TRENDS IN COMMERCIAL AIR TRANSPORT

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ABSTRACT

The past and future air travel market is discussed in the light of technical progress. In the realm of subsonic aircraft design, the general problems of economics, performance and propulsion system selection are discussed. Supersonic transports will likely handle the bulk of future long-haul traffic and major factors affecting their development are discussed. These problems include speed selection, economics, handling characteristics and sonic boom.

Any attempt to estimate future trends in air transport should be guided by our past technical progress and its influence on the travel market. The wood, fabric and wire era of only 30 years ago has changed into an aircraft age of aluminum and may soon become one of steel. Similarly, the passenger of the barnstorming days, local hop operation or even scheduled flights, at least in spirit, was a lot different from today's airline passenger. Different flight equipment has reached a different market.

As can be expected, traffic grew very slowly in the beginning. The reasons were low reliability, primitive equipment for all weather operation and lack of range. Not until the four engine equipment with good range capabilities was introduced, did the present growth rate materialize. Ingenious airline sales managers who previously had relied upon the railroads to take over their passengers for the night portion of a coast to coast flight were able to offer longer stage flights, some even with berths. With the advent of long range capabilities, the tremendous time advantage of flying became very evident.

The last two years have seen the introduction of the jet transport. In another ten years, indications are that long range flying will be supersonic. Where are we going and what equipment will be available to the airlines?

TRAFFIC GROWTH

Historically, there has been poor success and general lack of agreement in predicting air traffic growth. On Figure 1, the actual growth curve of United States domestic operations is compared to a forecast published by one public agency in 1950. It is seen that after only seven years, actual traffic was 100% higher than that forecast. Also shown on Figure 1, are all the forecasts for the market which were published in 1956 - 1957. The very sizable "fan" produced is equivalent to a large fleet of jet transports by 1970. In attempting to visualize equipment requirements for the future, we must recognize that many of the factors involved are beyond our control and none of the factors are precise. The recession of 1958, for example, caused a noticeable discontinuity in the air travel curve.

Figure 2 shows Boeing's forecasted free world air travel growth broken down into three different range categories. The most rapid growth is shown for ranges above 2000 miles, where the advantages of jet travel are greatest. In fact, the tremendous time saving and higher comfort level offered by the jet transport in long haul operation is expected to increase the traffic more than fivefold in this bracket between 1960 and 1970. The second fastest growth will be in the medium range brackets and the slowest growth is forecast for short ranges, although this traffic volume, of course, still is of great importance.

Figures 3 and 4 illustrate the need for additional equipment among United States and foreign airlines based upon the above traffic forecast and assuming gradual phasing out of propeller equipment.

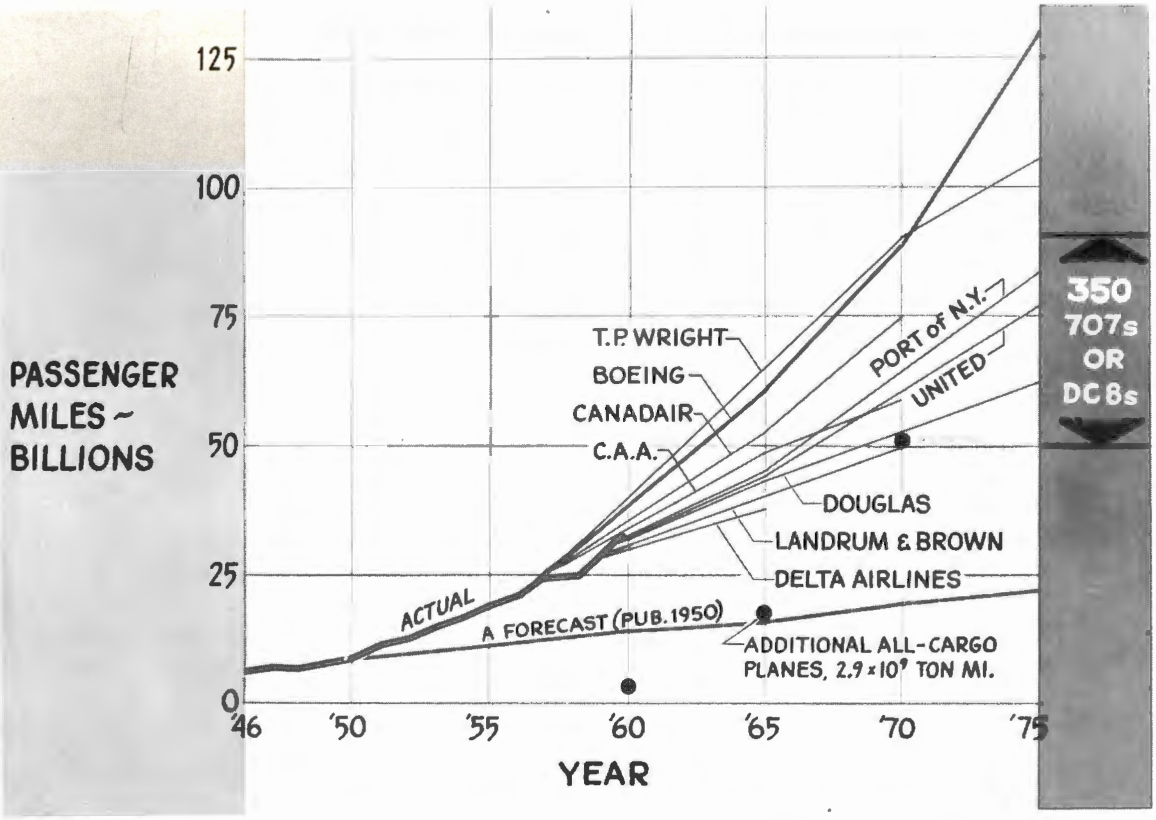


FIGURE 1. AIR TRAVEL FORECASTS, U. S. DOMESTIC FLIGHTS

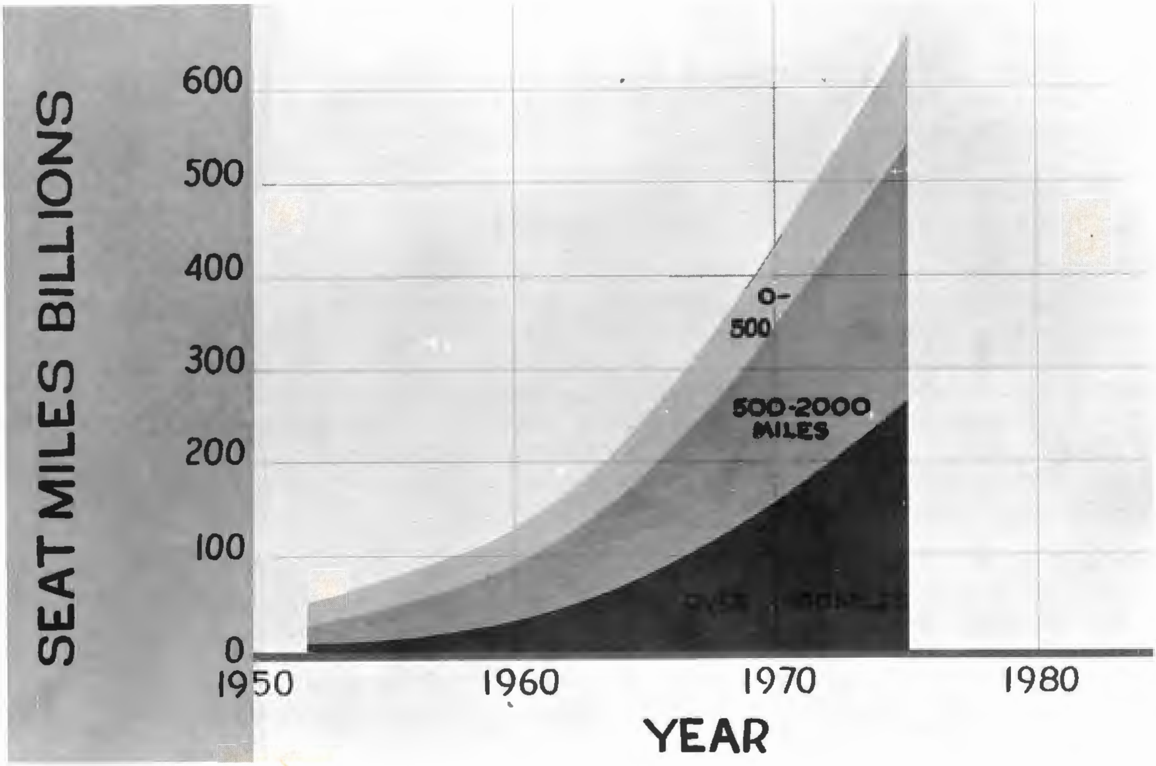


FIGURE 2. AIR TRAVEL FORECAST, FREE WORLD

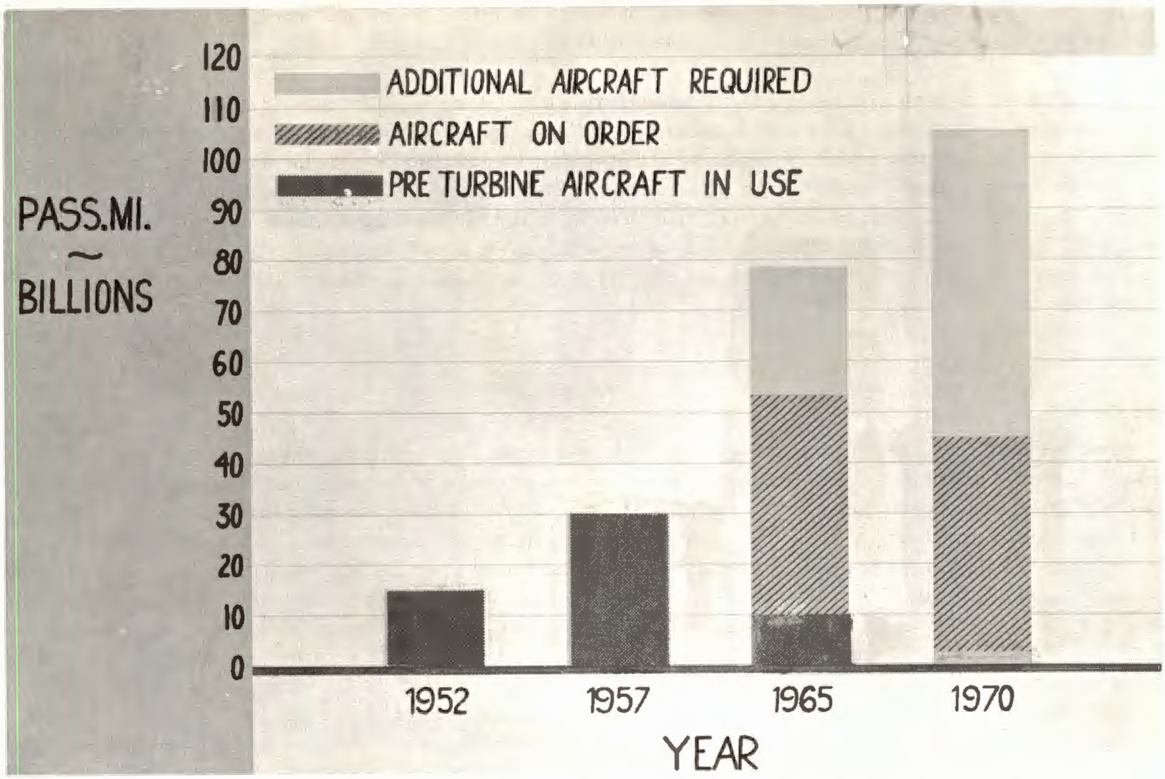


FIGURE 3. TRAFFIC GROWTH AND EQUIPMENT POTENTIAL, U.S. AIRLINES

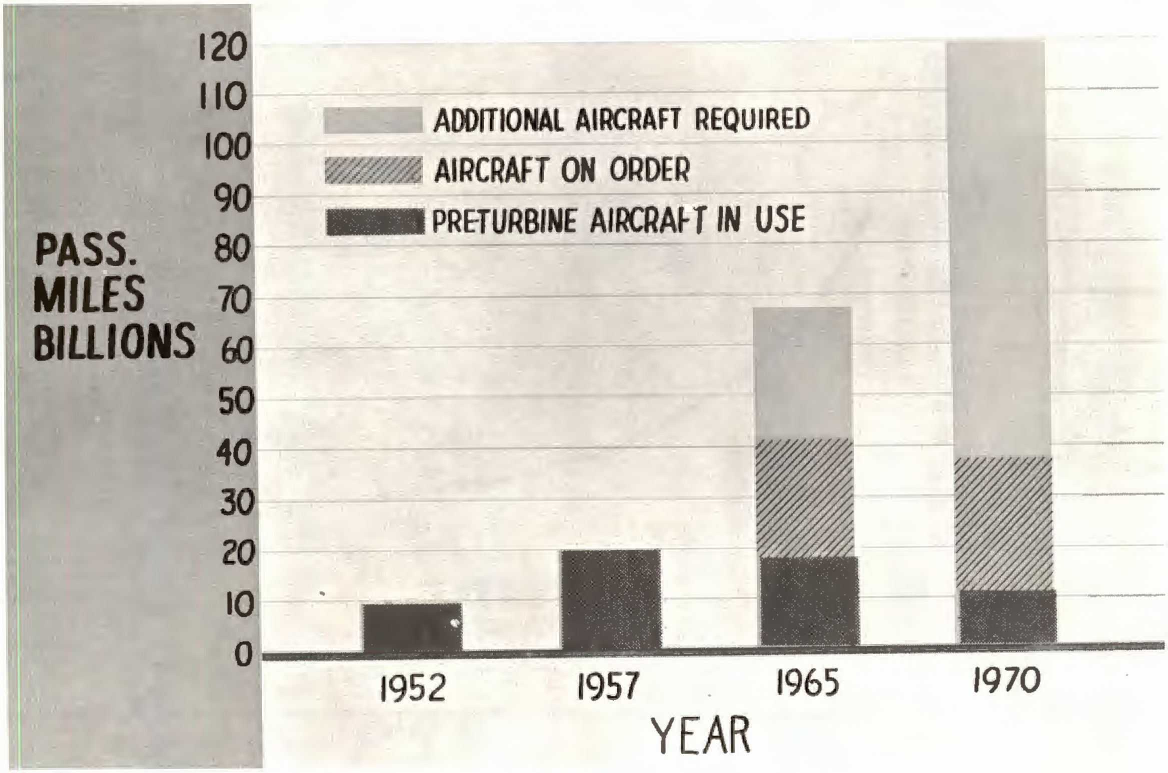


FIGURE 4. TRAFFIC GROWTH AND EQUIPMENT POTENTIAL, FOREIGN AIRLINES

Obviously, the need for additional equipment by 1965 is going to be substantial in spite of the very impressive turbine transport orders that have already been placed.

In the past, as traffic has grown, the airlines have generally downgraded their old equipment when purchasing a new generation of airplanes. Thus, former long range equipment has gradually become medium range and so on. If the same pattern prevails, it can be expected that main emphasis will be on new long and medium range equipment. Eventually, short range equipment will also have to be modernized with a design effort from scratch, but this can be expected much later than for other cagetories. The same factors that to date have prevented a successful "DC-3 replacement" will continue to make it difficult to design a competitive short haul transport until a breakthrough of some kind occurs.

CARGO

Another area of extreme importance is, of course, the controversial cargo market. Time and again market analysts predict that the air cargo business will start developing to its full potential which admittedly is tremendous, but, for different reasons, little or nothing happens. There are undoubtedly many reasons for this. Competition among passenger carriers has resulted in very heavy investments for passenger transports and equipment specifically engineered for cargo has taken a back seat. Recent developments, however, indicate that the cargo market finally will start developing at a faster rate than previously. The main reason is that most carriers, after the introduction of jets, find themselves with a lot of piston transports in good condition, but without a market for them. One solution has been to convert these airplanes for cargo operation and since they are depreciated to a great extent, a lower cost operation is possible. Lately, different types of basic cargo plane designs have also been offered and military requirements will probably eventually make way for a good all-cargo design.

The predicted air cargo market potential is illustrated in the following figures. Figure 5 shows the theoretical United States domestic market that would be available in 1965 at different fare

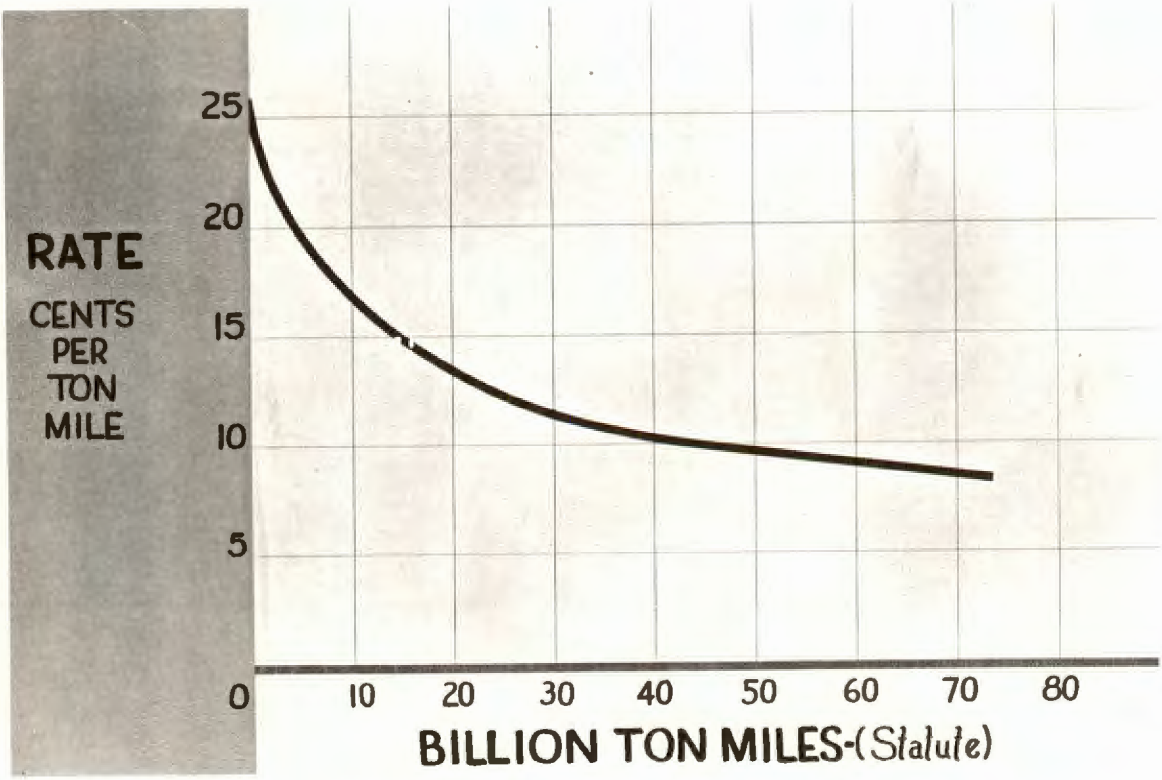


FIGURE 5. POTENTIAL RATE VS TRAFFIC RELATIONSHIP

levels. An enormous increase in available market is likely when new air freighters are introduced which will reduce ton-mile fares down to the 10 cents and below level. This, however, is theoretical availability and actual development will probably be much more limited. Figure 6 shows the growth that is expected to be realized on a world-wide basis. In 1957, more cargo was carried in passenger transports as supplemental load than was carried in all cargo transports. By 1965, a substantial volume will still be carried in passenger transports (current long-range passenger jets have ample cargo space), but the all-cargo operation has started developing in earnest and by 1970, should be the dominating part of air cargo.

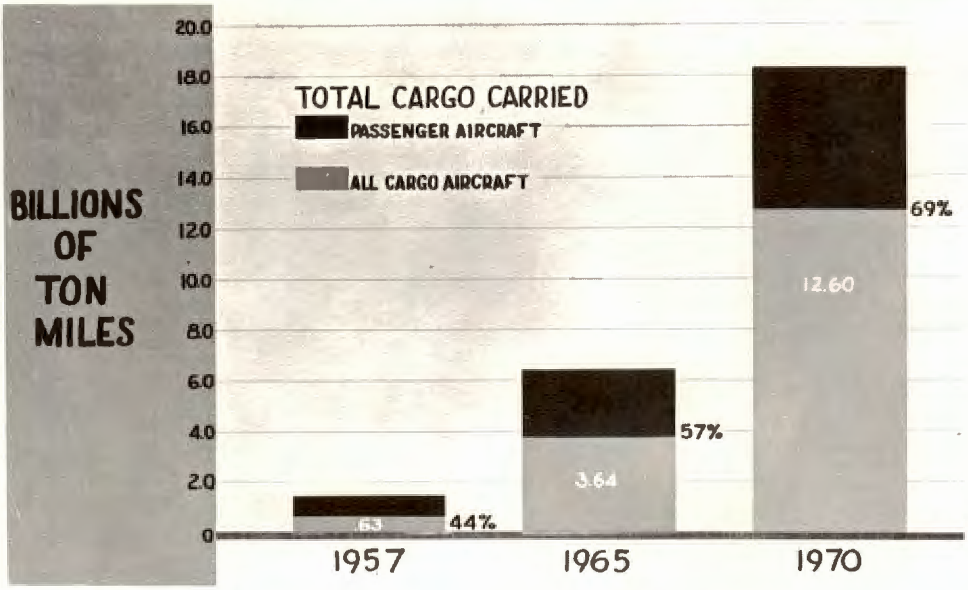


FIGURE 6. WORLD AIR CARGO BY AIRCRAFT TYPE

Figure 7 shows the expected United States international cargo potential. The long bars indicate total surface and air ton-mile production. The small bars represent the air cargo potential (all goods valued 70 cents/lb or over) and their dark bottom area finally is actual air cargo volume. With the above past and future market development in mind, let us examine what future progress to expect.

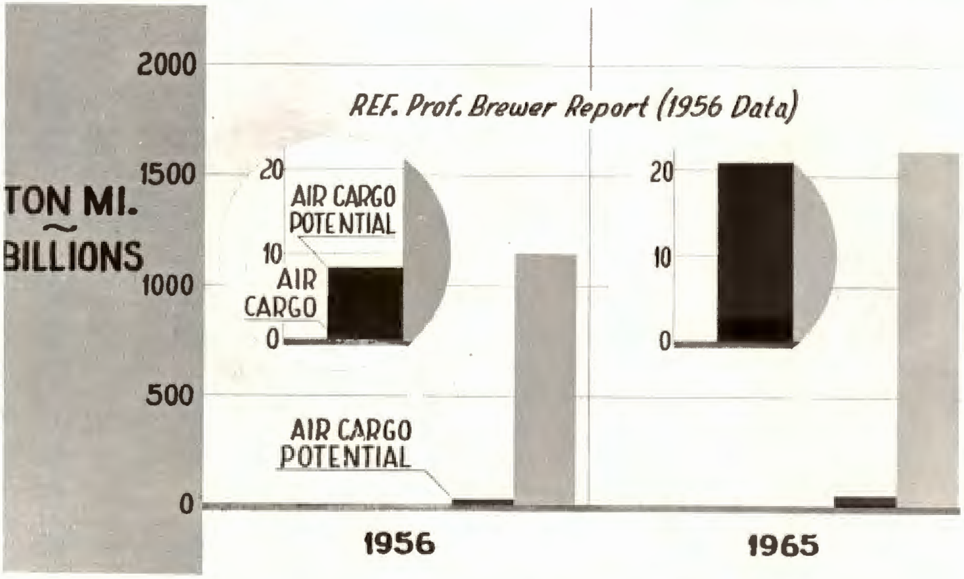


FIGURE 7. AIR CARGO POTENTIAL, U. S. INTERNATIONAL

EQUIPMENT DEVELOPMENT

In the mid-thirties, the DC-3 was the long-range airplane of the day. Figure 8 shows how the size (gross weight) of the biggest airliner of the day has changed over the years. The piston era growth has been relatively even and the curve is representative of the Douglas or Lockheed families of airplanes. The advent of the jet brings a discontinuity to our curve, which as illustrated by a Boeing family of jet transports, is much steeper than previously. The changed slope is mainly due to changes in power plants and speed levels. For the beginning of supersonic activities, most observers agree that 1970 is a likely time.

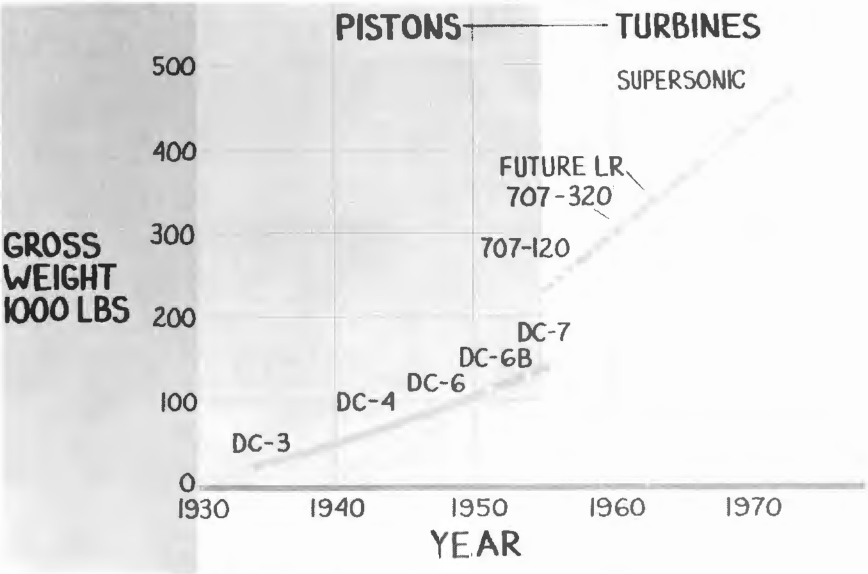


FIGURE 8. AIRPLANE GROWTH

A similar pattern is shown for speed growth in Figure 9. Again, we notice the steady progress of the piston era and the abrupt change with the arrival of jets. Based upon present knowledge, the low supersonic region is not of particular interest because of the very abrupt reduction in overall airplane efficiency which occurs at sonic velocity. The big question actually seems to be whether Mach 2 or Mach 3 should be the favored number. Both Mach 2 and Mach 3 have been shown for 1970 in the figure but the speed problem will be discussed later.

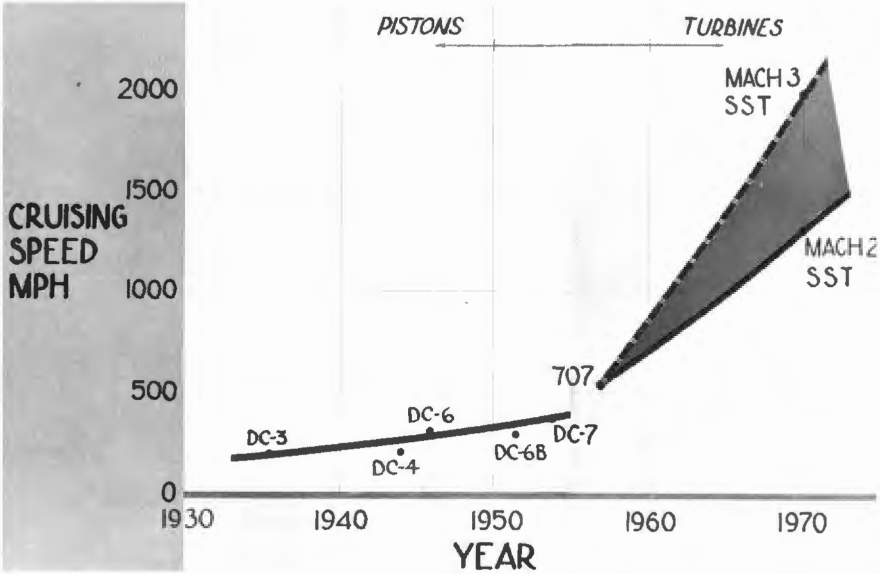


FIGURE 9. SPEED GROWTH

Figure 10 illustrates what these speeds actually mean to a traveler. Today we go from New York to San Francisco in the same time it took us to reach Chicago in the thirties, or Minneapolis after the last war; and tomorrow, the same time might take us as far as Cairo. With size and speed constantly increasing, it is obvious that airplane productivity (Fig. 11) has grown rapidly. The productivity curve represents a 5,000 pound payload in the mid-thirties and some 20,000 pounds for the last piston airplanes. With the introduction of jets, the payload grew to a 30,000 pound level and still larger figures can be foreseen. It is obvious that the much increased productivity of the

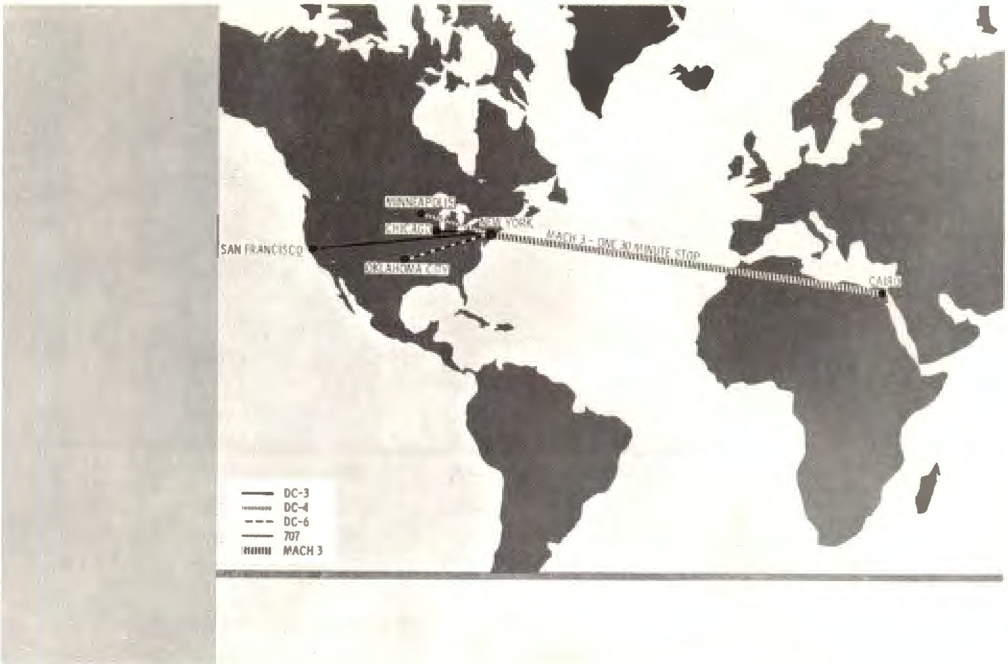


FIGURE 10. EQUAL TIME DISTANCES (5 HOURS)

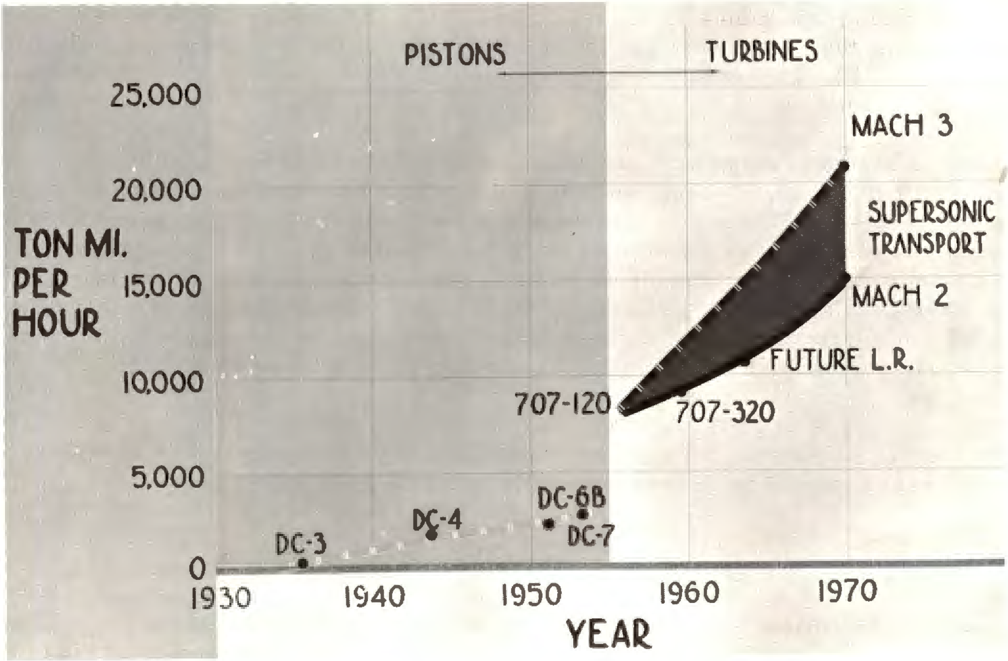
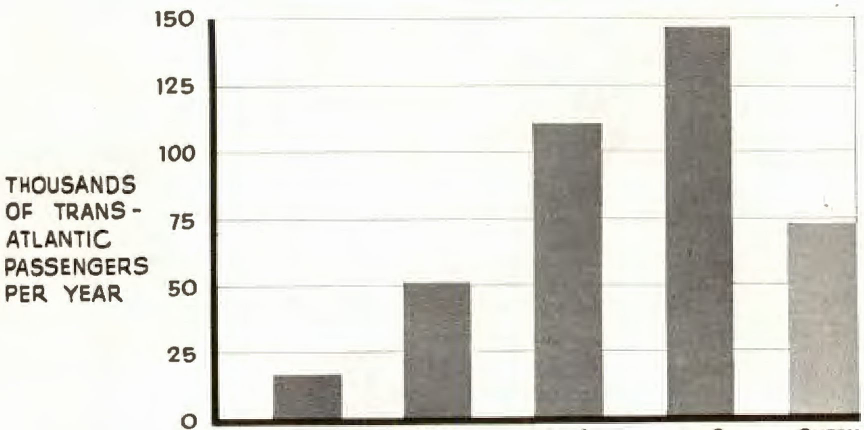


FIGURE 11. PRODUCTIVITY GROWTH

jets has caused the airlines many new planning problems. Another and maybe more illuminating comparison is shown on Figure 12 where passenger carrying capacities are compared.



	DC-7	707	M=2	M=3	QUEEN MARY
NO. OF SEATS	70	130	130	130	2000
BLOCK SPEED, Kn	270	450	960	1260	30
UTILIZATION	8	8	8	8	10

FIGURE 12. WORK CAPABILITY PER AIRPLANE

It appears that everything in connection with the commercial airliner has grown and the operational environments are no exception. In particular, operational altitude and the real estate required to successfully take off and land are discussed below.

Altitudes of 5000 - 8000 feet were standard before the pressure cabin was introduced. Then followed a period when maximum altitude was 20, 000 - 25, 000 feet or as close to this as our crowded airways would permit the operator to go. With the arrival of the jet, the maximum altitude bracket moved up to 35, 000 - 40, 000 feet and the supersonic transport appears to like it best at 60, 000 - 80,000 feet depending upon speed.

As regards airport real estate, we have gradually moved from the 3000 - 4000 foot level of runway length to 10, 000 - 12, 000 feet, and the width is now reaching figures such as 150 - 200 feet. This growth has been subject to much criticism and obviously we are rapidly approaching a practical limit if we want our airports anywhere near the big population centers. Undoubtedly, it would have been possible to curb runway requirements earlier. However, competitive pressure among operators has almost always resulted in increased payloads or range whenever more takeoff power became available instead of shorter take-offs, and the present compromise was probably necessary to assure the continued healthy growth of the comparatively young airline industry.

The change in type of power plants toward turbofans, which will be discussed later, and the tremendous power requirements for acceleration to and cruise at supersonic speeds would seem to indicate that the trend toward increased runway length may be at an end.

POWER PLANT TRENDS

During the mid-fifties, the outstanding question of the day in the air transport industry was whether to go turboprop or jet, and anybody who misses the heated arguments of those days would probably have to locate a current Mach 2 versus Mach 3 discussion to feel at home again. It should, however, by now be quite evident that for many reasons the jet transport will dominate almost the entire field. The public acceptance of the jet has been short of fantastic and as a result, the airlines are in a process to re-equip with jets for operational ranges that formerly were considered a natural market for turbo props or piston transports. How has all this come about?

Undoubtedly, the public acceptance of the jet is the key factor, but, developments in the power plant field have also changed the overall situation. Many airlines formerly felt that the expected higher load factor of the jet competing with the turbo prop would compensate for its higher operating cost. Today, this difference has been wiped out by new power plants and changes in other cost factors. Thus, the hourly cost has become more significant and favors high speed as influenced by insurance, depreciation, maintenance, and increasing crew costs.

The basic jet engine has been improved greatly and recent years have seen the arrival of the turbofan. Figure 13 shows how the propulsive efficiency compares between the three categories. It can be seen that the turbofan is superior in today's high-speed bracket,and,furthermore,when considering complications of propellers and propeller gears, the present trend is quite understandable.

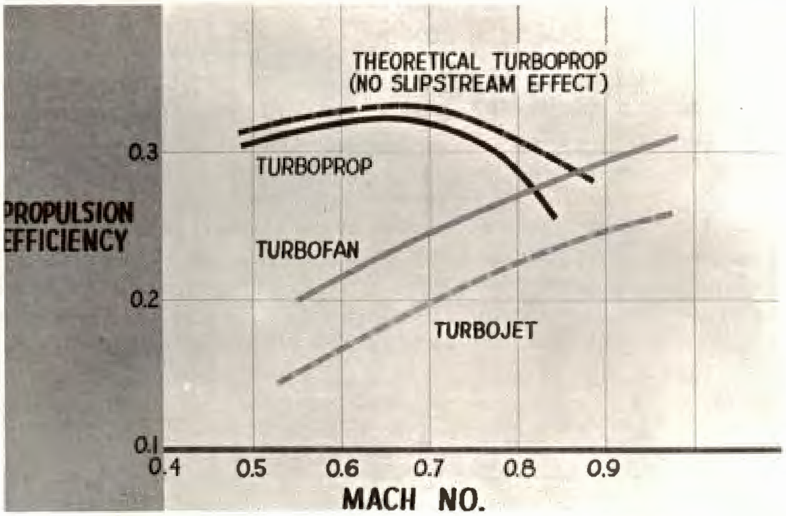


FIGURE 13. POWER PLANT COMPARISON

FUTURE SUBSONIC EQUIPMENT

The short-haul equipment will mainly be helicopters, new designs in the VTOL and STOL category and fan-powered turbine transports with greatly improved take-off and landing performance.

Scheduled helicopter operation is still very limited for economic reasons and in the free world, there are actually only four scheduled operators. The three in this country: Chicago, Los Angeles and New York are subsidized and the fourth, Sabena in Europe, operates its helicopter service as part of a long-haul transportation system which probably stimulates overall load factors, thereby paying for its high operating cost. However, the potential equipment market in the extremely short-range field is quite large. The seat-mile figures for short range shown in the traffic forecast may not appear large compared to other range brackets, but considering the comparatively low productivity of each unit, it becomes obvious that the number of vehicles that the market could absorb is substantial. It is therefore felt that technical efforts will result in a breakthrough that opens up this market to its full potential. Meanwhile, limited new equipment along conventional lines can be expected.

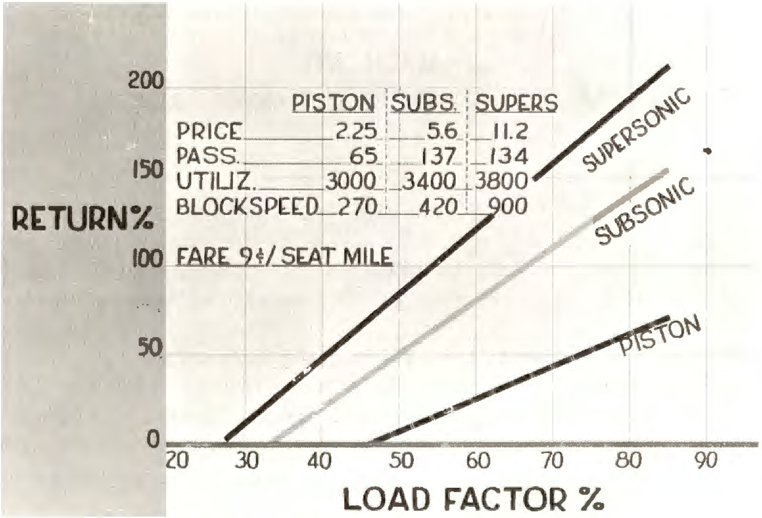
In the medium and low-range field, we will see a gradual change to fan-powered jet transports. The approximately 20% improvement of SFC will mean improved economy for all categories. Likewise, the take-off performance in general will improve since the turbofan provides more thrust than the straight jet in the lower-speed regions. Finally, the long-range transport also will offer a substantially improved range capability.

The all-cargo airplane of the future will almost certainly also be a fan-powered vehicle. Piston conversions are entering service in increasing numbers and will, together with existing turboprop designs, help to open a cargo market where fast high-capacity transports are essential.

The question is whether this transport should be a derivative of today's long-range jet or a completely new design for optimum cargo handling, size and overall economy. A cargo version of the passenger jet transport would be quite feasible and promises good operating cost. A completely new design, on the other hand, requires a fairly large initial market before an acceptable price level can be established through a large production run. Unless a sizable production materializes because of joint commercial and military requirements, it appears that a cargo version of current passenger transports would remain competitive for a long time.

OPERATING COST

The operating cost of commercial airliners has constantly improved and, with one exception, it can be stated that no new successful transport has been introduced without representing a lower seat-mile cost. Current long-range direct operating cost on the average is below 1.5 cents per seat-mile. The indirect cost likewise has been decreasing continuously. As a result, the airlines in spite of the inflationary process have managed to maintain or, through tourist and coach class service, decrease the overall fare level. It has been claimed that the current profit margin for the airlines is too thin and there is little doubt that a major undertaking such as the introduction of a jet transport fleet into operation has been a considerable financial strain to many operators. However, the economy of the jet transport promises a much better return on investment for the operators once the operation has stabilized and the industry has progressed further down the learning curve. Lagging airports and airways facilities are also partly responsible for a delayed fuller utilization of jet potentials. Figure 14 shows a comparison of return on investment for a piston, jet and supersonic transport. The jet is clearly superior to the piston transport, although admittedly more demanding in operational planning. Indications are that this advantageous trend of increasing returns will continue with the advent of the supersonic transport.



	PISTON	SUBS.	SUPERS
PRICE	2.25	5.6	11.2
PASS.	65	137	134
UTILIZ.	3000	3400	3800
BLOCKSPEED	270	420	900

FIGURE 14. RETURN ON INVESTMENT

SUPERSONIC TRANSPORT

The supersonic transport is today receiving a rapidly increasing amount of publicity. Most everybody agrees that it is going to come, although many an airline president under the strain of subsonic jet introduction has turned his head the other way hoping that the monster will go away - at least for the time being. The manufacturers also have a major problem. No United States airframe producer today has the financial capability to develop a supersonic transport without assistance. Some measure of governmental support will be required if a supersonic airliner is to be produced in this country at an early date. This fact is well recognized in Europe where plans for supersonic transport development are beginning to crystallize. All the evidence indicates that the Russians are well ahead of the western countries.

Certainly, the competition is going to be formidable within western countries and with Russia. However, no truly successful transport has been introduced in the past until the timing was right and the technology permitted an economically sound design. The first big question then appears to be when. As far as can be decided now, the airline industry should be able to finance the purchase of supersonic transports around 1970 provided a successful design can be available by then. The subsonic jets have a planned depreciation period of 10 years. This also points toward 1970 for introduction of the initial fleet. From the technical standpoint, supersonic transports can be introduced into airline service certainly by 1970, assuming that governmental financial support of research, development, and hardware programs is forthcoming in the near future. The exact timing will be influenced also by the design speed of the airplane.

Before discussing some of the factors which influence choice of cruise speed, let us take a look at a typical supersonic transport configuration, one of the hundreds which have been studied.

The configuration pictured on Figure 15 is representative of a transport designed for cruise at Mach 2 or 3. The wing has a shorter span than that of current long-range transports because it must be very thin for low drag. The body diameter is down and its length is up. Taper at front and back is more gradual. These changes also are necessary to reduce supersonic wave drag to a practical minimum. Because of the low aspect ratio wing, a canard surface is used rather than the conventional aft tail. If properly actuated, the canard surface can also provide direct pilot control of the airplane without black-box stability gadgets. Power plants are here shown pod mounted. Choice of a particular engine cycle will be dependent upon the design cruise speed. Figure 16 compares various engine cycles which might be used to power the supersonic transports. Here, size of the airplane to accomplish a given range-payload job is compared to the size of a subsonic jet designed to do the same job.

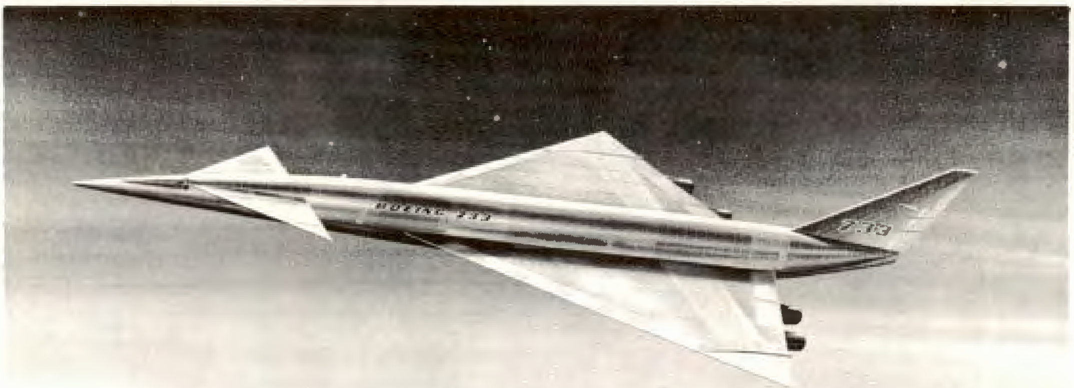


FIGURE 15. CONFIGURATION OF A MACH 2 OR 3 TRANSPORT

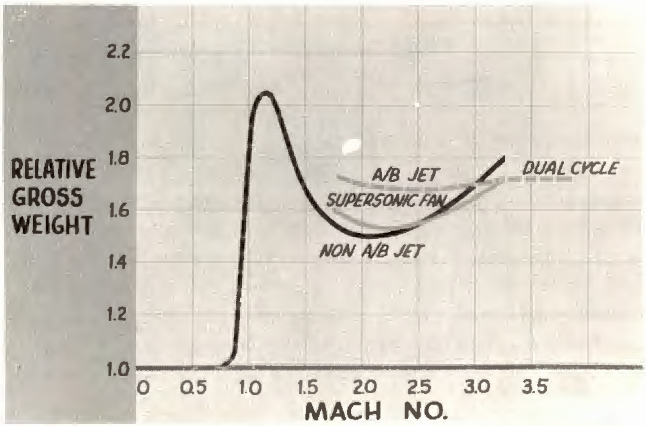


FIGURE 16. AIRPLANE SIZE AT CONSTANT PAYLOAD AND RANGE

CRUISE SPEED

Now, let us return to the question of speed. Figure 17 shows the effect of cruising speed on trip time for transatlantic ranges. Cruise time, of course, varies inversely with speed. Also, the time and distance to reach cruise speed and altitude increases with cruise speed. Therefore total block time rapidly levels off at the higher Mach numbers. Speed increases above Mach 3 will not result in appreciable time savings.

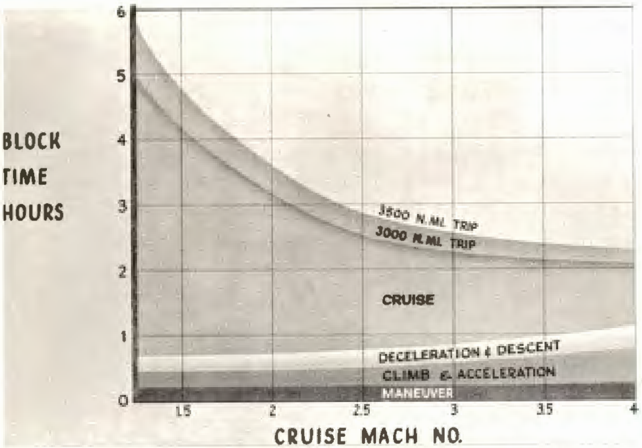


FIGURE 17. EFFECT OF CRUISE SPEED ON BLOCK TIME

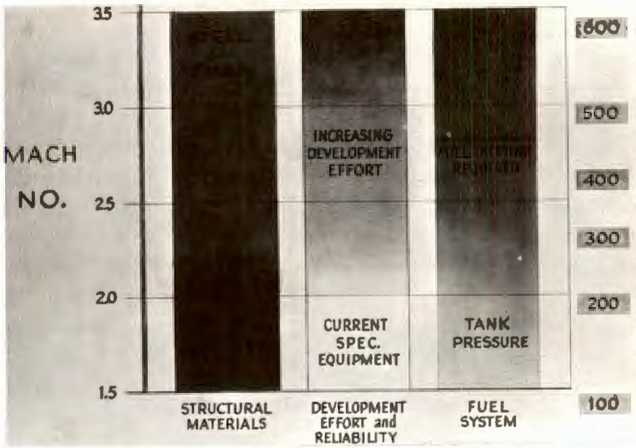


FIGURE 18. SPEED SELECTION

Slightly above Mach 2, aluminum structures must give way to steel and titanium (Fig. 18). At still higher speeds, an increasing development effort will be required to provide the high level of systems reliability necessary in commercial operation. Fuel tank pressurization to minimize fuel boiloff and a positively reliable inerting system to prevent spontaneous ignition are typical requirements at Mach 3.

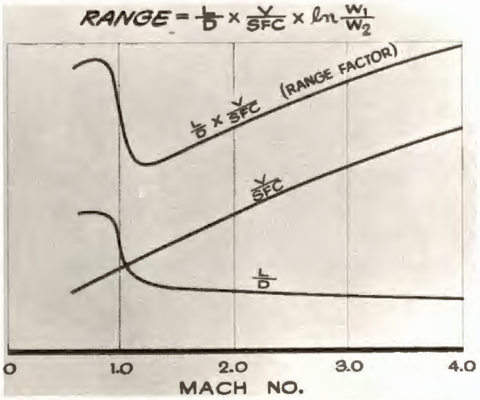


FIGURE 19. CRUISE EFFICIENCY

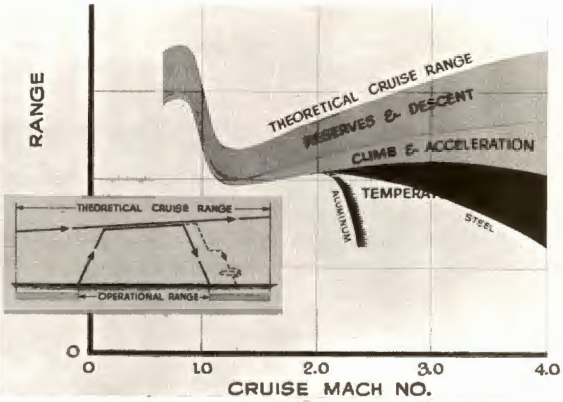


FIGURE 20. OPERATIONAL RANGE

From the aerodynamic and propulsion efficiency standpoint, a high supersonic cruise speed appears quite attractive as shown in Figure 19. The deterioration of lift to drag ratio which occurs near Mach 1 is offset by the rapidly improving efficiency of the jet engine at higher speeds. It is seen that range factor, and therefore cruise range, of a Mach 3.5 transport is equivalent to that of the subsonic jets. The potential operator will, however, be more interested in comparisons of total operational range. Figure 20 adds the other factors which must be considered to convert cruise range to operational range: the additional climb and acceleration fuel required as cruise speed increases, the change in descent fuel and reserve allowances, and the degradation of structural allowables with increasing temperature. When these factors are included, speeds above Mach 3 are not too attractive.

An important factor when selecting cruise speed will be operating cost variation with speed. The relationship is illustrated in Figure 21. It appears quite certain that operating costs can be expected to decrease with increasing speeds up to the Mach 2 region. What happens to operating costs above Mach 2 is still somewhat uncertain. The use of steel structure above about Mach 2, will tend to increase costs as will the use of high-temperature systems required for higher Mach numbers. On the other hand, a steel airplane will remain competitive much longer than an aluminum design and consequently, can be priced on a larger production run basis. Thus, at best, it might be possible to improve DOC all the way up to Mach 3 although at a very slow rate but we might also have to pay a high price for speeds essentially above Mach 2.

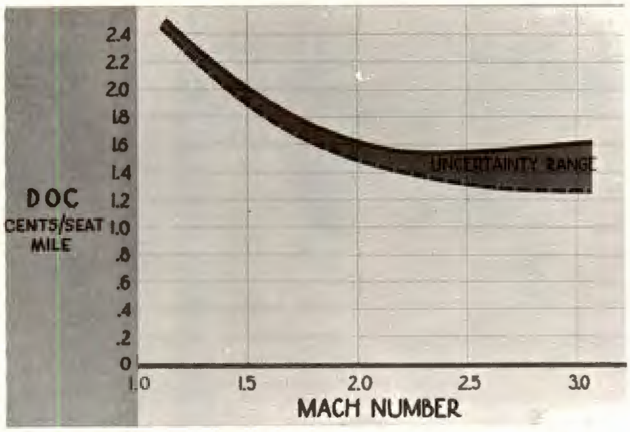


FIGURE 21. OPERATING COST VS. SPEED

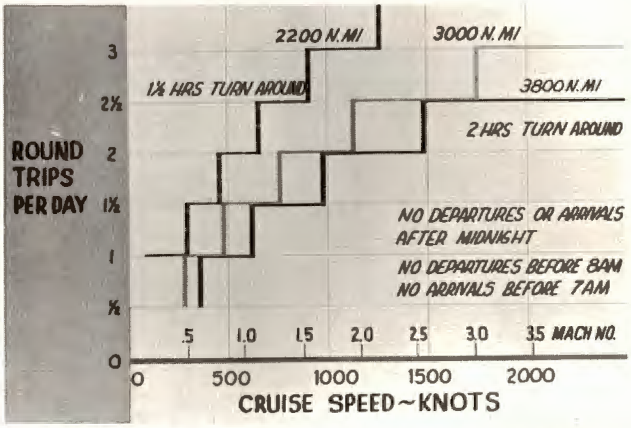


FIGURE 22. ROUND TRIPS VS. SPEED

From a practical standpoint, we also have to remember that speed increases may be difficult for the operator to utilize. Increased speeds that cut trip time without permitting additional trips simply tend to reduce annual utilization. This situation is illustrated in Figure 22 where number of round trips are shown as a function of speed for three different distances.

RANGE

The range, payload and size questions are closely related to each other. Since speed is the great advantage in supersonic travel, the airplane must have nonstop capabilities for the most heavily traveled long-range routes, primarily the North Atlantic (Fig. 23). However, the minimum North

FIGURE 23. WORLD AIR TRAFFIC FLOW

Atlantic distance of 3, 000 N. Mi. will no longer suffice, since many more cities in Europe will demand nonstop service. Intermediate stops at gateways such as London will mean too much additional trip time in the supersonic era. To meet such requirements, a range of 3700 - 3800 N. Mi. (New York - Rome) appears desirable. As shown in Figure 24, a 3800 N. Mi. range would be sufficient for most long-range travel on a global basis.

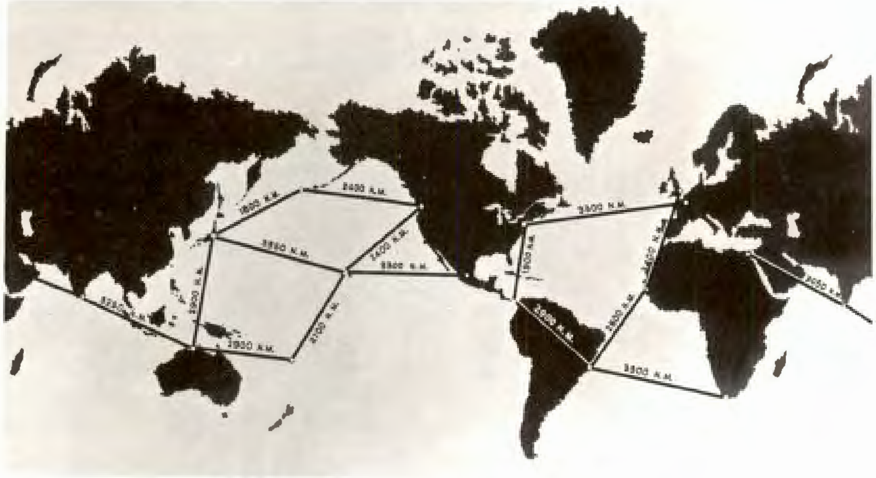


FIGURE 24. AIR DISTANCES

The all important economy is very sensitive to range selection. Figure 25 illustrates the different trades when selecting range, payload and gross weight for the supersonic transport. Three range lines are shown: 3000, 4000 and 5000 N. Mi. Note that a very large increase in airplane size and payload is required to increase range without increasing operating cost. This trade is much more severe than that for the subsonic jet, therefore, choice of supersonic transport size, payload and range will be much more critical. It would seem advisable for the airlines to select as low a range figure as practical for operational and competitive reasons and to choose as big a payload capacity as traffic, trip frequency and utilization will permit. If the North Atlantic is regarded the backbone of future supersonic operations, the above considerations might result in a gross weight of 400, 000 - 450. 000 lb and a payload of 30. 000 - 35, 000 lb (150 passengers).

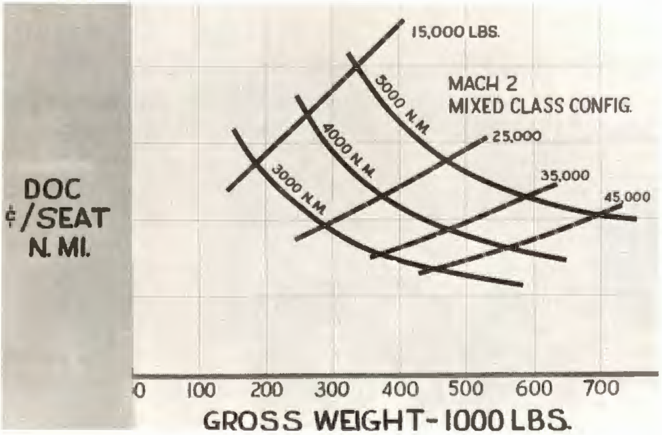


FIGURE 25. OPERATING COST VS. SIZE

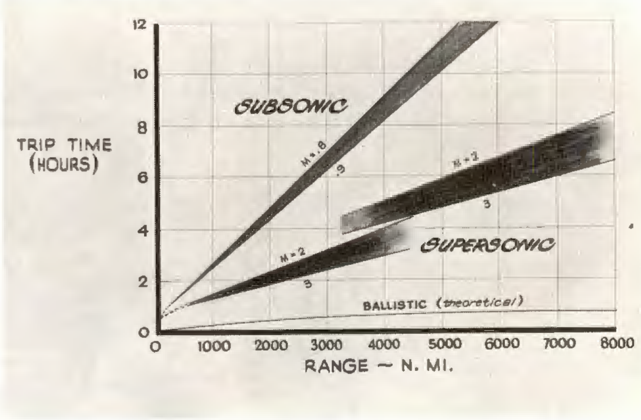


FIGURE 26. TRIP TIME

The present long-range jets have more range than 3800 N. Mi. and improved models promise to offer substantially more. This will certainly stimulate traffic on routes such as United States West Coast to Europe, but it will also open up new markets. The airline industry expects considerable business from such nonstop operation as United States East Coast to Hawaii and there are other areas with similar possibilities. Obviously, it would take an enormously heavy supersonic transport to match such range capabilities and the question is whether, initially at least, it is necessary. Figure 26 shows trip time for different ranges in subsonic and supersonic operation. It is noted that even with a refueling stop, the supersonic airliner retains a very substantial trip time advantage over the very long range subsonic jet. Thus, it seems likely that extreme range capability might come later as it has in the case of the subsonic jet. The big transport market is in the transatlantic range and will help pay for developments leading to the very long range capabilities.

SONIC BOOM

A paper on supersonic transports must include mention of the sonic boom problem because of its great potential effect on operation of the airplane. The need to carefully regulate climb-out and descent paths to minimize boom has been adequately covered in many papers. It is generally agreed that the transition to and from supersonic speeds must occur at altitudes of 35, 000 feet or higher. Unfortunately, however, the "boom" problem is not completely solved by adopting this operational procedure. The boom created by a large supersonic airplane in high-altitude cruise will likely have a higher intensity than people under the flight path of the airplane will accept. Not only will the noise level be in the range considered objectionable as defined by NASA subjective tests, but it will be at a high enough level to cause some window damage.

The supersonic airplanes flying today can cruise supersonically at high altitudes and cause no particular consternation below. The size of boom, produced by current equipment, is marked "small airplanes" on Figure 27. It is seen that at high altitudes the noise level is in the tolerable range. The much larger supersonic airplane required for the transport job is not so fortunate. The effect of lift, substantially negligible for the small airplane, becomes increasingly important as airplane weight, and therefore lift, increases. The "large airplane" or supersonic transport produces a boom well up in the objectionable range at cruise altitudes of 70, 000 feet or higher. It must be concluded, therefore, that the supersonic transport will be restricted to operations over water or land areas of very low population density. This, of course, is the reason so much emphasis in the preceding discussion has been placed on North Atlantic and other ocean routes. It would appear that supersonic trips across the heavily populated U. S. A. are extremely doubtful.

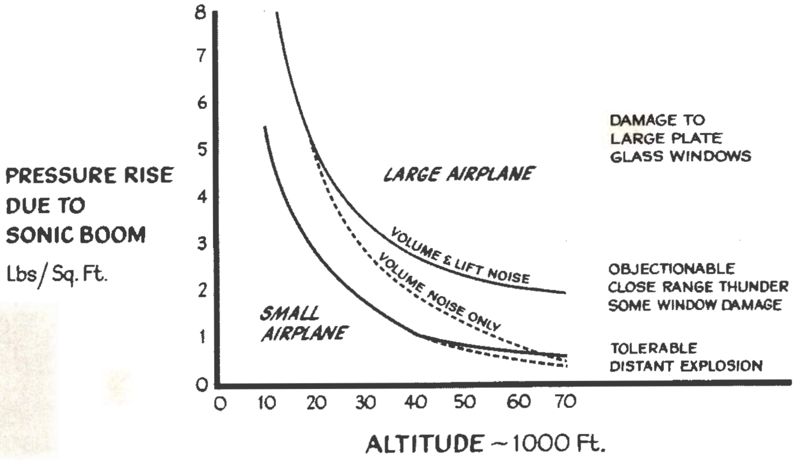


FIGURE 27. SONIC BOOM

FUEL CONSIDERATIONS

Fuel quality and price have always been important factors in airline operation and economy. The highly refined and sensitive piston engine was more demanding than the turbine as regards fuel quality. However, in the case of the jet engine, fuel price is becoming more important than ever before. This is illustrated in Figure 28 which shows a breakdown of operating cost items for piston, subsonic and supersonic jet transports. Note that the cost for crew and maintenance decreases gradually from piston operation to subsonic and supersonic operation. Conversely, fuel cost is rapidly increasing and represents approximately half the direct supersonic operating cost. Thus, it is obvious that fuel price will be an important factor in supersonic transport economics. It would be well in this connection to recall the very stringent requirements that the airlines originally were planning on for jet fuel as regard cloud and freeze points. These requirements would have resulted in very high fuel prices and fortunately, through cooperation between engine, airframe and fuel companies, it was possible to design for less stringent specifications.

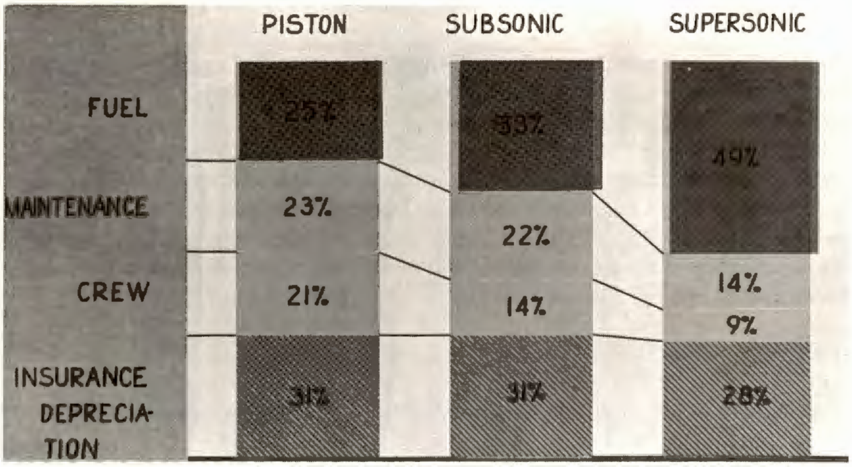


FIGURE 28. AIR TRANSPORT COST BREAKDOWN

A similar cooperation at an early stage will be vital to arrive at best possible supersonic transport fuels. The increasing importance of early planning is illustrated in Figure 29 which shows world airline fuel consumption as predicted by one oil company. The turbo fuel requirements will, by 1970, be more than three times greater than the highest recorded aviation gasoline consumption.

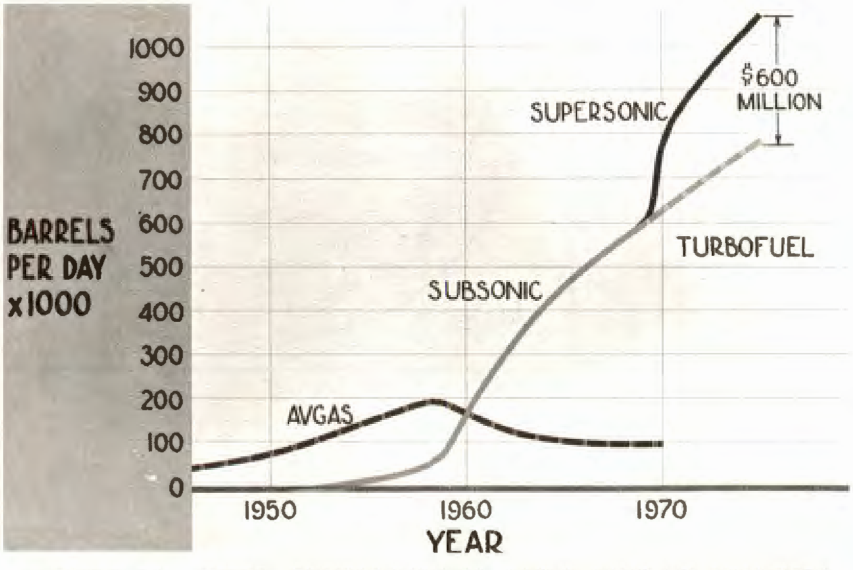


FIGURE 29. FUEL CONSUMPTION, FREE WORLD AIRLINES

The rapid consumption increase has already had some less desirable effects pricewise for the commercial operators. Most airlines are using kerosene for their turbine operation in lieu of the wide cut gasoline base JP-4. There are several reasons for the choice of kerosene but one important consideration should be how the two fuels compare in crash fires or in so-called "survivable" type of accidents such as overshoots, short landings, etc., around airports. There can be no doubt that kerosene, with its lower volatility and flame propagation speed, gives the occupants of an airplane much more time for evacuation.

Less demand for fuel products in the cracking range of JP-4 in certain areas of the world has resulted in this fuel being offered at a substantially lower price than kerosene in a number of places and some airlines may in such cases substitute JP-4 for kerosene. It is hoped that the industry, through early action, will be able to offer kerosene at competitive prices on a world-wide basis.

CONCLUSIONS

It is probably difficult to visualize the tremendous effect that technical progress is having upon travel habits and traffic volume. However, when looking at an extended period of 15 to 20 years, such as in Figure 30 where equipment requirements to meet traffic demands have also been entered, the magnitude of our progress becomes evident. The 1970 column shows the approximate number of airplanes by range categories to produce the forecasted seat miles. Airplanes currently on order are shown within parenthesis. Quite logically, the airlines have a tendency to meet their long-range requirements for competitive equipment first since that type of operation brings the greatest returns. Note, however, that the short and lower medium range market requirements will be quite large. The size of the top section representing current piston and turboprop equipment depends upon the airline industry's ability to meet the continously increasing investment requirements. However, in view of past experience, it is safe to assume that the world piston and turboprop fleet will be substantially reduced by 1970 as indicated.

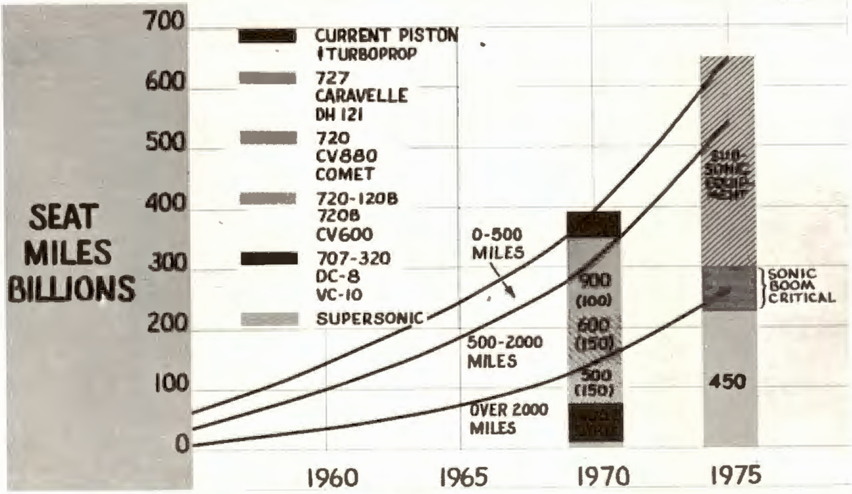


FIGURE 30. AIRCRAFT MARKET POTENTIAL

A few supersonic airplanes have been shown for 1970 to indicate approximate introductory date. By 1975, some 450 supersonic transports with a passenger capacity comparable to current long-range transports would be required, assuming operation on ranges down to 1700 - 1800 N. Mi. Routes which are critical from the standpoint of sonic boom have been avoided in determining the estimated size of the supersonic transport fleet. Note that in spite of the large supersonic transport increase from 1970 to 1975, a considerable increase of subsonic equipment is still required to meet growing traffic demands.

In summing up our look at trends in commercial air transports, it is felt that the next ten years will, on the one hand, mean a consolidation of the industry in the turbine era, and on the other hand, a large-scale preparation for the step into the supersonic future. The consolidation is needed for economic as well as technical reasons. Both manufacturers and operators are still feeling the financial strain of the gigantic changeover. The looks of the learning curve now promise builders and operators alike the expected economic return, and their full attention can be given to jointly refining the current equipment.

Regarding the step into supersonics, we must all realize that it is going to take the joint efforts of every facet of the United States aviation industry to advance and design our first supersonic transport in the best tradition of the past. This we must do if we are to maintain our dominant position among suppliers of air transport in the free world.