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CHARACTERISTICS OF FUTURE AIRCRAFT IMPACTING AIRCRAFT AND AIRPORT COMPATIBILITY

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SUMMARY

Results are reported of an opinion survey of selected individuals at the decision-making level within the five major manufacturers of transport aircraft in the United States and Europe. Opinions were obtained concerning both possible and probable existence of over 50 compatibility-related characteristics of transport aircraft in use in the years 1990, 2000 and 2010. Author's comments are also included on certain candidate new features as to technology status and developmental effort underway. The maximum size of aircraft is expected to increase, at a roughly uniform rate, to the year 2010 by 85 percent in passenger, 55 percent in airfreighter payload, and 35 percent in gross weight. Companion to the expected growth in payloads and gross weight was the identification of probable increases in aircraft geometrical dimensions and component capability, and use of fully double-decked passenger compartments. Wing span will increase considerably more than normally expected to provide wings of higher aspect ratio. New aircraft features coming into probable use include large turboprops, synthetic Jet-A fuel, winglets, wake-vortex-reducing devices and laminar flow control. New operational concepts considered probable include steep approaches, high-speed turnoffs, and taxiway towing for the aircraft, plus passenger bypass of the terminal building, expedited handling of belly cargo and an intermodal cargo container system for the payloads. Supplementing conventional transports by the year 2000 will be possible use of advanced supersonic transports and probable use of sizeable aircraft operable on short auxiliary runways.

INTRODUCTION

The selection of features and components to be incorporated into new transport aircraft involves striking a careful balance between the primary factors of customer demands, governmental regulations, technical state of the art, and economics. Compatibility of aircraft with the airport is also a concern, but on occasion, must suffer because of overriding considerations (e.g. introduction of the more economical jumbo transports). Compatibility with aircraft is a necessary design consideration in the modification of existing, or construction of all-new airports, both of which involve major efforts stretching over many years. It is therefore important to identify early-on any likely changes in the characteristics of future aircraft which would impact compatibility with the airport, particularly on the ground. Towards this end, the aerospace industry has a continuing effort underway to identify and periodically report on some of these characteristics, trends and growth projections for 15 to 20 years in the future (ref. 1).

Compatibility-impacting characteristics can range from increase in size of various parts of the aircraft, through use of new types of subsystem components, to unique operational procedures involving the aircraft or its payloads. Identification is not needed of overall configurations of new aircraft, but rather of only those features likely to be incorporated into the aircraft which will change their compatibility characteristics either positively or negatively. New innovations in aircraft oftentimes requires technology advancements before the concept can be put into service. As outlined and discussed in some detail by Hanks (ref. 2), the developmental status of most technology advancement falls into one of three sequential phases: concept assessment; proof-of-credibility; and product definition. As illustrated in figure 1, all phases must be completed before commitment to product development is made. Also shown in the figure are the objectives of each phase, the number of years of effort normally involved, and the prerequisites to initiation of effort in each phase. The entire process can stretch over several decades, with a number of major decisions required along the way as to whether or not to continue to the next phase. While technical viability is a consideration in all of these decisions, the importance of a particular problem can change significantly with time (e.g. energy conservation).

In the initial or early steps of the cycle, decisions are often made by researchers or their organizations, but the ultimate decision on product commitment to a production vehicle is made by the aircraft manufacturer. This decision requires consideration and evaluation of a host of factors, many of which are nontechnical in nature. Thus, the opinions of industry decision makers must be given considerable credence regarding the likelihood of future characteristics of transport aircraft, both for change in vehicle size and for use of new concepts where the technology status has reached the product definition phase. However, for features that are in the concept-assessment or proof-of-credibility phase, where information available to industry is less complete, the opinions of the research community is also important.

This paper identifies and examines, principally from the viewpoints of aircraft manufacturers, likely changes in future transport aircraft that will impact compatibility with the airport over the next several decades. To obtain such viewpoints, an opinion survey was carried out by mail of selected individuals within the organizations of the five major manufacturers of transport aircraft in the United States and Europe. These findings, treated collectively, on compatibility-related characteristics of future aircraft are supplemented with comments by the author, as an informed researcher, on candidate new features regarding their technology status and the level of research, development and demonstration effort presently underway. The time frame of the examination extends from 1981 until the year 2010.

The cooperation and effort of the considerable number of individuals within the community of transport manufacturers who generously provided opinions regarding selected characteristics of future aircraft is acknowledged. These perceptive and informed opinions, taken in toto, were the key ingredients not only in developing an interesting outlook regarding compatibility effects but also in lending a degree of credibility to this outlook.

PROCEDURE

Opinion Survey

The intent of the survey was to obtain informed opinions regarding the likelihood of existence at future times of certain features, characteristics, and operations (collectively referred to hereinafter as characteristics) of civil transport aircraft which could impact, either positively or negatively the airports in the following respects:

1. Airport overall configuration and operation
2. Runway properties (e.g. geometry, strength, operations)
3. Taxiway characteristics (e.g. geometry, operations)
4. Apron features (e.g. geometrical clearances, service facilities)
5. Terminal building (e.g., geometry, payload handling provisions)
6. Maintenance of both the aircraft and the airport
7. Safety in the operation of both aircraft and the airport

Impacts on the airport by an aircraft generally relate to the aircraft size and geometry, to certain aircraft systems, or to operations involving the aircraft and/or its payload. To keep the survey within manageable bounds, information was obtained only within areas judged to have the greatest impact, namely: (a) vehicle capacity and weight, (b) fuselage geometry, (c) landing gear system, (d) propulsion system, (e) aerodynamic system and (f) operations.

The survey was conducted by mail of selected individuals at the decision-making level within the airframe industry. Request was made for opinions relating to the probability of existence in the years 1990, 2000 and 2010 of certain characteristics of transport aircraft then in use at some of the world's principal airports. Because of considerable uncertainty in such speculation, two levels of opinion were sought. The first level was of considerable optimism about possible use, where the probability of existence in a given year could be as low as 10 percent. Demonstration use only of a characteristic, however, would not qualify it for inclusion. The second level was of more conservatism or probable likelihood, where the probability of existence in a given year was judged to be 50 percent or better. Participants were informed that personal (not corporate) considered opinions were needed, that opinions should address products expected of the industry as a whole, that replies would be treated collectively and that no identification would be made of the respondees or their affiliations.

Information was obtained concerning over fifty different characteristics. About one-half of these pertained only to the probability of existence of a given feature or operation (e.g. double-deck fuselage). The remaining one-half pertained to the probability of existence of a quantitative measure (generally for the limiting case situation) relative to a feature or operation (e.g. maximum landing speed). Bars with linear scales (e.g. knots, number of passengers) were provided for marking by the respondees at the appropriate scale locations. Two bars were provided for probabilities of existence greater than 10 percent and 50 percent, respectively. The marking system used for all questions consisted of the use of a "9" for the year 1990 an "0" for year 2000, and a "1" for year 2010.

Survey responses were received from either the selected individuals or small teams organized by the selected individuals within the five (three domestic, two foreign) major manufacturing organizations of civil transport aircraft. In some cases, information was obtained from more than one division of a manufacturer. A total of nine responses from the five manufacturers were received with six being individual opinions and three being collective opinions of small teams. In only one instance was there a response from only one person within a manufacturing organization. Where there were several responses from within an organization, the responses on each question were melded to provide a single representative response. For quantitative-measure characteristics, this melding consisted of averaging the several values. For probability-of-existence characteristics, it consisted of using either the earliest indicated date where two responses were being melded, or the date favored by the majority where more than two responses were melded.

Survey Results

The response information considered representative of the five major manufacturers of transport aircraft is presented in figures 2 through 18 for the years 1990, 2000 and 2010. Information pertaining to a quantitative measure (e.g. figure 2) is shown in bargraph form with each bar extending from the minimum to the maximum value and with the average (arithmetic mean) value indicated by a symbol. A symbol is also used to denote the value existing in 1981 for the measure. The optimistic and conservative levels of opinion are represented by dashed-line and solid-line bars, respectively. Varying degrees of conservatism were evident in the replies by the respondees, with several choosing to offer little or no optimistic speculation. Information pertaining to the probability of use of a given feature or operation (e.g., fig. 5) is presented as the sum of the responses pertaining to a given-year, given-probability combination. Since some respondees chose not to address all items of the survey, a notation is made at the bottom of each bar or column as to the number of responses represented (from 1 to 5). As considerable differences of opinion were sometimes evident regarding a given characteristic, interpretation of specific items in the survey results should include consideration of both the range in values of the responses as well as the number of responses represented. The discussion which follows generally will be directed toward the conservative (probability $\geq$50 percent) opinion results.

DISCUSSION

Aircraft Characteristics

Payload and weight. - The physical size of an aircraft, which is a prime factor in its compatibility with the airport, fundamentally depends on its payload. Accordingly, information was obtained on the upper limits of payloads expected over future decades in terms of maximum number of passengers for passenger aircraft and maximum gross payload weight for airfreighters. Opinions were obtained for aircraft using conventional runways, auxiliary runways of 3000-4000 feet for RTOL (Reduced Takeoff and Landing) transports and 2000-2900 feet for STOL (Short Takeoff and Landing) transports, and landing pads for VTOL

(Vertical Takeoff and Landing) transports. Results indicate a continuing growth in maximum capacity of conventional transports (figure 2a) with an 85 percent increase by the year 2010 to an average value of 930 passengers. Industry-wide opinions were reasonably consistent with little spread between replies. A similar trend in growth was not evidenced regarding the capacity of transports capable of operating onto auxiliary runways (figs. 2b and 2c). Maximum size is expected to increase to about 100 passengers by 1990 and then remain essentially constant thereafter. Apparently the use of large auxiliary-runway transports for shuttle or feeder service is not generally viewed by the airframers as a particularly attractive approach for relieving congestion in the system. Certainly there is no lack of technology for designing such aircraft, either with a conventional high-lift system and decreased wing loading (ref. 3) or with a powered-lift system and moderately high wing loading (ref. 4). A considerable difference of opinion was evidenced in the survey, however, with one response indicating probable use of a 150-passenger transport by the year 2000. The Japanese have plans to develop such a 150-passenger transport and is presently assembling a prototype of reduced size at Kawasaki. Only three respondees addressed vertical-takeoff-and-landing transports. They were in agreement that maximum capacity would increase to about 50 passengers by 2000 with little increase thereafter (fig. 2d).

Airfreighter maximum gross payload is expected to increase about 55 percent to about 385,000 pounds by 2010, with one-half of the increase occurring by 1990 (figure 2e). The need for larger airfreighters is consistent with the results of major systems studies carried out several years ago (ref. 5) which predicted significant growth in demand stemming primarily from international airfreighter services but with limited growth for U.S. domestic services. Also indicated by the study was the probable use of derivative widebody transports through the 1990's with all-new dedicated airfreighters not being used until sometime beyond the year 2000. The timing and size of such new airfreighters could well depend on factors such as a government's sharing of the RD and D costs by virtue of its need for a slightly modified version of a civil airfreighter (e.g. military airlifter). The study indicated such a civil airfreighter could fall anywhere within a wide range of sizes (up to one-million pound payload) and still be economically attractive. Such thinking leads to the high peak values in optimistic opinions shown in figure 2e.

Opinions regarding aircraft maximum gross weight at takeoff indicate an average-value increase of 35 percent to about 1,135,000 pounds by 2010 for both passenger transports and airfreighters (fig. 3). The near-term increase (to 1990) in maximum weight, however, indicates a much greater increase occurring for airfreighters than for passenger transports which is consistent with the trend indicated earlier for payloads. Similarly, the optimistic-opinion values ranged much higher for airfreighters than for passenger transports. For both type transports, the percentage increase over the three decade period is much less for gross weight than for payloads, which reflects the great savings expected in both airframe weight and fuel consumption by application of advanced technology.

Fuselage geometry. - An increase in the size of the fuselage generally accompanies any significant increase in the payload. Accordingly, opinions were obtained regarding the maximum fuselage length which is the fuselage dimension that most impacts compatibility. Incidently, adding 3 percent to fuselage length provides a close estimate of the overall length, including empennage overhang, which enters into the calculation of ramp area requirements. The survey results indicate an average value increase in probable maximum fuselage length of 16 percent to about 260 feet by 2010 (fig. 4a). Opinions of the respondees were in close agreement with the most optimistic estimated peak-value being 280 feet.

If fuselage shapes are similar, the 16 percent increase in fuselage length will provide a 55 percent increase in volume, which matches the percentage increase expected in airfreighter payload. The floor area of single-deck passenger aircraft will increase only 35 percent, however, which is insufficient to accommodate the 85 percent increase expected in maximum passenger capacity. At least one-fourth of the passengers will have to be carried on a second deck. Probable use of fully double-decked passenger aircraft by the year 2000 was foreseen by all respondees (fig. 5).

Increasing demand and congestion may lead to various innovations in the air transportation system (ref. 6) which will require use of new fuselage concepts. The survey addressed some of these concepts which could impact compatibility. Other than use of double-deck arrangements, there was no general consensus regarding use of any of the other candidate configurations as indicated by figure 5. However, two of the four respondees, who answered questions pertaining to cargo aircraft, indicated probable use by 2000 of high-wing configurations for large civil airfreighters. A single vote for probable use by 2010 was received for each of three concepts: the flatbed airfreighter, the multibody airfreighter, and integrated wing body configurations (identified by two respondees to a request for other candidate concepts).

Landing gear. - The maximum outer-wheel tread of the landing gear is expected to have an average value increase to about 47 feet for the years 2000 and 2010 (fig. 6a). This value amounts to 18-20 percent of the expected maximum wing span (fig. 13a) which lies well within the 15 to 27 percent region for existing aircraft landing gear (fig. 10 of ref. 1).

The maximum wheel base is expected to have an average value increase of about 15 percent to 97 feet by 2010, with essentially all of the increase occurring after 1990 (fig. 6b). As a percentage of expected maximum fuselage length, this value is in the middle of the 35-40 percent region in which lies the wheel base of existing widebody aircraft (fig. 11 of ref. 1).

The single-wheel maximum loading is expected to have an average value increase to about 67,000 pounds by 2010 (fig. 6c). To illustrate a dichotomy apparent in the opinions expressed, the average value for just the responses from the U.S.A. is also shown by a separate symbol on the bars of figure 6c. Maximum loading values cited by American respondees averaged about 7000 pounds higher than the overall average throughout the entire time period. A difference of opinion may exist toward utilizing the maximum capability of tires (one presently rated at 62,000 pounds) because of concern about tire dependability and economics (paper 30 of ref. 7). In addition, increased loading of a given tire requires an increase in tire pressure, which adversely affects braking and skid control capability.

Increase in the maximum horizontal distance from the cockpit (pilot's eye) to the main landing gear can impact design standards for turn fillets on the airport. The survey results for supersonic transports (fig. 7a), while insufficient to provide any statistically significant quantitative values, were in general agreement with the values of 150 to 170 feet previously postulated (fig. 12 of ref. 1). For subsonic transports, this distance will have an average value increase of about 10 percent after 1990 and before 2010 (fig. 7b).

Several candidate innovations in aircraft landing gear were included in the survey and evaluated by four respondees. The four respondees considered powered wheels (for maneuvering in the taxiway-apron areas) to have possible use by 2010, with two respondees indicating probable use as early as 2000 (fig. 8). The technology status for powered wheels is still in the proof-of-credibility stage with only limited effort presently underway on a prototype system driven by a hydraulic motor. Cross-wind landing gear, in which the wheels align with the aircraft direction of motion, could ease aircraft operation into airports with single-direction runways. In response to a querry about use of crosswind gear on large and small transports, a majority of the respondees indicate possible use by 2010 on aircraft heavier than 200,000 pounds while two of the four respondees indicated probable use by 2000 on aircraft lighter than 50,000 pounds (fig. 8). The technology status for cross-wind gear is considered to be through the proof-of-credibility phase. The third innovation considered was the air cushion landing gear which would permit operation of any size transport on surfaces additional to paved runways including uneven ground, swamp, water, snow or ice. Two of the four respondees considered use of air cushion gear on civil transport aircraft to be possible but not probable by 2010. Its status of technology is still in the proof-of-credibility phase with successful flight experiments to date limited to light aircraft. The military, which has indicated need for such gear on larger aircraft, has been reluctant to fund the considerable technology development effort still required.

Propulsion system. - Opinions were in remarkably close agreement regarding the outlook for turbofan propulsion. Single-engine probable maximum thrust level is expected to increase at a linear rate with time to an average value of 75,000 pounds by 2010 (fig. 9a). The percentage increase almost exactly matches the 35 percent increase expected in probable maximum aircraft weight (fig. 3). Maximum bypass ratio for large engines is expected to increase significantly during the 1980's to a probable average value of 7.5 by 1990, and then at a slower rate to a value of about 9.0 by 2010 (fig. 9b), which is considered to allow a cruise Mach number of about 0.8. Compatibility problems in clearance between the ground and the larger diameter nacelles (inherent with larger bypass ratios) may arise but effort is underway to develop aerodynamic integration technology to allow locating engines closer to the wing chord plane. The benefits in decreasing both the specific fuel consumption and the terminal area noise as a result of increasing bypass ratio might be even greater with bypass ratios of 10 to 12 but such application would likely be limited to engines for airfreighters and short-haul passenger transports cruising at Mach 0.7 to 0.75. From compatibility considerations, a medium size engine in this category would seem attractive for short-haul transport use. A trend toward use of a higher bypass ratio for smaller engines is not foreseen, however, in the results of figure 9b and 9c where essentially identical values are shown for both 25,000-pound and 60,000-pound thrust engines. The technology status for bypass ratio 10-12 engines essentially completed the proof-of-credibility stage in the NASA-QCSEE program (ref. 8) several years ago.

Opinions were quite diverse on use of large advanced turbopropellers which have been advocated for saving fuel at cruise Mach numbers to 0.8. While most opinions were quite optimistic, one respondee considered use of turboprops by the year 2010 as being probable (in moderate size) for airfreighters but only as possible for passenger aircraft. Not only does a wide spread exist between the upper and lower probable values shown in figure 10, but also (for a different mix of respondees) the range of the possible values is displaced downward, rather than upward, from the range of the probable values. Nevertheless, the majority of respondees consider as probable a large increase in the maximum power of turbopropeller units used on both passenger aircraft and airfreighters. The average value estimate of 28,000 horsepower by the year 2010, which is more than five times that of turbopropellers presently available, is a size appropriate for widebody transports. Perhaps the diversity in opinion on turbopropellers stems from the technology status which is still in the proof-of-credibility phase. A great amount of technology must be developed for: propulsion-unit integration in an aerodynamically efficient manner; achieving a satisfactory acoustic environment, particularly in passenger compartments; providing a suitable structure for the very thin swept blades; and providing the required large gas turbines plus speed reducers which are long-lived and have low maintenance. A high level of effort sustained over a considerable time period will be required to supply the technology necessary for the industry to provide aircraft with propulsion units of a size approaching those shown as probable in 1990, 2000 and 2010. Research and development efforts underway and planned are considered by the writer as inadequate in meeting such a schedule.

Recent problems in the availability and cost of petroleum have led to consideration of alternative aviation fuels. Only three candidates have been identified as viable for aircraft: synthetic Jet-A (synjet); liquid methane and liquid hydrogen. Use of synjet was considered probable as early as 1990 (fig. 11) while neither liquid methane or liquid hydrogen received much endorsement. This is not surprising as synjet is cheaper to manufacture from coal or oil shale and requires no change in either the aircraft or the airport. Liquid methane and liquid hydrogen (both cryofuels) require specially configured aircraft and major facilities at each airport for fuel storage and handling (ref. 9).

<u>Aerodynamic System</u> - Opinions concerning vertical tail height (fig. 12) indicate the maximum height is expected to increase after 1990 to an average value approaching 74 feet by the year 2010. A wide-band correlation curve (fig. 15 of ref. 1) exists between tail height versus transport aircraft gross weight and includes an extrapolation to higher gross weights plus an offset band postulated for multi-deck configurations. The coordinate point of maximum tail height and maximum gross weight expected in 2010 is located at about the center of the band (whose width equals 11 feet of incremental tail height) for conventional transports but at the bottom edge of the offset band for multideck configurations.

Opinions varied radically (by as much as 80 feet) regarding the probable increase in maximum wing span (fig. 13a). The average values indicate a span of 250 feet can be expected by the year 2010 if not sooner. Only sixty percent of this increase is required to accommodate the expected increase in gross weight, provided there is no change in either wing loading or geometrical shape. A change in shape to increase wing aspect ratio to a value of 8.5, however, would account for the additional percentage in span. Increase in aspect ratio to 8.5 or even higher is a design trend already underway to decrease induced drag. Recent improvements in wing structural efficiency through application of thicker supercritical airfoils and advanced materials place the technology status of higher aspect ratio wings as past the product definition phase.

Significant increase in maximum wing span, indicated above, can have an adverse impact on compatibility with the airport, as was experienced in 1970 with the introduction of the Boeing 747. To minimize or avoid major disruptive world-wide modifications of existing airports, a need exists for cost-effective alternative wing configurations, (e.g. wing folding) which are viable. The recently developed winglet is such a new concept which can reduce wing span appreciably. Most of the survey respondees agreed that winglets probably would be in use by 1990 (fig. 13b). Opinions as to the expected maximum span of wing-winglet combinations indicate average values throughout the entire time period will be about 10 feet less than for plain wings. This incremental decrease is less than one-half the potential available according to the results of an indepth analysis of optimized wing-winglet configurations, wherein it was found possible to decrease span by 10 percent without adverse effects (ref. 10). Perhaps some respondees view the winglet application primarily for improving aerodynamic efficiency rather than for optimally minimizing wing span while maximizing efficiency. The technology status for winglets is considered to be nearly through the proof-of-credibility phase, with flight experiments underway utilizing widebody aircraft.

The survey addressed two other concepts for improving aerodynamic efficiency. One is the use of laminar flow control (LFC) on the wing to greatly reduce skin friction drag. The majority of respondees consider use of LFC as possible by the year 2000 and probable by 2010 (fig. 14). The technology status is in the proof-of-credibility phase with rather formidable requirements for practical LFC use still to be met, but substantial and sustained R and D efforts have been underway by NASA. As LFC surface contour shape, smoothness and porosity are critical factors, in situ surface cleaning may be required between flights when insect strikes occur on the wing leading edge. Extra precautions in airport ground maintenance and surface movement of other aircraft also will be required to avoid LFC surface contamination and damage. The second concept is variable camber, wherein the wing cross-sectional shape can be continuously and smoothly cambered to optimize the lift-drag ratio throughout the flight regime. Benefits include potential fuel savings of as much as 4 percent (ref. 11) plus a decrease in noise level during takeoff because of slightly lower power requirements and absence of noise-generating slots and gaps in the wing. Survey responses were mixed, ranging from no foreseeable use to probable use as early as 1990. A majority considered variable camber use as probable by the year 2010 (fig. 14). The technology status is still in the concept assessment stage with considerable technology requirements yet to be addressed. No significant effort is presently underway.

The survey also addressed two aerodynamic concepts which impact aircraft behavior in terminal area operations. One concept is direct side-force control to provide and maintain more precise positioning in cross-wind approaches which may be required to achieve the precision in positioning needed when aircraft spacing is compressed. As need for such control was considered as possibly differing for various size aircraft, opinions addressed use of direct side-force control on commuters, narrow-body transports and widebody transports (fig. 14). Only a minority of respondees considered such use as probable by the year 2010. Technology readiness for direct side force control is beyond the proof-of-credibility phase with many years of experience accumulated on research aircraft. The second concept is the use of wake vortex reducers to minimize wake intensity downstream of an aircraft, a limiting factor in the spacing of aircraft. Opinions were obtained concerning use of wake vortex reducers as providing a reduction by 20 percent increments in the separation distance of following aircraft. Four respondees considered the use of wake vortex reducers by the year 2010 as probable in providing a 20 percent reduction (fig. 14). Two of the four respondees considered a 40 percent reduction in separation distance as probable by the year 2010. At present the technology status is only in the concept assessment phase. Following several years of exploratory studies with no preferred concept identified, NASA recently initiated an indepth long-range program to provide a more fundamental understanding of the phenomena to better identify viable approaches for wake vortex reduction.

Operations

Runway requirements. - Runway requirements depend not only upon the size and weight of aircraft but also upon their takeoff and landing characteristics. For example, as an aircraft's speed on the runway increases, its dynamic response to runway roughness or waviness increases significantly. The Concorde aircraft, with its limber fuselage and high takeoff speed, exhibited severe dynamic responses for some runways during early trial use, which required corrective action before regular use was initiated. Opinions were obtained in the present survey regarding maximum runway speeds. As shown in figure 15, responses were in reasonable agreement that little change is expected to occur in maximum speeds to the year 2010 with the average value being about 185 knots for subsonic transports and 200 knots for supersonic transports.

Use of advanced supersonic transports is indicated as possible by the year 2000 and probable by 2010 as evidenced by opinions expressed by three respondees who replied to guerries concerning characteristics unique to future supersonic transports (figs. 4, 7, 15 and 16). Results from Concorde operations indicate a demand exists for supersonic service, provided only modest fare surcharges are involved. Low surcharges are believed achievable in the future because of great advances in technology made in recent years. An advanced supersonic transport, with acceptable noise performance, should be able to achieve three times the productivity of a similar-size subsonic aircraft with the same payload while burning slightly less than two times the fuel (ref. 12). The first embodiment of such a design may well be a supersonic business jet as a significant worldwide market for this size aircraft is believed to exist. The start-up costs for this size transport aircraft should be significantly less than for a large supersonic transport.

The runway length required for takeoff increased with increase in aircraft gross weight until about the year 1965 but remained constant thereafter even though heavier aircraft were introduced (fig. 16 of ref. 1). The trend toward no further increase in field length is expected to continue to the year 2010 as evidenced by the survey data of Figure 16. Respondees were in agreement that the expected maximum runway length will remain essentially constant at an average value of about 14,000 feet for both subsonic and supersonic transports. Of course, variations in maximum length will exist between airports because of local factors including temperature, altitude, runway slope and obstructions.

The maximum length appropriate for short auxiliary runways at hub airports is also important because of the increasing need for such runways to off-load the main runways of commuter and feeder transport traffic. As discussed earlier, the survey indicated the average expected maximum payload for such transports to reach about 100 passengers by 1990. Advanced turbopropellers will likely be used if units of sufficient horsepower are available; otherwise turbofans will be used either with conventional mechanical flaps (and decreased wing loading) or with powered lift flaps (and conventional wing loadings). To sound out industry thinking about powered-lift applications, survey opinions were obtained concerning the minimum field length capability of powered-lift transports sized for 50, 100 and 150 passengers (fig. 17). Opinions were in close agreement that the minimum field length will increase as the payload becomes larger and that the accommodation capability of a given field length will increase with the passage of time. For example, a runway 3600 feet in length is expected to accommodate powered-lift aircraft whose capacities are 100 passengers by 1990, and 150 passengers by 2000. The status of powered lift technology is beyond the proof-of-credibility phase. For high thrust-to-weight configurations, product definition was accomplished in recent industry proposals submitted for the CX military transport competition. For moderate thrust-to-weight ratio configurations more suitable for civil transports, proof of credibility was accomplished in the flight test program of the NASA Quiet Short-Haul Research Aircraft (QSRA). Results indicate that transports having a wing loading of 90 pounds per square foot and a thrust-to-weight ratio of 0.30 can safely operate from runways 3000 feet in length (ref. 4).

Advanced Operational Concepts - Respondees were in general agreement concerning the probable use by aircraft of several advanced operational concepts at the airport (fig. 18). One such concept is directed primarily toward minimizing airport noise and fuel saving by the towing of transport aircraft on the taxiways. Use of taxiway towing is considered as probable by 2000. Several other operational concepts can be considered as elements entering into improved terminal area operations to improve capacity and efficiency, enhance approach and landing capability in adverse weather and reduce the impact of aircraft noise perceived on the ground. One such concept is the use of steep approaches, which the respondees consider as probable by 1990. Use of the companion takeoff procedure of steep spiralling climbouts, however, is not considered probable even by 2010. Related concepts are the use of high speed runway turn-offs, considered as probable by 1990, and high speed turn-ons, considered as probable by the year 2010. The technology status the several concepts entering into improved terminal area landing operations is nearing the product definition phase with major effort underway by the government which has produced considerable technology (ref. 7). Of particular interest to airports is the development of a system to extend automatic aircraft operations through runway rollout and turnoff. The system requires placement of a magnetic leader cable in the pavement to guide the aircraft (paper 4 of ref. 7). As effort to date has concentrated primarily on landing operations, the technology status of concepts entering into improved terminal area takeoff operations is less advanced and should be considered as still in the concept assessment phase.

Three advanced operational concepts for payloads was also examined in the survey (fig. 18). Passenger bypass of the airport terminal building was considered by a majority of respondees as probable by the year 2000. Use of concepts for expediting the handling of belly cargo from passenger transports is considered as probable by 1990. Such expediting to more closely match the time required for handling passengers certainly seems warranted by the increase in emphasis being given by the air carriers to the carrying of such cargo. Finally, the use of a truly intermodal cargo container system is considered as probable by the year 2000.

CONCLUDING REMARKS

A survey has been carried out within the airframe industry regarding characteristics of future transport aircraft that could impact aircraft and airport compatibility. Based on the survey results, the maximum size of aircraft is expected to increase, at a roughly uniform size, to the year 2010 by 85 percent in passengers, 55 percent in airfreight payload, and 35 percent in gross weight. Companion to the expected growth in payloads and gross weight was the identification of probable increases in aircraft geometrical dimensions and component capability, and use of fully doubled-decked passenger compartments. Wing span will increase considerably more than normally expected to provide wings of higher aspect ratio. New aircraft features coming into probable use include large turboprops, synthetic Jet-A fuel, winglets, wake-vortex-reducing devices and laminar flow control. New operational concepts considered probable include steep approaches, high-speed turnoffs, and taxiway towing for the aircraft, plus passenger bypass of the terminal building, expedited handling of belly cargo and an intermodal cargo container system for the payloads. Supplementing conventional transports by the year 2000 will be possible use of advanced supersonic transports and probable use of sizeable aircraft operable on short auxiliary runways.

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INCREASING TECHNOLOGY STATUS → PRODUCT COMMITMENT → IN SERVICE

PHASE:	CONCEPT ASSESSMENT	PROOF OF CREDIBILITY	PRODUCT DEFINITION	PRODUCT DEVELOPMENT
YEARS: (MEAN)	2-8 (4)	2-5 (5)	2-10 (6)	4-5
OBJECTIVE:	o ASSESS POTENTIAL	o ESTABLISH CREDIBILITY OF POTENTIAL	o INTEGRATED APPLICATION	o HARDWARE DELIVERY
PREREQUISITE:	o REAL OR PERCEIVED NEED	o POSITIVE INDICATED BENEFITS	o PROVEN TECHNICAL & BUSINESS BENEFITS	o ACCEPTABLE RISK o MARKET

Figure 1.- Technology development cycle for new concepts.

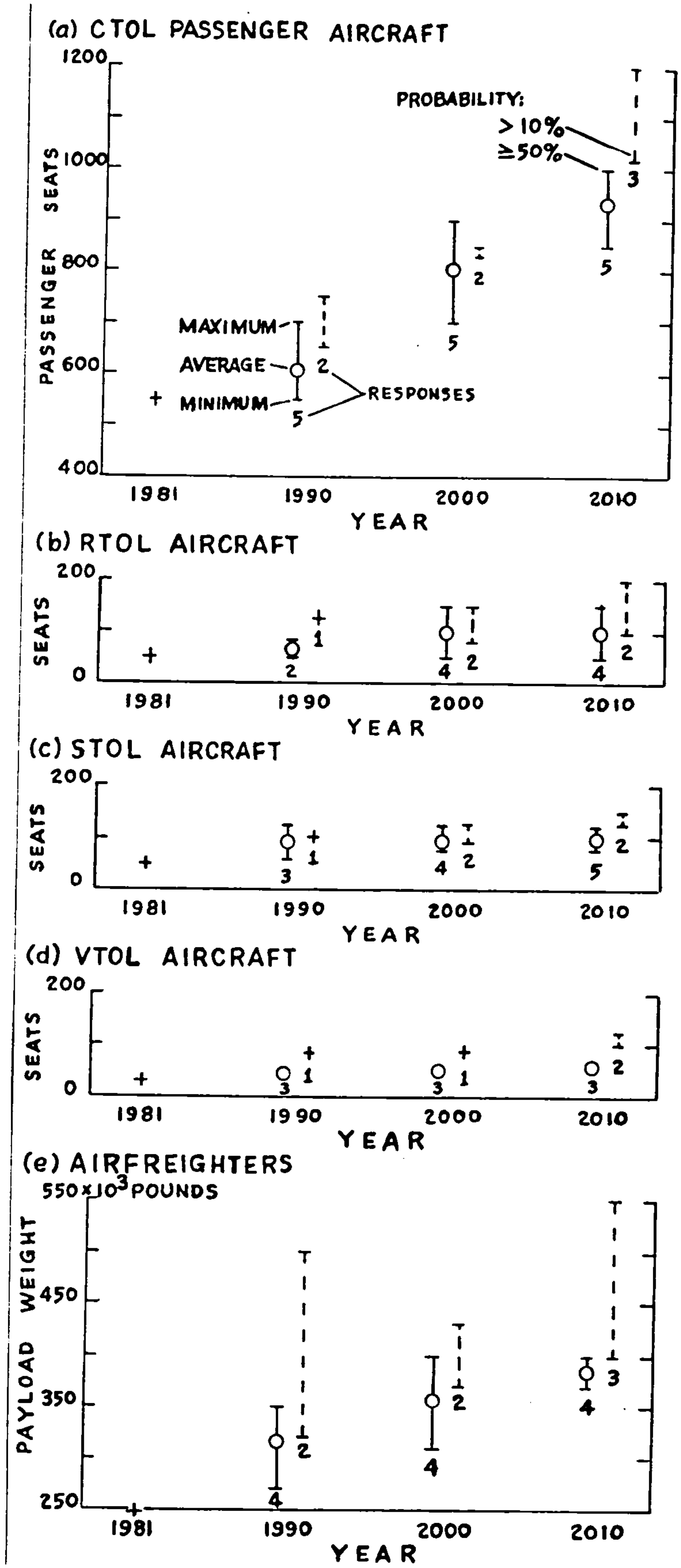

Figure 2.- Maximum payloads of transport aircraft.

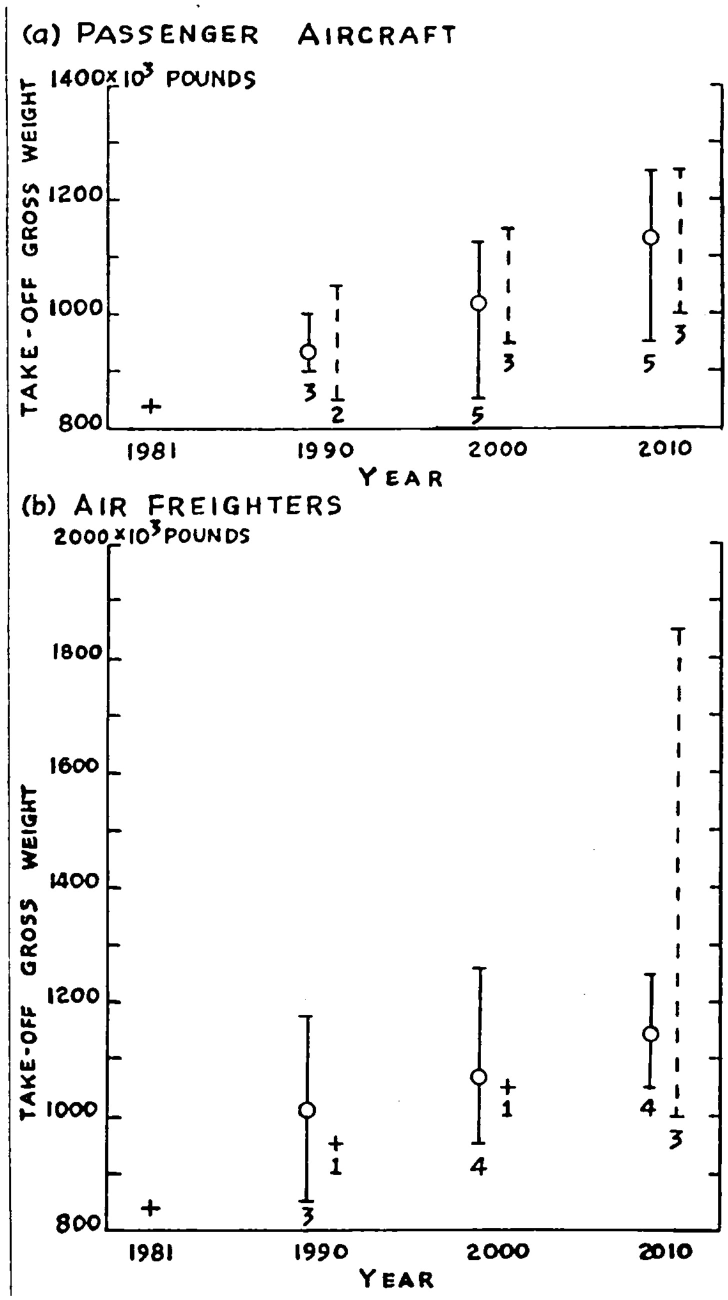

Figure 3.- Maximum takeoff gross weight.

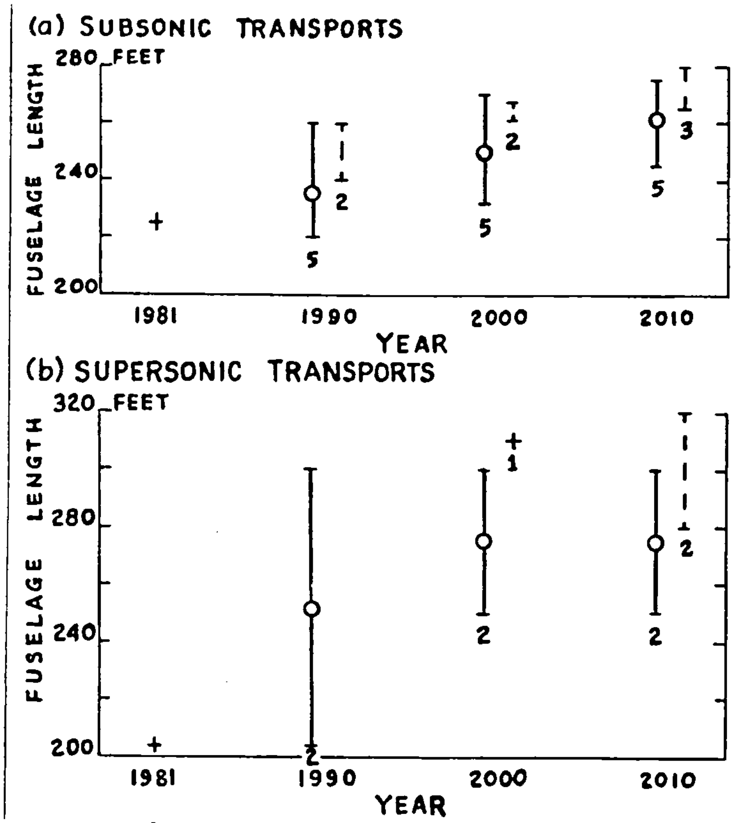

Figure 4.- Maximum length of fuselages.

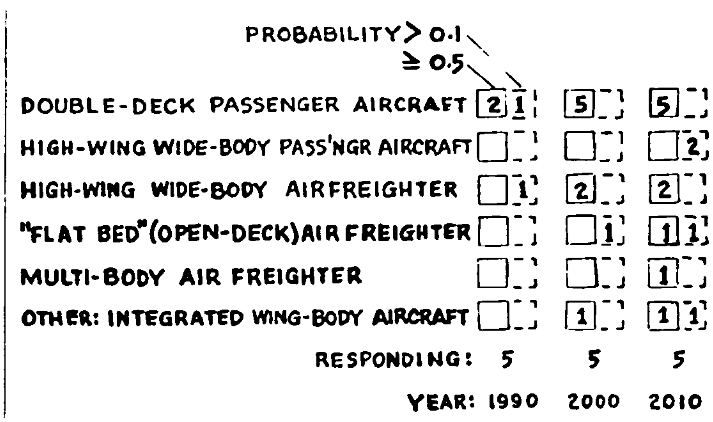

Figure 5.- Use of new fuselage concepts.

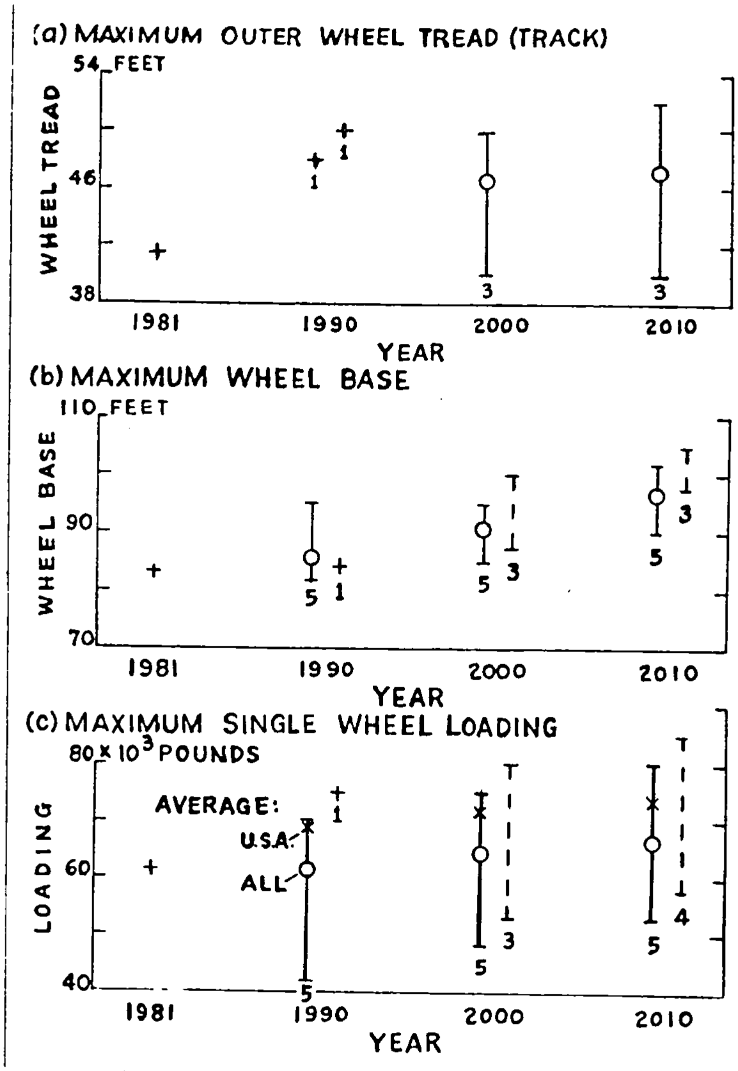

Figure 6.- Landing gear characteristics.

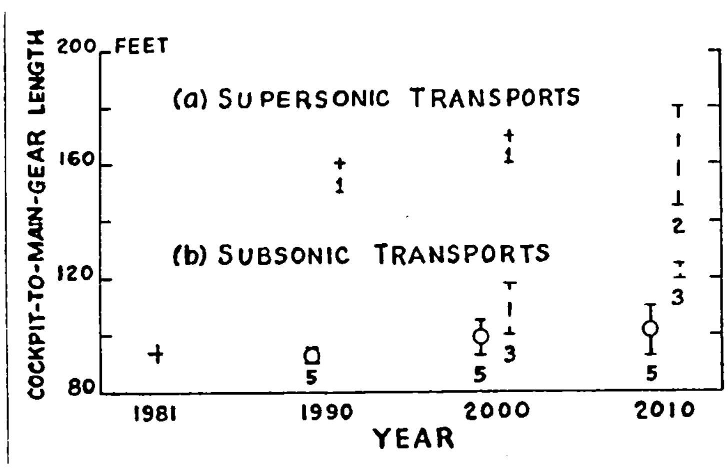

Figure 7.- Maximum cockpit-to-main-gear length.

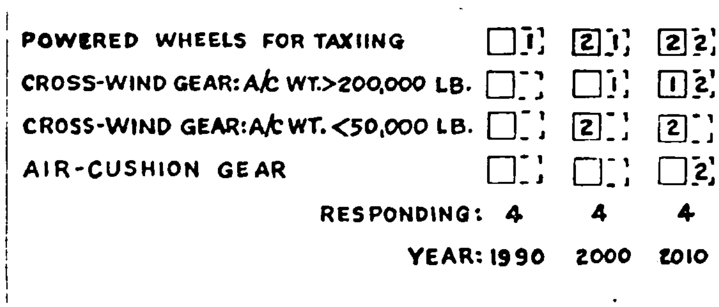

Figure 8.- Use of new landing gear concepts.

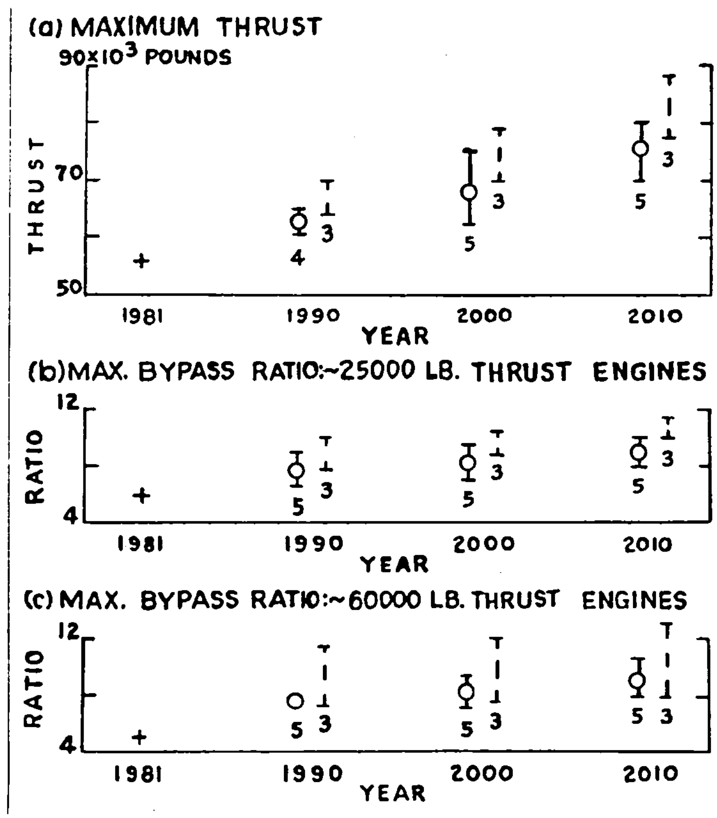

Figure 9.- Characteristics of turbofan engines.

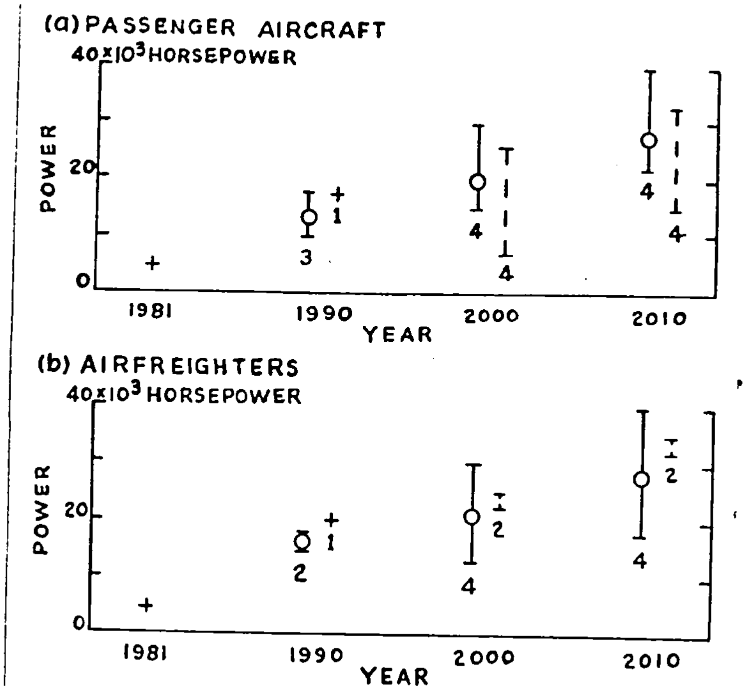

Figure 10.- Maximum power for turbopropellers.

	1990	2000	2010
SYNTHETIC JET-A	[3] 2	[4] 1	[5]
LIQUID HYDROGEN	[ ]	[ ] 1	[1] 3
LIQUID METHANE	[ ]	[ ] 1	[1] 2
RESPONDING:	5	5	5
YEAR:	1990	2000	2010

Figure 11.- Use of alternate fuels.

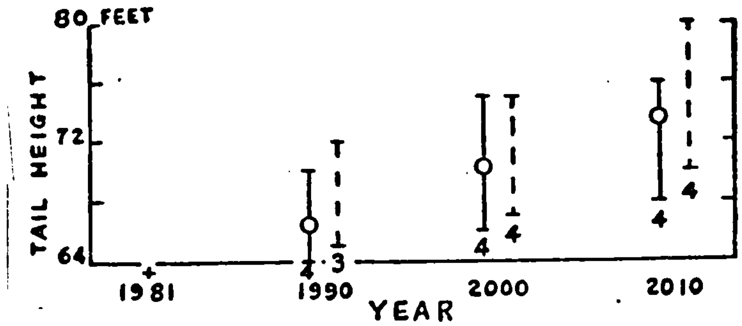

Figure 12.- Maximum height of vertical tail.

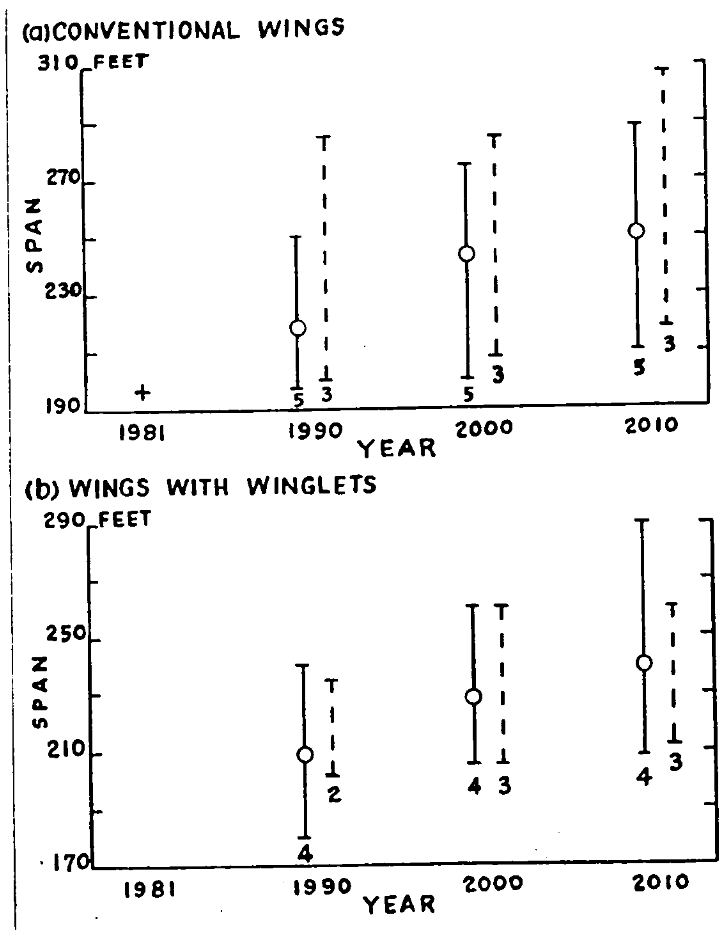

Figure 13.- Maximum span of wing systems.

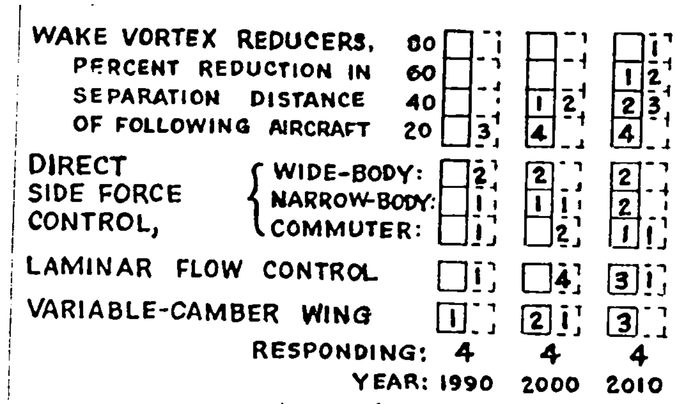

Figure 14.- Use of new aerodynamic concepts.

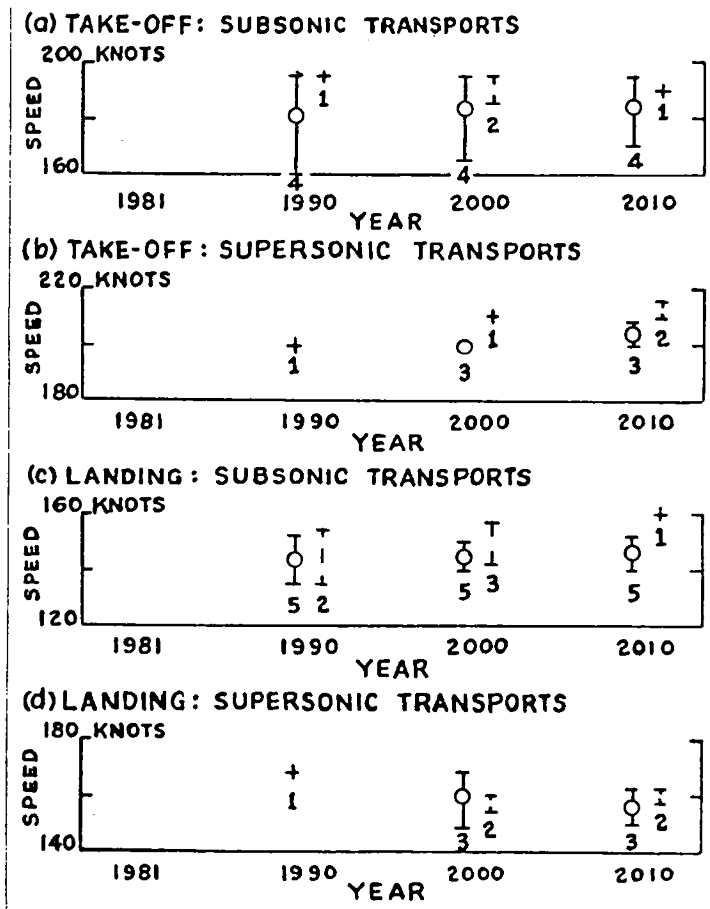

Figure 15.- Maximum runway speeds.

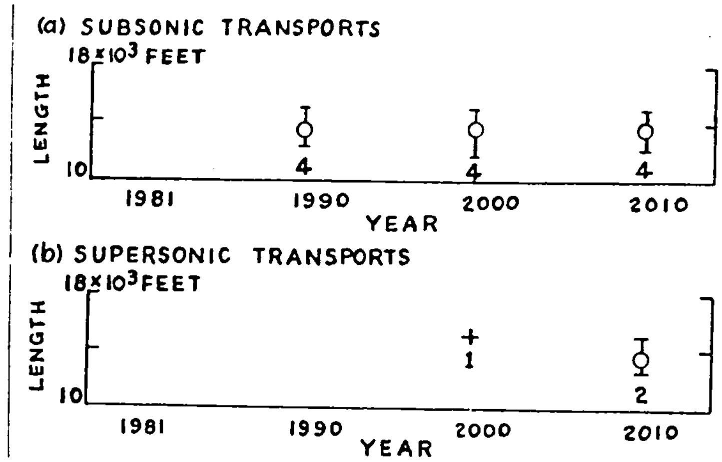

Figure 16.- Maximum runway length.

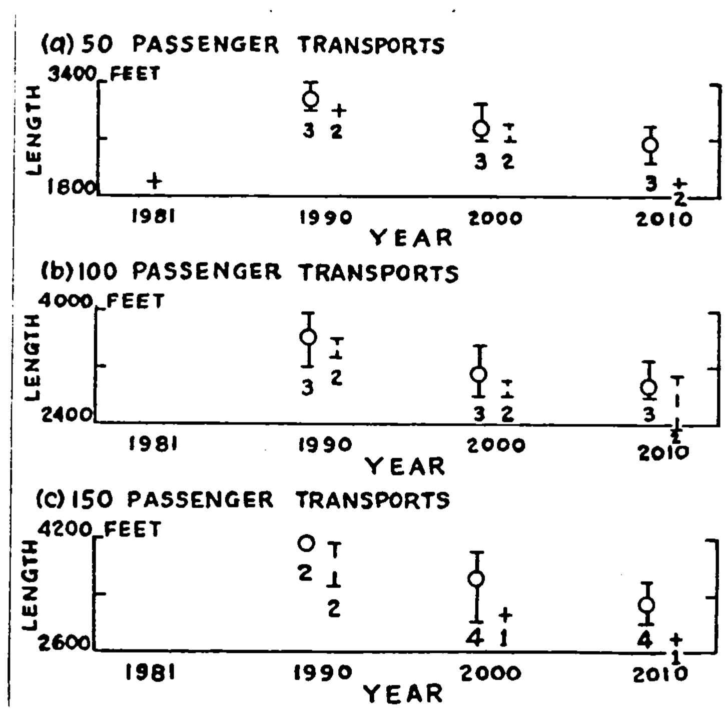

Figure 17. - Minimum field length of powered-lift aircraft.

(a) AIRCRAFT OPERATIONS

	1990	2000	2010
HIGH-SPEED RUNWAY TURN-OFFS	[3] 2	[4] 1	[5]
HIGH-SPEED RUNWAY TURN-ONS	[1] 1	[2] 2	[4]
TAXIWAY TOWING	[2] 2	[4]	[4]
STEEP APPROACHES	[2] 2	[4]	[4]
STEEP SPIRALLING CLIMBOUTS	[ ] 1	[ ] 3	[ ] 3
RESPONDING:	5	5	5
YEAR:	1990	2000	2010

(b) PAYLOAD OPERATIONS

	1990	2000	2010
PASSENGERS BYPASS TERMINAL BLDG.	[ ] 3	[3]	[3] 1
BELLY CARGO EXPEDITED HANDLING	[4] 1	[5]	[5]
INTERMODAL CARGO CONTAINER SYSTEM	[2]	[3]	[4]
RESPONDING:	5	5	5
YEAR:	1990	2000	2010

Figure 18.- Use of new operational concepts.

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16. Abstract

Results are reported in an opinion survey of selected individuals at the decision-making level within the five major manufacturers of transport aircraft in the United States and Europe. Opinions were obtained concerning both possible and probable existence of over 50 compatibility-related characteristics of transport aircraft in use in the years 1990, 2000 and 2010. Author's comments are also included on certain candidate new features as to technology status and developmental effort underway. The maximum size of aircraft is expected to increase, at a roughly uniform rate, to the year 2010 by 85 percent in passengers, 55 percent in airfreighter payload, and 35 percent in gross weight. Companion to the expected growth in payloads and gross weight was the identification of probable increases in aircraft geometrical dimensions and component capability, and use of fully double-decked passenger compartments. Wing span will increase considerably more than normally expected to provide wings of higher aspect ratio. New aircraft features coming into probable use include large turboprops, synthetic Jet-A fuel, winglets, wake-vortex-reducing devices and laminar flow control. New operational concepts considered probable include steep approaches, high-speed turnoffs, and taxiway towing for the aircraft, plus passenger bypass of the terminal building, expedited handling of belly cargo and an intermodal cargo container system for the payloads. Supplementing conventional transports by the year 2000 will be possible use of advanced supersonic transports and probable use of sizeable aircraft operable on short auxiliary runways.

17. Key Words (Suggested by Author(s))
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Aircraft-airport compatibility
Aircraft Design

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