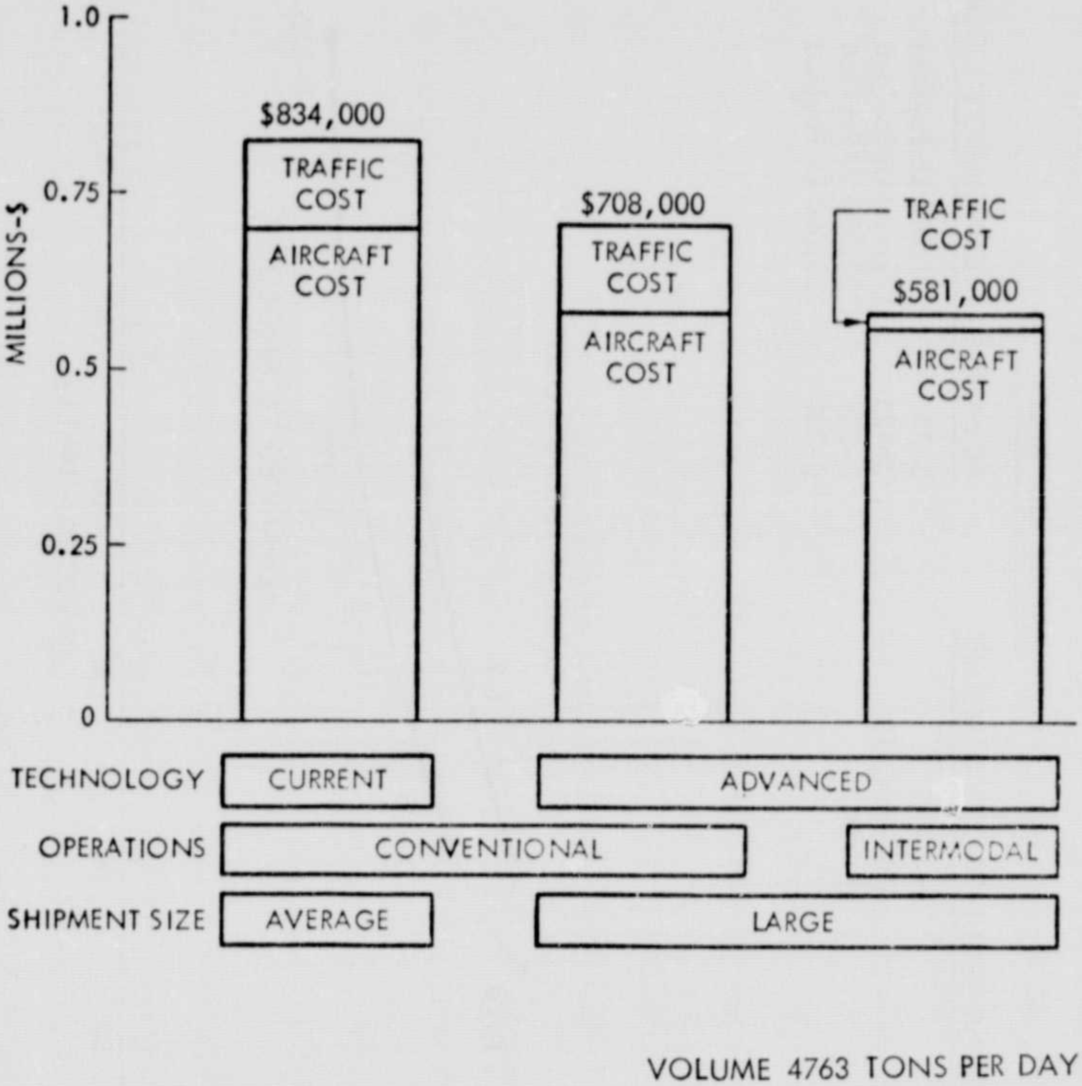

FIGURE 19. COMPARISON OF, COST AIRPORT-TO-AIRPORT

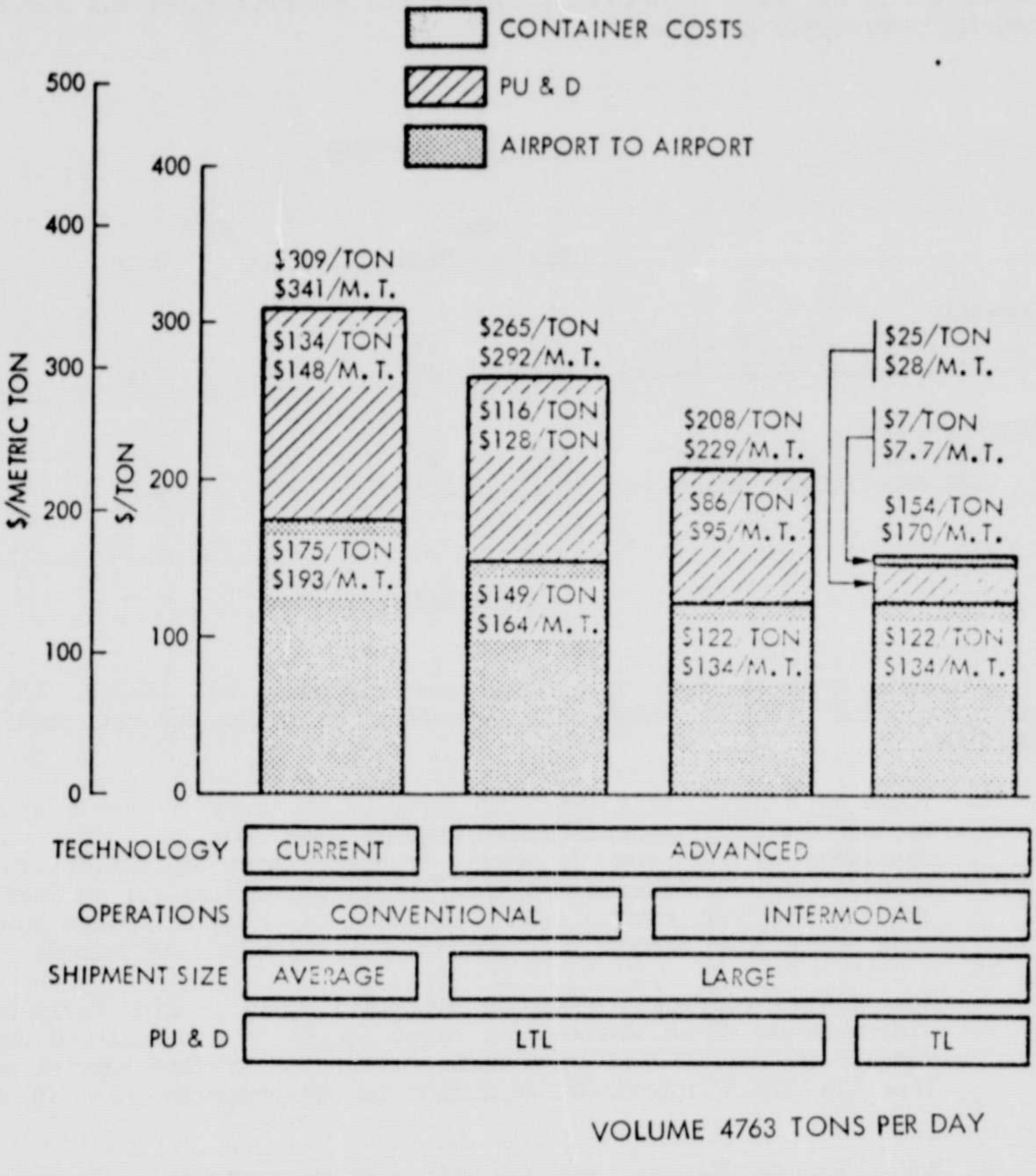

FIGURE 20. COMPARISON OF COST, DOOR-TO-DOOR

In addition to the 330,000 pound (150,000 kg) payload aircraft, there is a transient requirement for smaller aircraft. The analysis indicates requirements for 70,000 pound (32,000 kg) payload aircraft in domestic service an both 125,000 (57,000 kg) and 220,000 (100,000 kg) pound payload aircraft in the international operations. After 1990, the need for these aircraft decreases as the market continues to grow. The aircraft fleet mix and quanity required are summarized below.

Aircraft Requirements

	1990		2000	
	Low	High	Low	High
Domestic				
70,000 Lb.(32,000 kilos)	34	54	40	31
330,000 Lb.(150,000 kilos)	51	65	42	74
International				
125,000 (57,000 kilos)	105	45	64	39
330,000 (150,000 kilos)	61	213	104	408

CONCLUSIONS

Although a great deal more work and analyses are needed, the NASA Cargo/Logistics Airlift study has provided us with several preliminary findings:

1. There is a need for a dedicated advanced air cargo system as indicated by the industry/transportation company Case Studies. The shipper/consignee is interested primarily in lower rates and faster, reliable service. He is definite and specific in his desire for an intermodal container and/or trailer with dimensions of today's surface equipment that he can load himself as a partial load or a full truckload.

   The surface carriers -- truck, rail, and ocean -- also indicate considerable use of an advanced air cargo system as a substitute service, similar to that of rail piggyback. Again the surface carrier desires that his future intermodal equipment be accommodated directly by the aircraft.

2. Based on the domestic and international Case Studies, the air cargo demand forecast shows that the introduction of an integrated advanced air cargo system would in fact stimulate the market place to an extent that development of a next-generation dedicated air freighter is indicated. At this time, it appears that the international market for the

aircraft is approximately 3 to 4 times as great as for the U.S. domestic.

3. The economic analysis of the air cargo market indicates that, with the application of advanced technology and more efficient intermodal handling of the freight, door-to-door air freight reductions of 45 percent, from today's rates, may be achievable.

The results of the CLASS analysis certainly indicate that, by 1990, there will be a need for dedicated all-cargo airplane and its supporting system. Since this analysis was conducted for only one point in time, 1990, and since the trends beyond 1990 show an increasing need for such a system, Lockheed suggests that the study be continued to: (1) cover an extended time frame, and (2) make in-depth investigation to accomplish:

- o More definitive causal definitions of future market volume.
- o Further development of demand elasticities.
- o Establishment of cost factors in product distribution
- o Development of performance and design guidelines for the 1990 airfreighter and the supporting ground support system.

This continuing effort would permit better definition of the type and degree of technology development needed by providing more explicit data pertaining to airplane payload, fleet mix and size, and optimum level of applied technology. These areas will change with time and as the world markets grow. An extended analysis of this type will also provide a much better insight into the timing for technology development and the corresponding funding requirements.