Advanced Technology Applications to Present and Future Transport Aircraft

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The uses and need for continuing advances in aircraft technology are discussed. The costs of applying recent technology advances to reduce the noise of first generation jet aircraft are presented. Future technology advances are needed to help offset the effects of inflation and low noise requirements and congestion, and to meet the design challenges associated with future large aircraft. Aircraft types to serve the future transport market are discussed. Ticket surcharge levels required by the first generation SST and the resulting costs of time savings are shown. Predictions are made of the size and range of future subsonic passenger transports. Two future subsonic aircraft which illustrate the required timing and areas of desirable technology development are described.

Need for Advanced Technology

SINCE World War II commercial air travel has increased rapidly due to a combination of technology advances, which made lower fares possible, and increasing affluence in a growing population. Flight times have been drastically reduced (an eastbound transcontinental U.S. flight now takes less than 5 hr instead of approximately 14); ear pain, air sickness, noise and vibration induced fatigue, and delays due to engine mechanical failures have all been virtually eliminated by pressurization and the application of the jet engine. Just as important has been the concurrent improvement in aircraft economics which led to reduced fares. Rising industrial and agricultural productivity has generated a significant increase in disposable income, which has contributed to both business and pleasure travel growth.

Unfortunately, we are faced today with an increased rate of inflation which makes it more difficult to sell, and therefere justify new aircraft designs, since the aircraft to be replaced were developed and built with uninflated, and therefore less dollars. An example of this is the DC-3, which has never successfully been replaced in an economic sense. Figure 1 shows the recent and currently forecast labor rates for U.S. aircraft manufacturers. Data are also shown for the U.S. trunk airlines, which illustrate the operational cost pressures that also impact on fare levels. There is, therefore, great need for technology advances to offset these inflationary pressures.

Community exposure to noise has increased greatly since the advent of the jet engine due to increased flight frequencies and continued development of communities near airports. This is illustrated in Fig. 2.

Advances in noise reduction techniques, made since the first generation of jet transports were designed, provide a technical basis for reducing the noise of early jets by retrofit modification. Since these aircraft produce the bulk of current community annoyance, intensive studies of this approach are currently being made by both government and industry. While the high bypass ratio engine of the wide-body generation of transports has significantly reduced noise level per aircraft, still further reduction is required. Again, technology advances are required if new aircraft economics and our freedom to travel are not to be severely impaired.

Figure 3 contains forecasts of growth in U.S. gross national product and urban population, which together contribute to the expected growth in revenue passenger miles and aircraft flight frequencies. There is evidently a future need for larger airline aircraft fleets. Peak time congestion has recently reached saturation at some major U.S. airports, as illustrated in Fig. 4. Currently, 50% of domestic U.S. passenger trips involve the use of 14 airports and 75% involve 36 airports. Since this situation is likely to continue, it is clear that aircraft size must increase more rapidly in the future.

In summary, the need and application for advanced technology is primarily to help offset the effects of inflation, low noise requirements and congestion, and to meet the design challenges associated with future large aircraft. In the near term the noise of first generation jet aircraft may be reduced.

First Generation Jet Aircraft Noise Reduction

The desirability of reducing the noise levels of first generation jet aircraft is unquestioned. There is general agreement that this will be costly and, in view of the limited remaining life of some aircraft, has led to the question of whether the task should be attempted at all.

Two basic engine types power most of these aircraft: the Pratt & Whitney JT8D engine in the DC-9, 737, and 727, and the Pratt & Whitney JT3D engine in the DC-8 and 707. The rear engined DC-9 and 727, whose numbers in service are far greater than the 737, are not readily amenable to retrofit involving heavier engines since the added weight rapidly puts the aircraft out of balance. Further,

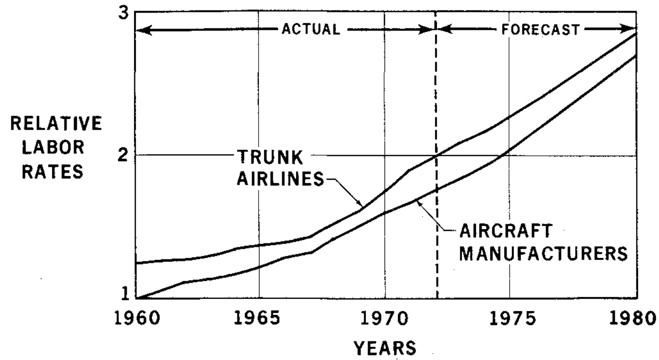

Fig. 1 U.S. wage trends.

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Table 1 Noise reduction costs and benefits for first generation jet aircraft

Approach	Modify nacelles (quiet pod)	Modify engines and nacelles (re-fan)	Replace engines (re-engine)	Replace aircraft (retirement)	
Aircraft	DC-8-50	DC-8-50	DC-8-50	DC-8-50 replaced by DC-10-30	
Engines	4, JT3D-3	4, JT3D-1X	4, new quiet engines	3, CF6-50C	DC-10-30
Noise relative to DC-8-50 with 3° glidepath:					DC-10-30
FAR 36 sideline (ΔEPNdB)	−4	−7	−9	−8	DC-10-30
FAR 36 takeoff (ΔEPNdB)	−5	−10	−15	−13	DC-10-30
FAR 36 approach (ΔEPNdB)	−12	−15	−17	−15	DC-10-30
100 PNdB footprint area for 1000 naut. mile mission (Δ%)	−54	−73	−87	−73	DC-10-30
Retrofit or retirement cost/aircraft (1972 $)	560,000	1,700,000	6,200,000	1,700,000	DC-8-50
Incremental spares cost/aircraft (1972 $)	100,000	300,000	1,200,000	0	DC-8-50
Average remaining aircraft life in 1975 (years)	7	7	7	7	DC-8-50
Increase in direct operating cost relative to continued use of noisy aircraft for 1000 naut. mile mission (%)	3	11	38	7	
Ticket surcharge to pay for retrofit and increased operating costs ($)	1.2	4.6	16.1	2.4	

the center engine intake design of the 727 precludes any major engine geometry change. The wing mounted engines of the four engined DC-8 and 707 present less of a problem. To illustrate the possible technical approaches and resulting noise reductions and retrofit costs, the DC-8 has been chosen as an example of the best circumstances for modification. The DC-8-50 series is analyzed since the age of these aircraft falls between the early DC-8-10 series and late model DC-8-60 series.

Four distinct approaches are possible: modify the nacelles by adding noise absorbing materials, modify the engines and nacelles to increase the bypass ratio, install new technology engines in new nacelles, and finally, order premature retirement with new aircraft substitution. Table 1 shows the estimated noise reductions achievable by each approach. A 70,000-hr structural life was assumed in deriving the average remaining aircraft life in 1975. Aircraft life was not extended because it was considered unlikely that the airlines would increase their investment to the extent needed to completely offset the fatigue and corrosion problems associated with aging. Such action would be in the face of the upward pressures on aircraft size, especially when the airlines are already operating larger wide-body aircraft. In computing the increased operating costs, it was assumed that indirect costs were unchanged and that interest costs on the increased investment were 8%/year. For the retirement case, the aircraft and spares value was spread over the average remaining life to derive the incremental direct operating cost. Since the average range flown by the DC-8-50 is approximately 1000 naut miles the average domestic U.S. revenue fare for this range was used along with a 55% load factor. Plotted in Fig. 5 are the relative noise levels, and ticket surcharges to pay for the retrofit, extra spares, increased direct operating costs, and interest on the increased investment. The benefits of a 6° glideslope, rather than the current nominal 3°, are also shown. The surcharge shown is per flight, and therefore would represent a higher percentage ticket price increase for shorter range flights. This surcharge would apply equally to first and coach class passengers. In practice the surcharge could be applied as a constant percentage ticket price increase.

It should be noted that these surcharge levels would only cover expenses and would result in a significant decrease in airline return on investment. Also, the premature retirement cost may well be overstated since by 1975 the average DC-8-50 will have been in service 12 years. The normal operational and economic advantages of a larger capacity new aircraft will probably lead to DC-8-50 retirement anyway.

The difficulty in reducing sideline and takeoff noise at reasonable cost is illustrated. This is due to the dominance of jet exhaust noise from the low bypass ratio engine. The community annoyance from the unmodified engine and the quiet pod approach is relatively high due to the low frequency components of jet exhaust noise being attenuated very little with distance through the atmosphere. The re-fan, re-engine, and new aircraft approaches

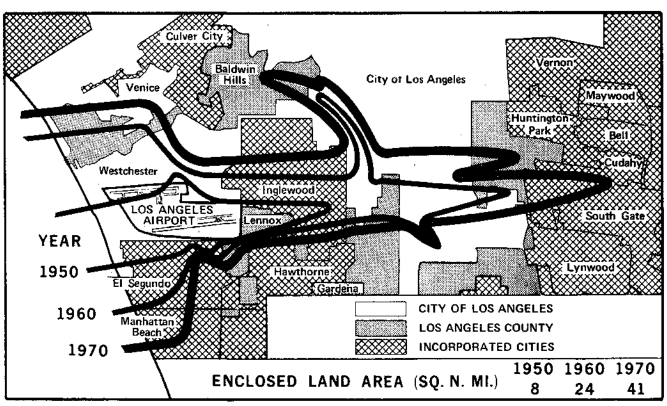

Fig. 2 The noise problem—noise exposure forecast = 30 contours.

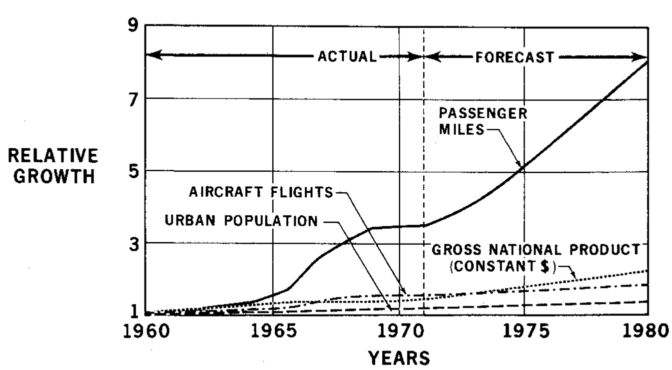

Fig. 3 U.S. growth.

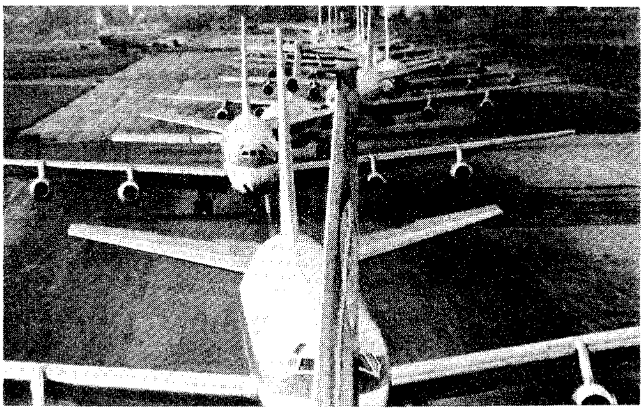

Fig. 4 Congestion.

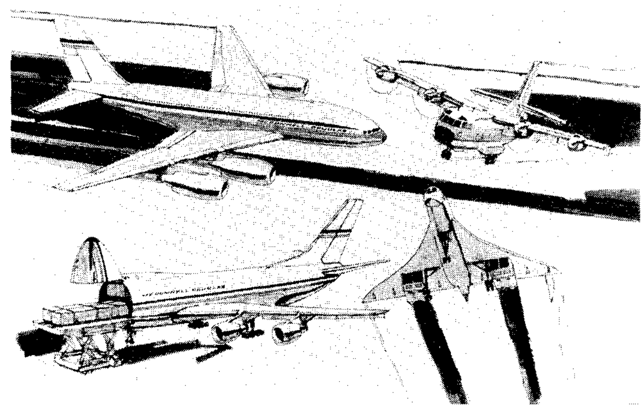

Fig. 6 Future aircraft types.

have high bypass ratio engines whose dominant high frequencies are significantly attenuated with distance through the atmosphere. The quiet pod approach, while being least costly, will not therefore significantly reduce community annoyance at takeoff.

While this is a simplified analysis, several valuable conclusions can be drawn. The remaining years over which these aircraft would produce less community annoyance is small in comparison to the economic costs. The cheapest and no doubt quickest means of reducing noise, though only on approach, is by flying a 6° glideslope which eliminates the need for costly engine pod changes. Finally, if noise must be drastically reduced quickly, the most cost effective approach is early retirement of the first generation jets and purchase of new wide-body aircraft that already incorporate much of this acoustic technology.

Future Transport Aircraft Market

Technology advances are now being made in so many directions that a new problem has arisen: the technology trap. Just because something is technologically possible does not mean that it should be developed into hardware.

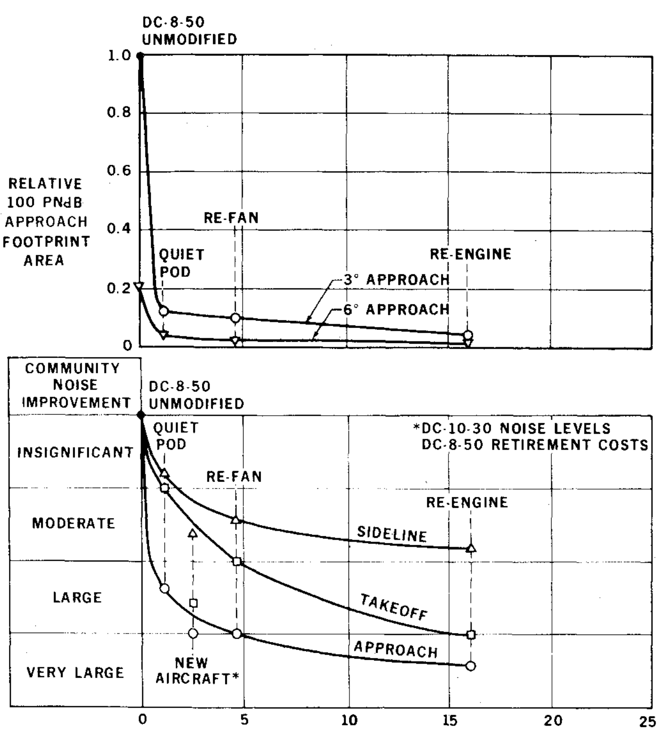

Fig. 5 Noise reduction ticket surcharges.

A technology development must be seen to contribute economically to a marketable aircraft before the expenditure of large sums of money is justified. An assessment of the market and environmental needs is therefore necessary. Possible aircraft types are illustrated in Fig. 6. Reference 1 contains a detailed discussion of these aircraft.

Up to now, conventional takeoff and landing (CTOL) aircraft have predominated in the transport market. Proposals are now being made for future short takeoff and landing (STOL) aircraft and for optimized all-cargo aircraft. Also, the first generation supersonic transports (SST) will soon be in service. STOL aircraft offer a possible solution to the short range (up to 500 miles) transportation problem. However, high operating costs and the difficulty of avoiding inflicting high community noise levels, coupled with powerful community resistance to new airports, indicate that considerable advances in STOL technology will be required before profitable STOL aircraft could enter service. The development of an all-new, uncompromised cargo airplane has been forecast for several years. However, as the cargo market has increased, so too has the availability of belly pit space in passenger aircraft.

The SST offers significant time savings, but at what cost? Calculations were made to determine the effect of ticket price and load factor on return on investment for both the DC-10-30 and a first generation SST. The estimated cost of time saving by first generation SST is shown in Fig. 7. In computing direct operating costs, the 1967 ATA method was used with the following assumptions: sale prices of $32 million for the SST and $19.7 million for the DC-10-30, seating capacities of 108 for the SST and 255 for the DC-10-30, and 16 years depreciation for both aircraft. The resulting SST seat-mile direct operating cost was more than double that of the DC-10-30. SST indirect costs per passenger mile were assumed to equal those for the DC-10-30. In computing return on investment, average international revenue fares were used

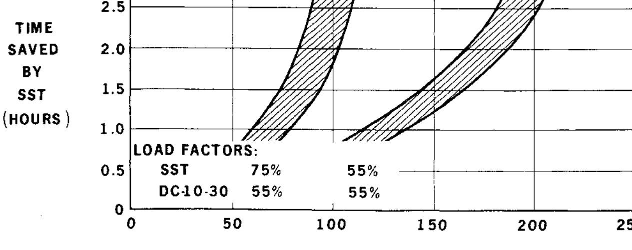

Fig. 7 Cost of time saving by first generation SST.

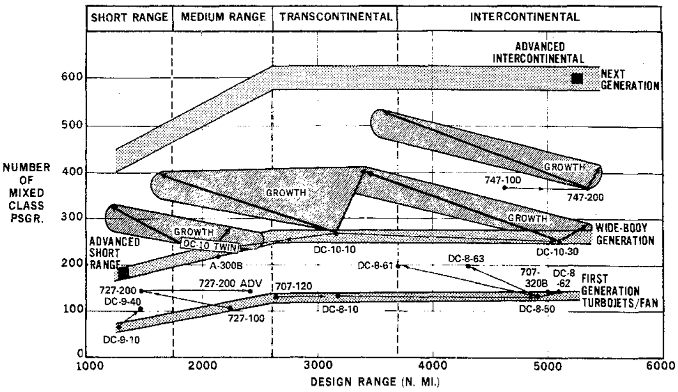

Fig. 8 Aircraft capacity trends.

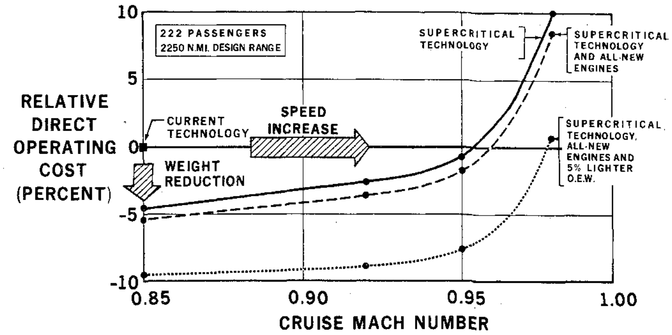

Fig. 10 Direct seat-mile cost trends.

for the DC-10-30. The cost of spares was assumed to be 15% of aircraft sales price, with an aircraft and spares residual value of 10% for both aircraft.

The required ticket surcharge above current fares is very large indeed, and is sensitive to SST load factor. An example is of interest. For a typical scheduled round trip flight between New York and London, a weighted average of current subsonic coach fares is $460, while the first class fare is $845. For a 55% load factor, a first generation SST would have to charge a one class fare of approximately $865 to produce the same return on investment. This is more than the current first class fare. A coach passenger would then be paying an 88% surcharge if he chose supersonic flight. It should be noted that these numbers are based on an SST sales price that is probably low. Considering that first class paying passengers constitute a declining percentage of total air travel, it is evident that little impact will be noticed on subsonic travel, and therefore the market for the first generation SST will be limited. A second generation SST will clearly require giant advances in technology to become economically competitive, even with current subsonic aircraft. This will take many years, or a dramatic breakthrough in technology.

With the obstacles confronting STOL, all-cargo, and SST aircraft development, it is evident that the bulk of passenger and cargo traffic will continue to be carried by conventional subsonic passenger aircraft designs in the future. The rest of this paper will therefore consider the CTOL passenger market and the technology developments that are desirable to support its profitable growth.

CTOL Passenger Market

While detailed and sophisticated market and financial analyses form a major part of the decision basis for an aircraft program go-ahead, a statistical trend analysis can provide considerable insight to the market applications of different aircraft and help to explain the basis for a successful aircraft program. These trends can also be used for predicting the need for future aircraft, so long as changes in market conditions are properly allowed for. The most important market parameters to be determined for a new passenger aircraft are its seating capacity, design range, and year of entry into service. Good economic and noise characteristics are, of course, a necessity. Figures 8–9 illustrate aircraft capacity and timing trends based on design range. The choice of aircraft plotted is intended to illustrate the distinction between initial designs and their derivative aircraft. Additionally, an indication is given of required wide-body generation and next generation aircraft. Design range was chosen as the basis for the curves since the passenger market is composed of people travelling different distances and it was concluded that range was the market variable nearest to being independent. In simple terms, cities do not move. While the number of people travelling increases with time, the routes flown are changing in stage length relatively slowly. More important, however, is the fact that initial designs are usually first introduced on an airline's prime routes for competitive reasons, and these routes are of relatively constant stage length.

Seating capacities were adjusted to represent a 15/85% split between first class and coach at 38/34 in. pitch, respectively. Wide-body generation aircraft used DC-10/747 seats and first generation jet aircraft used DC-8/707/DC-9 seats. Design ranges were based on a payload of mixed class passengers and baggage at 205 lb/passenger. Consistent reserve fuel rules were used within each range segment.

It is illustrated in Fig. 9 that the first initial design to be sold has been of transcontinental range. Figure 8 shows that the development of the transcontinental design into an intercontinental aircraft is possible because of the similar capacity requirements. However, the different smaller capacity requirements of the short and medium range markets have necessitated separate initial designs for each, since both range and capacity growth could not be built into a short range design without seriously compromising its short range performance.

Some general conclusions may be drawn; there are four main design range segments to the passenger aircraft market, each of which justifies and can support an all-new initial design. However, in practice, the intercontinental design is itself a development of the transcontinental initial design. (The 747 is a notable exception.) Also, the three engine configuration of the DC-10-10 lends itself to modification to a two engine medium range design.

A judicious choice of design parameters for the initial design (i.e., low approach speed and a design range in the center or toward the higher end of the arbitrary segments chosen) enables significant and profitable derivatives to be developed at a later date. These derivative, and usually larger capacity, aircraft, being more finely tuned in the

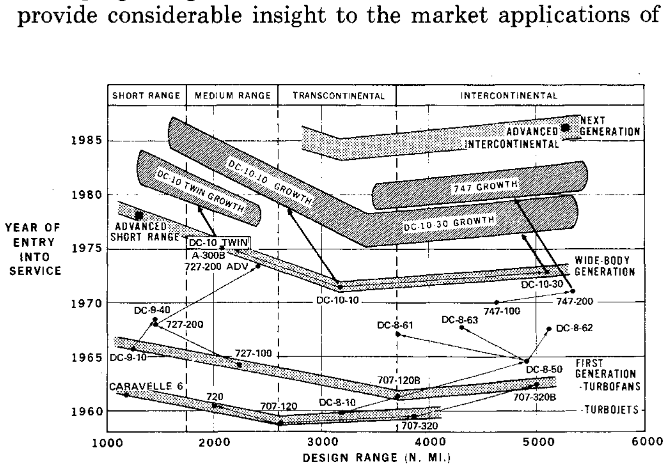

Fig. 9 Aircraft timing trends.

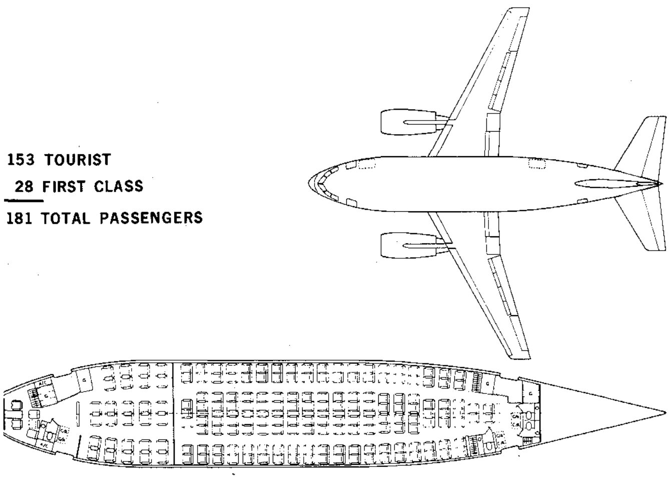

Fig. 11 Advanced short range aircraft.

engineering sense, tend at first to freeze out later all-new entries that employ similar technology. Eventually the need for even larger aircraft, coupled with advances in technology, provide such a large performance improvement that the development costs of an all-new initial design are justified. It should be noted that the wide-body aircraft only became possible because of the combined effect of high bypass ratio engines and increased capacity requirements. The wide body is more of a stimulant to the wide-body generation of initial designs than a cause of it.

There are now two market areas open for initial designs that have the economic and noise reduction advantages of high bypass ratio engines and the comfort of the wide bodies. The first is for a medium range aircraft for delivery in about 1975. The DC-10 Twin characteristics and performance closely correspond to those needed. In fact, the DC-10 Twin program appears to have all the necessary ingredients to become as successful as the 727. The second market area is for an advanced short range aircraft of approximately 180 seats, for delivery in about 1978. It should be noted that while the combined short and medium range market would justify an all-new engine development (as it did with the turbofans), it probably will not be necessary since the already available 40,000 and 51,000 lb SLS thrust engines are well matched to the requirements of the short and medium range aircraft, respectively.

The increasing number of new routes, usually more lightly travelled than the current prime routes, may not necessarily lead to an increase in the variety of derivative aircraft required. This is because depreciated older technology aircraft of suitable capacity that have been displaced from prime routes will be available. The unknown at present is the rate at which objections to their noisiness, and the passenger appeal of the wide-body, will affect the retirement rate of these narrow body aircraft.

It is to be expected that the considerable growth potential that exists in the DC-10-10, DC-10-30, and DC-10 Twin will be utilized to satisfy future demands for larger aircraft as the passenger market continues to grow. Their potential capacities and timing are illustrated. With further market growth the time will come when even larger capacities are required, since there are definite limits to increases in flight frequencies. At this point an all-new initial design will probably become economically justifiable, and the latest technology advances will be incorporated to improve market appeal, but mainly to minimize aircraft price and operating costs. It can be seen that, unless a quantum performance change occurs from a technology advance which does not increase operating costs, aircraft size is the driving force that leads to a new aircraft program. Neither the speed increase to Mach 0.95 nor the operating cost reductions shown in Fig. 10, which do not include offsetting inflationary effects, constitute such a quantum change.

A stabilizing influence on the 10–12 year period between generations of new aircraft is the adopted depreciation period. Premature retirement is very costly, while on the other hand equity levels have to be maintained above a certain level to form the basis for financing future aircraft purchases. Also, the time intervals between the introduction of each of the four range segment aircraft represent the airlines' need to limit variations in their cash flow and debt to equity ratio. The effect of an economic recession shows on Fig. 9 as a steepening in a trend line.

The applications for advanced technology to new CTOL aircraft would, therefore, appear to be twofold: in the near term to an advanced short range aircraft, and to the next generation of aircraft that will appear in the early 1980's. While the first aircraft of the next generation could well be of transcontinental range, the advanced intercontinental aircraft of Figs. 8–9 presents the greater technical challenge. The advanced short range aircraft and the advanced intercontinental aircraft should therefore be examined. A discussion of the likely advances in each of the basic technology areas is contained in Ref. 1.

Advanced Short Range Aircraft

Using Fig. 8, and similar trend curves of cruise speed, maximum takeoff distance, and approach speed, the following design requirements were established: 180 mixed class passengers, 1300-naut. mile design range, 0.78 cruise Mach number, 6500-ft maximum field length, and 118-knots approach speed. The opportunity to increase cruise speed with supercritical technology was not taken since the time saving over such short ranges would be barely discernible. Instead, supercritical technology was used to reduce weight by thickening the wing. The field length corresponds to that of the DC-9. It is recognized, however, that the possibility exists of reducing the takeoff distance, at some penalty to operating cost, to enable more airfields of shorter length to be served, thereby enlarging the sales market. The approach speed was the same as the DC-9. This is a balance between the benefits of a low speed to safety and aircraft design growth, and the significant operating cost reductions achieved by increasing the speed. A 3-knot approach speed increase provides approximately a 1% reduction in direct operating costs.

The resulting configuration is shown in Fig. 11. The heavy acoustic treatment level of Fig. 12 was used on an existing engine. The current production engine acoustic treatment arrangement is shown for comparison. A reduction of 5% in structural weight below current levels before aircraft resizing (with 7% after) was assumed in the analysis. It is believed that the use of composites and improved structural analysis and design methods will lead to

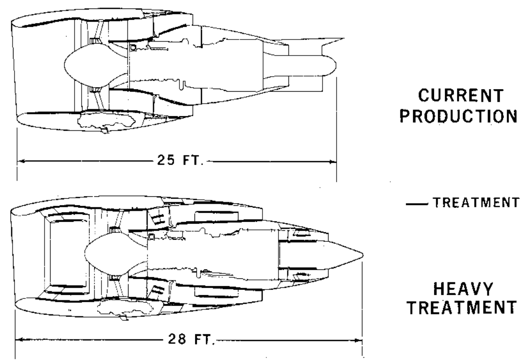

Fig. 12 Engine installations.

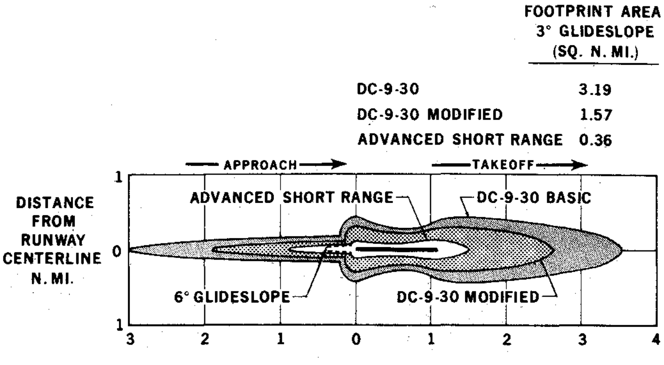

Fig. 13 100 PNdB footprints—500 naut. mile mission.

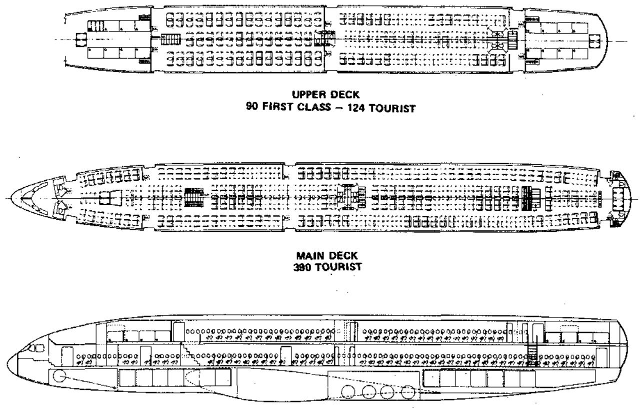

Fig. 15 604 passenger interior.

this reduction. The resulting aircraft characteristics are shown in Table 2, in comparison to the currently operated DC-9. Resulting typical operational noise footprints are plotted in Fig. 13. Improvements are to be expected for the DC-9 when modified for reduced noise. The modest benefit from a 6° glideslope is also shown for the advanced aircraft. This emphasizes the point that increased glideslope angles do not greatly benefit an aircraft that is already reasonably quiet. Considering the potentially large number of aircraft for this market, and the noise sensitivity of its operational environment, it may well prove to be economical for the engine manufacturer to modify the existing engine to incorporate recent advances in engine design. This would lower the noise levels shown here and contribute to enlarging the market.

Advanced Intercontinental Aircraft

Using the trend curves, as before, the following design requirements were established: 600 mixed class passengers, 5250-naut. mile design range, Mach 0.95 cruise speed, 11,000-ft maximum field length, and 133-knots approach speed. The range, field length, and approach speed are similar to current long range aircraft, while the increased cruise speed was selected based on Fig. 10 with the use of supercritical technology. It is not clear at this time what structural weight reduction will be achieved so three levels were chosen and the aircraft sized for each. Figure 14 shows the configuration and Fig. 15 the interior and inboard profile for the midweight level. It is noteworthy that the galleys are located on a main deck due to the underfloor space requirements for passenger baggage.

A new and costly large engine development program will obviously be required. In order to minimize the size of the new engine, a four engine configuration was selected rather than a three engine configuration. A bypass ratio of six was chosen to balance the opposing trends of weight and noise, as described in Ref. 1. Heavy acoustic treatment, as shown in Fig. 16, was adopted in order to minimize community noise levels. To illustrate the effect of this treatment level on aircraft noise, characteristics and economics, a current treatment level engine was used to resize the aircraft. The resulting characteristics of the aircraft studied are contained in Table 3. Noise footprints are shown in Fig. 17, which illustrate the effect of different treatment levels and glideslope angles in comparison with the DC-10-30. It is widely held that current noise measuring criteria are not adequately representative of annoyance. Since noise is evidently going to continue to be of serious concern to the manufacturers and the community, it is imperative that strong efforts be made to establish psycho-acoustical criteria that properly represent community noise annoyance.

The large increase in aircraft size presents a challenge to achieve an acceptable weight level due to the effects of the fundamental square cube law. Reference 2 comprises a clear explanation of this law. In the past, improvements in engine specific fuel consumption, which reduced fuel load, and high lift system advances, which reduced wing area and weight, have offset the size related weight increases.

One benefit of size is that there is a modest improvement in lift to drag ratio which reduces fuel costs. More

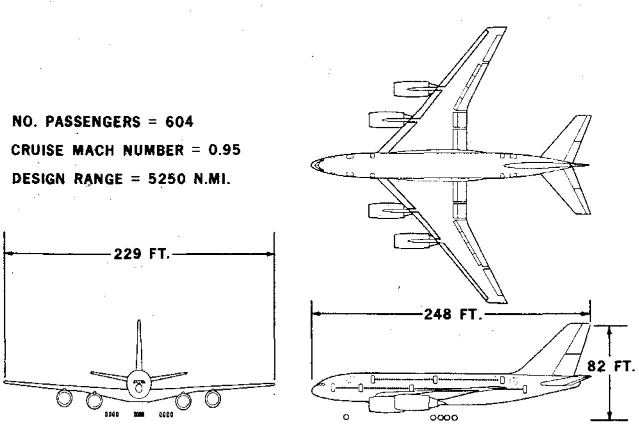

Fig. 14 Advanced intercontinental aircraft.

Table 2 Comparative characteristics

Aircraft	Advanced short range	DC-9-30
Engines:		
Number and type	2, existing	2, JT8D-7
SLS thrust/engine (lb)	36,800	14,000
Number of mixed class passengers	181	96
Design range with passengers and baggage (naut. mile)	1300	1280
Cruise: Mach number	0.78	0.78
Altitude (ft)	33,000	30,000
F.A.R. TOFL (SL, 84°F for design range) (ft)	6,560	6,550
Approach speed (passengers, baggage and reserves) (knots)	118	118
Wing: area (sq ft)	1,890	1,001
Sweep at C/4 (deg)	26	24.5
Span (ft)	128	93
Operator's empty weight (lb)	133,000	56,900
Maximum takeoff weight (lb)	209,400	108,000
Aircraft study price (1972 $)	10,840,000	4,900,000
Change in direct seat-mile cost at design range (1967 ATA)	−9%	0
Change in 100 PNdB footprint area for 500 naut. mile mission with 3° glidepath	−89%	0

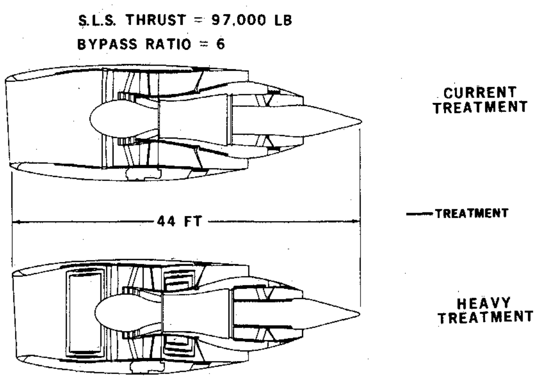

Fig. 16 Acoustic treatment levels.

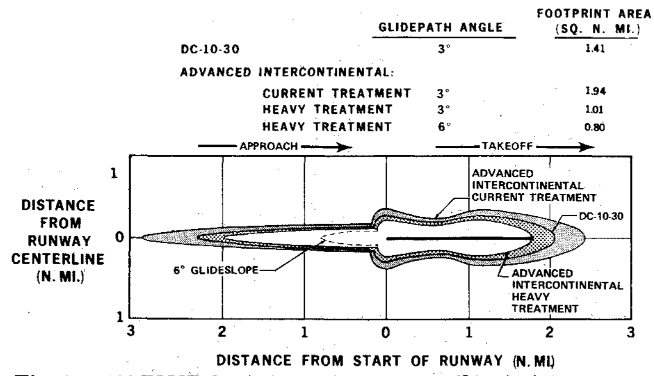

Fig. 17 100 PNdB footprints—1000 naut. mile mission.

importantly, crew costs are proportionately less and contribute to the size related seat-mile cost reduction of approximately 10%. However, such constant wage, price and dollar comparisons ignore the effects of inflation which will undoubtedly more than offset the reduction over the time period from now to the early 1980's. For this new aircraft to be competitive, advances that significantly reduce weight would be highly desirable. Specific fuel consumption and high lift system design cannot be expected to improve very much. However, composite primary structures offer the potential for just such a significant weight reduction. Problems that must be overcome include joint design, delamination, thermal expansion differences compared to metals, the current material price level, and new fabrication techniques that this material lends itself to. Figure 18 indicates the relative importance of price and weight level. Weight reduction from use of active controls to provide load alleviation and modal suppression offers promise but will require extensive development. The elapsed time required to validate such radical design advances will be several years. Accelerated effort will be needed to achieve incorporation in an aircraft entering service in the early 1980's. The demonstration of adequate reliability levels is of the utmost importance. Commercial airline operations involve far higher aircraft utilization and longer flight lives than military aircraft. Also, the financial investments now made in new large aircraft programs, both by the manufacturers and airlines, are so large that a major design deficiency virtually guarantees bankruptcy to the manufacturer and, depending on current fleet size, would threaten the airlines too.

The increased cruise speed of this aircraft will probably be determined by that speed at which fuselage indentations can just be avoided. External fairings to satisfy local airflow conditions to avoid drag will be acceptable. As soon as waisting is required the cabin interior becomes inefficient, extra body length is required to provide the same number of seats, and the high stress levels at the rear spar-body intersection have to be carried by the smaller diameter body. These effects combine to produce the rapid increase in direct operating cost of Fig. 10. It is judged at this time that Mach 0.95 will be close to the optimum speed. Developments in supercritical aerodynamics, nacelle design, high subsonic local flow, and stability and control are all required for a Mach 0.95 design.

These very high aircraft gross weights will require large and complex landing gear designs. New larger tires will be needed, and runway and taxi-way width and strength ver-

Table 3 Comparative aircraft characteristics

Aircraft	Advanced intercontinental				DC-10-30
Reduction below current OEW levels before resizing (%)	−5	0	−5	−10	0
Acoustic treatment level	current	heavy	heavy	heavy	current
Engines: number and type	4 new	4 new	4 new	4 new	3 CF6-50C
bypass ratio	6	6	6	6	4.4
SLS thrust/engine (lb)	92,000	105,000	97,000	91,000	51,000
Number of mixed class passengers	604	604	604	604	255
Design range with passengers and baggage (naut. mile)	5250	5250	5250	5250	5090
Cruise: Mach number	0.95	0.95	0.95	0.95	0.85
step altitudes (ft)	31,000/ 35,000	31,000/ 35,000	31,000/ 35,000	31,000/ 35,000	31,000/ 35,000
F.A.R. TOFL (SL, 84°F for design range) (ft)	9,900	10,300	10,100	9,700	10,100
Maximum initial cruise altitude (ft)	31,000	31,400	31,500	31,900	30,400
Approach speed (passengers, baggage and reserves (knots)	133	133	133	133	131
Wing: area (sq ft)	7780	8980	8090	7310	3610
sweep at C/4 (deg)	37	37	37	37	35
span (ft)	225	242	229	218	165
Operator's empty weight (1000 lb)	571	678	597	527	264
Maximum takeoff weight (1000 lb)	1,237	1,420	1,293	1,181	555
Block time at 5000 naut. mile range (hr-min)	9-30	9-30	9-30	9-30	10-34
Aircraft study price (1972 $ M)	42.87	50.89	44.82	39.48	19.70
Change in direct seat mile cost at design range (1967 ATA)	−20%	−8%	−16%	−24%	0
Change in 100 PNdB footprint area for 1000 naut. mile mission with 3° glidepath	+38%	−21%	−28%	−35%	0

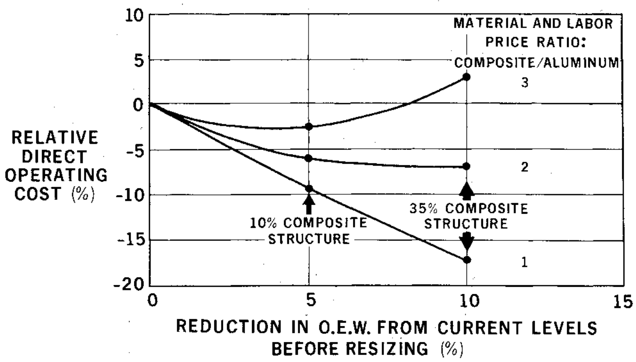

Fig. 18 Weight reduction and material price effects.

sus gear flotation characteristics require study, as well as the problem of inboard flap performance degradation due to the large gear trucks.

Evacuation from the upper deck is not expected to be a major problem. This is based on recent experience with the new double and triple width slides.

Probably the greatest problem associated with the size of the next generation of aircraft is that of finance. The investments required to develop such aircraft will be many times the net worth of the manufacturer. Current financing approaches will probably be inadequate. Since most non-U.S. aircraft manufacturing companies are already government owned or financed, the trend to greater U.S. government financial involvement appears inevitable.

Summary

Due to the many potential applications of technology, care must be taken in allocating funds and manpower for air transportation technology development. The greatest effort should be directed to assisting the development of

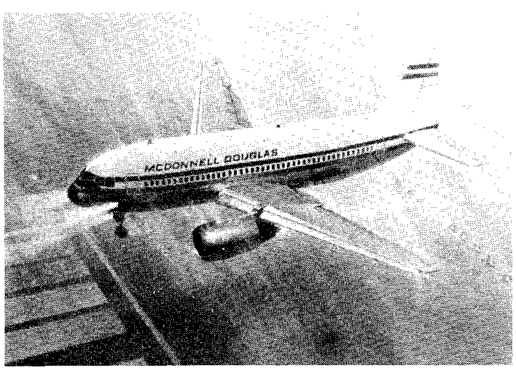

Fig. 19 Advanced short range aircraft.

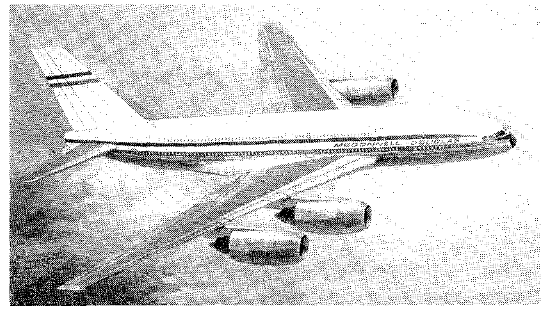

Fig. 20 Advanced intercontinental aircraft.

inexpensive and quiet air transportation for the benefit of the public as a whole. For the foreseeable future, the bulk of air travel will continue to be provided by subsonic conventional takeoff and landing passenger aircraft.

Technology development areas that should, therefore, be emphasized are listed as follows:

NEAR TERM APPLICATION
- Thick supercritical wings
- Noise reduction—Engine design
  - —Treatment
  - —Steep approaches

LONGER TERM APPLICATION
- Increased speed supercritical wings
- Composite structures
- Active controls
- Low noise large engines

In the near term, a thick supercritical wing will be needed for an advanced short range aircraft of the type illustrated in Fig. 19. Advances in acoustic treatment and modifications to existing engines are desirable in order to maximize the community acceptance of this aircraft. Steeper approaches may be an acceptable near term way of reducing the community annoyance from first generation jet aircraft.

In the longer term, supercritical wings designed for increased speed will be required. Large aircraft of the type shown in Fig. 20 will require large amounts of composite structures and perhaps active controls. The noise from the large engines involved must be minimized.

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