HIGHWAY RESEARCH RECORD

Number 234

International Transportation Topics

4 Reports

The Jumbo Jet,
Airport Access,
Changeover in Sweden,
and
The Channel Tunnel

Subject Area

11	Transportation Administration
51	Highway Safety
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Foreword

This RECORD consists of papers presented at the 47th Annual Meeting under the sponsorship of the Special Committee on International Cooperative Activities. The papers report on several topics related to international transportation. They will be of interest to all who are concerned with transportation development in the broadest sense.

The introduction during the next decade of large aircraft with passenger capacities up to 1000, will have a material effect on airport operation and the requirements for ground transportation. In a well-illustrated report, Pursifull gives detailed information on two jumbo jet-type aircraft, the Lockheed C-5A and the Boeing 747 and outlines some of the ground requirements for these aircraft and plans that are being made for their reception. Payne reviews the developments of air travel in Europe, considers the effect of new type aircraft on ground requirements and tells of some of the facilities that are under way and being considered in that area.

On September 3, 1967, Sweden changed from left-hand to right-hand driving. Baldwin describes the planning and preparation for the change and relates the early experience under the new system. With the elaborate preparation including signing, education and reduced speed limits, the change-over was made smoothly. During the two-month period following the change-over, fatal accidents were much below the average rate for the time of year and the total accident rate was about average.

A brief history of the consideration of a tunnel connecting England with the Continent and an outline of future plans are given in Davidson's paper. The present organization was established in 1957 following periodic studies that began as early as 1751. The tunnel, which is expected to be in service by 1975, will be 32 miles long with 23 miles under the sea. Automobiles will go through the tunnel "piggyback" on rail cars. Overall passage time including driving on and off and customs clearance is expected to be less than an hour.

The session at which these papers were presented was arranged by a subcommittee of the Special Committee on International Cooperative Activities, under the chairmanship of Mr. Robert O. Swain.

Contents

Jumbo Jet Aircraft and the Impact They Will Have on Transportation

L. J. PURSIFULL, Chief, Transportability Criteria Division, Transportation Engineering Agency, Military Traffic Management and Terminal Service

•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.

Paper sponsored by Special Committee on International Cooperative Activities and presented at the 47th Annual Meeting.

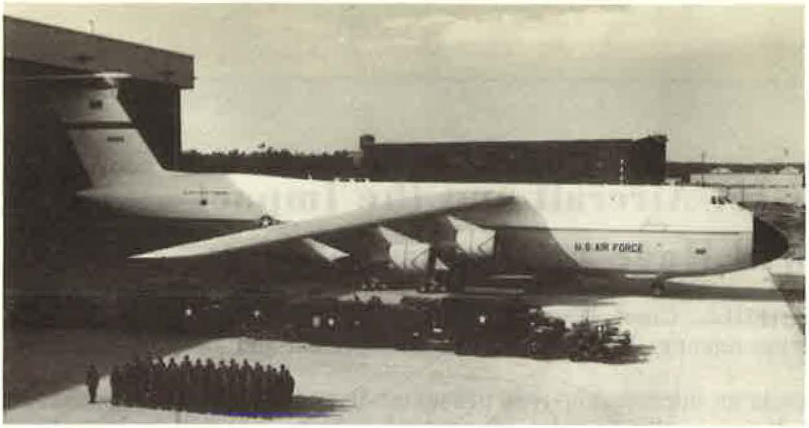

Figure 1. The Lockheed C-5A.

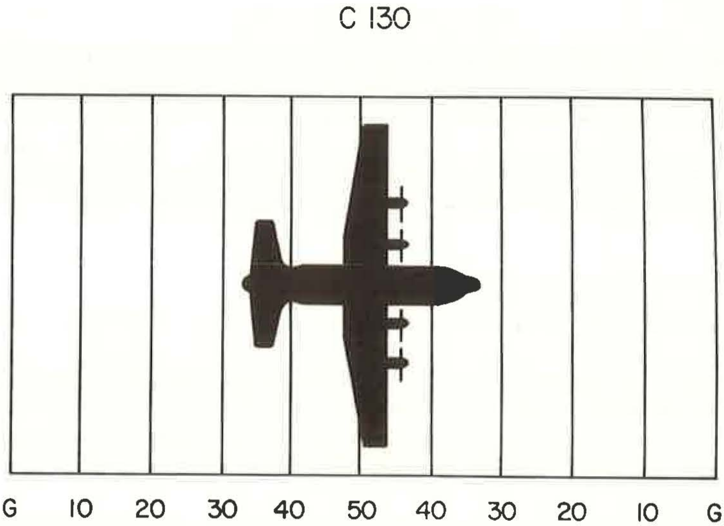

Figure 2. Plan view of the C-130 on a football field.

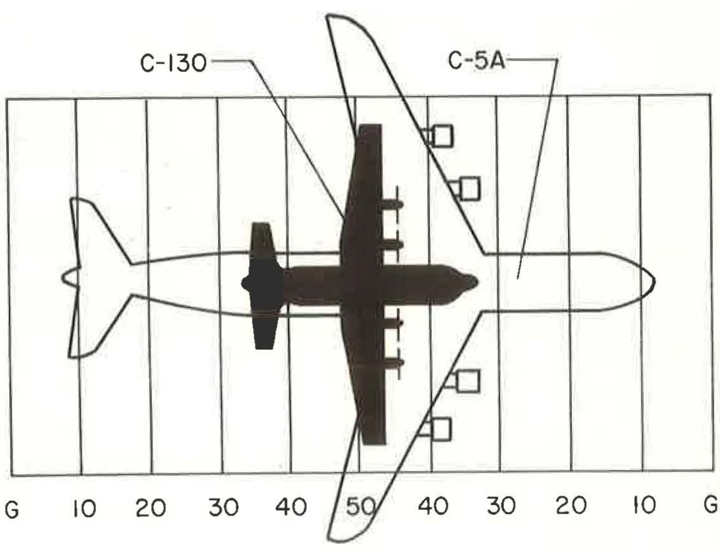

Figure 3. The C-5A compared to the C-130.

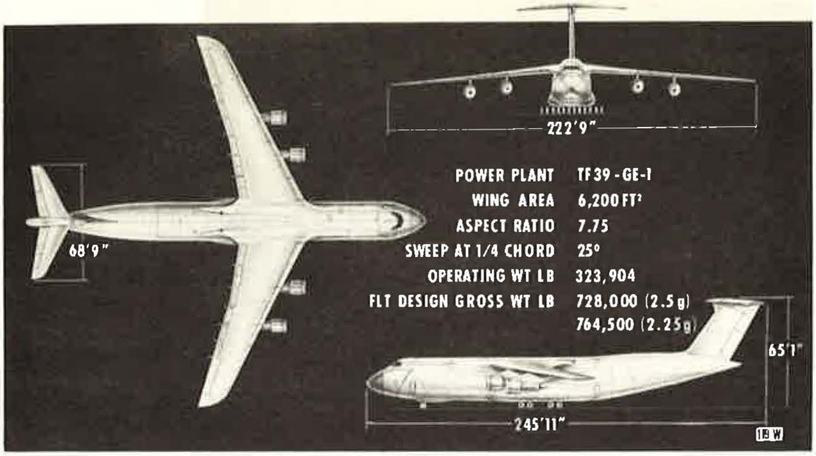

Figure 4. General arrangement of the C-5A.

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.

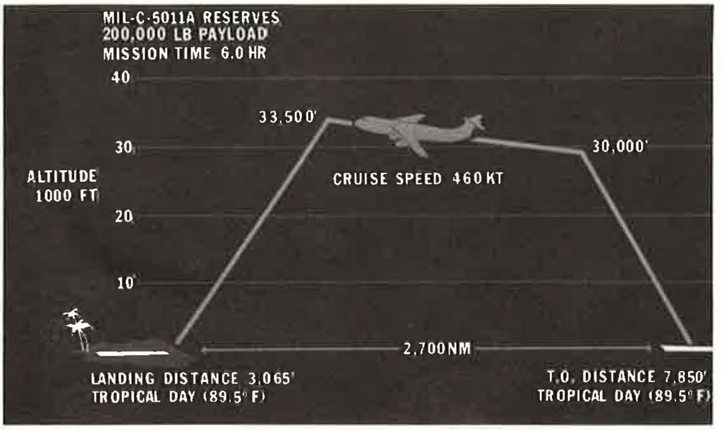

Figure 7. High-payload mission profile—high speed, C-5A.

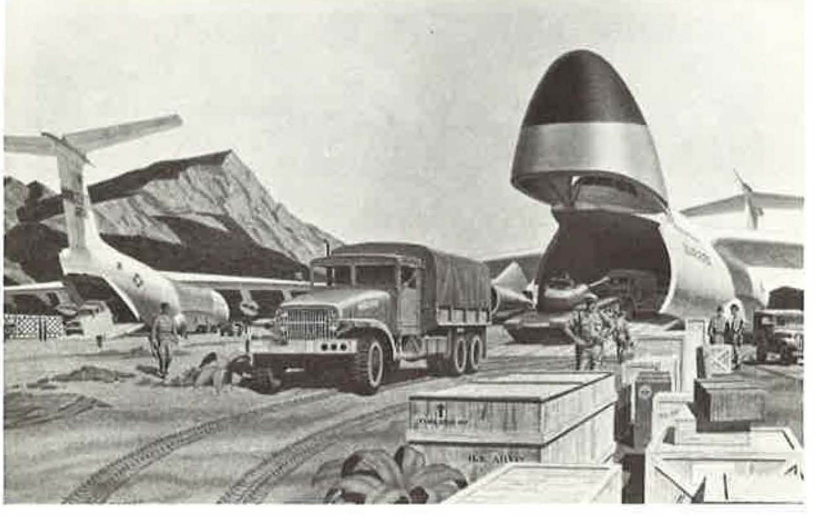

Figure 8. View at substandard airfield, C-5A.

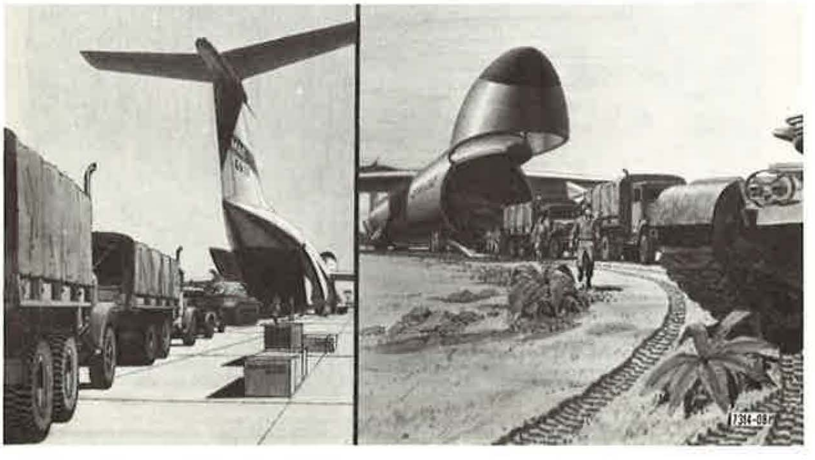

Figure 9. Drive-through capability, C-5A.

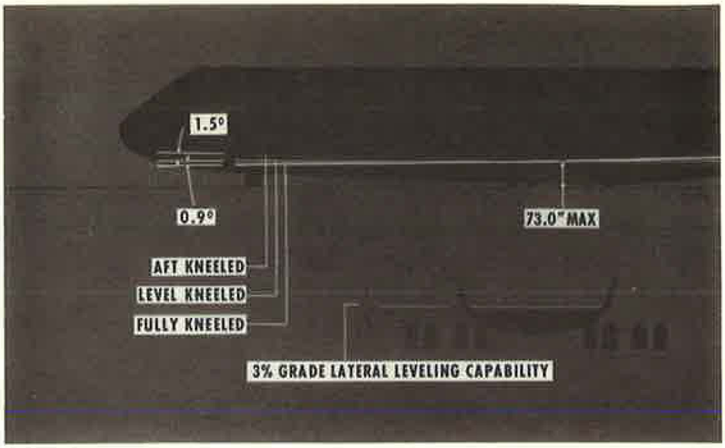

Figure 10. Cargo floor angles, C-5A—main gear fully kneeled.

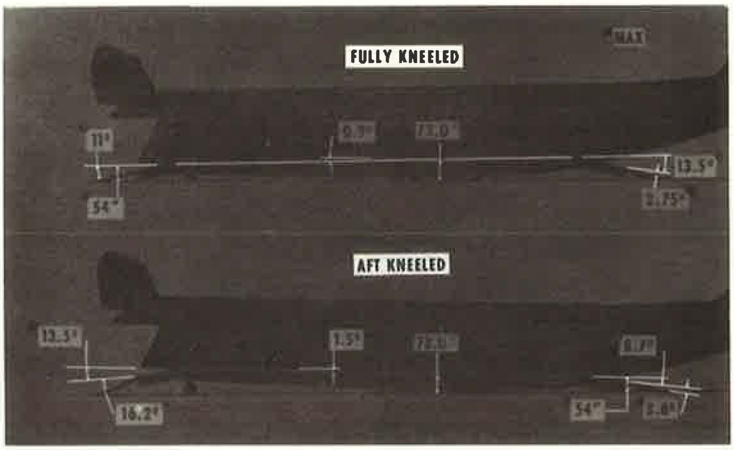

Figure 11. Ramp angles, C-5A.

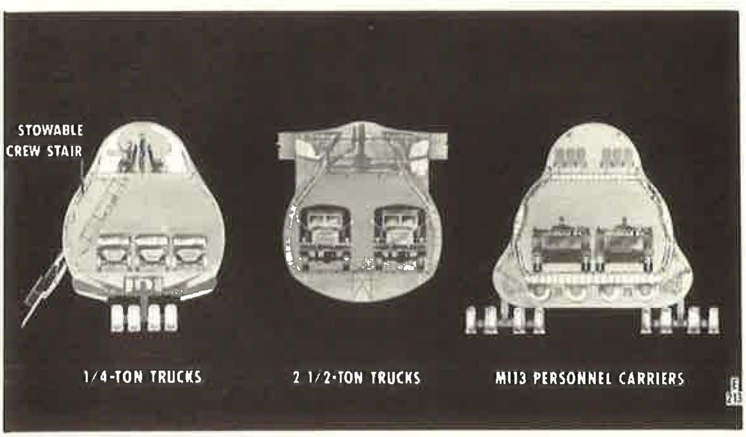

Figure 12. Typical fuselage sections, C-5A.

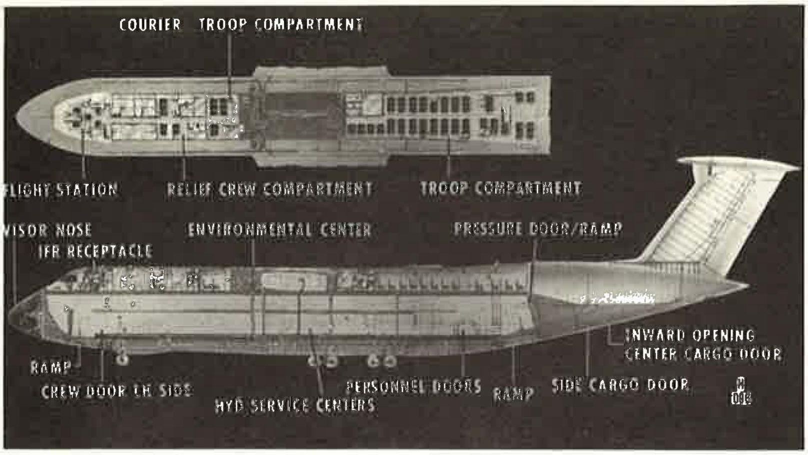

Figure 13. Inboard profile, C-5A.

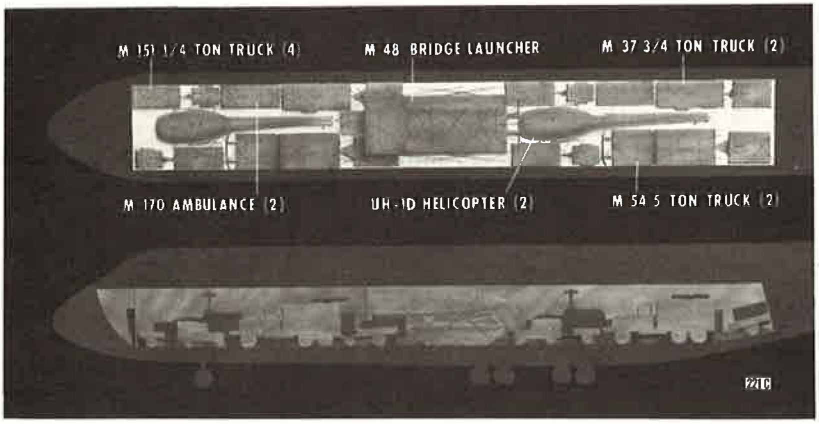

Figure 14. Deployment load flexibility and efficiency, C-5A.

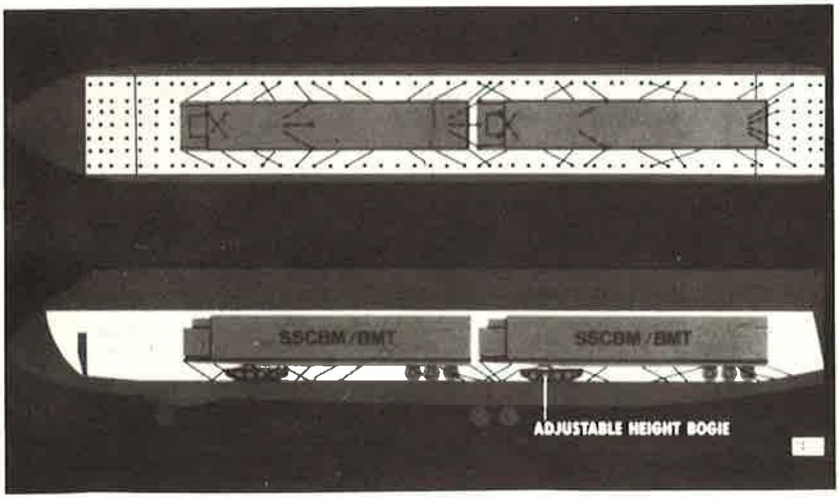

Figure 15. Minuteman loading capability, C-5A.

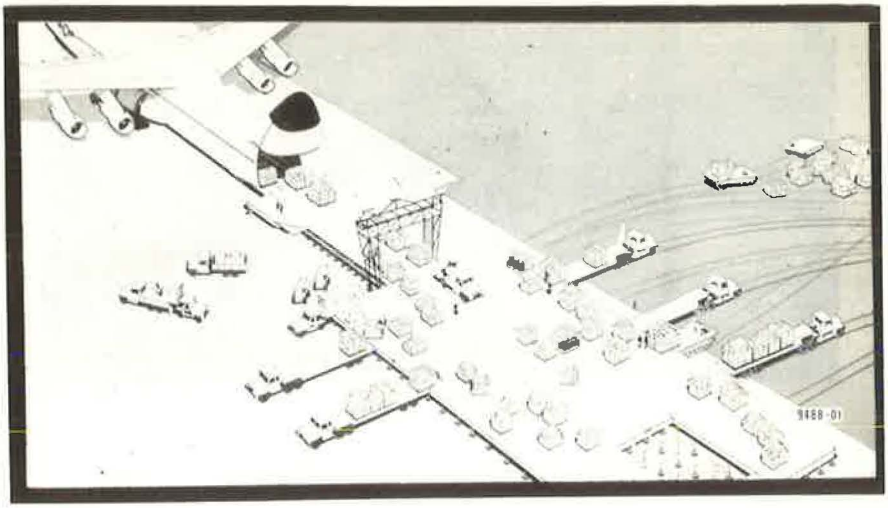

Figure 16. Air transportable dock, C-5A.

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.

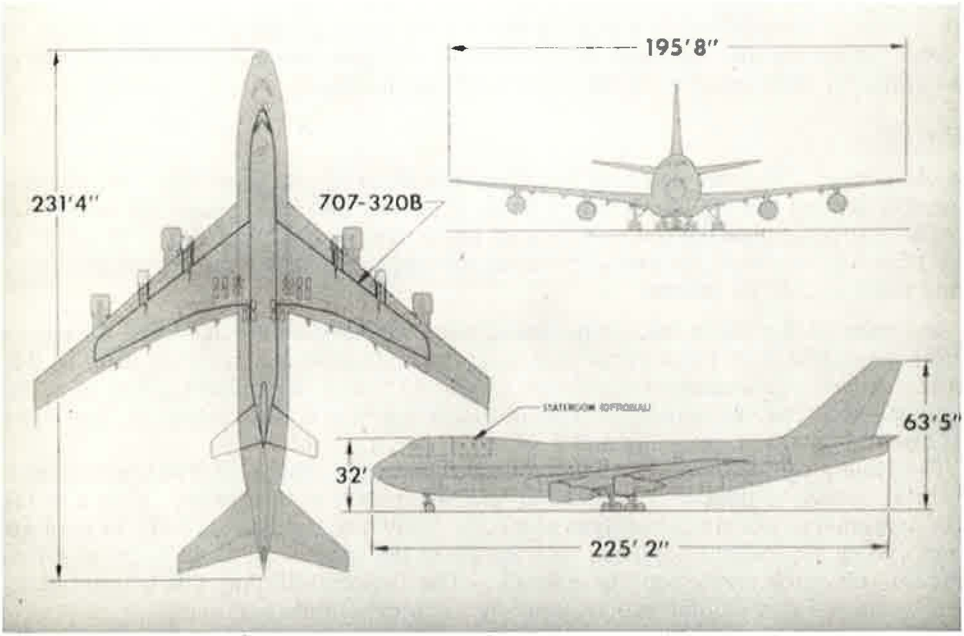

Figure 18. General arrangement, Boeing 747.

- 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.

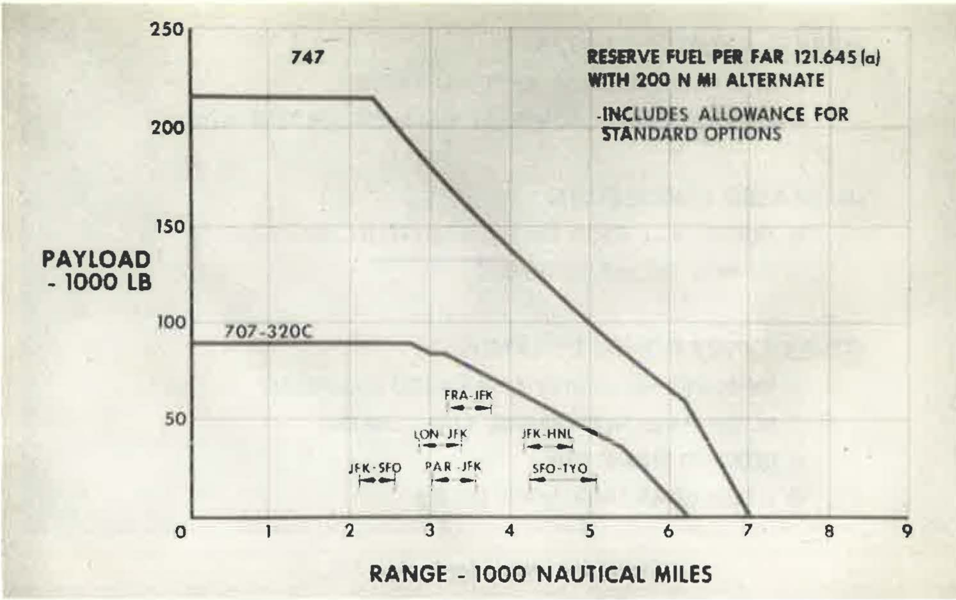

Figure 22. Payload range-freighter, Boeing 747.

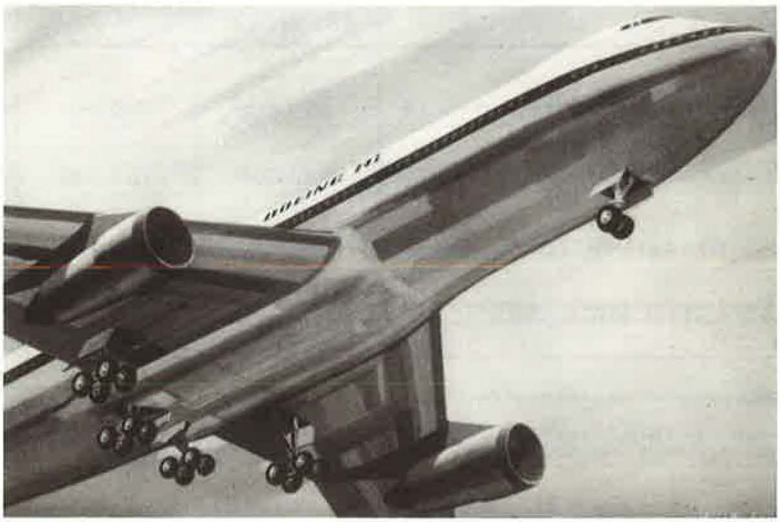

Figure 23. Landing gear, Boeing 747.

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.

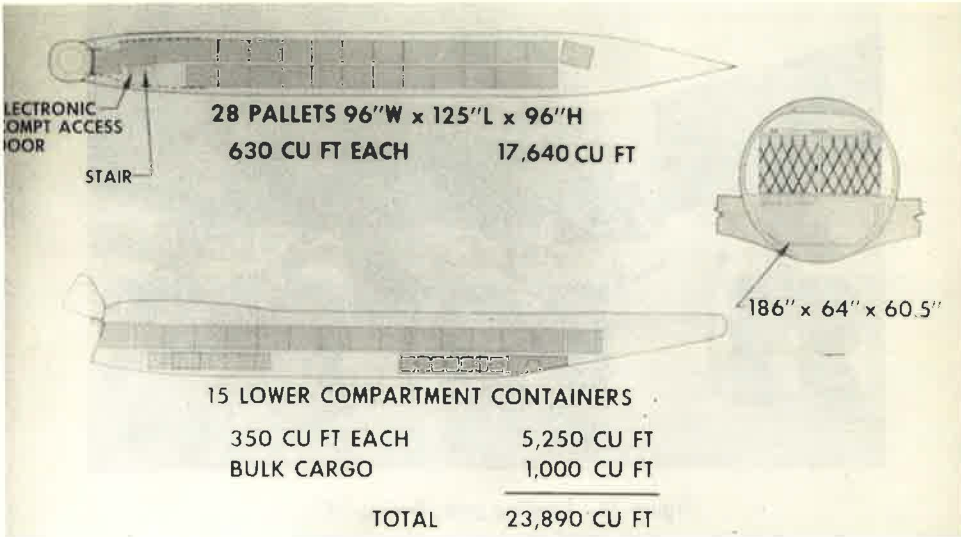

Figure 27. Basic cargo arrangement, Boeing 747.

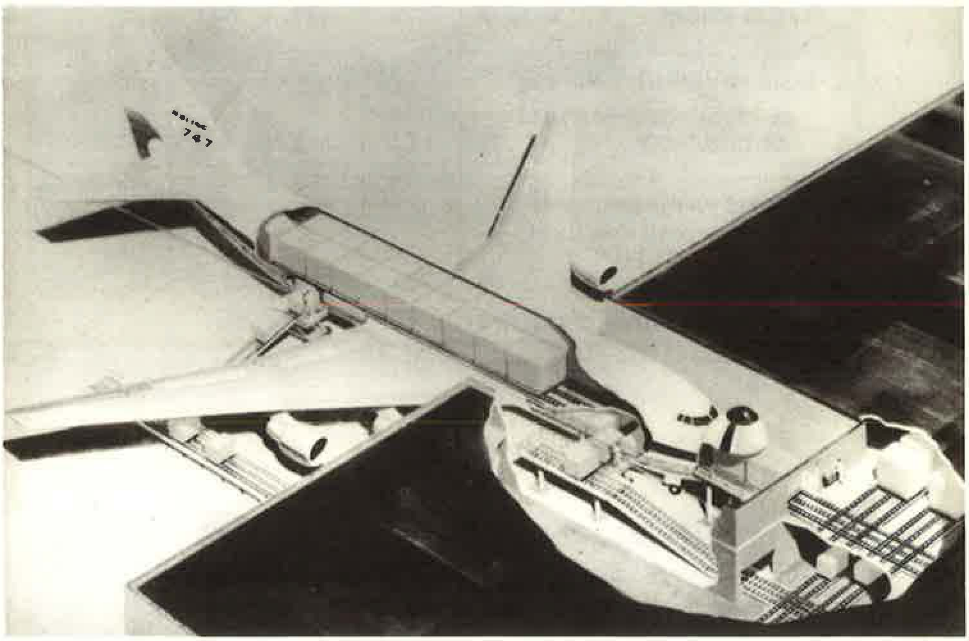

Figure 28. Cargo loading, Boeing 747.

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.

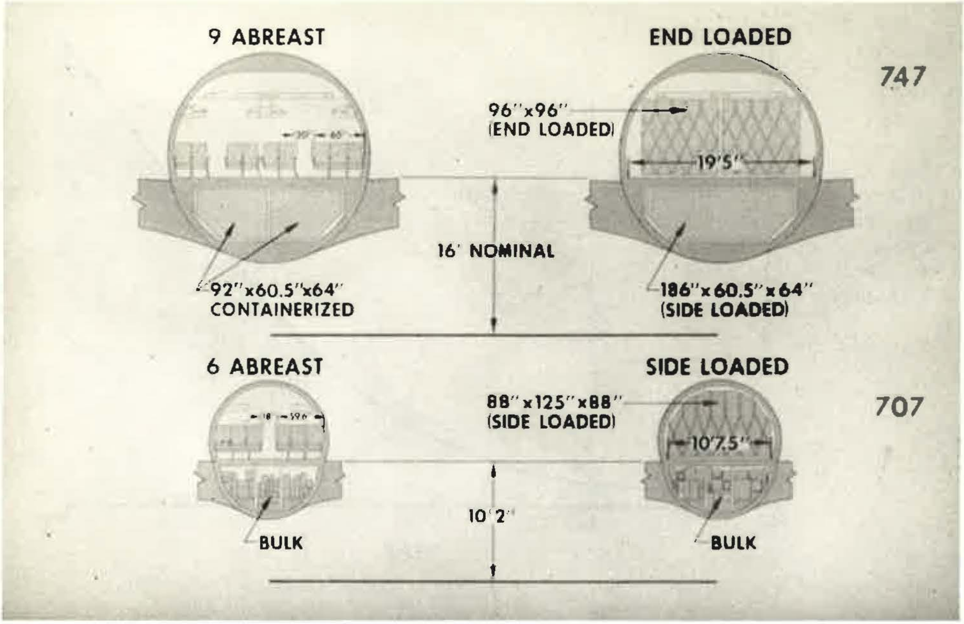

Figure 29. Body cross sections, Boeing 747.

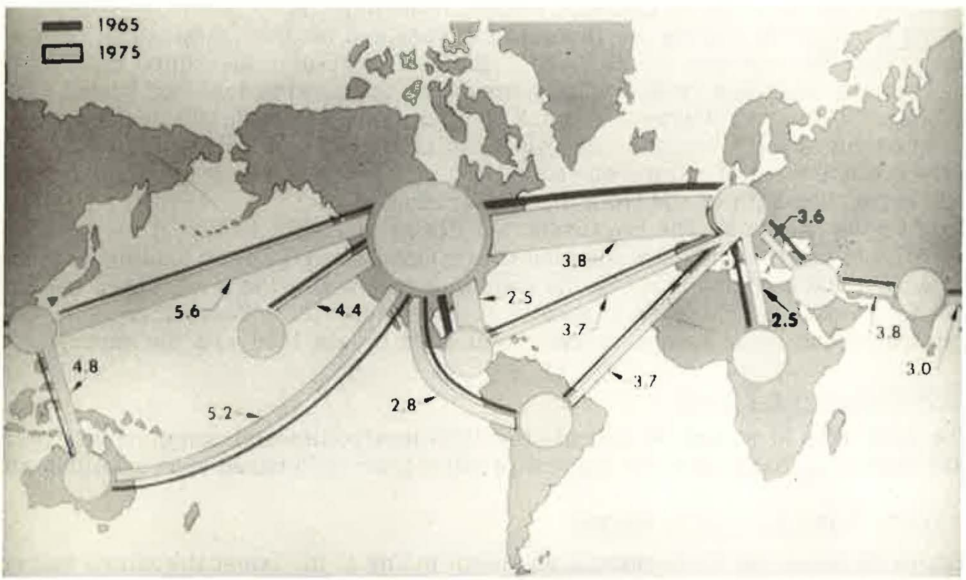

Figure 30. Intercontinental air traffic.

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

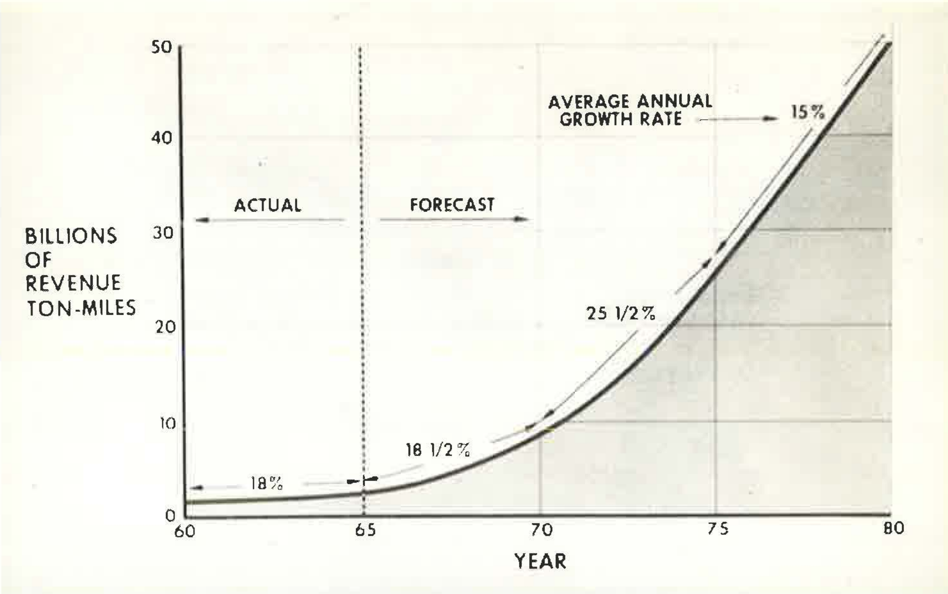

Figure 31. Free World total air market.

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.

Ground Transportation at Major European Airports

NORMAN J. PAYNE, Director of Engineering, British Airports Authority

EUROPEAN AIRPORT TRAFFIC

European airport traffic is currently growing at an average rate of 13 percent per annum, which is in line with the growth rate in the United States. Table 1 gives the terminal passengers handled at the top ten European airports in 1966.

The percentage of international passengers handled at European airports is significantly heavier than at airports in the United States. At London's Heathrow Airport, for example, 9 million of the 11.7 million passengers in 1966 were international passengers, the remainder being on domestic flights. This is the largest number of international passengers for any airport in the world. At Paris (Orly) airport, 4.4 million of the 5.6 million passengers in 1966 were international. These figures can be compared with J. F. Kennedy International Airport where in 1966 there were 5.7 million international passengers out of a total of 17 million.

In this paper, the discussion of ground transportation problems at European airports will be principally confined to London and Paris since both these cities have airports where these problems are significant factors in the expansion of the airport.

At many other European airports, such as Amsterdam and Frankfurt, the level of traffic to date and anticipated in the near future allows for a ground transportation solution by improvements to the existing highway network, but at Heathrow, London, and at the city's third airport planned at Stansted[1], and also at Orly, Paris, and the new Paris Nord site, the ground transportation requirements are of sufficient volume, either now or in the near future, to justify the investigation of exclusive public transport systems.

TABLE 1

TERMINAL PASSENGERS AT TEN TOP EUROPEAN AIRPORTS

Airport	Passengers (millions)
London (Heathrow)	11.7
Paris (Orly)	5.6
Frankfurt	5.1
Rome (Fiumicino)	3.6
Copenhagen	3.6
Berlin (Templehof)	3.3
Amsterdam	2.7
Zurich	2.5
Palma	2.4
Madrid	2.3

The high growth rate of air passenger traffic is expected to continue unchanged throughout the 1970's into the early 1980's. For example, forecasts of the total terminal passengers in the London area, i.e., at Heathrow, Gatwick and Stansted, indicate not less than 50 million terminal passengers at the airports by 1981. What will affect the transportation problem more is the magnitude of the annual increment in the late 1970's where at airports such as Stansted the annual increase in terminal passengers will be of the order of 3 or 4 million.

Therefore, even if the current ground transport situation is under control intensive planning and development must be continually undertaken to deal with the effect of this high growth rate in the future.

[1]Since this paper was written, the British Government has decided to reconsider the proposed siting of the future third London Airport at Stansted. All references to Stansted can be taken as referring to the future third London Airport wherever it is sited.

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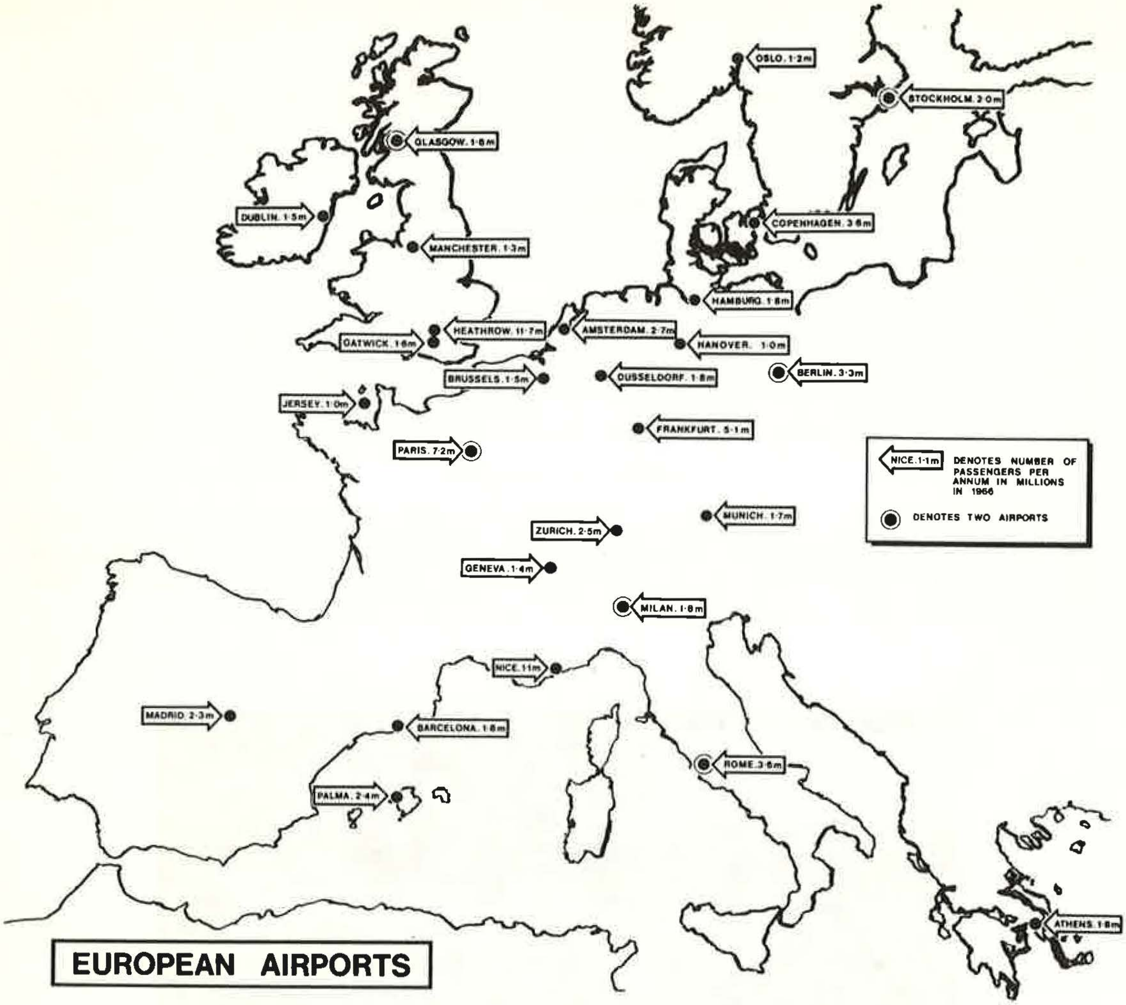


Figure 1.

AIRCRAFT

In the air this growth rate is being sustained not only by increases in the number of aircraft movements but also by increases in the size of aircraft. The aircraft movement rate at some major European airports is now only growing very slowly due to air traffic control limitations and safety requirements. The increase in aircraft size will take a leap forward in 1969-70 with the introduction of the first "Jumbo Jet," the Boeing 747, and it is anticipated that there will be a further jump in the late 1970's to 1,000-seater aircraft. For purposes of comparison the present 707/DC8 aircraft have capacities of about 150 passengers.

The introduction of the Boeing 747 into significant commercial service at European airports in the Spring of 1970 will

Figure 2.

involve considerable capital investment on new installations at airports. Construction work must soon be put in hand if the ground facilities are to be available.

In its maximum configuration, the Boeing 747 will carry 490 passengers and in Europe these passengers would generate some 300 private car or taxi trips to the airport if public transport is not available. Many of these vehicles will require parking facilities, whether on a short or long-term basis, and in addition, fast turnaround times for the aircraft of the order of one hour will involve an overlap of departure and arrival passengers and their associated vehicles.

This 490-seater aircraft will be used primarily for long-haul intercontinental traffic such as the North Atlantic route. The nature of this traffic is such that there are frequently considerable variations in planned schedules and the effect of delayed departure flights and bunching of arrival flights on ground transportation facilities, particularly car parking, will be just as acute as the effect on the operation of terminal buildings.

TYPE OF ACCESS

With few exceptions, all European airports are served only by road accesses of varying capacity. Some exceptions in Europe are London's Gatwick Airport (27 miles from the city center) which makes use of an existing major commuter railway, and Brussels which has a special rail link from the airport to the city center.

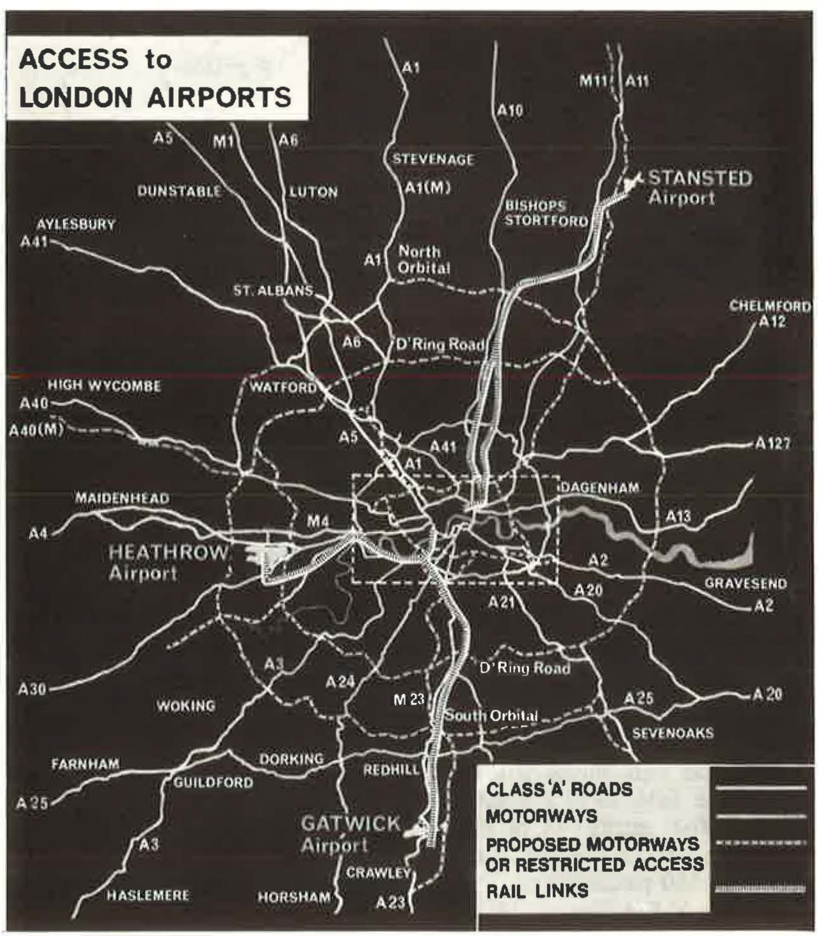


Figure 3.

Existing road accesses are almost invariably overloaded and at the larger airports serious consideration is now being given to the development of a public transport link with the city center.

As far as ground transport is concerned the choice is generally confined to the following alternatives:

1. The existing road system can be improved and new roads provided where necessary to improve this means of access to the airport; or
2. An exclusive public transport link can be constructed between the city center and the airport.

In both cases, economic considerations and cost/benefit studies can be deciding factors although the final decision may well be taken in the light of national policy in relation to urban transportation.

CHARACTERISTICS OF AIR PASSENGER TRAFFIC

The majority of large European airports serve old cities with a defined city center; they usually have a road system of limited capacity. The city centers are usually the location of tourist and business activities which are closely allied to air transportation.

It is not surprising, therefore, that a recent traffic survey (1) for London's Heathrow Airport showed that the city center is the major area of air passenger traffic generation. The results of this survey may be summarized as follows:

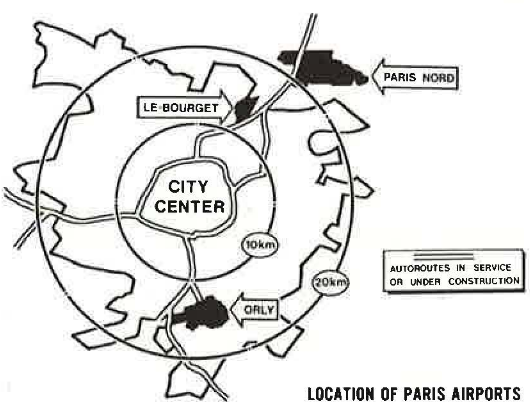
1. Of all departing passengers arriving at the airport by ground transport, 40 percent originated in Central London. A further 30 percent originated in the Greater London Area, excluding Central London.
2. The proportion of nonresidents of the United Kingdom using Heathrow is very high. They form 50 percent of all passengers and 80 percent of those passengers originating in Central London.
3. About 50 percent of all passengers used public transport to reach the airport—40 percent by the regular airline coach service from Central London and 10 percent by other means such as charter coach and public bus.
4. Air passengers from Central London made the greatest use of public transport with 70 percent of them using public transport in the peak season.
5. Public transport was used to reach the airport by 63 percent of nonresidents of the United Kingdom.

Similar surveys for Orly Airport, Paris, show even heavier concentrations at the city center. This distribution of passengers' origin and destination may be assumed to apply to most major European airports and is the major factor in considering the development of a transport link between airport and city center.

TOTAL JOURNEY TIME

It is essential when considering the ground transport stage of an air passenger's journey to realize that this is only one of a number of stages which in aggregate give a total journey time. The various stages can be summarized as follows:

1. The passenger's journey from his point of departure to the airport (this may be direct or via a town terminal);
2. The processing and waiting time at the airport prior to departure;
3. The aircraft flight;
4. The processing and waiting time at the airport on arrival; and
5. The journey from airport to destination, possibly via a town terminal.



LOCATION OF PARIS AIRPORTS

Figure 4.

'The air passenger's prime consideration is the total journey time imposed by these five stages and, even more important, the reliability of this journey time.

There has been considerable improvement in processing times at airports over the last few years and European airport practice is now approaching American practice although it must be borne in mind that the formalities imposed by the Control Authorities, Customs, Immigration and Health, apply to a greater percentage of European trips. Latest times for checking in at European airports for long-haul flights are now in the region of 40 minutes before take-off, whereas they were in the region of 60 to 70 minutes a few years ago.

Improved facilitation by the use of magnetized card passport and immigration information, which can be checked instantaneously by computer, will reduce processing times even further. Computerized techniques are also being developed for baggage handling. The net gain, however, may only be of the order of 10 to 15 minutes or so, which is not a large fraction of the total journey time, but nevertheless, may be considered significant by the passenger.

As far as the ground transportation stage of the journey is concerned, there has been an improvement in roads, but not necessarily journey time, to major European airports over the past few years as investment in major road projects has increased. Car ownership is increasing at different rates in different European countries and the extent of road congestion tends to vary from country to country.

The crucial effect on the passengers' total journey time is that it is becoming increasingly difficult for passengers to estimate the time needed for the ground transport stage of their journey and excessive margins of time are necessary to allow for possible traffic congestion. With the introduction of supersonic aircraft and the consequent significance of the aircraft flight time, a passenger's consideration will be diverted to the remaining stages of the total journey time.

When a passenger has possibly paid the price of speed in the air, he will be extremely critical of the ground transportation times and factors which may lead to any delay.

In a recent study (2) a comparison was made of the proportion of the total journey time which would be spent on the ground for a typical long-haul international journey of about 3,500 miles between a city in Europe and a city in the United States, for a conventional subsonic jet, such as a 707, and a supersonic aircraft. Whereas with the conventional jet the time spent on the ground amounted to 25 percent of the total trip, with the supersonic aircraft about 50 percent of the total journey time would be spent in ground operations. The effect of any unreliability or deterioration in ground transport times would be felt most acutely on supersonic flights and the situation might well be reached where the benefits accruing from a reduced flight time would only be noticeable on the longest of intercontinental flights.

These considerations lead to the conclusion that with growth and increase in speed of air transport a fast reliable public transport link should be available between the airport and the city center, which is the predominant area of air passenger traffic generation.

THE PUBLIC TRANSPORT LINK

Assuming the creation of a fast public transport link, two benefits can immediately be seen to arise:

1. The number of private cars, taxis and coaches using the airport will almost certainly be reduced. This eases the pressure on existing roads and car parking facilities and will undoubtedly facilitate the handling of larger aircraft without major extensions to existing installations.
2. The safety and reliability of the service will assist the development of the new aircraft and remove a significant portion of the uncertainty from passengers' minds concerning the time allowances for the journey between airport and origin or destination.

If the basic requirements of reliability and speed are to be met by any public transport link, it is clear that the current system of coaching between town centers and the airport on public roads, which is the current European solution, will not meet the needs of the 1970's. It is also doubtful whether a conventional rail link forming part of a suburban service would meet these requirements since it would be deficient in the equally important requirements of comfort and baggage handling. Therefore, if a transport link is to be provided which will meet the stated requirements and encourage passenger usage, it must be located on an exclusive route between the city center and airport.

Having studied the requirements for a public transport link and the benefits which would accrue from the presence of such a link, it is essential to review the factors affecting its viability. They may be summarized as follows:

1. The distribution of land origin and destination of air passengers: a high concentration in the city center as met in European cities is a basic requirement.
2. The proportion of nonresident passengers: these passengers are normally without private cars and must rely on public transport, taxis and hired cars for their journey to or from the airport.
3. The extent of private car ownership and availability for the residents of the country concerned: for example, greater use is made of private cars to travel to or from Heathrow on weekends compared with weekdays due no doubt to the fact that cars are more often available for this purpose on weekends.
4. The number of passengers who would use the link: its profitability depends solely on airport traffic and therefore the airport must be handling a substantial number of passengers per year before a link can be justified. Traffic at Heathrow in the early 1970's will be sufficient to insure the economic viability of such a link.
5. The availability and price of taxis and hired cars and other specialized means of road transport such as self-drive hired cars or limousines: taxis and hired cars are not popular modes of transport between Heathrow and the city center in view of the distance and the high fare relative to the coach fare (at least eight times the coach fare) and only about 9 percent of the passengers use these modes. In Paris, the taxi fare is only about four times the coach fare and some 25 percent of passengers use this mode. Self-drive hired cars and limousines are relatively undeveloped in European countries in comparison with the United States.
6. The previously discussed road traffic congestion on roads serving the airport.

As stated previously, 40 percent of the passengers using Heathrow originate or terminate in Central London and many others pass through Central London on their way to or from the airport. Of all passengers, 50 percent are nonresidents of the United Kingdom. The nature of the traffic is such that a fast direct link with Central London would be very attractive and detailed studies show that it would be profitable. The relief which would be afforded to ground transport facilities at the airport by the mid-1970's would be significant.

For Orly Airport, the dispersal of origin and destination of air passengers is similar to London. However, proportionally, slightly fewer passengers travel between the regions of France and Orly via Central Paris. Most of the passengers from the regions are air passengers changing flights at Orly.

The ownership and use of the private car in Paris has risen steeply in the past few years and it is the policy of the French Government to develop a system of autoroutes for Paris to provide facilities for these vehicles rather than apply a policy of restraint. The outcome of this situation is that the use of private cars for journeys to and from the airport is increasing at a parallel rate to the growth in private car ownership. Orly is at present served by a major radial autoroute and when Paris Nord, which is to be developed as an airport to serve Paris by the mid 1970's, is in operation it will be similarly served.

TYPE OF LINK

A recent study (3) for rapid transit links in the Manchester area indicated that conventional steel on steel or duorail with improved signaling and other techniques provides the best answer to the urban rapid-transit requirement and would also be applicable to an airport link. This study considered four systems which have reached a stage of development where there is a reasonable prospect that they could be operating by the early 1970's.

1. Alweg Monorail—bottom supported vehicles with rubber tires;
2. Safege Monorail—suspended vehicles with rubber tires;
3. Westinghouse Expressway—lightweight rubber-tired vehicles on concrete running surface; and
4. Duorail—either conventional steel-flanged wheels or rubber-tired wheels on concrete running surface.

It did not consider hovertrain or aerotrain forms of transportation which are now under development both in the United Kingdom and in France. These, with the possible exception of a linear induction motor, need examination to establish their position in relation to duorail.

A detailed study was carried out last year of all possible forms of rapid transit systems to serve Heathrow Airport and, in addition to the four mentioned variants, the possibility of exclusive traffic lanes for coaches was also considered. Each system was studied from the point of view of social cost-benefit and profitability and the report came out firmly in favor of a conventional duorail.

Arising out of this study, it has been agreed that Heathrow is to be served by a conventional duorail link between Victoria and the airport, which will be in operation by 1972. The service will be non-stop between city center and airport providing a 10-minute frequency of service through the day and a journey time of about 23 minutes. It will be capable of handling 3,500 passengers and their bags per hour in each direction and by 1981 will be used by 12 million passengers each year.

At Paris, Orly is at present served by an autoroute which is shortly to be improved to provide exclusive lanes to and from the airport over part of its length. There are similar plans for Paris Nord; in fact, the proposals for this airport assume that only 20 percent of the passengers will use public transport. However, there are plans to develop an express metro service between Orly and Paris Nord via the center of Paris with a limited number of intermediate stops. If road congestion develops to intolerable levels it is therefore possible for the Paris Airport Authority to divert their policy towards public transport.

ROAD TRAFFIC

The emphasis which has so far been placed on public transport links does not imply that the private car is unwelcome at airports. For many journeys from the suburbs and metropolitan regions of large cities, it is the most convenient mode of transport and has the advantage of complete flexibility. The private motorist does, however, suffer from the fact that he cannot establish any priority over other road users and in situations of acute traffic congestion is likely to suffer to a greater extent than the other users to whom delays are not so significant. The dispersal of land origins and destinations and the relatively small volumes of airport traffic compared with urban traffic as a whole means that, apart from the approach roads adjacent to the airport, funds are rarely allocated to road developments on the basis of airport requirements.

In addition the private motorist directly associated with the conveyance of air passengers is obliged to share the immediate approach roads to an airport, and in many instances the roads within the airport with other airport traffic such as staff, servicing traffic and spectators.

At Heathrow some 37,500 vehicle trips are currently made to the airport daily. Only one-third of these vehicles are conveying air passengers, the remaining 25,000 vehicles being associated with staff or other essential airport traffic. The peak-hour inflow is at present 4,700 vehicles per hour and by 1981 this figure will have risen to about 10,000.

Spectators are at present a serious problem at the largest airports in Europe which is some indication of the novelty of international flying. On summer weekends at Heathrow, those that arrive by private car can be a serious problem, occupying road and car parking space to the detriment of air passengers. Apart from adopting a policy of discouragement, it is impossible to segregate the "legitimate" airport users from spectators. This problem will no doubt decrease as flying becomes more universal and this position has now been reached in the United States.

AIR CARGO

The growth of air cargo is usually termed "explosive." In Europe the annual increase over the last few years has average 20 percent per annum. However, the total weight of cargo carried by air is relatively small compared with other forms of transportation and at most European airports ground transportation of air cargo does not yet present a serious problem. In fact, due to the low volume and high value characteristics of the cargo, the road traffic associated with its delivery to or dispatch from the airport, is usually less than that associated with staff working in the air cargo sector of airport activity. At Heathrow, 1,800 employees' vehicles enter the cargo areas each day compared with 600 vehicles delivering or collecting air cargo.

The emphasis on air cargo also varies from airport to airport depending on the policy of the major air carriers.

At Heathrow the volume of cargo handled last year was $\frac{1}{4}$ M tons although by value Heathrow was the third largest port in Great Britain. By 1970, the throughput is anticipated to have risen to $\frac{1}{2}$ M tons reaching 1 M tons in the mid-70's. The probable ultimate capacity of the cargo handling installations, which are being constructed by the Airport Authority and the airlines, is 2 M tons per annum, with containerization of air cargo becoming a commercial reality.

In the future, therefore, road transportation of cargo is likely to cause some problems at airports when significant volumes are reached in the 1970's, but the road capacity necessary to meet the needs of employees at peak periods should prove adequate for the ground movement of air cargo throughout the day.

Figure 5. Car Park No. 3, Central Terminal area, London Heathrow Airport.

CAR PARKING

As far as parking facilities at airports are concerned, Heathrow is probably ahead of any other airport in the world in the provision of multi-storey car parks to meet the ever increasing demand for parking space. By the spring of 1968, five multi-storey car parks will be in operation at Heathrow, providing 3,500 spaces for public use and 2,000 spaces for the use of airport staff.

This public parking space is located in multi-storey car parks immediately adjacent to each terminal building to reduce walking distances to a minimum. They are primarily intended for vehicles delivering or collecting air passengers and the storage of air passengers' cars for the duration of their stay is mainly carried out off the airport.

Future projections show that there will always be space for vehicles delivering or collecting air passengers but the storage of air passengers' cars will be predominantly carried out off the airport as at present.

Orly has provided sufficient surface parking space to meet the demand to date and is, at present, engaged in the construction of underground car parks outside the passenger terminal to serve primarily short-term needs. Multi-storey car parks are being constructed some distance from the passenger terminal to meet the long-term needs.

At other European airports, parking is normally provided at surface car parks but as expansion continues, multi-storey car parks will not only become necessary due to lack of space for horizontal expansion, but will also be economically justified.

SUMMARY

Only London of the major European cities has sufficient volume of air traffic to justify an exclusive public transport link with the city center. However, the configuration of other cities and the characteristics of the air passenger traffic will mean that when this traffic reaches certain levels, it will be possible for airport and city center to be linked by a fast, reliable mass transit system.

As aircraft speeds increase, the proportion of the air passenger's time spent on the ground will increase. This will focus attention on the need to improve ground facilities.

Future emphasis must be on the integration of an airport into the overall transportation system for a city, of which it forms an important part. Where public transport can play its part in serving the airport, it should be as fully developed as can be economically justified.

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Discussion

V. SETTY PENDAKUR, University of British Columbia—N. J. Payne's paper is important and timely both for Europe and North America. The increasing congestion on urban arterials, combined with increasing air speeds, continues to widen the gap between the efficiencies of ground and air transportation technologies. An increasing portion of the total travel time is now being spent on the ground due to problems in baggage handling, terminal waiting time and other delays. These problems threaten to nullify the advances made in air transportation.

In the United States, a greater number of airports are "tying in" to freeway systems. Average travel times of 40 to 70 mph prevail between major city centers and their airports. In a study of airport access (4), circulation and parking problems, Voorhees pointed out that it was possible in 1965 to get from downtown to most of the outlying airports in 25 to 30 minutes by car. Travel times from the city center to the airports at 20 top air hubs of the United States varied from 20 to 56 minutes (4, p. 74). Most of these airports have been able to tie in to the Interstate Highway System, built with federal funds.

Airport accessibility clearly affects air passenger development. In a study of several midwestern airports, Brown pointed out that decreasing airport accessibility would decrease the rate of growth of air passenger traffic (5). The loss in passengers is a result of the efforts of passengers to avoid the additional costs of inaccessibility by using alternatives to air transportation wherever more attractive.

When air transportation is considered as merely a portion of the overall communication spectrum, its vulnerability is highlighted. Stronger intermodal competition, which is primarily typical for short to medium-haul trips, increases the elasticity of demand for each mode. In the North American context this is particularly important because a large portion of air trips fall into this category: one-third of all U.S. air trips are shorter than 300 miles and one-half of all U.S. air trips are shorter than 500 miles (6). The elasticity of demand for air travel in relation to airport accessibility is much lower for long than short-haul trips. Therefore, ground transportation systems and their efficiency is a very important factor in air passenger traffic development in North America.

Central business districts are the strongest single origin-destination points of air passengers, yet, this passenger flow is not high enough to justify the construction of special rapid-transit links as pointed out by Jordan (7). However, higher passenger volumes and decreasing accessibility could combine to accentuate rapid-transit links. Examples of this are the systems in Cleveland, Ohio, and Tokyo, Japan. Payne's point about public transport links to airports is indeed an element of public transportation policy decision to be made on a systems basis.

Unlike the strong role assumed by the United States Government as a result of the Urban Mass Transportation Act of 1964, the Government of Canada has no policy as yet with regard to ground transportation to airports. It is only recently that the Central Mortgage and Housing Corporation, an agency entrusted with the administration of the National Housing Act, has become interested in studying the possible acquisition of transportation corridors, with the Federal Government participating financially in such acquisition. The pilot studies are being conducted but the policy is not yet clear.

The present involvement of the Government of Canada is limited to ground transportation within airport property only. If any assistance is extended beyond the airport property, the generated ground traffic will have to be the exclusive result of airport activities in order to qualify for assistance. However, the National Capital Commission in Ottawa is now negotiating with the Government of Canada for assistance to construct a freeway between the city center and the Uplands Airport. The publicly announced intention to construct a $1 million dollar two-lane toll bridge across the middle arm of the Fraser River to connect to the Vancouver International Airport is an indication of federal involvement without stated policy (8).

What is urgently needed is an understanding at the policy level that all elements of the transportation system (air, rail, water and ground) are integral parts of the same system and must operate at the highest level of their efficiency and continue to provide proper linkages. Federal involvement indirectly underwriting the costs of airport development to the tune of millions of dollars but totally ignoring the ground transportation link, is leading to decreased efficiency of the total system and undue chaos. As the urban areas grow and the vehicle systems change, it will be necessary to clarify and/or change the policy towards systems integration. Payne's conclusion that "...the configuration of other cities and the characteristics of air passenger traffic will mean that when this traffic reaches certain levels it will be possible for airport and city center to be linked by a fast, reliable mass transit system," is indeed a valid one. Yet the drastic need now is at the policy level where the federal involvement in air transportation must be related to all elements of transportation to form linkages in the total portal-to-portal transportation process. Only through an understanding at the policy level can we accomplish the final conclusion of Payne: "Future emphasis must be on the integration of an airport into an overall transportation system for a city, of which it forms an important part."

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Sweden Changes to Right-Hand Driving

DAVID M. BALDWIN, U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads

•WORLD attention was centered on Sweden on September 3, 1967, when that country, a nation of 8 million people and 2 million motor vehicles, changed from left-hand to right-hand traffic.

With this change, all countries on the European continent now drive to the right. In the European area, left-hand traffic is now the rule only in Great Britain, Ireland, Cyprus, Malta and Iceland—and Iceland will switch in 1968. The remainder of the world is still divided, with Japan, Australia, New Zealand, India, parts of Africa, and many former British colonies driving on the left and the rest of the world keeping to the right.

The reasons for right-hand or left-hand traffic are clouded in antiquity. The fact that man is essentially right-handed has undoubtedly influenced the decision, but sometimes in one direction and sometimes in the other. Presumably the need to keep the sword hand free so as to fight effectively from the back of a horse had something to do with it. Later the choice between controlling a horse-drawn coach from a seat on the coach versus riding one of the horses played a part in the decision between right and left traffic. The coach-seat driver kept to the left and the postillion rider to the right—and the differences began.

The first known legislation on the subject came in 1736 in Saxony; an English law appeared in 1756. By the time that the motor vehicle arrived on the scene, the world was greatly divided on the matter. The Swedish change, however, was by no means the first. Canada changed in 1922, Portugal in 1929, Austria, Hungary and Czechoslovakia between 1930 and 1941, Argentina in 1945, and Ethiopia as recently as 1964. Undoubtedly this list is not complete, but in none of the previous changes was a vehicle population of 2 million involved, nor was the problem approached in as careful and scientific a manner as in Sweden.

The history of the change-over in Sweden goes back at least 40 years, for the first bill on this subject was introduced in the Swedish Parliament that long ago. Public opinion was not favorable, however, and the matter was set aside. As recently as 1955, when a plebiscite was held on the subject, the vote was 83 percent in favor of retaining left-hand traffic. The decision to make the change was not reached until May 1963, when the Parliament voted almost 6 to 1 in favor of making the switch.

Parenthetically, it is worth noting that nearly two months after the change, a public opinion poll showed 57 percent of the populace favorably disposed to the change and only 20 percent opposed. Perhaps this is only acceptance of the inevitable, but it is a major shift from the opinion expressed in 1955.

The motives which prompted the decision to make the switch were a mixture, as might be expected, of political, economic, and social reasons.

The Scandinavian Council and the Council of Europe both urged Sweden to make the change. International traffic developments were cited as rendering closer coordination of traffic regulations a necessity.

International traffic crossing the Swedish frontier in 1955 totaled 1.5 million vehicles, with the 1970 total estimated at from 15 to 20 million vehicles and between 75 and 95 million people. The bridge to be built over the Great Belt in Denmark and that contemplated over the Sound between Denmark and Sweden will provide a land route from Germany through Denmark to Sweden. This, together with the long common border with

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Figure 1. New signs in Stockholm covered prior to the changeover.

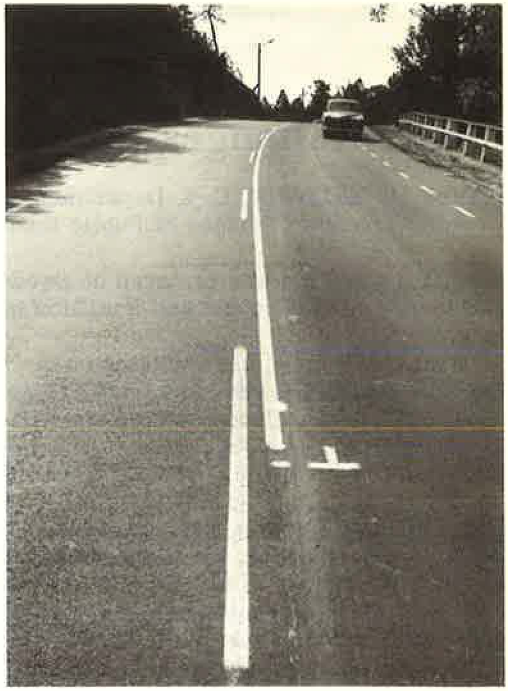

Figure 2. New pavement markings installed before the changeover while left-hand traffic was still operating.

Norway and the proximity of Finland to the east, will greatly increase the amount of tourist and commercial traffic to and from Sweden in the near future.

The social aspect was emphasized by a study of accidents involving Swedish vehicles abroad and those involving foreign vehicles in Sweden. Both types were increasing faster than the number of vehicles crossing the frontier. It was assumed that this disproportionate increase was due to the difference in traffic rules.

The benefits, some tangible and some intangible, were thus felt to be great enough to justify the change-over. The costs of the change were estimated at over 600 million Swedish kronor, or about $120 million. Of this total amount, slightly more than half went for the conversion of buses, street cars and other vehicles; about 40 percent was for physical changes in streets and roads, and for new traffic controls; about 5 percent for information and training; and the remaining amount for administration.

It is interesting in this connection to compare these estimated 1967 costs with earlier figures. It was estimated that the transition in 1943 would cost about 16 million kronor ($3.2 million), that the costs in 1946 would be about 27 million kronor ($5.4 million), and that the costs in 1959 would be 215 million kronor ($43 million).

The costs of the change-over were borne almost entirely by the government, through a special tax on vehicles from 1964 to 1967 of 20 kronor ($4) on motorcycles, 40 kronor ($8) on vehicles weighing up to 1,100 kg., and 75 kronor ($15) for all other vehicles.

The cost of the change, $120 million, has been estimated as 5 percent of the annual cost of motor vehicle transportation in Sweden, including vehicle purchase costs, road and street building, operating costs, accidents, and all secondary investments.

Once the decision was made by the Parliament, the government appointed a national commission to serve as a decision-making body in planning and executing the change-over. The commission itself was a small group of six, but it was advised by two 10-member groups, one concerned with technical and economic questions and the other dealing with matters of safety. A secretariat was created, and several committees of experts were created to work with the staff, which was set up in sections to deal with (1) highway safety, (2) street and highway changes, (3) conversion of vehicles, (4) economic and other surveys, (5) legal and administrative problems, and (6) public information media. Special committees were established to perform scientific studies and to develop necessary educational programs.

The scientific group recognized that the change-over would seriously disturb the mutual adaptation of man and environment, imperfect as that might be. To provide at least the same degree of adaptation after the change as before, it was accepted that changes would be involved in the environment (the road, the vehicle, and the law) as well as in the road user.

In the environmental area, for instance, it was decided that new or modified highway signs ought to be introduced well in advance of the change date and that the duplication would serve to assist the road user in learning the new signs before he was also faced by learning many other new tasks connected with right-hand driving.

Although the change-over involved many projects which extended over a substantial period of time, the switch itself was a relatively momentary phenomenon. For the road user himself, this requirement for instantaneous adaptation was regarded as the most serious problem. New reflex actions would have to be learned and old reflexes forgotten.

It was recognized that this would not happen at once, and that education would be a gradual process which would continue for a period of time after the change-over.

This concept affected the decision as to the exact date of the change-over: September 3, 1967, was selected. This date would provide an opportunity to reach road users through their normal communication channels for a brief intensive period just prior to the switch. Schools would open the week before, with special attention to traffic education. More importantly, it would be possible just after the switch to use fully the facilities of the schools, employers, organizations, and all mass media to educate and to remind both drivers and pedestrians.

The question of timing for training in right-hand driving was given early study. It was decided, on the basis of experimentation, that such training prior to the change-over could cause more harm than good. Simulation demonstrated that drivers who drove in left-hand traffic, then in right-hand traffic, and then again in left-hand traffic made more mistakes than drivers who had not experienced the intermediate step of right-hand driving. This was confirmed by a questionnaire study of Swedish drivers who had driven abroad in right-hand traffic and then come back home to left-hand traffic.

Another interesting conclusion was reached in connection with changes in environment. It was determined, through simulation, that a driver who changed his environment

Figure 3. A main street in Stockholm with three lanes of traffic before the changeover.

at the time of the change-over made fewer errors than a driver who remained in the same environment. But when the first driver returned to his familiar environment, he made more errors than the one who had remained in the same area. It was concluded, therefore, not to recommend a change of environment after the date of the change-over.

The scientific group also looked into the amount of knowledge of the traffic law, highway signs, and safe driving practices possessed by school children and adults. The results of a survey carried out in late 1965 and early 1966 showed that such knowledge was far from complete, and the planned educational effort carried out in the autumn of 1966 was designed to correct these deficiencies.

A number of traffic studies were conducted to identify possible problem areas and to guide the planning for the change. One such study examined the matter of lateral placement of vehicles on the road. In Sweden, most vehicles already had the steering wheel on the left side, so the switch to right-hand traffic would move the driver from the curb side to the center of the road. Measurements of the lateral placement of vehicles in Sweden and in Denmark (which has right-hand traffic) indicated no substantial differences, however, between the two situations.

It was decided that the change would place the driver in a relatively poorer position to see overtaking vehicles, and it was recommended that outside rearview mirrors be installed on the left side of all vehicles. Forward visibility was examined on a number of horizontal and vertical alignment configurations, and it was concluded that the switch would not create problems.

The overtaking maneuver was examined by comparing results of Swedish studies with those in other countries where right-hand driving is the rule. The results indicated that the average duration was the same in right-hand and left-hand traffic, but that the distance was shorter in right-hand traffic. In an effort to explain this, the Swedish authorities guessed that the better visibility afforded in right-hand traffic (as compared with the pre-change Swedish situation where the driver was at the curb side of the vehicle) might mean that Swedish drivers made their overtaking maneuvers at higher relative speeds.

The behavior of pedestrians when crossing a roadway was recognized early as a major factor. It was taken for granted that it would be difficult for pedestrians to remember to look first to the left before stepping off the curb. A photographic study of pedestrian actions was made, which showed that 70 percent of the pedestrians looked to the right before leaving the curb, but that only 15 percent looked to the left. A total of 80 percent looking to the left was not reached until 7 feet from the curb. In the case of a divided

Figure 4. The same street on H-Day.

Figure 5. The same street operating with four lanes of traffic keeping to the right.

highway, the 80 percent looking to the left figure was not reached until 20 feet from the curb. A report published late in October indicated that about twice as many pedestrians are looking first in the wrong direction in right-hand traffic as looked wrong in left-hand traffic, so the lesson has not yet been learned.

Because of the common use of vehicles with the steering wheel on the left side, few changes were needed in passenger cars. It was necessary to change asymmetrical headlamps, however, and this was the single item of cost borne directly by each vehicle owner.

The situation in regard to buses was by no means as easy to solve. Some 7,000 buses were operating in Sweden, and because several street car lines were abandoned at the time of the change-over, 700 additional buses were added at that time. Prior to 1963, all buses had doors on the left side and were designed throughout for left-hand traffic. No left-side doors were to be used after the change, so a massive rebuilding or replacement operation was obviously required.

Three alternatives were open: partial rebuilding (doors only), complete rebuilding (a mirror change for right-hand traffic), or replacement with a new vehicle. Because the bus changes could not be made instantaneously but had to be spread over many months, a number of buses with doors on both sides resulted. It is planned to close the left-hand doors eventually.

At the time of the change-over, the fleet of 7,700 buses was composed of 2,900 partially rebuilt buses, 630 completely rebuilt buses, 150 old vehicles with doors on both sides, and 4,020 new buses. Of this last group, 2,520 were designed for right-hand traffic only, with the other 1,500 having doors on both sides and thus capable of operating in either left-hand or right-hand traffic.

Of the buses in the Swedish fleet in 1963, about 3,700 are in use after the change-over. More than half of the 4,020 new buses represent replacements for older vehicles which would have been withdrawn from service in any case. About 1,000 additional buses were needed, due to cessation of street car lines, school organization changes, and other factors, so only about 1,000 buses were withdrawn from service one or more years earlier than expected.

The necessary adjustments in streets and highways and in traffic control devices represented the next greatest item of expense. Plans for these changes were prepared by municipal authorities and the regional road authorities, and then submitted to the national commission. Based on these plans, the costs were distributed about as follows:

In general, major reconstruction work was carried out in advance of the date of the change-over. It was not possible to complete all projects in advance, however, and some work was left for the change-over day and some for even later completion. For

Cost Item	Percent	Cost Item	Percent
In urban areas:		In rural areas:	
Traffic circles, etc.	49	Freeway access	30
Street intersections	25	Intersections	20
Bus stops	10	Bus stops	18
Miscellaneous	16	Left-turn lanes	14
		Visibility improvements	7
		Slow traffic lanes	6
		Miscellaneous	5

instance, it was not possible to remove street car loading platforms before the cars stopped operating, and this did not occur until the last few hours.

The fact that more than three years advance notice of the change was available meant that some work which would otherwise have been carried on between 1963 and 1967 was postponed, waiting for right-hand traffic. In Stockholm, for example, it was estimated that from 15 to 20 percent of the total cost was for work delayed in anticipation of the change. This was principally for new paving and for new traffic signals.

In Stockholm, the largest city in the country with over a million people, there were 175 traffic signals which had to be revised for right-hand traffic. In addition, 29 new signals were installed because of different traffic patterns following the change.

Many of the previous signals were traffic-actuated. Although signal heads could be modified or new heads installed in advance of the change-over, it was felt that right-hand detectors should not be installed while left-hand traffic was still operating. As a result, at the time of the change most signals in Stockholm were operating on a fixed-time basis. Interconnection was similarly delayed and thus progression, or the "green wave" as it is referred to in Europe, was not present in the early days of right-hand traffic.

About 800 traffic signals were revised throughout the country, and an estimated 220,000 highway signs were replaced or newly installed. As was mentioned earlier, left-hand signs were duplicated on the right-hand side, partly as an education measure. This was not practical in all cases (for example, in the case of directional arrows) and so many of the new signs had to be erected and then covered or masked out. Following the change the old signs were removed as rapidly as possible. Some critical signs were covered the day of the change, with removal scheduled for later.

In Stockholm the authorities took the occasion of the change-over to up-grade numerous signs, particularly overhead directional signs. Suspended signs at many important circles and other important junctions were replaced by internally illuminated signs on fixed supports.

The change-over was also used as an opportunity to bring Sweden into conformity with the rest of the Continent in the matter of signs. Although Sweden had followed the European standard in general, there had been a few differences, chiefly in colors, which were eliminated when the new signs were installed.

Road or pavement markings had to be changed, and this presented a special problem because it could not be done at the last minute and left-hand traffic would be forced to operate for some period of time with any new markings for right-hand traffic. Yellow had been used for all pavement markings, and the authorities decided to solve the problem by using white for all markings for right-hand traffic. Drivers were instructed to obey the yellow markings up to the date of the change-over, then to obey the white markings. Certain arrows were left without heads, with these all-important features added the day of the change-over.

The details of changing curb, removing islands, revising signals, replacing signs and providing new pavement markings required much planning and scheduling. A substantial amount of effort very obviously went into the task of coordinating all the work so that left-hand traffic could continue up to almost the last moment. For most of the country, traffic was stopped only for 5 hours early Sunday morning. In the big cities the suspension was longer, but the longest time (in Stockholm) was only 28 hours.

In Stockholm, the change-over was accompanied by the development of a revised traffic circulation plan, which together with other changes, was designed to improve greatly the traffic capacity of the street system. The number of one-way streets was increased, many complicated intersections were rebuilt, and the abandonment of street cars made possible the correction of a number of traffic bottlenecks. New parking regulations, which prohibit daytime parking in virtually all the downtown section, were placed in effect, although this did not appear to be an essential element in the change-over and seemed rather to be riding on the coattails of the larger program. Several new traffic facilities, including an important urban freeway section, were also timed to open with the change-over. All in all, traffic patterns in Stockholm were substantially changed and it may be impossible to isolate the effect of the change-over to right-hand traffic in the city.

In addition to the changes already cited, a number of new regulations went into effect at the time of the change-over or shortly before. Beginning on January 1, 1967, pedestrians have been required to obey traffic signals and to use nearby pedestrian crossings. Drivers have been required to yield to pedestrians crossing on a green light.

The basic right-of-way rule was revised as of the day of the change-over. Where drivers yielded to a vehicle on the left under the old system, they must now yield to the vehicle on the right. The authorities announced that the new rule would be applied much more strictly than had been the case for the old rule.

Beginning with the date of the change-over, another new regulation went into effect, prohibiting the crossing of a solid line to the right of a broken centerline. Also new was the use of a single solid white line to indicate no crossing or straddling of the line.

Last but not least in importance, speed limits were reduced, at least temporarily. It was stated that the duration of the reductions would depend upon the accident experience. Specifically, the previous 50 kph limit was reduced to 40 kph; the limit for freeways was set at 90 kph; and the general limit elsewhere was set at 60 kph for two days, then raised to 70 kph.

It is interesting to note that by the end of October, the freeway limit was raised to 100 kph (up to 62 mph from the earlier 56 mph) and the general rural limit was upped from 70 to 80 kph (from 43 to 50 mph). Local authorities were given the option of increasing the 40 kph (25 mph) limit up to 70 kph (42 mph).

The change-over itself was made with what appeared to be a minimum of difficulty. The actual shift took place at 5 a. m. on Sunday morning, and a surprising number of people were up to watch it. In places there was applause and even a few cheers when vehicles moved over to the right side. By Sunday afternoon, Stockholm was flooded by "Sunday drivers" anxious to try their wings. The greatest difficulty appeared to be the result of the changes in the circulation pattern in the city core—a taxi driver delivered me a block from my destination with the explanation that he "couldn't get there from here."

Great interest was expressed over the initial accident experience. Two general theories were advanced ahead of the change: either the rate would be immediately high and decline slowly over a long period of time, or the initial rate would be moderate and then would slowly increase before dropping again to an average figure.

On the basis of experience during the first two months of right-hand traffic, neither theory appears to have been entirely correct. Fatal accidents have been much below the average rate for this time of year, and total accidents have occurred at a rate about average.

The first few weeks saw a higher than average experience in injury accidents involving bicycles and mopeds, of which there are many in Sweden as in most of Europe. Traffic volumes were down very slightly during the first weeks, but not enough to account for the lower accident totals. It is perhaps too early to tell the full story, but it appears that the transition has been accomplished without undue blood-letting.

Relapses to left-hand driving practices appear to have been fairly common among drivers. A survey conducted by a committee of the official commission reported that such relapses had happened at least once to the average driver. As previously mentioned, pedestrians appeared to have fallen short of making a complete adjustment to right-hand traffic, with many still looking the wrong way first before stepping off the curb.

In the initial days of right-hand traffic, nearly 150,000 volunteers manned both ends of busy crosswalks throughout the country to assist pedestrians. The volunteers included teenagers, members of the military services, and others, both male and female. Wearing white cuffs for identification, these "living reminders" exercised no police power but did serve to alert pedestrians to the new traffic conditions and new regulations. Such reminders would be useful for a long time, according to one Swedish psychologist, who stated that it would not be until the year 2020 that Sweden would be entirely free from people who might react incorrectly in right-hand traffic, reverting to the reflex action associated with left-hand driving.

That the change-over occurred as smoothly as it did is a tremendous tribute to the Swedish people. As the Minister of Communications, Olof Palme, said in a press conference, it was not possible to foresee the atmosphere and spirit which prevailed during the switch. It is perhaps most significant that the change was attempted at all, for this took considerable courage. Great praise is due those who planned so thoroughly and organized so skillfully that the transition went off with no major hitches. Finally, and most importantly, major credit must be given the Swedish road users for their display of discipline in adapting to such a major change in traffic operation.

The Channel Tunnel: 1751-1975

FRANK P. DAVIDSON, Technical Studies, Inc., New York, N.Y.

•THE Channel Tunnel enjoys the dubious distinction of having undergone a longer period of research and preparation than perhaps any engineering project in history. In a sense, the project may be said to have been discovered rather than invented: in 1753, Nicolas Desmarets published a paper entitled "Une Mémoire sur la Question de Savoir si l'Angleterre et la France Avaient Eté Autrefois Réunis." This paper marshalled persuasive evidence that a geological link did at one time exist between France and England.

Monsieur Desmarets had won the prize offered by the Academy of Amiens in 1751 for the best design of a cross-channel link. The young geologist's work attracted the attention of the king's cartographer and, in due course, Desmarets was named a member of the Institut de France. Half a century later, the engineer Mathieu submitted (in 1802) the first known detailed engineering concept of the tunnel (including a mid-channel island "to breathe the horses"). It was this proposal which was discussed by Napoleon with Charles James Fox during the short-lived Peace of Amiens. In 1803, Tessier de Mottray put forward the earliest suggestion of the main alternative method of construction—an immersed tube to be laid on the sea bed.

The re-discovery by Desmarets of the land bridge which, until about six thousand years ago, linked England with the Continent, led to two centuries of surveys, resolutions, petitions and international conferences.

As Thomas Whiteside has reported in an amusing and authoritative book (1), the main promotional activity on behalf of a Channel Tunnel occurred, not surprisingly, in France, where insular modes of thought were of little consequence. But the Victorians—among them, Isambard Kingdom Brunel, builder of the first sub-aqueous tunnel (under the Thames)—could not resist the lure of a great tunnel under the channel itself, and companies formed in both the United Kingdom and France started digging toward each other in 1878. Five years later, fears of a French invasion led the British Government to halt further work. By this time, however, each of the tunnels had reached a length of over a mile. The information acquired in the course of this work was of immense value: it was found that the Lower Chalk was virtually impermeable to water; moreover, new boring machines had been successfully utilized, one of which (designed by Colonel Beaumont of the Royal Engineers) is commonly regarded as the direct ancestor of the powerful modern tunneling machines now in use throughout the world.

It was only after two world wars, in which both the French and the British found the absence of a tunnel a hindrance to effective military cooperation, that British public opinion—long prompted by Churchill—moved decisively into the tunnel camp. In 1964, a Gallup Poll reported only one Englishman in ten in opposition; and a powerful committee, representing all parties in both Houses of Parliament, sponsored the project as one of vital importance for the future of Britain. This committee has had as joint chairmen Mr. E. L. Mallalieu, Q. C. (Labour) and Sir William Teeling (Conservative). It was Mr. Mallalieu's question, in 1955, addressed to the then Minister of Defence, as to possible strategic objections to the project, that elicited Mr. Macmillan's famous reply, "scarcely any." Two years later, the Channel Tunnel Study Group was founded.

The London Times, expressing the new spirit in an editorial on August 28, 1961, pontificated: "A channel link would be there primarily to do a job; but it would be there also as a visible token of new times and new relationships. Shakespeare had the first words, but Donne deserves the last: 'No man is an island, entire of itself'."

Paper sponsored by Special Committee on International Cooperative Activities and presented at the 47th Annual Meeting.

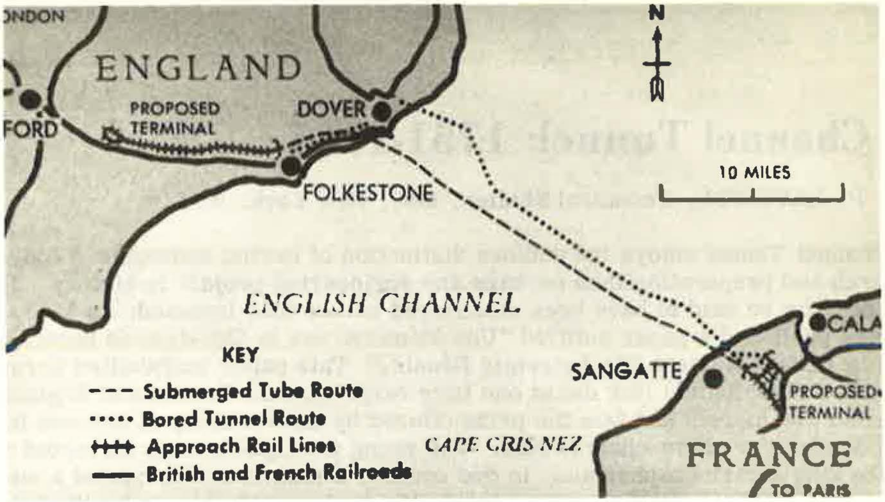

Figure 1. Map of tunnel and tube routes and proposed terminal areas.

Figure 2. Napoleon described the Channel Tunnel to Charles James Fox as "one of the great enterprises we can now undertake together."

Figure 3. Charles James Fox, leading English exponent of a reconciliation with France, visited the First Consul in 1802.

This paper, however, is limited to a description of the studies carried out in recent years, and it concludes with some comments on the implications, for the engineering profession, of the financing by private means of a project which many thought to be of such magnitude that it could be accomplished only on a wholly governmental basis.

Not the least interesting aspect of this venture is the form of the body established to conduct the studies. The Channel Tunnel Study Group came into existence during the summer of 1957 as a joint venture of five distinct entities: the International Road Federation (Paris Office); the Suez Canal Company (on whose initiative the first meeting was called); the Société Concessionnaire du Chemin de Fer Sous-Marin entre la France et l'Angleterre (whose predecessor Association was formed in 1875, and of which the French National Railways owns half the shares); the Channel Tunnel Company, Limited (also formed in the 19th century and of which the British Railways Board remains the leading shareholder); and Technical Studies, Inc., of New York. The Study Group was fortunate in having as its co-chairmen Ambassador René Massigli, former Secretary-General of the Quai d'Orsay, and the late Sir Ivone Augustine Kirkpatrick, G.C.B., G.C.M.G., former permanent Under-Secretary of State of the Foreign Office. (Viscount Harcourt now serves as British co-chairman.)

A small engineering staff was set up under M. René Malcor, Ingenieur-Général des Ponts et Chaussées, and Sir Harold J. B. Harding, recently president of the Institution of Civil Engineers in London. Extensive geophysical and geological investigations, including a preliminary program of core borings, were conducted in the Straits of Dover, and a report presented early in 1960 indicated the technical and financial feasibility of building a tunnel, either through the lower chalk or by laying prefabricated sections in a specially prepared trench in the channel bed. It was concluded that road vehicles could best be carried on railway flatcars because of (a) the greater capacity that this method would provide, (b) the evident disadvantages of driving for more than twenty miles in a closed tunnel, and (c) the high cost of efficient ventilation.

Meanwhile, an influential international group proposed the construction of a bridge for road and rail traffic and, to evaluate the rival proposals for a channel tunnel or a channel bridge, the British and French Ministers of Transport, on November 17, 1961, named a Working Group of British and French officials. Their joint report, published as a White Paper in 1963, considered not only the "established means" of cross-channel transport by sea and air, but also new developments such as hovercraft, hydrofoils and hovertrains. Both tunnel and bridge were found to be technically feasible, but the bridge was adjudged "a new and serious hazard and a source of delay to mercantile and naval shipping." Moreover, the bridge project could not be carried out, having regard to the principles of international law, until the United Kingdom and France had sought the concurrence of the States principally concerned with navigation in the channel, whereas "the construction of a bored tunnel linking France and Britain would not appear in law to require prior consultation with third States." A combination road and rail tunnel was considered by the Working Group, but its capital cost was thought prohibitive.

In February 1964, Queen Elizabeth II and General de Gaulle exchanged messages announcing the decision, as a matter of high policy, to authorize construction of the Channel Tunnel. The Governments then set in motion the machinery for a final and detailed survey of the channel bottom; the Study Group was appointed to supervise the program, for which the Governments supplied the equivalent of five and one-half million dollars. Field Headquarters were established in Dover Castle and a fleet was assembled to undertake a program of more than sixty core borings in the open sea. Geophysical surveys linked up the information from the core samples and a satisfactory route for a bored tunnel was identified and mapped in considerable detail. At the same time, feasible routes were confirmed for an immersed tube. The Study Group's reports on the final survey having been satisfactory, the Governments commenced a more detailed review of the financial and legal arrangements appropriate for construction of the tunnel. It was decided to finance the project with recourse to private investment, and qualified bankers were invited to submit proposals. Offers to underwrite the costs of construction were received by the Governments during 1967 from three consortia of international bankers. Last summer, The Illustrated London News asserted that "work will start in 1969 and . . . the link will be in operation by 1975." It is expected that underwriters for the tunnel will be selected during the current year.

THE SUNDAY TIMES

FEBRUARY

De Gaulle praises tunnel

In a telegram to the Queen published yesterday President de Gaulle says that the French are deeply aware of the historical importance of the decision to build a Channel tunnel. He adds: "I am convinced that Great Britain and France will find strong reasons to strengthen still further their solidarity and friendship."

In her reply the Queen said: "I thank you very warmly for your friendly message regarding the tunnel under the Channel. I am sure that the carrying out of this important project will have happy long-term results for the people of our two countries."

Figure 4. The Sunday Times, Feb. 9, 1964, carried the announcement of the historic exchange of messages by Her Majesty the Queen and President de Gaulle, authorizing the construction of the Channel Tunnel.

Figure 5. Dover Castle, headquarters for the survey which the Study Group carried out for the British and French Governments.

Inasmuch as valid routes have been delineated for either a bored tunnel that would be embedded in the lower chalk, or an immersed tube laid in a trench dredged in the sea bed, the actual decision as to the type of construction may depend upon the terms and conditions submitted by contractors.

The total length of the tunnel is expected to be thirty-two miles (of which twenty-three will be under the sea). The distance between the coastal terminals has been estimated at forty-four miles, permitting a shuttle service taking less than an hour, including twenty minutes for driving on and off and for clearing customs, etc. The tunnel will be well illuminated, as will the piggyback wagons, which are expected to be enclosed and sound-proofed.

Twenty-four hour service will be available, with trains departing every five or ten minutes during peak periods. This will eliminate the long delays characteristic of the existing services. With the

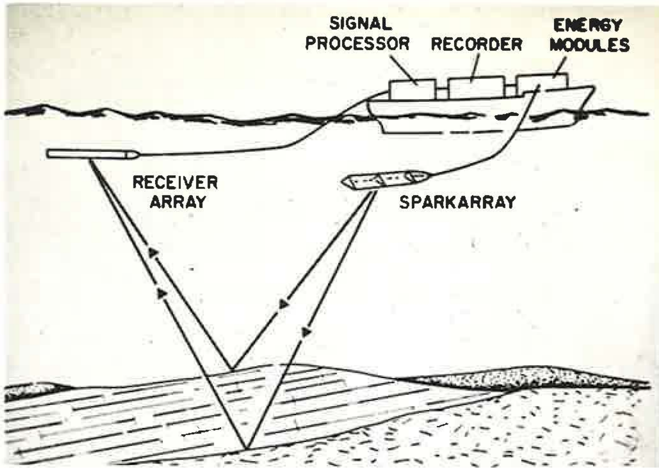

Figure 6. Modern geographical devices such as the Sparkarray have confirmed the general findings of the survey carried out in 1875 by the French Geological Commission.

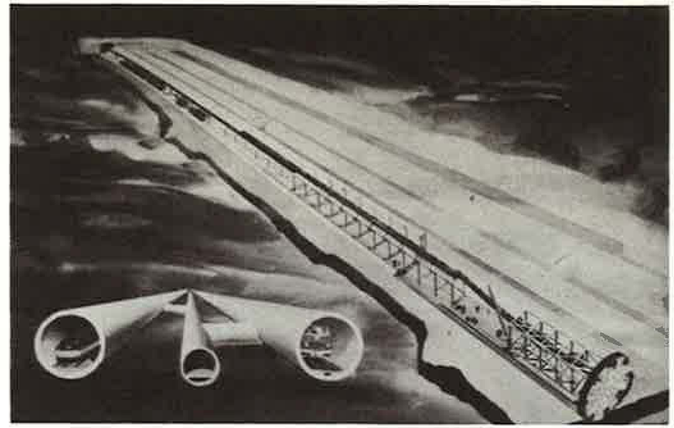

Figure 7. This schematic sketch of the construction of a bored tunnel was prepared by Morrison-Knudsen Company, Inc., Brown & Root, Inc., and the Bechtel Corporation.

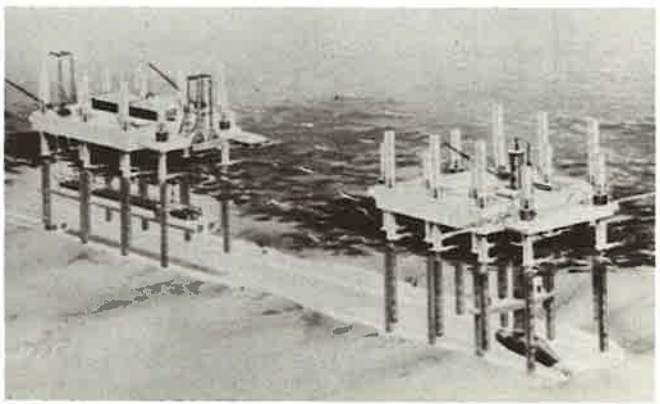

Figure 8. The construction of an immersed tube is illustrated in this diagram prepared by Raymond International, Inc.

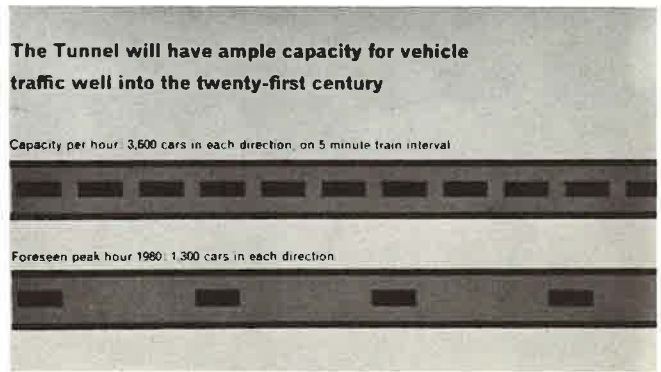

Figure 9. The tunnel capacity will be ample.

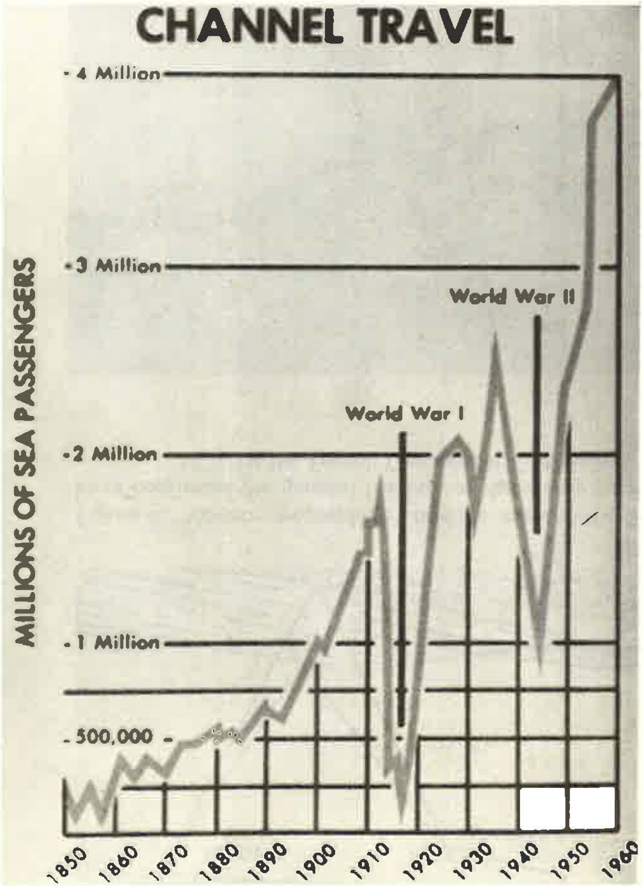

Figure 10. Cross-channel traffic provides an assured economic base for the Anglo-Continental link.

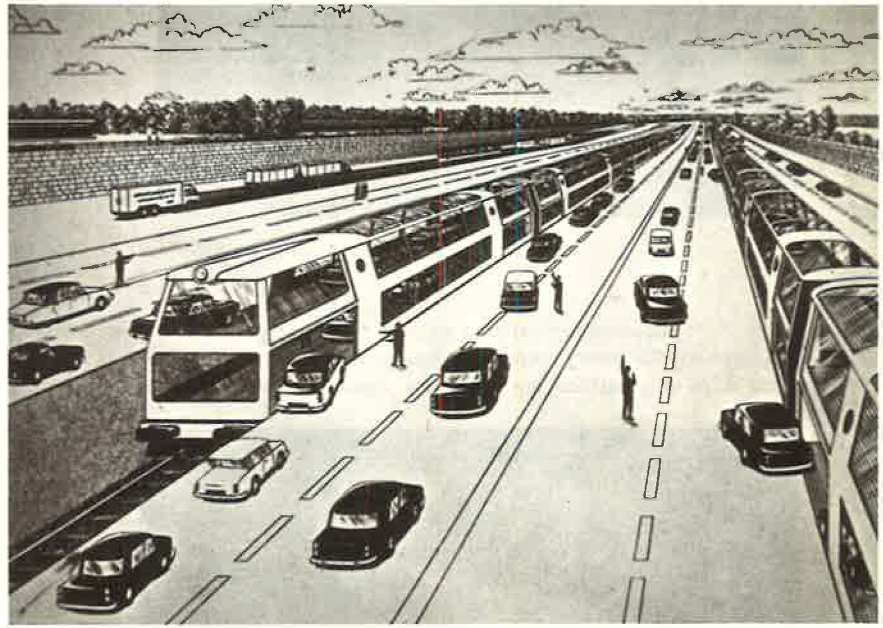

Figure 11. An artist's conception of the loading and unloading of trans-channel shuttle trains.

"Chunnel" in operation, no advance bookings will be necessary, even at the height of the tourist season.

Shuttle trains, operating at five or ten minute intervals in either direction, could carry at peak periods a combined total of seven thousand automobiles per hour. The cost of transporting cars will be approximately 30 percent less than current sea-ferry charges. Charges for freight—estimated to account for only slightly more than 20 percent of the total traffic—will be close to 50 percent less than at present.

From one point of view, the building of a Channel Tunnel is a less dramatic affair than the choice of transport systems that are to use it: in other words, the transit time from Folkestone to Calais may be of less significance than the travel time (for instance) from Birmingham to Bonn. It is not inconceivable that by 1975 hovertrains will be capable of carrying passengers via the tunnel from the center of London to the center of Paris in less than two hours.

The total cost of the tunnel, including financial charges, will be well over half a billion dollars. That sums of this magnitude have been assured by the private sector, on a basis of cooperative arrangements with sovereign governments, has important and encouraging implications for the development of world commerce in the years to come. The Channel Tunnel, following by a century the construction—under Ferdinand de Lesseps—of the Suez Canal, provides in our contemporary setting an example of the efficacy of private initiative in a field aptly described by Dr. Shannon McCune of the American Geographical Society as that of "geographical engineering." When the British and French Governments select underwriters for the tunnel, the event is almost certain to lead to reconsideration of similar macro-engineering projects, long delayed, but which may now be regarded as within the range of practical realization. Among such projects may be mentioned the Hudson Institute's brilliant concept of a series of "Great Lakes" based on the river systems of South America (to provide cheap hydro-electric power and access, on economic terms, to the interior of the continent); agro-industrial complexes based on nuclear energy centers, as persuasively proposed by AEC's Commissioner Ramey; the Great Belt Bridge in Denmark; novel transport systems using the air cushion principle, and the steady improvement of inter-modal technology.

By 1975—the target date for completion of the Channel Tunnel—we shall be living in a world where cooperative procedures involving the public and private sectors alike may be more widely understood. If this is so, perhaps the greatest achievement of the "Chunnel" will be its demonstration of a practical method whereby national governments can utilize the resources and skills of the international capital markets for the re-engineering of the world's transport and communications infrastructure.

REFERENCE

1. Whiteside, Thomas. The Tunnel Under the Channel. Rupert Hart-Davis, London, 1962.