# Jumbo Jet Aircraft and the Impact They Will Have on Transportation

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•THIS paper is an information-type presentation and all matters discussed are unclassified. It is intended to point out several impacts that will be brought about in the field of transportation with the advent of extremely large subsonic jets.

The order of presentation will be, first, the Lockheed C-5A, and second, the Boeing 747.

## THE LOCKHEED C-5A

The C-5A (Fig. 1) is being developed by Lockheed Aircraft Corporation, Marietta, Georgia, for the Air Force. It is similar to its successful predecessor, the C-141, now in operation by Air Force Military Airlift Command, including wing sweep and T-tail, with a gross weight well over twice that of the C-141. This aircraft will be the world's largest when it flies in June 1968, according to present schedules. Each of its four engines will produce 41,000 lb of thrust and will be larger than the average private plane.

### Comparison of the C-5A and C-130

Figure 2 will help orient you as to the size of the C-5A. This plan view of the C-130 on a football field makes it easy to visualize its actual size. The field and plane outline are drawn to scale. In Figure 3, the C-5A is the larger outline, and you can readily note that its nose extends beyond the 10-yd line of this regulation football field. The tail extends beyond the 10-yd line at the other end of the field, and enough of the wing tip extends beyond the side to house two football teams as if it were a roof.

### General Arrangement

Figure 4 shows that the empennage is approximately seven and one-half stories high. If the pilot were to walk from his seat to a platform at this height, he would be on top of a three-story building.

### Significant Features

In order to provide the necessary flexibility in its role of strategic deployment, the C-5A must be able to operate into support area airfields. These are defined as having load-bearing capability of CBR-4 soil overlaid with M-8 matting, or a gross CBR rating of 9. Figure 5 shows the significant features of the C-5A.

The C-5A's unique high-flotation landing gear permits 130 passes on such fields before repair to runways is necessary. The principal design features which yield high flotation are the large number of low-pressure tires, wide tire spacing and the gear geometry which result in four main landing gear tires running in the same track.

The truck-bed loading height and visor nose, as well as the cargo opening, will be covered in more detail later.

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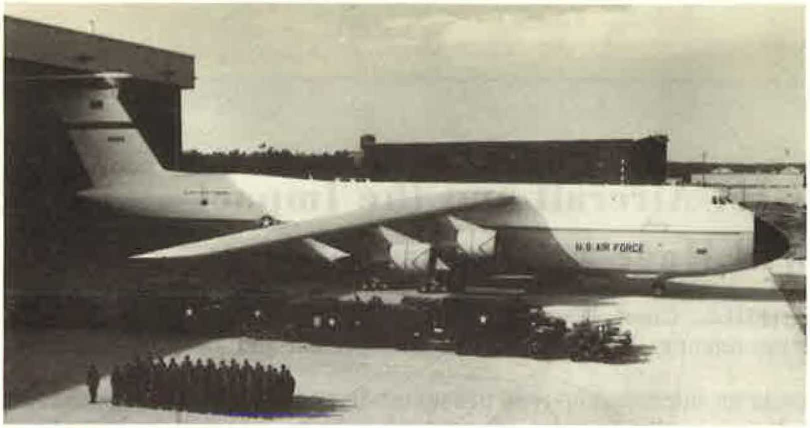

Figure 1. The Lockheed C-5A.

C 130

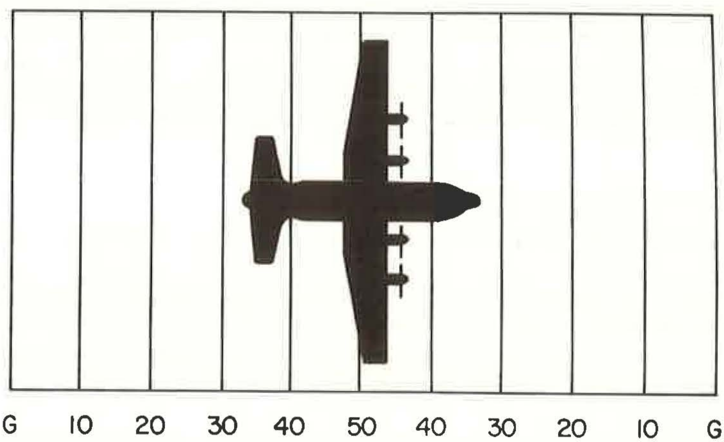


Figure 2. Plan view of the C-130 on a football field.

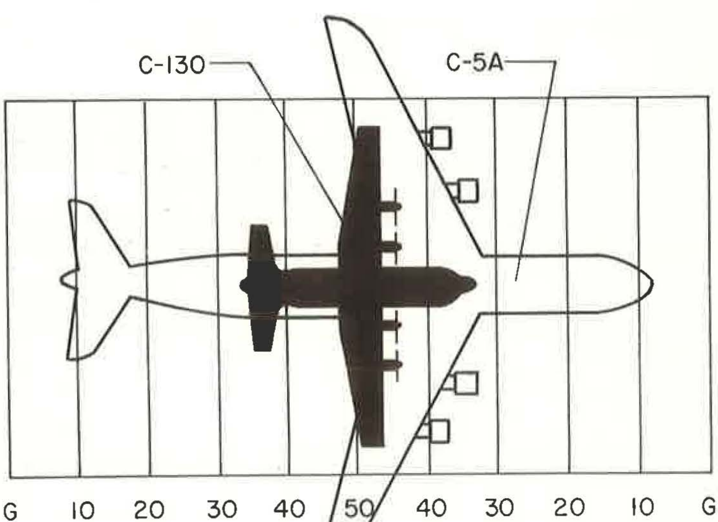


Figure 3. The C-5A compared to the C-130.

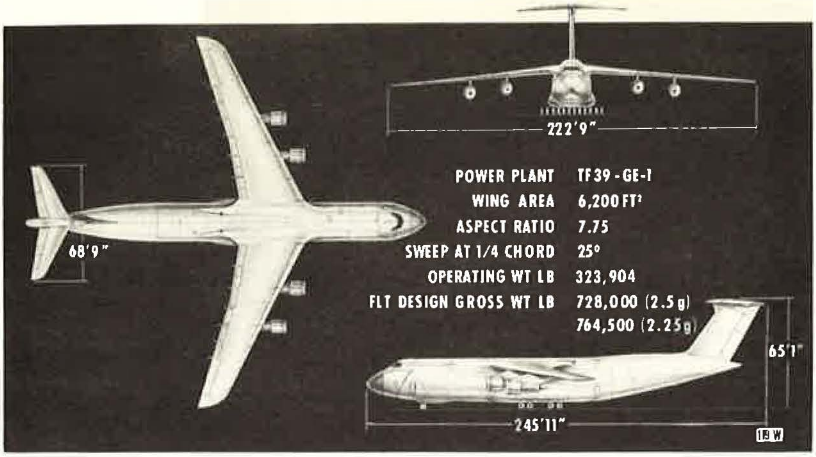


Figure 4. General arrangement of the C-5A.

**HIGH FLOTATION LANDING GEAR**

**TRUCK BED HEIGHT LOADING**

**VISOR NOSE**

**FULL WIDTH FWD AND AFT CARGO OPENINGS**

**VEHICLE CREWS ACCOMPANY THEIR EQUIPMENT**

Figure 5. Significant features, C-5A.

| | | |
|---|---|---|
| WEIGHTS | BASIC MISSION | 712,000 LB |
| | FLIGHT DESIGN - 2.5G | 728,000 LB |
| | FLIGHT DESIGN - 2.25G | 764,500 LB |
| CARGO COMPARTMENT | LENGTH (INCL RAMPS) | 144.6 FT |
| | WIDTH | 19.0 FT |
| | HEIGHT | 13.5 FT |
| | TOTAL VOLUME | 34,734 CU FT |
| PERSONNEL CAPACITY | CREW COMPARTMENT | 20 |
| | TROOPS - UPPER TROOP COMPARTMENT | 75 |
| | CARGO COMPARTMENT | 270 |
| FUEL CAPACITY (JP-4) | 49,000 GALLONS (318,500 LB) | |
| LANDING GEAR | 28 WHEELS, (4 NOSE AND 6 EA ON 4 MAIN BOGIES) | |

Figure 6. Airplane characteristics, C-5A.

This plane is provided with a double deck. The aft top deck or personnel compartment is designed to accommodate 75 people in MAC-type seats. In brief, the provision is available for the crews required to accompany their equipment.

Airplane Characteristics

Figure 6 shows that the cargo compartment is 19 ft wide and about 145 ft long, with full width openings at each end. The fuel capacity and landing gear characteristics are of particular interest.

High-Payload Mission Profile

I would like to point out in Figure 7 the 200,000-lb payload with a mission time of 6 hours. The basic mission of the C-5A is to carry 100,000 lb of military cargo 5,500 nautical miles at a cruising speed up to 460 knots. The C-5A will carry any standard item in the Army inventory, including many which are too big or heavy for any existing aircraft.

C-5A Substandard Airfield

Figure 8 depicts the simple, rigid, symmetrical visor nose mentioned earlier and the way it exposes the full-width cargo openings. This is a typical view of what might be anticipated at substandard airfields scattered throughout the world. The high-flotation landing gear will minimize field damage and permit sustained operation.

Drive-Through Capability

To assure the most rapid turnaround of the aircraft as possible, the C-5A is designed with the drive-through capability provided by the full-width openings at both ends of the cargo compartment, as shown in Figure 9.

Cargo Floor Angles

Operation of an airplane as large as the C-5A into areas with limited terminal facilities requires built-in capability to adapt to a variety of loading and unloading conditions. A kneeling landing gear facilitates these operations by permitting variable positioning of the cargo floor (Fig. 10). The airplane can also be leveled laterally on uneven ground.

Ramp Angles

As noted in Figure 11, the forward end of the floor can be positioned at a height of 54 in., and the forward and aft ramp angles are 11 and 13.5 deg, respectively. As shown in the lower part of the figure, the rear opening can also be positioned at 54 inches off the ground, reducing the aft ramp angles considerably.

Typical Fuselage Sections

The three fuselage sections in Figure 12 are shown at the nose gear, the wing box, and the main landing gear. The double-lobe arrangement, the cargo compartment cross section, and the efficient stowage of retracted landing gears are readily apparent. The floor is 19 ft wide, and this width is maintained to a height of 9½ ft. The width then tapers to 13 ft at the 13½-ft high ceilings.

Note the stairs to the flight station; there is a similar stair at the rear of the plane to the aft troop accommodations. Each stair is located over a ramp for minimum interference with cargo.

Inboard Profile

Figure 13 shows the flight station, crew compartment, troop compartment, and a side cutaway of the complete cargo compartment.

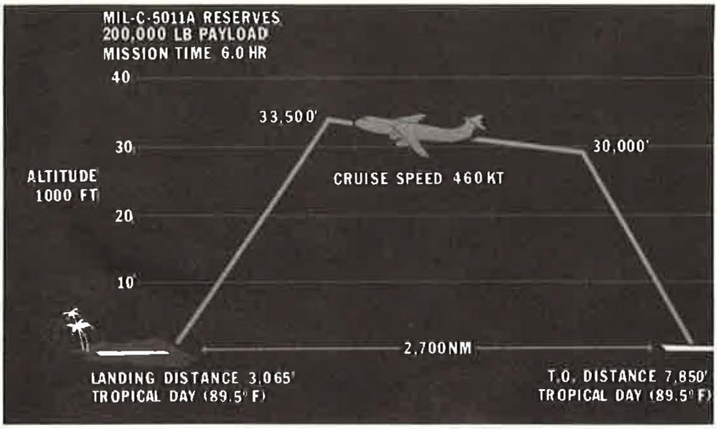


Figure 7. High-payload mission profile—high speed, C-5A.

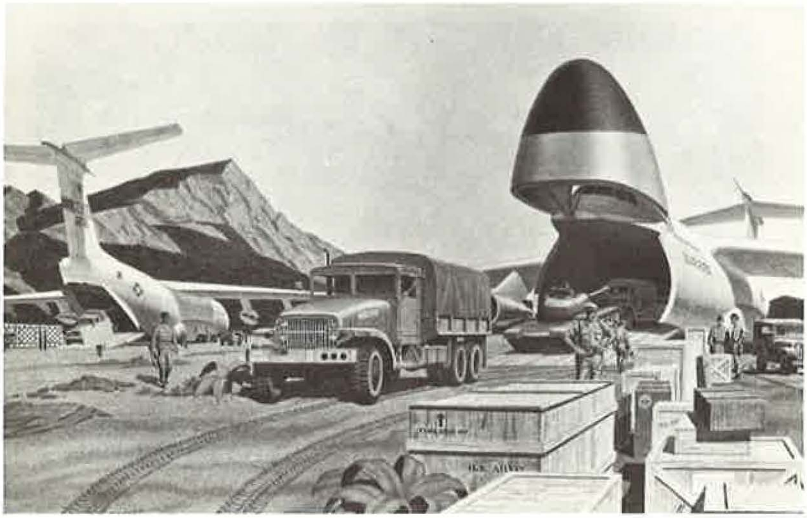

Figure 8. View at substandard airfield, C-5A.

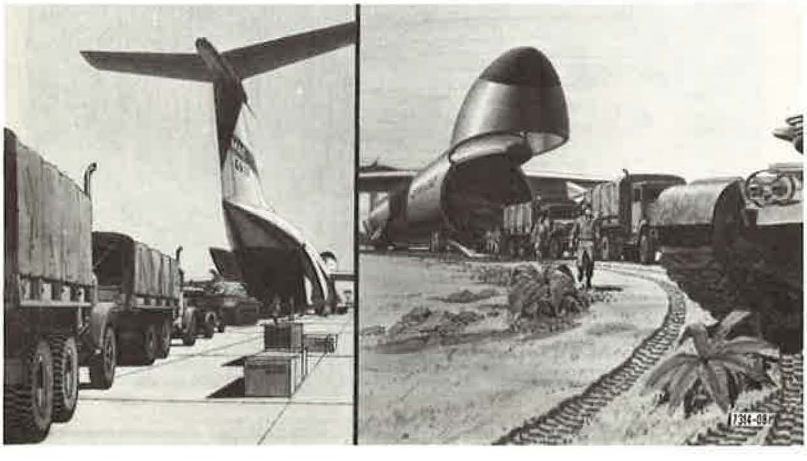

Figure 9. Drive-through capability, C-5A.

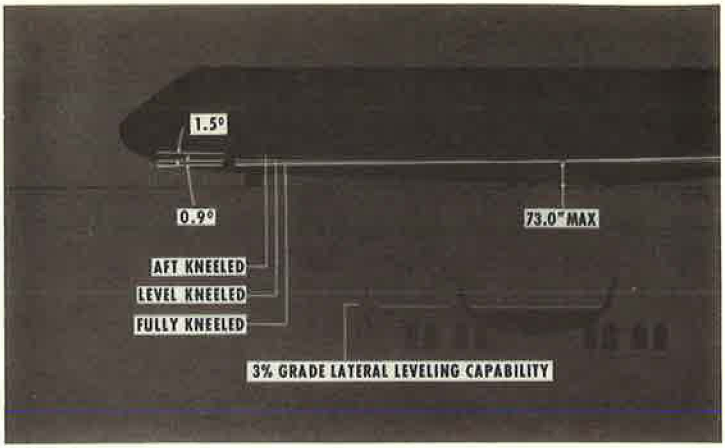


Figure 10. Cargo floor angles, C-5A—main gear fully kneeled.

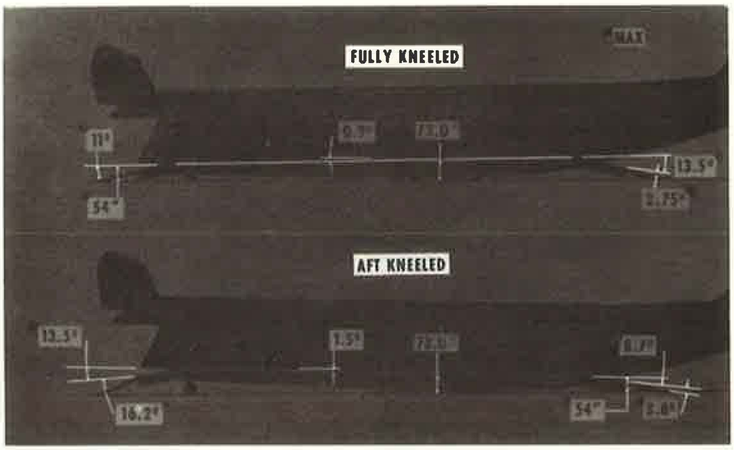


Figure 11. Ramp angles, C-5A.

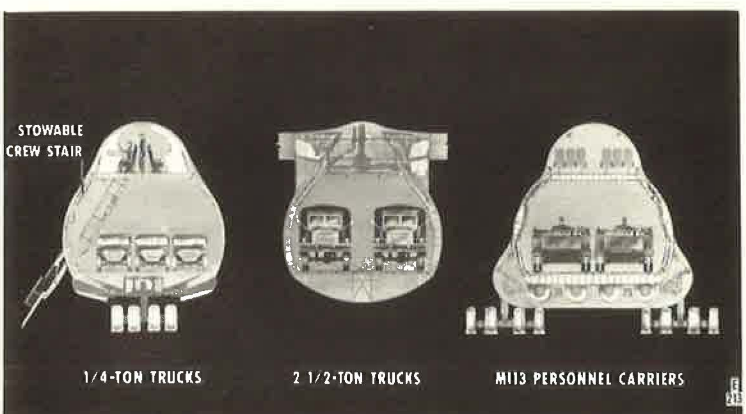


Figure 12. Typical fuselage sections, C-5A.

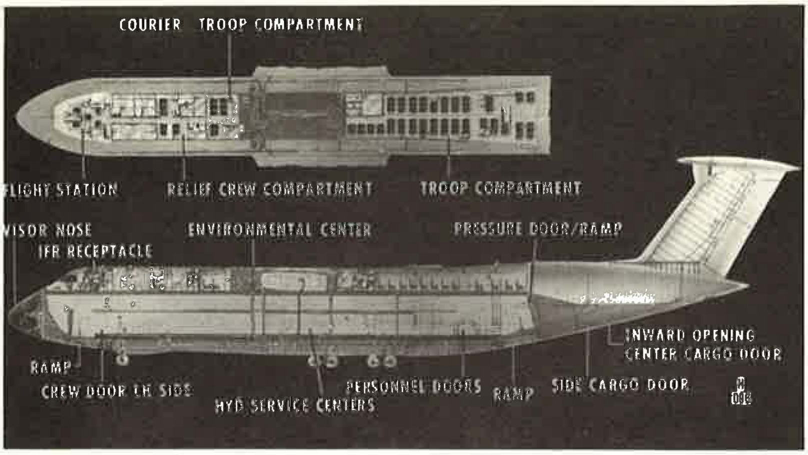


Figure 13. Inboard profile, C-5A.

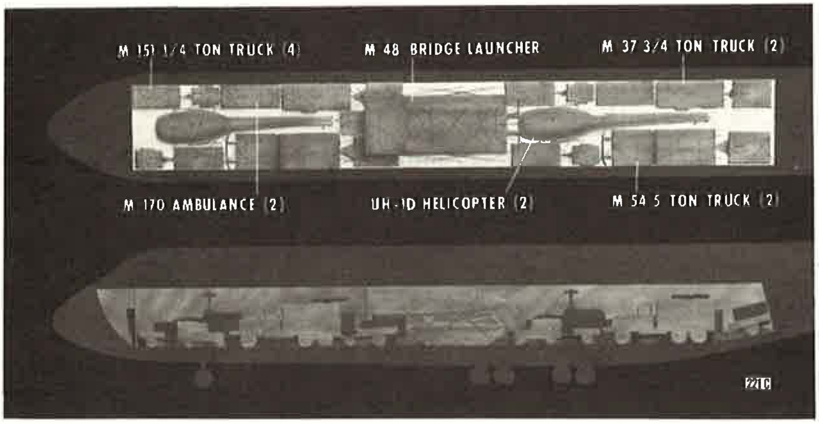


Figure 14. Deployment load flexibility and efficiency, C-5A.

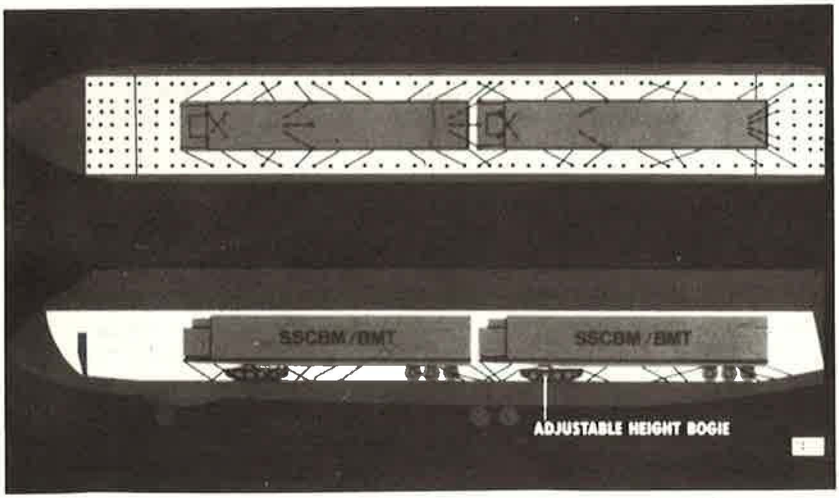


Figure 15. Minuteman loading capability, C-5A.

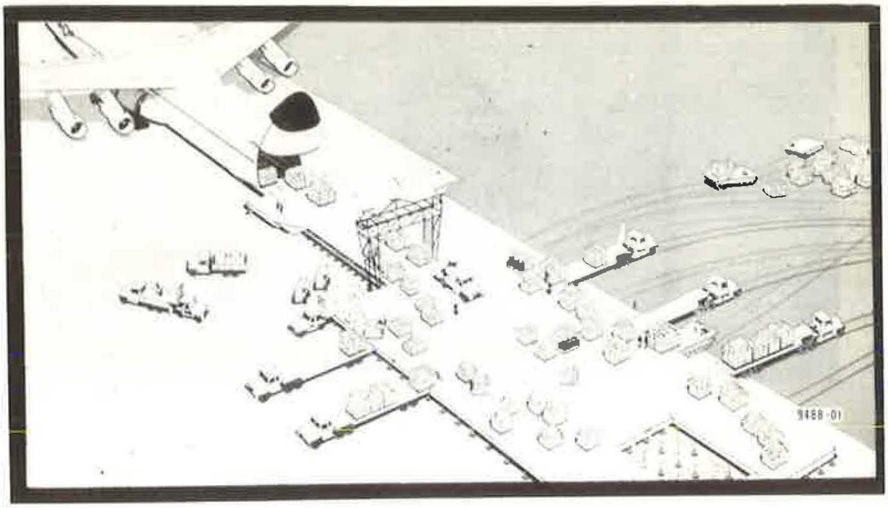

Figure 16. Air transportable dock, C-5A.

Deployment Load Flexibility and Efficiency

An example load that can be carried in the C-5 is shown in Figure 14, such as two UH-1D helicopters, two M-54 5-ton trucks, two M-170 ambulances, two $\frac{3}{4}$-ton trucks, four $\frac{1}{4}$-ton trucks, and one M-48 bridge launcher.

Minuteman Loading Capability

As shown in Figure 15, a capability is provided by this airplane to transport two minuteman missiles in their shipping and storage containers mounted on ballistic missile transporters. The length of each of these trailers is approximately 57 ft. This is 7 ft longer than the standard 50-ft truck-tractor combination allowed without an oversize permit.

Air Transportable Loading Dock

At support area fields, one method of unloading that the Air Force is considering is an air transportable loading dock, consisting of an off and on-load dock, a build-up and break-down dock, and a storage dock (Fig. 16). A double pallet string can be extracted at the center dock, meeting the required 15-min turnaround time. The outer two docks can be positioned laterally to line up with the center dock. This arrangement can accommodate one C-5A arrival every 30 minutes, limited only by the ability of the ground support operations in keeping the dock unloaded.

## THE BOEING 747

The Boeing 747 (Fig. 17) is being developed by Boeing Aircraft Company, Commercial Airplane Division, Renton, Washington. The Boeing 747 passenger and cargo airplanes will be able to operate on any airport that accepts the 707-320 B/C Intercontinentals. The size and weight of the 747 will require reviews of the layout of terminal aprons, parking areas, passing clearances and overpass strength. The volume of traffic to be generated by the use of this aircraft indicates necessity for examination of road capacities involved in movement of persons and cargo to and from the air terminals.

General Arrangement

As a matter of comparison, the length of the C-5A is 245.11 ft, its wing span is 222.9 ft, and the height of the empennage is 65.1 ft. Basically, the 747 is about 5 per-

Figure 17. The Boeing 747.

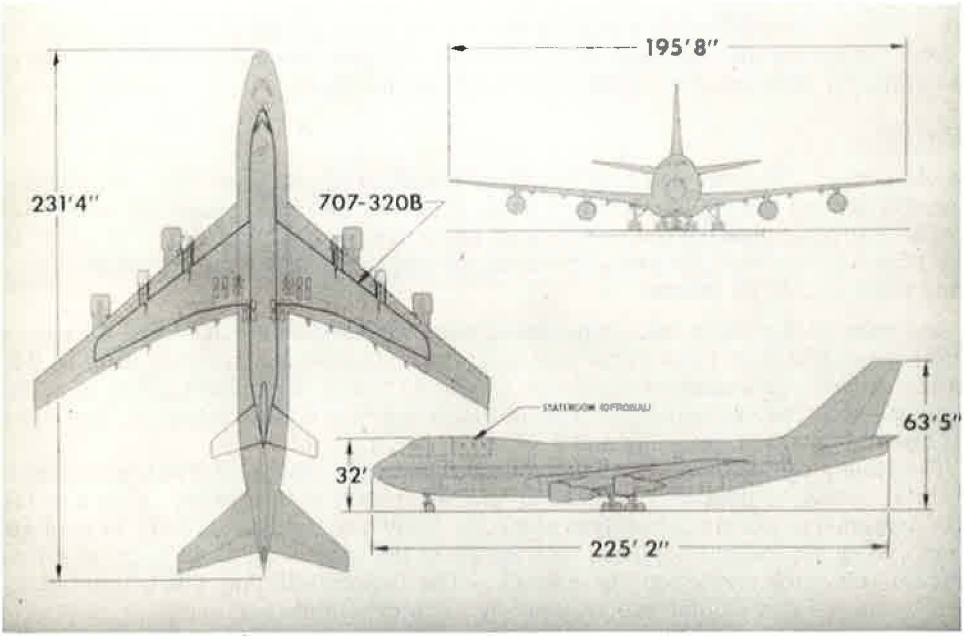


Figure 18. General arrangement, Boeing 747.

- TO CREATE A VERSATILE, RELIABLE, PROFITABLE LARGE SIZE COMMERCIAL AIRCRAFT FOR THE 1970-1980 TIME PERIOD.
- TO COMBINE IN ONE BASIC DESIGN PASSENGER AND CARGO CHARACTERISTICS CLOSE TO OPTIMUM FOR EACH.
- TO OPERATE FROM EXISTING AIRPORTS AT ACCEPTABLE NOISE LEVELS.
- TO ATTAIN SIGNIFICANT IMPROVEMENT IN CARGO AND PASSENGER ECONOMICS, PASSENGER COMFORT, CARGO HANDLING, CRUISE SPEED, AND OPERATIONAL RELIABILITY.

Figure 19. Design objectives, Boeing 747.

cent smaller in size than the C-5A. In Figure 18, the dark outline shown superimposed on the 747 shows the difference in size of the 707.

## Design Objectives

In regard to design objectives (Fig. 19), it is apparent that Boeing is meeting all of the design objectives at this time except the profitable part, and only time will tell in this respect. However, according to the company's preliminary calculations they feel confident about this objective also.

This aircraft will be produced in three models, a passenger version, a convertible version (passenger and cargo), and a freighter (all cargo). The following figures are of interest because they might be of use in future planning. Sales to date of the 747 that can be publicized are for 94 passenger, 20 convertible, and 6 freighter models. The actual sales are in excess of these figures. Roll-out of the first model will be the third quarter of this year. By the end of 1971, Boeing plans to have produced 200 of the 747 aircraft and to produce approximately 8 per month after that.

With a total of over 100 C-5's and the 200 747's, one can visualize some of the impacts these jumbo jet aircraft will have on transportation, such as crowded skies, overloaded highways, and complete airport facilities saturation.

## Need for 747

The old adage, "Figures don't lie but liars can figure," does not hold true here. Noticing the market growth as shown, I doubt if anyone has any doubts that in 1975 there will be three times the present rate of passenger-miles (Fig. 20). In order to begin to plan for, or shall we say to reduce, the impact of this phenomenal growth, the following facts should be known.

1. The new $8.5 million freight terminal built by Pan American World Airways at J. F. Kennedy airport is the largest and most sophisticated air cargo facility of its kind in the world. This new terminal can handle 10 times the amount of cargo as formerly managed at the old facility. It should be noted that this terminal is "the culmination of over 5 years in planning and 2 years in construction."

2. The first automated-computerized overseas cargo system of PanAm will be in operation at London's Heathrow Airport in the latter part of this year. This new terminal is designed to enable all freight aircraft, including the Boeing 747, to turn around in 1 hour. With the freight business increasing at the rate of 30 to 40 percent a year, the need for the quick turnaround is obvious. The PanAm building will be part of a 160-acre terminal center that will be used by 15 international airlines.

3. KLM opened a butterfly-shaped building at Schiphol Airport in Amsterdam the latter part of last year. This cargo-handling center is similar to a big erector set. Its predominant feature is a central vertical storage system over 35 ft high for cargo handling.

4. "Los Angeles moves to meet traffic gain by planning to meet anticipated traffic increases through 1975 with a modern international airport." It is planned to have a total of 155 gate positions, multimode passenger inflow, new airport facilities, extension of present runways, etc. The reason for mentioning these items is the anticipation at Los Angeles of the following: Increased total road-access capacity from the present 31 million to 48 million passengers annually which, with another 14 million transported by air, will bring the total to 62 million estimated to be the maximum volume of passengers that could be handled by the airport in the configuration planned for 1975.

5. "New Air Travel Era for Europe Seen"—this kind of headline is seen almost daily. It is predicted that the Paris Nord Airport will usher in a new era of airport development the likes of which will be unheard of anywhere in Europe at that time. This new airport, with five massive terminals, each capable of docking 15 jumbo jets and 50 personnel transports at the same time, is scheduled for completion in the next 5 years. The first section of this airport (the initial single runway and terminal plus the cost of land and related preliminary work) will run about $200 million.

**MARKET GROWTH BY 1975**

- REVENUE PASSENGER MILES WILL TRIPLE
- REVENUE CARGO TON MILES WILL INCREASE TENFOLD

**INCREASED CONGESTION**

- TRAFFIC WILL SOON EXCEED THE PROJECTED CAPACITY OF MOST MAJOR TERMINALS

**OTHER OPERATIONAL DEMANDS**

- IMPROVED PASSENGER AND CARGO HANDLING
- BETTER PASSENGER APPEAL AND COMFORT
- REDUCED FLIGHT TIME
- LOWER COMMUNITY NOISE LEVELS

Figure 20. Need for Boeing 747.

| | | 707-320C FREIGHTER | 747F |
|---|---|---|---|
| MAX TAKEOFF GROSS WT | LB | 332,000 | 710,000 |
| LANDING WEIGHT | LB | 247,000 | 564,000 |
| ALLOWABLE PAYLOAD | LB | 90,320 | 221,000 |
| SEA LEVEL STATIC THRUST | LB | 18,000 | 43,500 |

*INCLUDES 3250 LB ALLOWANCE FOR 15 PALLETS AND NETS

**INCLUDES 7950 LB ALLOWANCE FOR 28 MAIN DECK PALLETS AND NETS AND 8100 LB ALLOWANCE FOR 15 LOWER COMPARTMENT CARGO CONTAINERS (16,050 LB TOTAL)

Figure 21. Freighter airplane characteristics.

6. Last fall, Trans World Airlines' first fully-automated air freight terminal was started at Dayton, Ohio. The $8 million facility will be the first of 10 fully-automated terminals planned by the airline. TWA also plans to build 15 semi-automated freight terminals at a minimum cost of $5 million each.

One might think these jumbo jets have caused the problems—but they offer a preferred solution to the problems.

## Freighter Airplane Characteristics

Figure 21 compares the 707 and 747 so that one can visualize the difference in the two aircraft. The 747 maximum takeoff gross weight is more than double the 707.

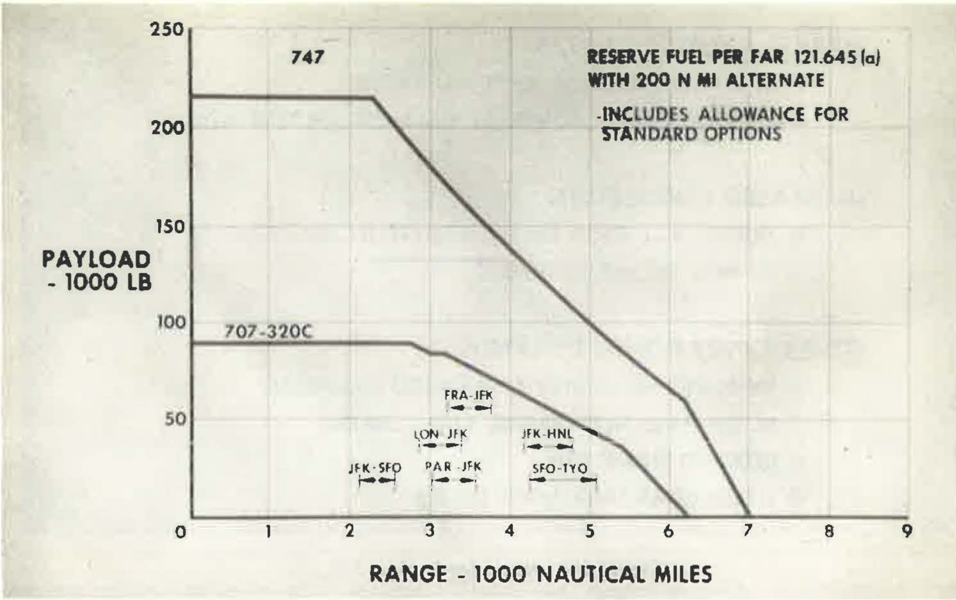


Figure 22. Payload range-freighter, Boeing 747.

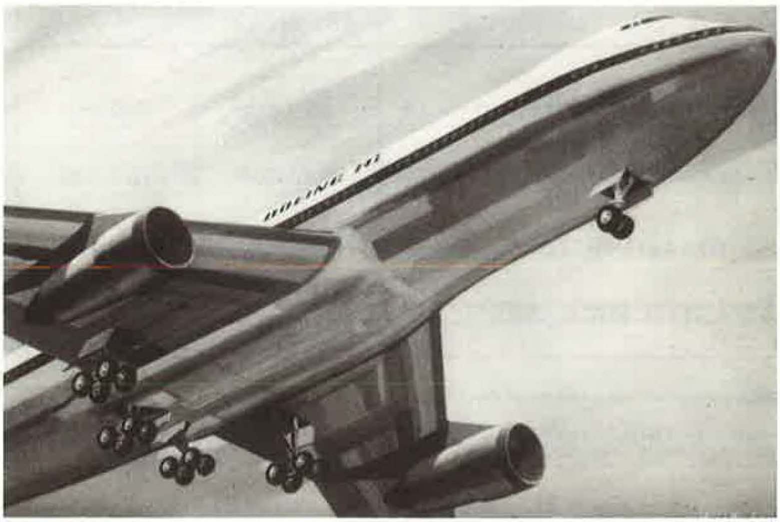

Figure 23. Landing gear, Boeing 747.

## Payload Range—Freighter

Figure 22 is similar to the high-payload mission profile shown for the C-5 (Fig. 7). The payload of approximately 225,000 lb for 2,250 nautical miles is compared to today's 707 payload of only about 90,000 lb for about 2,800 nautical miles. The difference in handling and distribution of freight this increase will create, is apparent.

## Landing Gear

Figure 23 shows the landing gear, including the 18 wheels, which requires less concrete thickness for the runways for landing the 747 than that required for the 707. De-

Figure 24. Landing gear, Boeing 747.

| | DC8-55 | 707-320C | 747 |
|---|---|---|---|
| GROSS WEIGHT 1000 LB | 328 | 336 | 683 |
| RIGID PAVEMENT MID CG ■ REQUIRED THICKNESS OF CONCRETE IN. | • 325 K POUNDS AOC* REF 12.0 | 11.9 | 11.6 |
| FLEXIBLE PAVEMENT MID CG ● REQUIRED THICKNESS OF ASPHALT PLUS BALLAST IN. | 23.1 | 22.9 | 22.9 |

· AIRPORT OPERATORS COUNCIL REF
■ K=300, STRESS= 397 PSI
● CBR= 15

Figure 25. Pavement loading.

- SINGLE DECK
- NOSE LOADING
- COMPATIBLE WITH ALL CURRENT COMMERCIAL CARGO AIRCRAFT
- FULL POWER LOAD AND UNLOAD (MINIMUM CREW REQUIRED)
- NO BARRIER NET REQUIRED

Figure 26. Cargo handling system, Boeing 747.

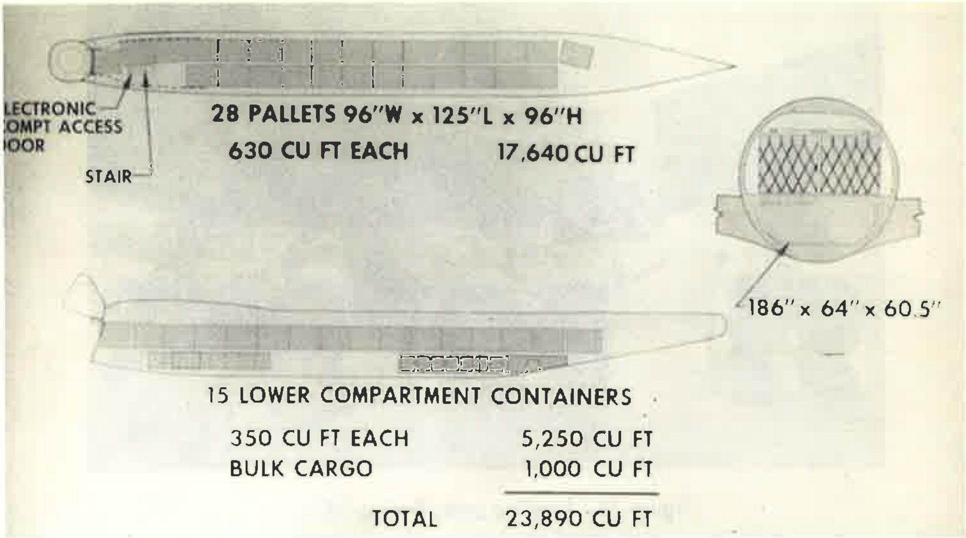


Figure 27. Basic cargo arrangement, Boeing 747.

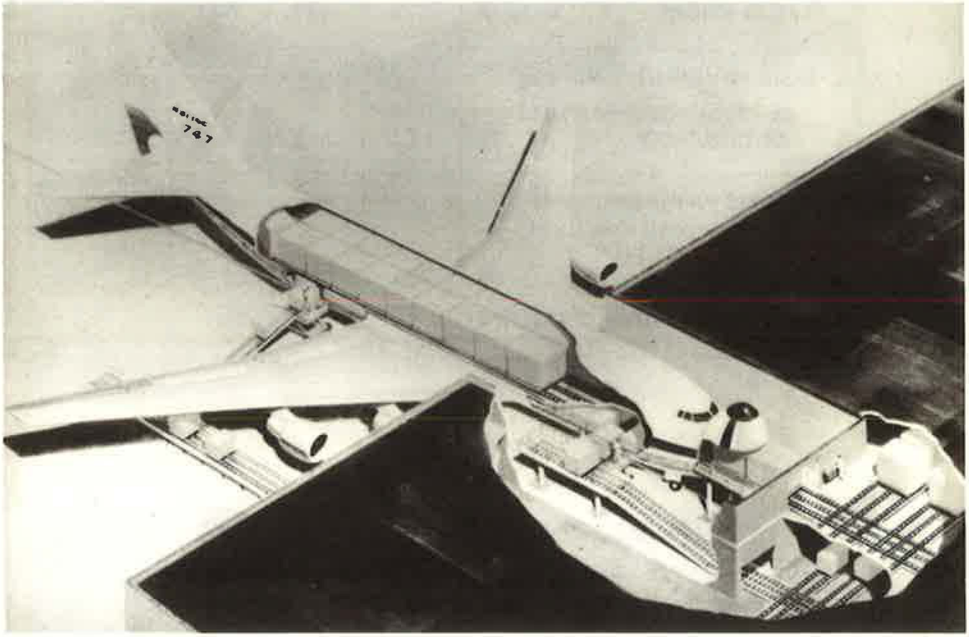

Figure 28. Cargo loading, Boeing 747.

tails of the landing gear are shown in Figure 24. Note the size of the wheel in comparison to an average man.

Pavement Loading

The DC-8, 707, and 747 rigid and flexible pavement requirements are shown in Figure 25. The 747 requires less concrete than the DC-8.

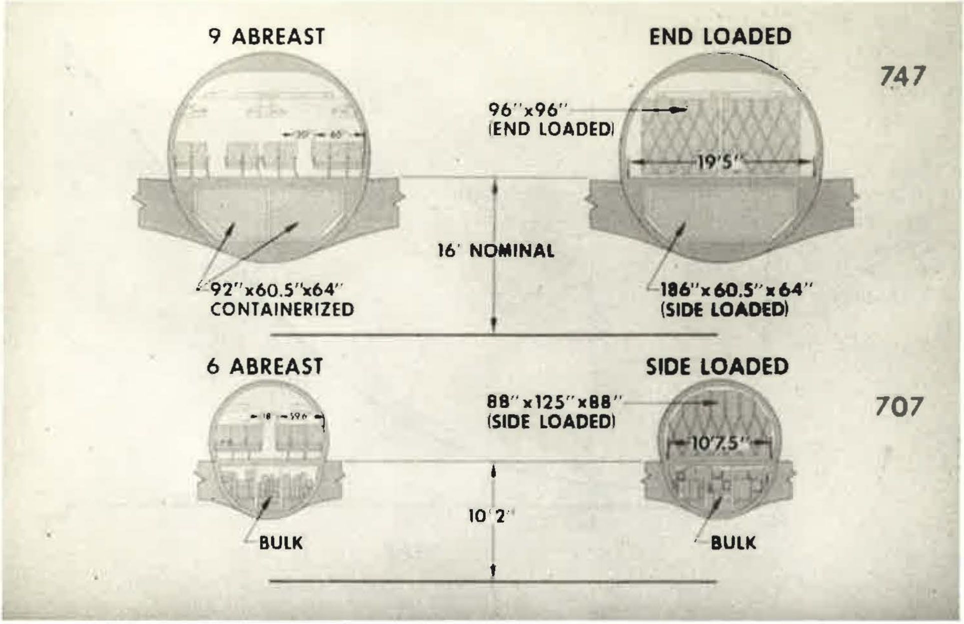


Figure 29. Body cross sections, Boeing 747.

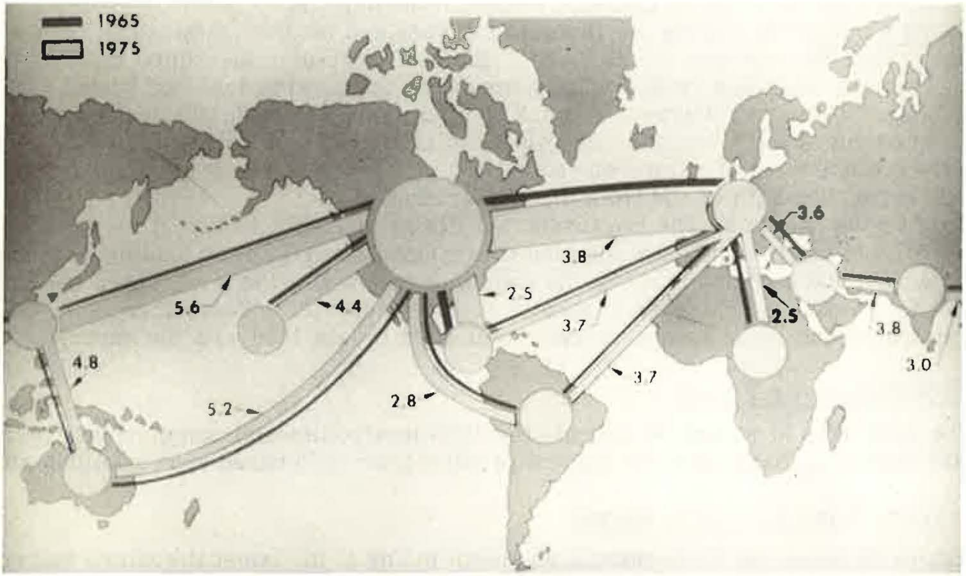


Figure 30. Intercontinental air traffic.

## Cargo Handling System

The system used for cargo handling is outlined in Figure 26 and is shown pictorially in Figures 27, 28 and 29.

Basic Cargo Arrangement—The main deck is used for large container loading (Fig. 27). This loading can be through the nose or one of the five doors on either side of this aircraft. The belly containers and bulk cargo make up some 6,000 cu ft of the

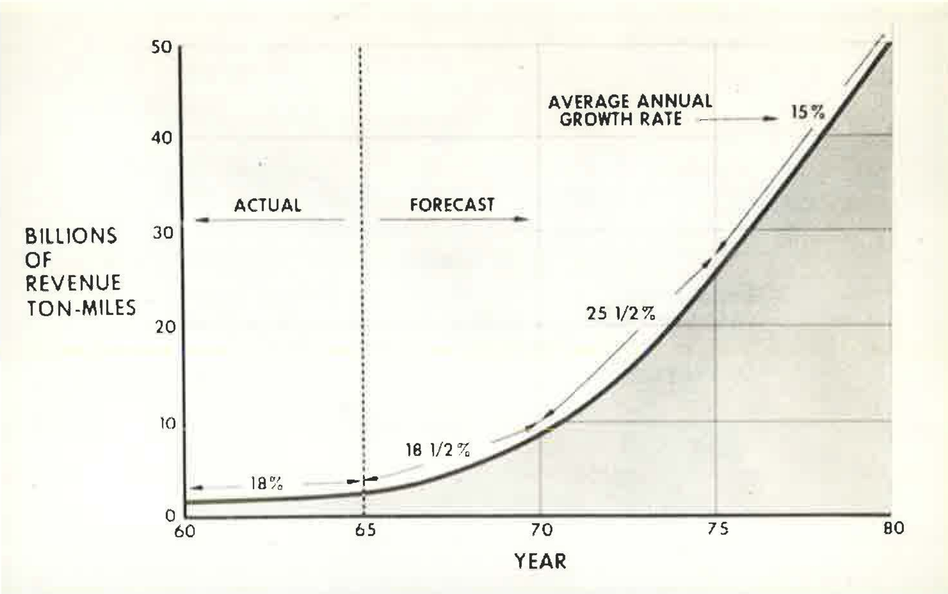


Figure 31. Free World total air market.

total of 23,890 cu ft. Again, one should think of the impact of 6 to 8 of these jumbo aircraft on facilities of handling, distribution and storage—not to mention the problem of documentation in order to maintain control of shipments.

Cargo Loading—In Figure 28, the various types and loading stations can be visualized. Note the operator in the lower right-hand portion of the figure manning the control panel. This is a typical loading operation through the nose and belly at the same time. There are drive units in the floor of the upper deck that help move the cargo in or out of the aircraft. The volume of traffic that will be generated by the increased large amount of cargo carried by this type aircraft surely requires a good look at road capacities both to and from the air terminals.

Body Cross Sections—The two fuselage sections in Figure 29 are at the wing sections of the 707 and the 747 and show the size comparison as well as the loading height above the ground. The size and shape of the containers show how the large cargo volume is obtained. PanAm is scheduled to receive its first superjet in September 1969, and it is anticipated that its passenger service will start in late 1969 with the superjets.

## Intercontinental Air Traffic

The dark bars in Figure 30 indicate the 1965 intercontinental commercial air traffic, and the wide gray bars show the amount predicted for 1975 based upon a Boeing study.

## Free World Total Air Cargo Market

Figure 31 bears out the forecasts as shown in any of the latest literature that one reads as to the future in the air cargo market.

## CONCLUSIONS

This paper covers only the high points of tomorrow's aircraft, but the charts and figures spell out "sudden death." I would like to explain what this means. Mr. Oscar Bakke, formerly the Eastern Region Director of the Federal Aviation Administration, predicted about 6 months ago that one day, late this year, New York City may die a little. This is not an Orson Welles fantasy—but facts. What Mr. Bakke predicts is that John F. Kennedy International Airport will face "complete saturation."

New York is not alone in this disaster. The Air Transport Association of America is considering 23 major hub airports that are fast coming up against this saturation barrier. Gigantic traffic jams at the airport, on the runways, in the sky, and on connecting downtown highways are getting worse. Many people have experienced something of this if only at the ticket or crowded baggage counter.

The technological needs in transportation, worldwide, are mammoth. Maybe it should be compared to needs of the educational requirements that most of us are intimately familiar with. The cause which should be considered first is population growth. This we cannot do anything about except plan ahead, and provide money required for expansion. My point is that sufficient planning, coordination, and control have not been exercised. No one is recommending any kind of curtailment at this time. Scientific advancement, growth of this country financially, and progress are our keys to better living.

What are some of these mammoth transportation needs? The following list can be woven into a systematic pattern.

1. A standardized group of intermodal containers.
2. A standardized intermodal pallet or pallets.
3. A standardized modern intermodal materials handling system.
4. Additional modern air terminals.
5. Double-deck and/or triple-deck parking lots.
6. High-speed commuter traffic systems.
7. High-speed advanced design highway systems.
8. Safety systems for airplanes and highway traffic, such as to allow two objects on a collision course to alert each other and take evasive action.
9. Computerization and automation as much as possible; for example, a plastic passport, ticket, and baggage check. The passport and ticket will be cleared automatically by a seeing-eye detector. The baggage check will start your baggage on its travel path as soon as you get out of your car, to be picked up at your destination.

This discussion on the expansion of air transportation illustrates vividly the relationship to the other modes of transportation and points out many technological needs requiring consideration in a total transportation evaluation.

## ACKNOWLEDGMENT

I wish to acknowledge the invaluable aid given me by personnel of the Lockheed Aircraft Corporation and the Boeing Company. Many of the data and slides were furnished by them.