sufficient to take the Earth from the last ice age to the warmest period known to man. It is a major issue that is going to move very quickly. It will require a rapid response, not a kind of a laissez faire, "wait until it all happens and then we will worry about it" kind of attitude, which is unfortunately the way we tend to deal with these problems.

TECHNOLOGY

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The technologies emerging over the next decade will provide the basis for the next generation of aircraft whether they come about through evolutionary changes in derivative aircraft of the current generation, conventional new aircraft, or revolutionary new designs with significant new capabilities. Technology developments will also allow for significant improvements in air traffic control capabilities.

Air Traffic Control

New ATC technologies being considered for use within the coming 10 to 15 years include precise four-dimensional navigation and guidance systems, improved capability for the transfer of weather, traffic, and ground information to the flight crew, and computerized controller aids for optimum aircraft spacing and sequencing. For the very near term, the Traffic Alerting Collision Avoidance System (T/CAS), now being evaluated, will provide aircrews with onboard capability for detecting and avoiding potential mid-air collisions. By 1991 the FAA will require aircraft that carry over 30 passengers, to be equipped with T/CAS. These capabilities will help accommodate the substantial growth in air traffic that is expected to occur in the future. Air travel should also become more convenient in terms of reduction in unanticipated ATC delays, and maintaining on-time departure and arrival schedules.

Subsonic Aircraft

In an evolutionary fashion, the aircraft manufacturers will continue to introduce new subsonic transport aircraft that will incorporate major technology advances in aerodynamics, structures, propulsion, and systems.

The most apparent change to the vehicle may well be the introduction of new propulsion systems incorporating advanced turboprop technology. General Electric has recently tested a gearless, counter-rotating unducted fan advanced turboprop engine, and Pratt and Whitney/Allison/Hamilton Standard are developing an advanced, geared, counter-rotating turboprop engine. Both Boeing and Douglas are currently investigating aircraft designs using these propulsion systems. The timing of their introduction will depend on economics as influenced by fuel prices.

In aerodynamics, further gains in cruise performance and efficiency are expected from new airfoils, fuselages, and nacelles, which incorporate advanced technology for improved laminar flow control and high-aspect-ratio wing designs. The ability to achieve the contour of these airfoil shapes, and at the same time reduce weight, will be realized by advanced composite materials which are anticipated to be used as primary structure in wing and fuselage designs for the next generation aircraft.

Flight control systems using power-by-wire technology will replace the heavier hydraulic and cable systems. These designs offer potential improvements in direct operating cost (DOC) of 25 percent relative to current jet transports, particularly those that were introduced 10-20 years ago. These same technology advances are also applicable to future generations of improved general aviation or commuter aircraft.

A major technology driver will be operating and equipment cost, as affected by fuel prices, maintenance, and manufacturing techniques.

Advanced Aircraft

In a more revolutionary sense, technology developments also under way will allow for the introduction of new aircraft with greatly extended capabilities: vertical or short takeoff and landing (V/STOL) aircraft, high speed rotorcraft, and supersonic cruise aircraft.

V/STOL. Recently, the success of NASA's V/STOL technology effort has led directly to the development of the V-22 Osprey tiltrotor aircraft by the DOD. The technology for the V-22 is based on over 20 years of NASA and Army research on the tiltrotor concept for high-speed rotorcraft flight, which culminated in proof-of-concept flight, testing with the XV-15 Tiltrotor Research Aircraft. The 900-aircraft V-22 program marks the introduction of a revolutionary aircraft concept into the nation's military fleet. The experience gained from the V-22 development will provide the basis for possible early transfer to civil application. The opportunity for large-scale intercity and interregional transportation using civil tilt rotor transports with the speed and comfort of a turboprop aircraft has led to a joint agreement between NASA, FAA, and DOD to study and quantify the civil technology benefits than can be derived from the V-22 tiltrotor program. Civil derivatives of the V-22 could provide an early opportunity for the development of tiltrotor transports capable of payloads of 20 to 70 passengers, ranges of 300 to 400 miles, and operating cost reductions of more than 25 percent relative to the V-22.

The specific advances in technology necessary to the success of the civil tiltrotor aircraft include control and guidance systems technology and lightweight fuselage designs. The controls and guidance systems must enable precision approaches and landing guidance that exploit the unique features of the aircraft and yet maintain compatibility with conventional aircraft operating in the National Airspace System. The fuselage design must be lightweight and yet large enough for payload economy and strong enough for cabin pressurization. Forecast topics which address the future viability of the tilt rotor as a commuter include sensitivity analysis of passenger fare prices versus added convenience or reduced travel time. Also, what are the potential impacts of improvements in other modes of transportation, such as high-speed trains or improved automobile highway systems?

Supersonic Aircraft. It has been 20 years since the first test flight of the Concorde, which has now provided 13 years of active commercial service. Thirteen years is long enough for the novelty to have worn off, and it is evident that there is a steady demand for high-speed transportation, even at premium fares. During the last 20 years, there have been significant advances in technology -- aerodynamics, propulsion, structures, and control systems -- that are applicable to a new generation of high-speed transport aircraft.

Design studies conducted by major aircraft manufacturers indicate that an advanced technology high-speed transport could economically carry up to 300 passengers over transpacific ranges (5000 to 6500 nautical miles) at 2.0 to 3.2 times the speed of sound. Operating cost estimates suggest that little, if any, surcharge over current fares would be required. These aircraft could be operated with kerosene-based fuels and be capable of using existing airports with a reasonable chance of satisfying community noise requirements. These projected improvements are based on several major technological advances: aerodynamics research indicating that a new wing design could achieve major reductions in cruise drag; propulsion technology advances, most of which have evolved from the subsonic quest for improved fuel efficiency; new materials for reduced airframe and engine weight; and flight control systems that allow more efficient flight profiles and two-man crew operation. Other factors critical to the success of a new supersonic transport which require additional technology development are methods to reduce the takeoff and landing noise, sonic boom reduction, atmospheric impact, and overcoming the high development costs. The projected cost for the high-speed transports is currently estimated to exceed $200 million per aircraft, assuming a total fleet of 500 aircraft.

Impact of Technology on Aviation Forecasting

Technology improvements over the next 10 to 15 years will provide major opportunities to future air transportation for both short-haul and long-distance travel requirements. The attempts to capitalize from these improvements will place increased pressure on forecasting. Especially critical will be forecasting the impact of technological, economic, and social factors that are outside the boundaries of current experience and not amenable to extrapolation from current trends.