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NASA SP-265

JOINT DOT-NASA

CIVIL AVIATION RESEARCH AND DEVELOPMENT POLICY STUDY

REPORT

MARCH 1971 WASHINGTON, D.C.

DEPARTMENT OF TRANSPORTATION
AND
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

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1. INTRODUCTION

The Civil Aviation Research and Development Policy Study was undertaken jointly by the Department of Transportation and the National Aeronautics and Space Administration in response to a recommendation by the Senate Committee on Aeronautical and Space Sciences (90th Congress). This recommendation was in part:

> *An in-depth study should be made to analyze the relationship between benefits that accrue to the Nation from aviation and the level of aeronautical R&D effort. The study should try to determine – or at least develop criteria for such a determination – what level of R&D should be maintained in order to achieve the desired results. The study might also include a detailed analysis of the divergence of military and civilian aeronautical requirements in order to assess better the diminishing benefits to civilian needs from military R&D (ref. 1).*

The results of the more recent report (ref. 2) of the Subcommittee on Advanced Research and Technology of the Committee on Science and Aeronautics of the House of Representatives were also used to guide the effort.

From this charter, the Study evolved as a comprehensive review of policies affecting civil aviation, of the problems confronting it, and of the potential it possesses for future contributions to the Nation. A concerted effort was made to treat each area quantitatively and to collect, analyze, and present all pertinent related data. The results should provide a sound basis for the continued evolution of national policy to guide the future course of civil aviation.

The benefits that accrue to the Nation from civil aviation were examined from a broad or macroscopic view. This approach was deemed both necessary and appropriate because of the breadth and diversity of civil aviation and because the present Study was not intended to propose specific systems. Specific systems proposals were not considered to be an appropriate subject for the present Study since they must normally be considered during the annual process of program planning and budgeting. The investments in research and development to achieve the benefits of civil aviation were also examined macroscopically. In addition, the Study was confined to the subject of civil aviation and did not treat in detail other transportation modes that are complementary and competitive. In the absence of corresponding studies for the other modes, it was not possible to treat secondary effects in the benefit analyses.

It was recognized that many factors other than research and development influence the contributions that civil aviation makes to the Nation. The legal, regulatory, and organizational environments affect the ways in which the products of research and development are applied and the ways in which civil aviation grows in response to new technology. Social attitudes and financial conditions are also important. There are many examples of these effects. Public opposition based on concern for the impact of civil aviation on the environment effectively impedes the expansion of airport facilities. Regulatory policies opposed to intermodal mergers can impede the growth of air cargo and its related R&D. Since an understanding of these institutional factors is essential to any realistic study of civil aviation research and development, it was necessary for the Joint Study to analyze nontechnological factors important to civil aviation. The decision to include these factors in the Study was one of the most important steps taken.

During the Study, therefore, analyses were made of such varied subjects as long- and short-haul passenger service, air cargo, general aviation, air vehicles, air traffic control, airports, complementary surface transportation, financial considerations, institutional and environmental factors, foreign competition, military contributions to civil aviation, benefits, and several key policy issues. Supporting papers on each of these subjects are contained in a second volume complementary to this report. For reference purposes, a brief outline of the contents of this complementary volume is contained in Appendix A. These individual analyses formed the foundation for the present report.

The present Study also made use of the results of past related efforts. For example, "Survival in the Air Age" (the Finletter Report, ref. 3) and "National Aviation Policy" (the Brewster Report, ref. 4) date from 1948. Surprisingly, however, many of the results of these early studies are as valid today as they were then. More recent efforts that contributed both general background and specific results to the present effort include "Policy Planning for Aeronautical Research and Development" (ref. 5), prepared for the U. S. Senate by the Library of Congress; "Civil Aviation Research and Development" (ref. 6), prepared by the Aeronautics and Space Engineering Board of the National Academy of Engineering; "Air Transportation 1975 and Beyond: A System Approach" (ref. 7), a study co-chaired by Schriever and Seifert; and the "Report of the Department of Transportation Air Traffic Control Advisory Committee" (the Alexander Report, ref. 8). The very recent "Report on Selected Independent Regulatory Agencies" (Ash Council Report, ref. 9) is also pertinent to the present Study. (Other references are omitted from this volume; however, sources are identified in detail in the volume of Supporting Papers.)

Much of the Joint Study was completed prior to the recent proposal for revenue sharing of transportation funds with local governments. For this reason the impact of this proposal is not reflected in detail in the Study analyses or in the conclusions or recommended actions. With the passage of the Special Revenue Sharing Program for Transportation, the responsibility for funding airport landside development will be shifted to State and local governments. The Federal Government will, however, still retain its role in planning leadership and safety regulations.

In order to carry out the Joint Study, personnel were detailed from the two primary participating agencies as well as from the Department of Defense and the Civil Aeronautics Board. Cooperation and part-time participation were also received from various groups in the Department of State, the Department of Justice, the Department of Commerce, the Department of Housing and Urban Development, the Interstate Commerce Commission, the National Aeronautics and Space Council, the Export-Import Bank, and the National Transportation Safety Board. In addition, a committee was organized by the National Academy of Engineering to advise the staff during the course of the Joint Study. This committee, which had representation from leaders of the academic, aerospace, airline, airport, engineering, and financial communities, made many important contributions to the Study. Membership of this committee and that of the full- and part-time staff of the Study are listed in Appendix B. Advice and counsel were also received from a variety of professional and industrial organizations, and this assistance is also acknowledged in Appendix B. A special acknowledgement is also due the Congressional Committees whose recommendations led to the cooperative DOT–NASA effort that produced the present report.

2. SUMMARY

Summary

HISTORICAL SUPPORT AND GROWTH

Even before the flight of the Wright Brothers, the Federal Government recognized the need to maintain a policy supporting and encouraging the growth of civil aviation. Initially this policy was based on the contribution of civil aviation to *military preparedness*. Later the requirements for *public safety* were considered, and still later the role of civil aviation as a *public service* was also recognized. The Government implemented these policies in many ways. The airline industry has been given regulatory protection governing fares and market entry and exit. Since the establishment of the regulation system in 1938, the Government has paid direct subsidies of more than $1.6 billion to the airlines. The interstate character of air travel was early recognized, and thus the Government assumed responsibility for operation of the Nation's airways and for regulation of certain operational aspects of airports. The FAA operations budget for these purposes has totaled about $5.7 billion in the last 10 years. In the same 10 years, the aircraft manufacturing industry spent about $3.6 billion for civil aviation research and development, while the Government added another $2 billion in support. Clearly past policies have been supportive and past investments have been significant, just as they have been for other transportation modes. As a result, civil aviation has experienced impressive growth especially during the 25 years since World War II. *Today, civil aviation is the dominant mode of intercity, for-hire transport, serving almost twice the passengers and representing about four times the passenger miles of the combination of all other modes – rail, bus, and water.*

The products of research and development have been major contributors to this growth. Increased airline productivity can be directly correlated with increases in the level of R&D expenditure. It is noted that there is a lag of about 5 to 15 years between research and development producing a result and that result being applied in an operational system. Research and development have produced increases in aircraft speed, capacity, and range. Since World War II, aircraft productivity has thus been increased by a factor of 20 while direct operating costs have been reduced by a factor of 3. Both the industry and the public have been quick to take advantage of these improvements. In the same period, revenue passenger-miles increased by a factor of about 30, revenue ton-miles by a factor of about 50, aircraft handled by the airways system by a factor of about 8, and the general aviation fleet by a factor of about 4.

CIVIL AVIATION'S COMPREHENSIVE BENEFITS

Today, civil aviation has a major influence on the way of life in the United States. Only the automobile is more important to the mobility of the population. Air travel is accepted and used by all economic levels. In 1967, the median family income of the air traveler was less than $12,000 per year. This figure shows that *air travel is no longer the domain of the elite few.*

The improvements in productivity, reliability, and safety created by research and development and the wide acceptance by the public of the resulting service have produced a host of benefits to the user and to the Nation. Some of these benefits can be measured in savings to the user; for example, improvements in air travel in the 20 years preceding 1968 resulted in passenger time savings totaling about 1 billion man hours, passenger fare savings of over $8 billion, and cargo tariff savings of over $1 billion (constant 1968 dollars). Advances in safety have resulted in substantial reductions in accident rates for commercial aircraft over the past 20 years. Had improvements not been made, an additional 7700 fatalities would have been expected in commercial aviation over the 3312 that actually occurred. In 1970 *there were no passenger fatalities in domestic scheduled service.*

Other benefits accrue to the Nation as a whole. Even with the current decline, the total employment in civilian aerospace and airlines is about 740,000. In 1969, civil aerospace was the third largest manufacturing employer behind the motor vehicle and steel industries. Civil aviation's total contribution to the GNP in 1969 was about $10 billion and over the past 10 years it has grown about three times as fast as the total economy. The net contribution to the U. S. balance of trade by the civil aviation manufacturing industry was $1.77 billion in 1969 – more than the Nation's entire favorable balance that year. This contribution was recognized in the February 1970 Economic Report of the President which stated, "The growth of U. S. exports has been fostered by high technology, exemplified in such manufactured items as computers, *jet aircraft,* and control instruments." (emphasis added).

As a result of the Government's supportive policies, the contributions of research and development, and the domestic success of civil aviation, the United States currently enjoys a well-recognized position of world leadership. The magnitude and scope of this leadership can be measured in many ways. The *seven* largest free-world airlines (in terms of passenger-miles flown) are U. S. carriers. Over half the free-world passenger-miles are flown by U. S. carriers. *Three-fourths of the free-world commercial aircraft are of U. S. manufacture.* The United States exports over 2-1/2 times as many general aviation aircraft as the rest of the world. The importance of this leadership and the need to maintain it have been recognized in recent statements by the President.

The statistics are impressive but they serve only to confirm what most people already recognize: the Government has supported and fostered civil aviation; civil aviation has responded with impressive growth and has achieved widespread acceptance; in return, the user, the public, and the Nation have received a variety of benefits.

CHANGING MOOD AND GROWING PROBLEMS

The growth pattern of the past is not likely to continue in the future. The principal problems civil aviation will encounter and the public environment it will face will be different in the future than they have been for several decades. Further growth in civil aviation and in the benefits it provides to the Nation will require the recognition of changing attitudes and the establishment of new priorities. *The years around 1970 represent an important transition period.* The change can be seen by comparing present problems and public attitudes with those of the past.

A few years ago it was a popular pastime to visit airports and to watch aircraft operations. Today, as a result of noise, pollution, and ground congestion, airports are considered bad neighbors and their growth is often opposed. A few years ago, an air trip was regarded as an adventure. Today air travel is regarded as routine, and congestion, delays, and other inconveniences often result in disgruntled and irate passengers. A very few years ago, the airlines and aerospace industry were profitable and growing. Today profits are gone and employment is being reduced. The situation has become so out of balance that some airlines have made more money (considering the strike fund) when their operations were restricted by a strike than when they were in full operation.

These examples serve to emphasize the present problems of civil aviation that could become more severe in the future. The importance of each of these problems depends on the viewpoint of the observer.

To the *general public,* deeply concerned with the *environment,* the major problem is aircraft *noise.* As a result, regulations are being imposed to limit the noise levels associated with operations of new aircraft. There has also been pressure to retrofit existing aircraft with acoustically treated nacelles at a cost estimated at $0.5 to $1.2 billion, depending on the extent of the treatment and the classes of aircraft modified.

To the *user,* concerned with *service,* delays caused by *terminal congestion* are important. For example, the cost to passengers of airborne delays has been estimated at about $100 million in 1969. The costs to carriers from aircraft terminal-area delays due to congestion have been estimated at over $150 million. Without corrective action, these costs could grow to about $400 million and about $600 million, respectively, in 1980. The cost of ground access congestion to the passenger could be even greater. In addition, idling aircraft lined up on the ground contribute many times the amount of pollution than they do in flight.

To the *operators,* concerned with *finances,* the losses due to congestion are only part of the problem. They are also confronted with other operating losses, especially those related to the *short-haul* market. This market is a major contributor to airline industry losses which preliminary estimates place at over $150 million in 1970. Today the median domestic air-passenger trip is about 600 miles. About 85% of the domestic trips by common carrier longer than 500 miles are now made by air, but less than half of those shorter than 500 miles are made by air. Because of the potential for growth in this market, improved short-haul economics may be very important to the future of civil aviation. Not only is the potential short-haul market large, but the possibilities for short-haul service of civil aviation to make a contribution to our society and to our way of life are also great. Based on many current examples, civil aviation can affect regional development, population distribution, and land use, and can contribute to many other social and economic goals of the Nation. Considering the country's future growth, short-haul transportation will become vitally important by the mid-1980's.

The manufacturing side of the industry is also having severe financial problems. The research, development, and initiation of production for modern transport aircraft require a peak commitment on the order of $1 billion, several times the net worth of the producing company. Production runs of several hundred aircraft are required to reach the break-even point. If the market for these aircraft falters, as is presently the case, serious financial problems are created for the aerospace industry. The present situation is such that many believe major failures are imminent.

In many ways, the problems of civil aviation are the results of its growth and of policies that did not fully recognize that growth. The greater number, size, and power of present aircraft contribute to the noise problem. The overwhelming acceptance of aviation in certain regions of the country and the pattern of travel produced by that acceptance contribute to congestion. The problems are interrelated because public opposition caused by noise problems prevents the creation of new facilities that might alleviate congestion. Congestion contributes to economic problems. Present regulatory policies – developed when civil aviation was an infant industry – can contribute to economic problems and also to the congestion problem. Some of the financial problems of the aerospace industry are a result of the very large manufacturing capacity that was created to satisfy the needs of both the military and the rapidly growing airlines.

THE ENVIRONMENT FOR R&D

Research and development are essential to the solution of some of the current problems, just as they have been essential to the solutions of problems in the past. They are also essential if civil aviation is to realize its full potential in such important future areas as regional development. It is important to recognize, however, that these contributions will be increasingly affected by the fact that neither today's nor tomorrow's problems are solely technological. Solutions will involve not only traditional applications of the physical sciences but far greater future emphasis on economics and the social sciences. This view is supported by the evidence that the problems facing civil aviation have been well known for a long time but progress toward their solution has been slower than desired because of the nontechnological factors. Technological advances are subject to a variety of *institutional constraints* which can be categorized as *regulatory and legal, market and financial, attitudinal and social, and organizational.* All of these factors were examined in the present Study as an essential part of developing a thorough understanding of both the problems and the potential of civil aviation.

THE PRIORITIES

Noise: Aircraft noise abatement deserves highest priority because of widespread concern for the environment and because the success of the noise-abatement program will affect the solutions to other problems. The need for noise abatement research and technology will continue until aircraft noise is suppressed into the background. It is a key recommendation of the present study that until this objective is reached, time-phased research goals be established calling for reductions of about 10 to 15 dB per decade. The program should be comprehensive, covering research in psychoacoustical phenomena, basic noise generation mechanisms, and quiet engine technology. Operational procedures such as the use of steep-curved approaches should be proven. Land-use studies are needed. In the immediate future, new goals should also be established for regulation.

Congestion: Congestion is next on the list of priority problems. *Congestion is a complex problem and has many elements. Its solution will involve an organized effort directed at the combination of air traffic control, runway capacity, ground control of aircraft, terminal processing, access and egress, parking, and airport location, acquisition, and development.* The airways system must be upgraded to increase both capacity and safety as well as to bring rising operating costs under control. As a result of growing traffic, airways operating costs, especially those due to the increasing number of controllers and maintenance personnel required, could be substantially greater in the future. The Government, as operator, has sole responsibility for the R&D required to hold operating costs to a minimum. A careful assessment of the relative merits of new concepts of ATC and the related technology alternatives is required on a continuing basis to assure that the airways system is upgraded as rapidly as resources and technology will permit. This continuing assessment would minimize the possibility of making too large an investment in capital improvements that would be prematurely obsolescent and, at the same time, guard against overoptimism about the time-availability of new technology.

Another key recommendation of the present study is that several airports – commercial as well as federally owned, including NAFEC and Edwards Air Force Base – be used for demonstration and experimental purposes to develop technology and procedures related to alleviating terminal congestion. Areas of emphasis should include off-site passenger and cargo processing, automated passenger processing, aircraft ground control, and alternate procedures to set takeoff and landing priorities. Also, in view of the very large acreage requirements associated with modern airports, greater emphasis should be given to early purchase of land and the establishment of airport land banks.

A new short-haul system, separate as much as possible from the present long-haul system, could help relieve congestion at existing airports, especially those in areas of high traffic density. A current contender for this new system is one making use of STOL aircraft. While many parts of this system are under study, there is a need for a coordinated effort to assure that all elements are integrated and proceeding at a consistent pace.

Low-Density Short Haul: While lower in priority than noise and congestion, *solutions to the problems of low-density, short-haul service will be important to the future of civil aviation and to its ability to contribute to the goals of the Nation.* This service of civil aviation can be a positive force in future regional development. In order to obtain a better definition of the problems and potential of low-density, short-haul service, a program should be established to determine accurately market sensitivities to changes in service, fare, frequency, and equipment. A government-sponsored market demonstration is required for this purpose. Concurrent and integrated with this demonstration, the Government should fund studies for the conceptual design and analysis of economical vehicles for the low-density, short-haul market.

OTHER IMPORTANT AREAS

The problems just discussed are those requiring priority attention but civil aviation has many elements, and other areas will require continued attention. The long-haul market, for example, has long been the backbone of the U. S. civil aviation industry. *Constant improvements in technology for long-haul vehicles and their propulsion systems are essential to continued U. S. leadership.* Included in this area of R&D is that related to supersonic transports. If R&D can help remove objections to these vehicles, they offer the promise of increased productivity, especially for international routes. Important areas include research to reduce noise and a sharply focused program to assess upper atmosphere pollution. (Both of these areas have been recognized for some time.)

Another area requiring continued attention is pollution from engine exhaust emissions. Jet aircraft produce only about one-seventh the pollution per passenger-mile when compared to automobiles. In the future, however, this level will not be acceptable and continued research in engine cycles and fuels is required.

There are several areas where research and development activities funded by the Federal Government might be limited. Two of these are general aviation and air cargo. Although both areas are important to the future of civil aviation, the Government's roles for the present should become primarily those of setting standards and assuring safety. In accepting the responsibility for standards and safety, it is important that the Government sponsor the R&D necessary to discharge this obligation effectively. It appears, therefore, that Government support for research related to safety for general aviation is justified while support for that related to improved utility of general aircraft is not at present, primarily because this area lacks a demonstrable public benefit.

The character of U. S. leadership in civil aviation could change as a result of the increased technological and marketing capacity of other nations. To make certain that the status and trends of our leadership are accurately known, a series of indicators should be developed and tracked. Because of the similarities between this problem and that of determining the state of the general economy, responsibility for measuring these indicators would best lie with the Department of Commerce.

THE CASE FOR REGULATION REFORM

The Government should examine carefully its regulatory role in several areas to be certain that regulatory policies are not inhibiting innovation by industry. One example of such a problem is the current policy opposing multimodal mergers involving air carriers. This policy was originally established to protect civil aviation from the then financially stronger ground modes, but today it represents a barrier to realizing the full potential of air cargo and impedes the incentive for R&D needed to improve intermodal cargo shipment (containerization, handling equipment, terminal processing, etc.). To provide results to guide future industry R&D related to air cargo, the DOT and the regulatory agencies should develop a demonstration program to explore the market for multimodal service involving air cargo. These actions might be facilitated by the establishment of a single transportation regulatory agency as recommended by the Ash Council.

R&D COORDINATION

Other organizational actions that would be beneficial to the future of civil aviation would include the interchange of personnel among DOT, NASA, DOD, and possibly CAB. This interchange would involve middle-management personnel and would provide a cadre of trained and experienced people with broad knowledge of all of the systems and elements in civil aviation. In addition, it is recommended that the National Aeronautics and Space Council develop a permanent mechanism to review and recommend those policies affecting civil aviation that embrace several agencies. In performing its policy role, the NASC should engage the cooperation of leaders of industry.

Another subject that should be given constant attention is the transfer of technology between military and civil aviation. The present study of this problem revealed no lessening in the funding provided by the military to support aeronautical research and development and it appears that there will be no major reduction in the benefit military R&D provides to civil aviation. One area in which the military have an interest but where civilian needs appear to be more urgent is short-haul (probably STOL) technology. Projections do suggest that the aerospace industry will, in the future, derive a lower percentage of sales from military programs and will thus become increasingly dependent on civil markets to pay the costs of R&D.

A general result of the Joint Study is that *the varied problems of civil aviation require broad-base programs in research and development.* Such programs will include research and development related to systems engineering, simulation, and trade-off studies of new concepts for air traffic control and airport design; improving the accuracy and increasing the applicability of aerodynamic theory; aircraft configurations suitable for both the long- and short-haul markets and incorporating advanced technologies such as new VTOL and STOL concepts and supercritical aerodynamics; improved engine cycles to minimize noise generation, increase thrust-to-weight ratio, and reduce specific fuel consumption; and improved structural concepts, materials, and fabrication techniques to reduce the structural weight fraction and thereby permit greater payloads and longer ranges for advanced aircraft.

The technology provided by these programs not only will assist in solving civil aviation's problems but also will permit civil aviation to achieve more fully its potential. It is important to recognize, however, that technological advances will not be made in a vacuum. They will be subject to a variety of institutional constraints as discussed earlier. Recognition of the need to consider these institutional constraints is important to civil aviation's future. One conclusion of the present study is that the *scope of civil aviation research and development should be expanded to increase emphasis on nonphysical sciences such as economics and sociology.*

COMBINED ATTACK ON PROBLEMS

While the problems of civil aviation are varied, the three priority areas identified earlier deserve special attention. *These areas – noise, congestion, and low-density, short-haul – are of sufficient importance and complexity that special offices should be established in the Department of Transportation to manage coordinated programs in each area.* These offices should be staffed by personnel from DOT, NASA, CAB, and DOD as appropriate. When several elements must be integrated within a program, separate project offices responsible for each element could be located in different agencies. These separate project offices would report to a systems office located and staffed as just described.

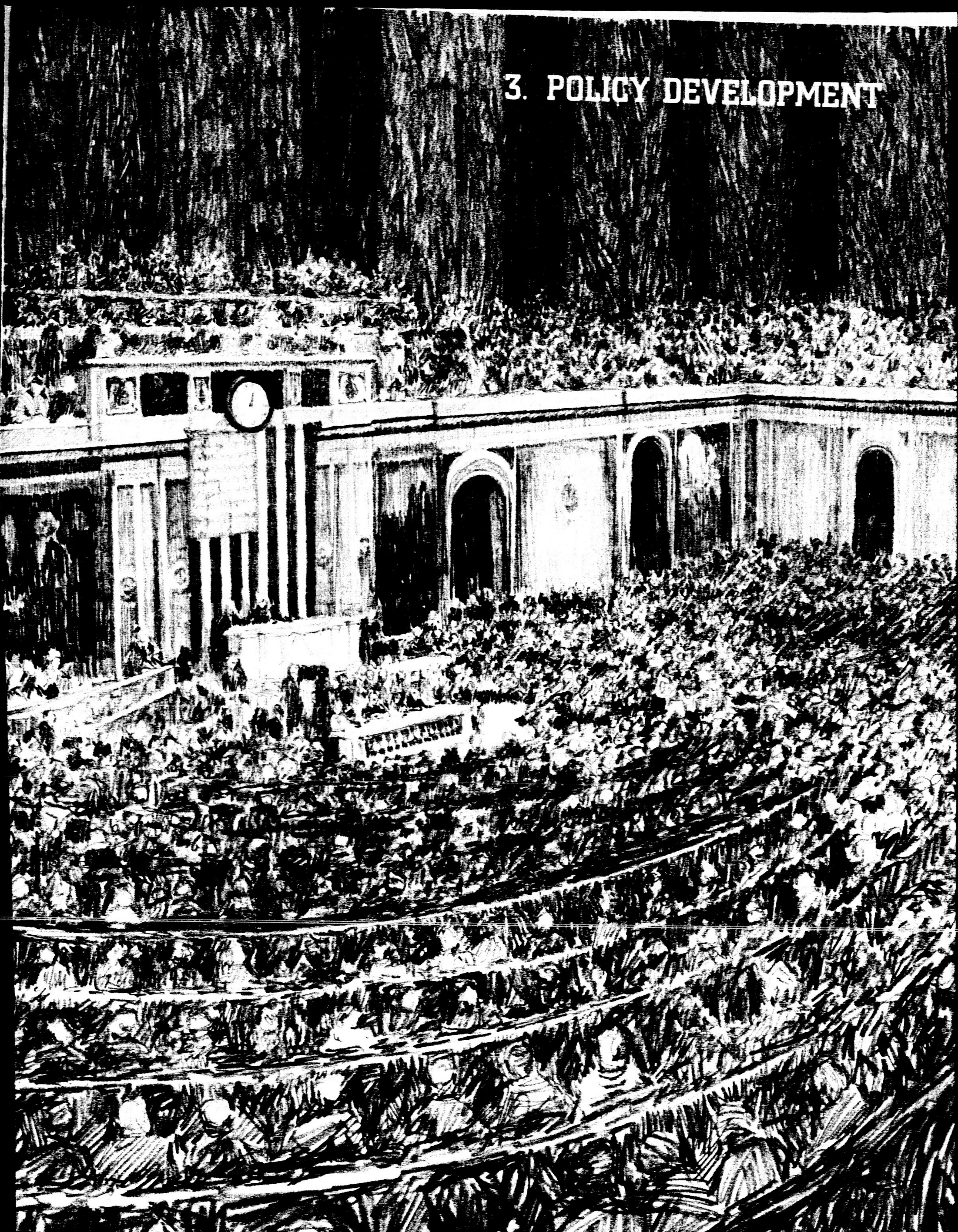
A major task for the office concerned with congestion should be the establishment of a coordinated program to develop an improved short-haul system to serve high-density markets and alleviate terminal congestion. A STOL system is a current leading contender for this application. Elements of such a program include efforts to develop microwave instrument landing systems, a STOLport program, and an experimental aircraft program. *To take full advantage of the expertise and other resources in the airline and aerospace industries, joint enterprises between Government and industry should be considered for major experimental hardware and demonstration programs.*

FUTURE POLICIES

Overall, the present Study revealed that all past bases for existing Federal Government policies of support for civil aviation still exist. These bases include civil aviation's contribution to military preparedness, concern for public safety, and civil aviation's role as a public service. Civil aviation is an industry of high technology and it is important to this country's position in world trade. Both the airline and aerospace industries are undergoing current financial crises that are similar to but more severe than those experienced in the past. *Continued Government support for research and development is necessary at a high level to assure the maintenance of a strong civil aviation technical base.* It may also be necessary to make use of Federally guaranteed loans for aircraft purchases. Services similar to those provided to foreign airlines by the Export-Import Bank could also be extended to domestic airlines. These approaches would help provide the stabilized finances the industry so desperately needs.

In the future, civil aviation's role as a contributor to social goals of the Nation will become increasingly important. Civil aviation's contribution will depend on its ability to influence regional development, to affect favorably population distribution, and to aid in conservation of land resources. Both a broader approach to R&D and an adjustment in the regulatory environment will be necessary for civil aviation to make these contributions effectively.

3. POLICY DEVELOPMENT



Policy Development

Historically, a primary reason for the U. S. support of aviation and related R&D has been to maintain military preparedness. The War Department supported aeronautical research by the Smithsonian Institution even before the flights of the Wright brothers. Despite this, however, the United States entered World War I with essentially no modern warplane designs and little production base. The United States had to borrow British designs and never did achieve production goals. Also, during the war, rapid design improvements occurred, leading to rapid obsolescence. Neither of these lessons was lost on the post-war military leaders. Consequently, by the end of World War I, the Nation realized the importance of *maintaining an aircraft industry in time of peace, if only to support military requirements whenever they developed.* In 1918, the U. S. Post Office Department began flying the mail, initially using military planes and pilots, but later that year running its own service by contract. This air mail service, underwritten by the Government, was the first demonstration in the United States of the practical use of commercial aviation and laid the groundwork for the expansion of Governmental policy to foster civil aviation because of nonmilitary as well as military benefits.

During the 1920's and the 1930's, it became apparent that air travel could become an important means for promoting commerce and moving travelers. This period gave birth to legislation that first established the Federal Government's role in *air travel*, then detailed the terms under which the air transportation system would function. The legislation reflected a recognition that civil aviation could not at that time flourish as a free-market process alone and that it provided a valuable public service which deserved to be fostered, supported, and protected by the Federal Government. There was also a recognition that there were strong public safety interests that must be protected.

Interest in commercial aviation, and contract air mail service in particular, was further enlivened when, in the spring of 1926, Congress passed a bill known as the "Air Commerce Act of 1926," which, briefly stated, imposed upon the Secretary of Commerce the duty of fostering the development of commercial aviation in the United States. Among other things, it authorized the Secretary of Commerce to establish airways insofar as funds were made available by Congress from year to year and to establish, operate, and maintain along such airways all necessary lights and emergency landing fields.

From that time on, three policies have dominated the Federal Government's approach to air traffic control:

- There is a public right to freedom of transit through airspace.
- Air traffic is national in scope (interstate), with strong public safety implications.
- It is in the national interest to have a single organization operate the airways and air traffic control systems.

Despite the policy on free use of airspace, the Federal Government has been pressed to limit the public freedom of transit through airspace for safety reasons. It has restricted the use of portions of the airspace to aircraft under positive air traffic control and the use of other portions of the airspace to military training operations.

The Air Mail Act of 1925 had turned over the carriage of domestic mail to the private airlines. In 1930, an additional boost to air transport was provided when passenger hauling was made a condition for the award of air mail contracts, with the objective of establishing a network of interconnecting airlines that carried passengers.

During the 1930's, Government-sponsored basic research work continued to grow in the National Advisory Committee for Aeronautics (NACA) and at the universities, but the Government funding of R&D efforts by industry was reduced to some minor prototype funding and sufficient procurement of military aircraft and engines to assure a market for the development of improved products. A large reservoir of technology was developed during this period, which later was significant during World War II. In many ways industry is still benefiting from this technology base.

By 1938, the airline industry had grown to the point where the operators themselves were concerned about the strong competition among airlines. Yet, the industry was still considered to be in a weak competitive position relative to other transport modes. The need was seen to broaden the Government role in aviation safety beyond the operation of airways. Also, air transport had become such an important public service that it was determined to be a proper Federal role to insure service in certain areas where the profit potential was not adequate to attract an air carrier.

Therefore, flavored by Government policy in legislation relating to other modes (e.g., the Interstate Commerce Act, the Motor Carrier Act, and the Merchant Marine Act), the Civil Aeronautics Act of 1938 created the independent Civil Aeronautics Authority and provided for a major enlargement and extension of the Federal role in fostering civil aviation beyond the development and operation of the airways system. It protected the airlines from undue competition from other modes by controlling mergers and acquisitions involving an air carrier and other modal operators. It protected the airlines from unreasonable and destructive competition within the airline industry itself. It provided for adequate service in the public interest by the certification of new carriers when deemed desirable, making new route awards, encouraging low fares and rates, and the use of subsidies. It provided for safer operations by requiring the "licensing" of pilots, the airworthiness certification of aircraft under minimum legal criteria, and the promulgation and enforcement of safety regulations.

Through the years, Government approval has generally been given to proposed mergers between two air carriers, and denied for proposed mergers between air carriers and other aviation activities or between air carriers and operators of other transport modes. The traditional rationale behind the restriction in the latter case has been to prevent the weakening of air transportation in the hands of financially stronger surface transportation interests.

Regarding route awards, a Government certificate of "public convenience and necessity" specifying terminal points and routes to be served is required to operate interstate, territorial, or international passenger, freight, express, and mail services. Foreign-flag air carrier operations to and from the United States are also regulated.

In the early period of regulation, all of the basic air transport services required and received Government financial assistance in the form of mail subsidy. In establishing the rates of compensation to air carriers for the transportation of mail, the need of each air carrier for such compensation was considered, together with other revenues of the carrier, to enable the air carrier "under honest, economical, and efficient management, to maintain and continue the development of air transportation to the extent and of the character and quality required for the commerce of the United States, the Postal Service, and the national defense."[1] As the industry gained in size and strength, more and more carriers were found to be self-supporting, without direct subsidy support.

Thus, a large part of the Federal Government's regulatory role (pilots, aircraft, airways, and commercial carrier operations and economics) had been established prior to World War II. The R&D roles of Government and industry were still evolving, and the Government's planning, funding, and safety regulatory roles in airports had not yet emerged.

[1] Section 406(b) of The Civil Aeronautics Act of 1938.

World War II brought a major change in the Government-industry roles in R&D. The need for productive capability and capacity in aircraft, engines, aviation fuels, and aluminum was enormous. The Government financed huge plant and production facilities and mobilized all civil transport production for military needs, including new design. Production-line techniques were developed and the use of specialized producers or subcontractors became important. At the conclusion of World War II, a completely developed production capability with a wide range of technology, brain power, a backlog of new commercial transport designs, and an ample supply of pilots and mechanics were available – all part of the military legacy to aviation and technology. The manufacturing industry was now able to take the initiative in significant independent research and development efforts.

The period following World War II brought a substantial escalation of Government commitment to aviation R&D. The sustained requirements of the Cold War led to military R&D with considerable civilian aviation applications. Funding came primarily from the Department of Defense (DOD), but the civilian sector benefited both from the transfer of technology from the military and from a greatly expanded industry and technological base. NACA and its successor agency, NASA, continued to sponsor aeronautical research, but its support of civilian R&D performed by industry has consistently been an order of magnitude less than that funded by DOD. To a certain extent, the absorption of NACA by NASA in 1958 diverted talent and emphasis to the space program. Renewed emphasis on aeronautical R&D in NASA began in 1967.

Although airports are generally owned and operated by local governments, the Federal Airport Act of 1946 established a Federal leadership role in airport planning and authorized a 50/50 shared-funding approach for Federal and local governments for airport development. This has been strengthened by the Airport and Airway Development Act of 1970, which requires the Federal Aviation Administration to certify the compliance of airport operators with safety standards, similar to the airworthiness certification of aircraft. It also established a user trust fund for revenues from a fuel tax on general aviation purchases, passenger ticket and cargo waybill taxes in lieu of a fuel tax for commercial aviation, and an aircraft licensing tax. (Prior to 1970, there was an aviation fuel tax, but the revenues went to the Federal Highway Trust Fund.) Subject to the Congressional authorization of programs and the appropriation of funds, the DOT can draw upon this user trust fund for the development and implementation of air traffic control facilities and equipment. (The first $50 million is earmarked for R&D as a priority allocation, not as a limitation.) This was a major step toward a "user pays" policy for civil aviation activities supported by the Government.

In the Federal Government activities in civil aviation up to 1960, three Federal organizations were affecting the system in a specific, direct, and significant way, with one Federal organization having a major indirect impact on the system. Two of them, the Civil Aeronautics Board[2] and the Federal Aviation Administration, control the operations and the economics of the system. Two of them sponsor and perform directly applicable R&D, FAA and NASA, and one, DOD (really the three military departments), sponsors and performs indirectly applicable R&D. In 1966, the Congress established the Department of Transportation to provide leadership, a planning focus, and a policy and management overview for all transport modes. Both the FAA and National Transportation Safety Board were made elements of this new department.

[2] Established under the Civil Aeronautics Act of 1938 as an independent agency regulating civil aviation, the Civil Aeronautics Board (then called the Civil Aeronautics Authority) is today a strictly economic regulatory agency. All of the Board's former safety regulatory functions were transferred to the Federal Aviation Administration or the National Transportation Safety Board in 1958 and 1967.

From the beginning, civil aviation development has been characterized by the close and intricate involvement of Government and industry in virtually every aspect of the system. In fostering civil aviation, the Federal Government has assumed significant roles in the sponsorship of R&D, the regulation of safety, the operation of the airways, the control of economics, and in overall policy planning and leadership. These roles and the implementing policies have developed separately over a period of 50 years. The responsibilities for these roles is vested in a number of independent Government agencies. In addition to these Federal agency roles, state and local governments have been involved in the planning and operation of airports and their access sytems.

These policies of the Federal Government to support and foster civil aviation have been backed by the commitment of substantial funds, both for subsidies and for research and development. Air carrier subsidies have totaled approximately $1.6 billion during the fiscal years 1939 to 1970. Payments to the international carriers ended in 1958; those to domestic trunk carriers followed in 1959. Only subsidies to local service and intra-Alaska and Hawaii carriers, which have amounted to over a billion dollars, continue. The local service carrier subsidy peaked at $67.6 million in FY 1963, and amounted to $34.3 million in FY 1970. The funds committed to the direct support of civil aviation research and development by the Government have been substantially greater, amounting to nearly $2 billion in the last ten years. Industry expended approximately $3.6 billion during the same period.

The favorable Government policies and the related support for research and development have been major factors in producing the civil aviation system that exists today. This system in turn produces a variety of benefits, both to the user and to the Nation as a whole. These benefits will be examined next to assess the impact of the Government policies just discussed.

4. BENEFITS

Benefits

OVERVIEW

As noted in the foregoing section, the Federal Government has recognized for many years the need to maintain policies that provide a favorable environment for civil aviation and encourage its growth. These policies have been supported by large investments in direct subsidies and in research and development. As a result, civil aviation has grown impressively, especially during the 25 years since World War II.

Research and development have been major contributors to civil aviation's growth and have produced significant improvements in safety, economy, speed, capacity, and range. Since World War II, aircraft productivity (measured in seat-miles per hour) has been increased by a factor of 20; direct operating costs have been reduced by a factor of 3; and accident rates have been reduced by a factor of about 5. Both the industry and the public have been quick to take advantage of these improvements. In the same period, revenue passenger-miles increased by a factor of about 30, revenue ton-miles by about 50, the number of aircraft handled in the airways system by about 8, and the general aviation fleet by about 4.

Today civil aviation has a major influence on our way of life. It has altered personal patterns of living and influenced techniques for conducting business. Civil aviation has acted as a stimulus to regional development. It has contributed to national defense, to international prestige, and to the well-being of the economy.

The sophistication and pace of many business activities today require the use of air transportation for those businesses to remain competitive. Production processes and inventory distribution concepts have changed as a direct result of civil aviation. Today, production stages may be widely separated to optimize skills and minimize costs, while the speed of air transportation helps eliminate large inventories. Speed has also allowed businessmen to increase the sphere and rate of their activities. As a result, it has become practical to decentralize operations and centralize management. The speed, capacity, and flexibility of civil aviation have allowed business to compete more efficiently in an era of rapidly rising costs. Consequently, consumers today are enjoying more products for less cost than would have been possible if business were forced to use pre-World War II air transportation and other methods for movement of people and goods.

The private citizen and user have similarly benefited from civil aviation. For example, the available air network permits the heart surgeon, labor negotiator and architect to extend their unique, nonreproducible talents to larger segments of the population. The legislator has a more direct tie to his constituency, while the ordinary citizen has an even greater mobility to job markets. People are less reluctant to locate farther from their families, knowing that air transportation can move them anywhere in the country in a matter of hours. Like the businessman, the pleasure traveler has capitalized on the speed of aviation which allows the vacationer the option of visiting distant places while spending much less time enroute than for any other mode of travel.

The general public has also benefited from advances in civil aviation. Studies have shown that the economy is generally healthier in areas where civil aviation is available. Airport activity centers generate a substantial number of supporting jobs, and despite the negative aspects of noise and air pollution, land around airports is invariably valued at a premium for business activity. The benefits of civil aviation are even more visible in rural areas where the economic potential has not yet been fully tapped. Two different studies have attributed to civil aviation the role of catalyst in increasing economic activity in addition to reversing the migration of farm workers from those areas where farm mechanization is replacing manual labor.

In a more general way, civil aviation has brought prestige to the Nation and has served as an instrument of foreign policy, besides contributing positively to the maintenance of U. S. balance of payments. The large number of civil aircraft in existence today and the reservoir of highly trained technologists from the U. S. aviation industry contribute to the military preparedness of the Nation as well.

None of the benefits discussed in this section would have been realized without the products of R&D. Examples of important R&D contributions include the jet engine (and its later fan version), aluminum frames and skins, the swept wing, instrument landing systems, air traffic control radar, and a large number of less dramatic but none-the-less important advances in technology. Social, economic, political, and organizational factors can increase the benefits of these advances by providing a suitable environment for their application, but the prime mover is R&D. In the material that follows, the many benefits of civil aviation are assessed but it was not possible to isolate exclusively the particular benefits resulting from individual R&D efforts or levels of effort. Rather, the benefits are treated as the products of the total system operating in a complex environment and making use of the capabilities provided by R&D.

CONTRIBUTION OF R&D TO CIVIL AVIATION

As a result of a favorable environment, civil aviation has experienced impressive growth. The increases in speed, range, and size of commercial aircraft and the resulting growth in revenue passenger-miles are shown in Figure 4.1.

While progress in increasing vehicle speed and range seems to be slowing, the addition of supersonic transports to the fleet in the late 1970's will overcome the present limit of subsonic flight. Market projections suggest the need for larger aircraft by 1985, carrying about 800 to 1,000 passengers.

While aircraft, especially the commercial transport, have been setting the pace, other elements of civil aviation have responded with equivalent growth. Some examples of past and projected future growth are shown in Table 4.1.

To date, most advances in civil aviation can be traced to improvements in aircraft, their propulsion units and avionics. These improvements can, in turn, be related to research

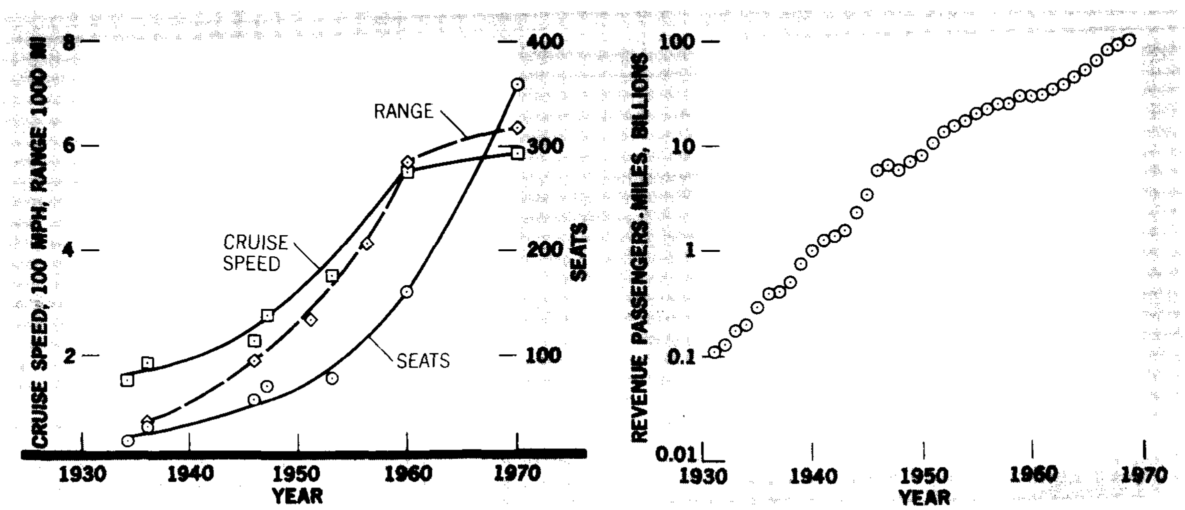


Figure 4.1. Growth in selected aircraft characteristics and U.S. domestic revenue passenger-miles.

TABLE 4.1. GROWTH IN CIVIL AVIATION COMPONENTS

ELEMENT	1945	1960	1970	1985 (EST.)
REVENUE PASSENGER-MILES, BILLIONS	3.8	39	133	685
REVENUE TON-MILES, BILLIONS (CARGO)	0.1	1.3	5.9	67
GENERAL AVIATION AIRCRAFT, THOUSANDS	37	68	131	287
PILOTS, ACTIVE CERTIFIED, THOUSANDS	297	348	720	1,900
VFR OPERATIONS MILLIONS	1.0	16	38	160
IFR OPERATIONS, MILLIONS	8.2	9.4	18	62
AIRPORTS	4,026	6,881	11,165	15,000

and development activities. An analysis of this relationship revealed that acceptance of R&D results followed a remarkably similar pattern. As shown in Figure 4.2, from 5 to 15 years elapse between development and acceptance for the 517 R&D events examined. Therefore, in 1970, we enjoyed the benefits of R&D performed largely in the late 1950's and early 1960's. Similarly, the R&D funds expended today and in the next few years will provide the basis for many of the advances in the early 1980's. As is true with rapidly developing risk-venture enterprises, many R&D events have not been adopted since they are no longer relevant, practical applications have not emerged, or implementations are planned for later dates.

With this correlation established, the effects of the level of R&D funding on productivity can be examined. In Figure 4.3, the growth in the combined productivity of all U. S. air carriers is shown in terms of available ton-miles per dollar of operating expense. Also shown is the budget for military and civil aviation R&D. The rate of growth in productivity from 1947 to 1959 was 0.12 ton-miles per dollar per year. The slight dip in the curve from 1959-1961 resulted from expenses incurred by jet fleet purchases, training, and changeover to new maintenance procedures. Introduction of the jet accelerated growth in productivity by 1962 to a level almost three times greater than that of the preceding period. As shown in Figure 4.3, both civil and military R&D increased substantially around 1955. Many of the developments required for the introduction of the jet were accomplished during this period. The most notable effort was the evolution of the fan engine. The turbine engine developed in the 1950's offered the promise of greater payloads and led to a more economic air carrier operation in the mid-1960's. These results show both the

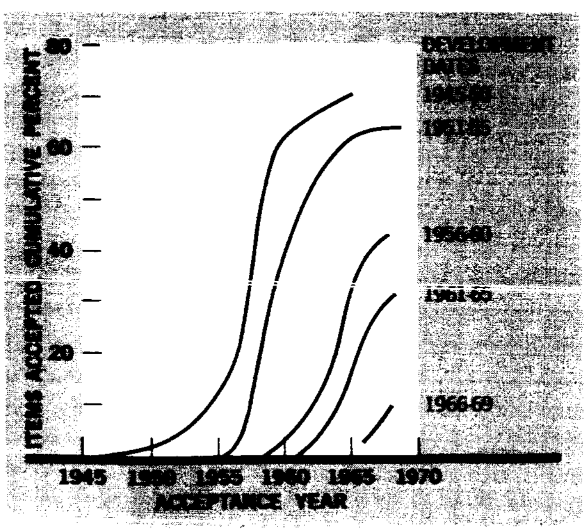
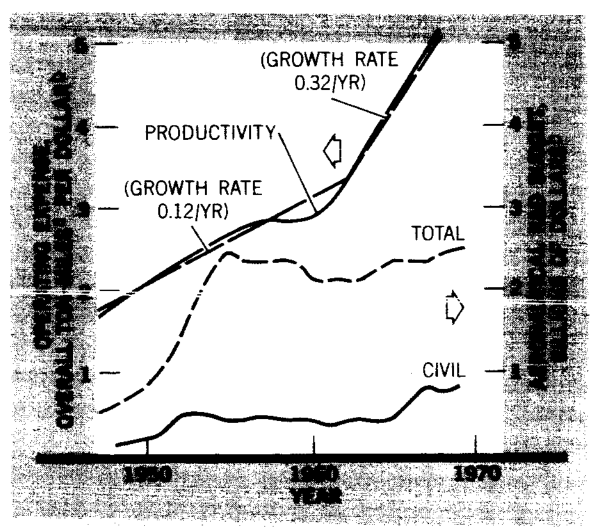


Figure 4.2. Utilization of technical advances in civil aviation (517 events).



[a]All services.
[b]1968 dollars.

Figure 4.3. U.S. commercial transport productivity index and aeronautical R&D budget.

overall impact of R&D on the system and the previously noted time lag before the results of R&D are felt.

Research and development will continue to be important to civil aviation in the future. This importance is apparent when it is recognized that more than 50% of the aerospace industry sales in 1973 are expected to come from products that were not marketed in 1969. This figure and corresponding ones for other industries are shown in Table 4.2.

TABLE 4.2. PERCENT OF 1973 SALES FROM PRODUCTS NOT MARKETED IN 1969

INDUSTRY	PERCENT
AEROSPACE	52
OTHER TRANSPORTATION EQUIPMENT	37
INSTRUMENTS	35
AUTOS, TRUCKS, PARTS	30
ELECTRICAL MACHINERY	20
CHEMICAL	17
PETROLEUM	6

The 52% for aerospace compares with 37% for other transportation equipment and, as is shown, even greater differences exist between expected new technology sales in the aerospace industry and those expected in other selected industries. While all of these new products may not be the exclusive result of R&D, it can be said that research and development have played a significant role in the evolution of most of them, particularly in the aerospace industry. These advances have benefited both the user and the general public.

BENEFITS TO THE USER

The users have realized substantial improvements or advances in service over the past two decades in terms of cost savings, time savings, safer transportation, and business stimulation. Air carrier direct operating costs have dropped from 3¢ per available seat mile to 0.9¢ per available seat mile. A substantial portion of these savings has been passed directly to the user. If the users had been required to continue to pay 1948 rates from 1949-1958, they would have paid an additional $4 billion in fares (computed in 1968 constant dollars). Similarly, if air fares had not improved beyond 1958 levels in the following decade, passengers would have paid an additional $4.5 billion in fares. This $8.5 billion savings over the $55.5 billion the users actually paid occurred during a period when huge capital outlays were required first for the postwar fleet, then for the present jet fleet.

Even though air cargo is still a relatively small portion of air carrier revenues, reductions in air freight rates have also been significant. Had the shippers continued to pay 1948 rates in the 1949-1958 period, an additional $441 million would have been required over the $1.2 billion actually paid. Similarly, if the shippers had continued to pay 1958 rates from 1959 through 1968, they would have paid $1.2 billion more than the $4.6 billion they did pay. (It is recognized that reducing fares and freight rates stimulated traffic and that increasing the rates to 1948 and 1958 levels would have reduced demand.)

During the past two decades, while the user was experiencing benefits in passenger and freight rate savings, travel time was decreasing dramatically. Using 1948 as the base year, about 140 million passenger-hours were saved from 1949 through 1958 as a result of reductions in flying time. With the advent of the jet, more than 840 million additional hours were saved between 1959 and 1968 (using 1958 as a base year). This has amounted to 980 million hours saved over a 20-year period by businessmen and pleasure travelers, estimated to be worth about $5 billion.

Advances in safety have reduced death rates from 1.25 per 100 million passenger-miles in 1948 to 0.27 per 100 million passenger-miles in 1968. If aviation had been subject to the 1948 fatality rate over the 20-year period, then an additional 7,705 fatalities could have been expected over the 3,312 that occurred. The improvements in safety occurred during this period when the fleet doubled, aircraft departures and landings more than doubled, and a new technology base was implemented by the industry.

During the past 20 years, civil aviation has helped shape the pattern of commercial and industrial activity in this country. Fast, efficient air travel and communications have made new techniques of industrial management and control possible. In fact, a fundamental change in American business has occurred since World War II – the decentralization of economic activity coupled with the centralization of management. This form of organization would be difficult to maintain efficiently without effective personal travel and communications. Civil aviation has also contributed to the emergence of the multinational companies.

Civil aviation also has a profound impact on the production process itself, by causing it to depart from traditional ways of doing business. Lower production costs have been achieved by making possible the geographic separation of the stages of production. Examples include: U. S.-manufactured electronic parts assembled in Puerto Rico to utilize lower labor costs; and computer systems units manufactured in different parts of the country, with integration of the units into a functioning system at a customer's facility. To be workable these processes are dependent on civil aviation.

In addition to the production process, air transportation is reshaping the concepts of distributing people and goods. The productivity of highly specialized employees and management has increased due to the dramatic reductions in travel time and increased choices of flights and schedules offered to the businessman. Highly skilled, nonreproducible resources such as heart surgeons, architects, sports and entertainment figures, and Government and business leaders can be more productive to society as a result of their enhanced mobility. Air travel, as an integral part of their work patterns, is thus stimulating the economy.

Many progressive businesses use air transport not only to provide mobility to key people but to optimize the distribution of goods. The higher cost of shipping cargo by air is far outweighed by such advantages as reduced spoilage of perishable foods, extension of markets, and lower warehousing costs because of reduced inventory requirements. Some examples include: the air shipping of melons from Venezuela to New York between December to May extending market boundaries, and the air shipping of women's high fashion apparel, thus avoiding the need for maintaining large inventories that may quickly become out of date. As more companies continue to gain insight into optimizing inventory, warehousing, shipping time, shipping cost, packaging and handling, air shipment is expected to become more extensive, providing even more stimulation to business.

Looking ahead to the future, civil aviation is expected to play an even larger role in facilitating business. The U. S. economy is shifting from a hard goods to a service-oriented society. Today the split is about 50-50, but it is anticipated that seven out of every ten people will be employed by the service industries in 1980. Tourism and government are two current examples of that orientation. Analysis from the Department of Commerce on the U. S. economy shows that air transportation contributes twice as much to the service industries as it contributes to the output of any other sector. (It is also interesting that these service industries are very labor intensive, employing a broad cross section of socioeconomic classes.)

BENEFITS TO THE GENERAL PUBLIC

Regional Development

The Federal Government has only recently begun to use civil aviation as a tool for community and regional development. In this regard, more than $1.2 billion in aid for airport development has been distributed since the inception of the Federal Aid to Airports Program in 1946, in addition to expenditures of $2.0 billion for the development and operation of the national airways system. While these funds have been allocated with little knowledge of their impact on the regions affected, the few studies that investigated their impact indicated that significant social and economic benefits accrue from airport development, in both metropolitan and rural areas.

A recent study of the economic impact expected by 1975 from the addition of new maintenance facilities for both American and Trans World Airlines at Los Angeles International Airport projected the following benefits:

- 23,000 additional jobs (direct and indirect)
- $86.2 million in additional construction
- $630.2 million per year economic impact (direct and indirect)

Based on 1975 projections for the Dallas–Fort Worth area, analyses indicate a similar impact from the airport on the economic health of North Central Texas:

- 46,612 employees
- $600 million per year economic impact (direct and indirect)

A recent study by the Economic Development Administration (EDA) on the growth ratio of 34 pairs of cities showed that airports can significantly affect the economy of medium-sized towns as well. The members of each pair were reasonably close geographically and had approximately the same socioeconomic characteristics with the exception that one had scheduled airline service and the other did not. The differences in the number of new manufacturing jobs per capita over the 1958-1963 period were calculated as a measure of the relative rate of growth for the cities with and without airline service. The study concludes that civil aviation can have a positive impact on the manufacturing growth of a city, and that the extent to which a city can realize the full benefits of air service depends upon the city's population size, its proximity to the interstate highway system, its regional location, the growth of established industry in the region, and the mileage from center city to the airport.

The impact of civil aviation is more readily evident in less-developed regions than in a large metropolis. Another historical impact study was made on Ohio's County Airport Development Program. Under this program, the state granted $100,000 toward the expansion or construction of airports to each of 50 Ohio counties on the premise that each new general aviation airport would create increased economic activity and air traffic. Between 1966 and 1970, 62 new airports resulted from this program.

The Ohio Department of Development has traced the following benefits directly to these airports:

- 60,000 new jobs were added.
- An additional $250 million in personal income was generated.
- Trade was generated to support 200 retail establishments.
- 1,500 manufacturing firms were added or expanded.
- An additional $1 billion in capital was invested.
- Within one year after an airport was completed, the value of the adjacent land rose 100%.
- Twenty new industrial parks were established.

The study concluded that "the installation of airports, capable of accommodating large business aircraft, is likely to generate an improved economic base to the communities which surround each facility."

Other studies by the ATA of general aviation airports in South Dakota and an FAA study of five general aviation airports have also indicated that "accelerated economic growth" can result from airport development if other community conditions are favorable. The FAA study credited the airports in its sample with being the catalyst for the substantial increases in the census index of value added by the manufacturer, wholesale and retail trade, and services recorded in each community in the period following the construction of the airports. Perhaps even more importantly, the survey revealed that where new airports were not added, farm mechanization had been a major factor contributing to the decline of population, labor force, and employment in the rural areas surrounding the communites, as has been happening throughout the entire farming economy. However, where new airports were added, the rural labor force was effectively retained by the increased business and industrial job opportunities in the community. Its retention has benefited new industry by providing a source of skilled and semiskilled labor in nonurban areas.

GNP Contribution

Contributions to the gross national product and employment are general benefits in the same way that any business activity exerts positive influence on the economy. Balance of trade and cultural understanding are specific benefits to which civil aviation makes a unique contribution. Rising from a 0.2% GNP contribution in 1949 to a 1.0% contribution in 1969, civil aviation has grown two to three times faster than the economy as a whole. This contribution compares to a 1.6% GNP contribution by the communication industry and 4.6% by the largest industry group—construction. Over the jet era the civilian portion of aerospace has grown at 9.5% per year to $3.5 billion while the air carriers have grown even faster, at 13.3% per year, to $6.3 billion including both direct and indirect contributions to GNP.

Employment

Civil aviation (civil aerospace manufacturing industry plus air carriers) is one of the largest employers in the Nation. In 1968, direct plus induced employment was 390,000 for civilian aerospace and 440,000 for air carriers, averaging about a 9% growth rate for both sectors. In 1969, civil aerospace was the third largest employer among manufacturers, behind only the motor vehicle and steel industries. Growth was curtailed in 1970 with severe cutbacks in employment in both groups; the industry has reduced employment by 90,000 to about 740,000. Nevertheless, the industry is of particular importance to the nation in that it is a large resource of highly skilled, scientific, engineering, production, and management talent.

Balance of Trade

Unlike GNP contribution and employment, the balance of trade of aviation products is a unique asset in that the highly favorable balance maintained by the inudstry over the years could probably not be replaced by another industry if the aviation dollars were invested elsewhere. In 1969 the civil aviation manufacturing industry accounted for a net balance in trade of $1.77 billion, which was more than the entire favorable U. S. trade balance that year.

Cultural Understanding

Besides acting as an instrument of defense, civil aviation has facilitated communications between nations, which has led to an unprecedented level of cultural understanding. The State Department's Cultural Exchange Program and many other educational exchange projects have promoted visits to the United States by official foreign representatives of the cultural and academic communities, as well as reciprocal visits abroad by similar U. S. representatives. Air travel has provided great mobility in achieving this benefit. Additionally, the bargain value of international travel has encouraged individuals and groups to travel abroad on pleasure trips.

In the past eight years, 95.3 million people have arrived in or departed from the United

States, 82.7 million (87%) traveling by air with about half the total number (43.5 million) using U. S. carriers. During this same period, the number of U. S. students studying abroad rose from 17,000 to nearly 26,000, and the number of foreign students studying in the United States jumped from 57,000 to 135,000. This great interaction between members of different cultures has helped foster an increasing amount of understanding among people of the world – a benefit to the Nation, facilitated by aviation.

As other nations continue to increase their economic levels, more foreign citizens will have the means to travel to the United States, which will further improve the cultural balance between the United States and other nations.

U. S. LEADERSHIP

As a result of the large domestic market for U. S. civil aviation, the Government's supportive policies, and the contributions of R&D to the productivity of the system, the United States enjoys a well-recognized position of world leadership in aviation. This leadership position has provided the general public with a spectrum of benefits and has provided the industry with certain advantages as a consequence of its preeminent position in world markets.

The demand for U. S. aviation products abroad has contributed to the Nation's prestige through its demonstrated capability to manufacture high technology products. As a result, it has also contributed to the Nation's defense preparedness. The success of the U. S. position in civil aviation has clearly benefited the entire Nation.

The industry also enjoys certain advantages that competitive countries cannot match. Since a larger portion of the aircraft are manufactured in the United States, the industry is in a position to specify other parts of the system, such as air traffic control, as well as to set its own standards on vehicle design which can be weighted primarily to its own domestic market. In addition, the industry has a built-in lead on the introduction of new products because of its existing base of products already in place. Unlike that of other countries in the free world, the U. S. domestic market is of sufficient size to justify production for it alone.

U. S. aviation did not attain leadership through any single planned action but through many different events and circumstances. The need for very large numbers of *long-range* strategic aircraft during World War II and the need and availability for U. S. aircraft during postwar recovery provided the Nation with a momentum that was difficult for others to match. The manufacturers' demonstrated ability to move quickly into fields often originated by others and the acquired expertise to market a total package, consisting of an optimum blend of technology, sales skills, adaptability to customers' needs, financing, production techniques, together with reliability and after-sales service, have been important factors contributing to this position.

Proof of U. S. leadership can be seen in the following statistics:

- 76% of the free-world commercial aircraft are U. S. manufactured.
- 63% of the airplanes operated by foreign airlines of the free world are U. S. manufactured.
- U. S. airlines have 41% of the free-world airplanes.
- The seven largest airlines in the free world, from the standpoint of revenue passenger-miles or ton-miles flown in 1969, are U. S. carriers.
- Over 57% of the scheduled passenger-miles flown in 1969 were by U. S. carriers (domestic and international).
- Over one-third of the total value of U. S. civil aviation products is exported.
- The United States exports about two and one-half times as many general aviation airplanes as the rest of the world.

- Production leadership can be seen in the fact that aerospace employment in Western Europe is about one-third that of the United States, with sales valued at only 15% of U. S. sales. This disparity in output is largely associated with the more sophisticated production methods that U. S. manufacturers can afford to use because of the size of their domestic market.

Recently, President Nixon affirmed the U. S. policy of maintaining world leadership in aviation. Leadership has many facets in addition to the market dominance just discussed. It also involves a willingness to advance technology, to explore new concepts, and to bring the benefits of civil aviation to a larger part of the world's population. In the future, several factors will influence the ability of the United States to maintain its present leadership – foreign competition and the financial status of the industry.

Current trends indicate that the large margin of U. S. leadership in civil aviation acquired after World War II is slowly being reduced as other major nations recover economically and increase their technological and industrial capabilities. The U. K. and U.S.S.R. are the only countries with technical capabilities and comprehensive aerospace industries comparable to those of the United States. However, Japan, France, Germany, Sweden, The Nethelands, and Canada are not far behind. While the United States spends four times as much for space and defense R&D as the combined spending of Western Europe, Japan, and Canada, these countries are spending more on R&D for *civil aviation* at the present time than is the United States. At present, foreign countries *equal* the United States with such developments as the BAC VC–10 aircraft and all weather landing, and they *lead* in such areas as supersonic aircraft, STOL airplanes, lift engines, and cold-weather operating equipment. While U. S. leadership is not immediately threatened in these areas, aggressive action on the part of these countris can make competition for world markets more difficult in the future.

The potential expansion of the European Economic Community by including the U. K. will make the European "equivalent domestic market" as large as that in the United States. Collaboration and combination of the aerospace companies of several nations are taking place today. Consequently, Western Europe could be a much more potent rival to the United States than in the past. One factor currently favoring foreign competition is that Western Europe is not having the economic slump that prevails in the United States today. Both U. S. airlines and manufacturers are experiencing a recession partly because the introduction of a major change in aircraft and facilities has produced a temporary overcapacity. The recession is further accentuated by inflation in the country, cutbacks in military and space production, and the high cost of delays caused by airport congestion and air traffic control limitations. Consequently, the aircraft manufacturers cut employment by 20% in 1970. With sales dropping, R&D is being cut back as well, affecting future sales. Manufacturers' annual interest on long-term debt is $186 million and is climbing, further compounding the problem.

Airline excess capacity and cutbacks in other businesses have created the worst loss for the air carriers in their history. Losses in 1970 are estimated to be over $150 million. Another contributor to airline losses is the rapid increase in wages, which have risen 64% in the ten years prior to 1969, and have risen approximately another 11% in 1970. Terminal congestion contributes an estimated $158 million per year in increased operating costs to the carriers. Without some relief in the long term, the basic health of the industry could be undermined.

Today, an aircraft manufacturer must invest approximately $1 billion to place in service a 747, a DC–10, or an L–1011. Such investments represent several times the net worth of the manufacturers. Furthermore, they are long term investments since no appreciable financial return accrues to the manufacturer for a period of five to ten years after program commencement.

Large military production runs are generally beneficial to civilian business in that they provide substantial production know-how, tooling, and continued search for new methods of manufacture and management. Civil aviation has benefited from military aircraft procurement, either directly as in the case of engines, or indirectly through the transfer of technology from military-oriented R&D programs. Substantial portions of company-run independent research and development are funded indirectly by the Federal Government as an allowable cost of hardware contracts. If cutbacks in military procurement occur, they will not only affect military R&D programs but could also affect future civil sales through reduced funding of industry research. In addition, a healthy civil aviation industry can be a bulwark of defense.

If maintaining U. S. leadership is a matter of concern, then knowledge of the potential loss of that leadership is important. Some economic indications may provide an advance warning. The financial status of the industry is important because of its effect on the ability to compete in the future. Furthermore, in an environment of rapid change, accurate knowledge regarding the status of civil aviation leadership and expected trends may point to early corrective action so that the benefit stream will continue uninterrupted. The problem of assessing the status of leadership has many similarities with that of assessing the status of the Nation's economy. The magnitude and direction of change in several parameters are needed to give a valid picture of the economy. Examination of the elements contributing to U. S. leadership also points to a wide spectrum of factors that must be considered to understand the issue adequately. These factors, when quantified, can then provide a solid basis for action should these measures indicate an erosion of position. The primary elements believed to influence U. S. leadership include:

Military R&D and procurement
R&D expenditures
Production skills and productivity
Marketing of the total package
Financing
Air carrier competitive strengths.

A number of leadership indicators have been developed that reflect these six areas which depict the present condition and trends of the industry. Some results are shown in Table 4.3.

TABLE 4.3. UNITED STATES LEADERSHIP INDICATORS [a]

INDICATOR	1961	1963	1965	1967	1969
AEROSPACE SALES TO DOD, BILLIONS OF DOLLARS	16.2	16.2	12.5	16.5	15.1
U.S. AEROSPACE SALES: CIVIL SALES	8.6	12.2	6.7	5.4	4.7
PROPULSION R&D, MILLIONS OF DOLLARS	400	379	320	347	331
IR&D, MILLIONS OF DOLLARS	701	658	723	1057	1010
U.S. CIVIL AVIATION R&D: CIVIL SALES	0.17	0.23	0.14	0.17	0.16
VALUE ADDED/EMPLOYEE, MANUFACTURING, DOLLARS	7036	6517	7795	8819	
U.S. PLANES ON ORDER: FOREIGN PLANES ON ORDER	1.3		3.4		5.4
U.S. CIVIL AVIATION MFG. BALANCE OF TRADE, $ BILL.	0.89	0.81	0.83	1.30	1.77
NET FOREIGN AVIATION, BALANCE OF TRADE, $ BILL.			0.2		–0.1
EXPORT-IMPORT BANK FINANCING: EXPORTS		0.11		0.40	
REVENUE PASSENGER-MILES, PERCENT U.S.	54.8	55.2	55.7	58.2	58.6
REVENUE TON-MILES, PERCENT U.S.	53.7	54.7	58.9	64.0	64.1
VALUE ADDED/EMPLOYEE (CARRIERS), DOLLARS	11,710	13,100	14,000	14,100	
TON-MILE LOAD FACTOR - U.S. AIRLINES, PERCENT		49.2	50.3	50.9	46.7
- ALL ICAO AIRLINES, PERCENT	51.7	50.6	51.7	50.7	47.7
U.S. AIRLINES PROFITS: FOREIGN AIRLINES PROFITS	1.0	1.8	1.8	1.9	

[a] *All dollars expressed in constant 1968 dollars.*

An examination of these indicators reveals that two are trending downward – one military and one R&D measure. The ratio of the total U. S. aerospace sales to civil sales shows an approximate 40% decrease over the past ten years. Further examination of the elements making up the ratio shows that civil sales are gaining at a much more rapid rate than total aerospace sales even though both are growing in absolute terms. Since this trend reflects a strengthening of the civil sector, the decreasing ratio is viewed as a healthy sign with one caution. As civil sales increase the Government allowance for IR&D as a part of the overhead expenses may decrease. In a period of tight funds, the civil aviation manufacturers are more likely to channel funds into near term payoffs, such as development and production. These two factors together will defer research and technology projects that may influence long term profits and the U. S. position of leadership.

Propulsion R&D has dropped about 25% from 1961 through 1969. Since propulsion advances usually precede the development of new vehicles, propulsion R&D may provide an early glimpse of future market strength.

On the other hand, balance of trade, revenue passenger-miles, revenue ton-miles, value added per employee for both carriers and manufacturing, and IR&D reflect a highly favorable position with the present trends suggesting continued improvement. The large margin of U. S. leadership, however, should not encourage complacency. History shows that once the momentum of leadership is lost, it is likely to be significantly harder to recapture than to have retained it through consistent minor actions. While certain actions, such as increasing the level of financing by the Export-Import Bank, permitting greater flexibility in allowable expenses in military contracts for company sponsored research and development, and production techniques R&D, are expected to strengthen U. S. leadership in civil aviation, the indicators suggest that no immediate Government action seems necessary to prevent erosion of the U. S. position. It should be recognized, however, that the suggested indicators have not been tested for validity and their response to changing conditions may lag to the point that future leadership may be jeopardized before the indicators show significant change. It is recommended, therefore, that these leadership indicators be monitored on a continuous basis. The Department of Commerce is best equipped to develop, refine and monitor leadership indicators, and to inform the aviation community when several indicators point to an unfavorable trend.

It is important to recognize that maintaining leadership in civil aviation does not imply that it is necessary to have superiority in every area. It is necessary, however, to retain a capability to keep options open and to have full recognition of the consequences of a deliberate decision when it is decided to forego future markets.

In many ways, world leadership is a by-product of our domestic markets, or at least there is reason to believe that there is a very strong correlation between the strength of our domestic market and our position of leadership. In the future, for example, if the country were to develop an economically sound short-haul system, other countries would also find it attractive. Similarly, a quiet jet engine is as important to European countries as it is to the United States. In addition, if the United States aggressively moves to produce a balanced system of all the aviation elements, the rest of the free world will find this desirable as well. The key to U. S. leadership appears to be the ability to solve the problems in the domestic civil aviation system and to remove the constraints to its continued growth and advancement.

BENEFIT PROJECTIONS

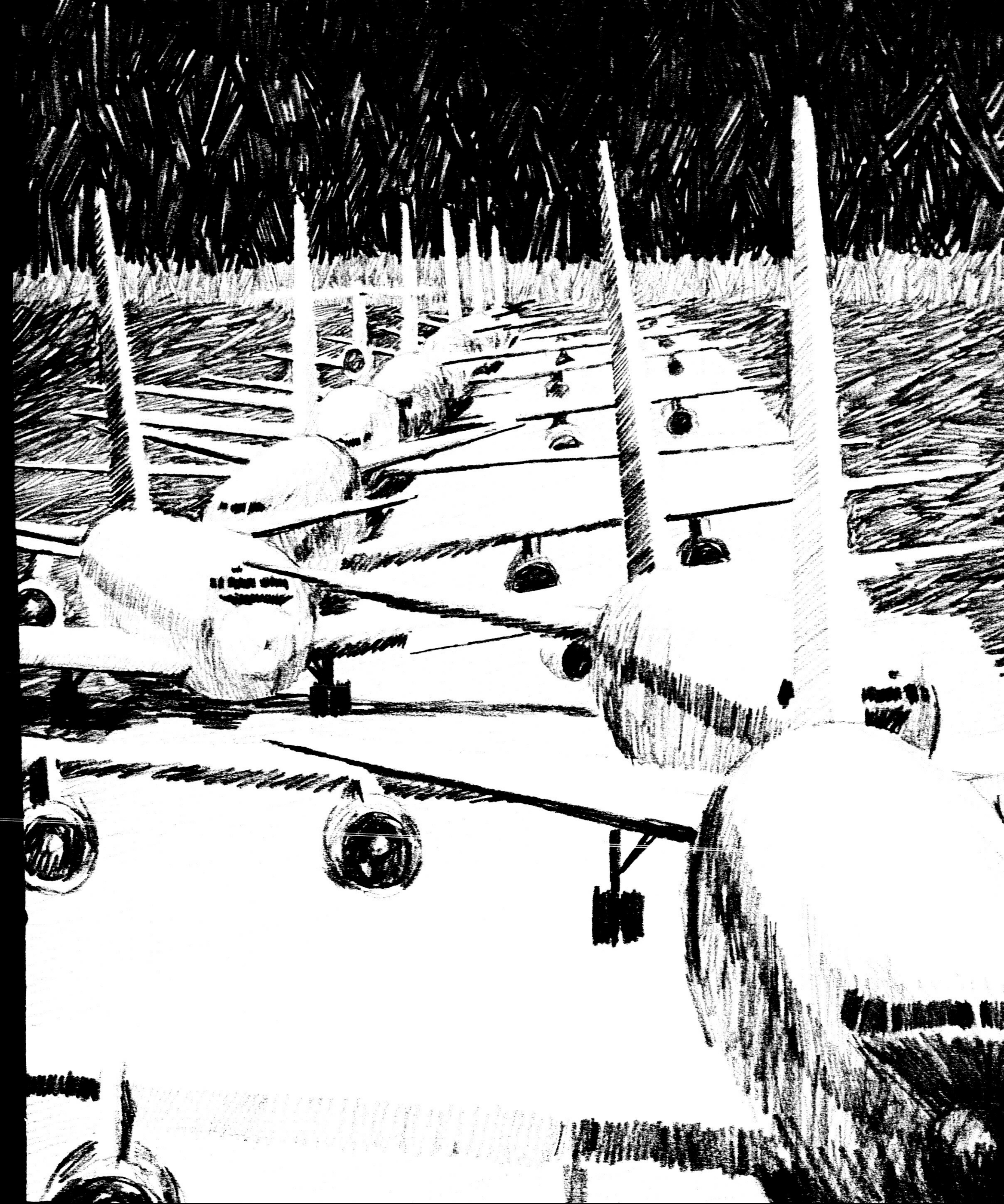
Turning from a historical treatment of civil aviation, one can examine the implications of forecasted growth in demand for air travel on the production and sale of large civil air transports and how they influence future benefits. The free world's air carrier fleet is projected to grow from 5,100 to 8,300 planes by 1985. Many existing technology aircraft will be phased out during this period, providing a large potential world market for U. S. aviation manufacturers, assuring a continuing stream of benefits to the users and the Nation. At the peak production in 1983, output would easily double over 1970 levels if the United States were to capture a conservative share of the projected market and would drop to one-fifth of its 1970 value if the United States were to *capture no new technology production*. The 15-year U. S. projected share of cumulative sales of new technology aircraft will total $34.5 billion with another $35.0 billion based on existing technology aircraft. These sales projections amount to a 5.7% annual increase compared to a historical growth rate of 9.5%.

Employment follows a similar trend to production. If the United States attains its share of both existing and new technology production by 1980, the direct and indirect average employment (transport manufacturing only) will be 296,000. This 4.7% annual increase compares with the recent historical growth ratio of 8.4%.

Projections for a U. S.- and foreign-shared market for the same period indicate that the total U. S. trade balance will be $21.8 billion. This reflects relatively unchanged civil aviation balance of trade from today's position due to a maturing of the market.

Many of the benefits just discussed are not new or unique to civil aviation. Other transportation forms – water, rail, and auto – have contributed similar benefits in years past. Civil aviation is building on these past achievements so people might enjoy a more enriched quality of life in the technical age of twentieth-century America.

5. OPERATING PROBLEMS



Operating Problems

While the growth and success of civil aviation have produced many benefits for the Nation and have established this country's current position of world leadership, the industry is also being confronted with a number of serious problems that are rapidly growing more severe. The relative importance of these problems depends in many ways on the viewpoint of the observer. For example, the general public is becoming increasingly aware of the problems of the environment and, for this reason, the public is most concerned with aviation's major pollutant – noise. The direct user of civil aviation is interested in the service he receives and thus to him a major concern is increasing airport congestion, both in the air and on the ground. The air carriers are concerned with congestion because of its impact on operating costs. Operators are also concerned with achieving profitable short-haul operations. These three problems – noise, terminal congestion, and low-density, short-haul economics – are the major ones confronting civil aviation today and warrant further examination.

ENVIRONMENT (NOISE)

STATEMENT OF PROBLEM

The impact of civil aviation on the environment is evident in the public concern regarding noise, air pollution, water pollution, esthetics, ecological disturbances, and meteorological changes. Of these effects, noise is judged to be the most important and presently a critical constraint to the future growth of civil aviation. This constraint is already manifested in the inability to site and construct new airports in locations required to meet demand and in the reduction of existing airport capacity by noise restrictions and operational limitations. With the increasing awareness and concern of the public with the environment and with the "quality of life," increasing resistance to aircraft operations can be expected at the very time these operations should increase significantly to meet the growing travel demand.

CAUSES

The principal causes of this problem are:

- Insufficient concern and action in designing the air transportation system to meet environmental considerations. Although noise has long been recognized as a problem for aviation, trade-offs in system design in favor of noise reduction were considered low priority compared to the traditional optimization factors of speed, payload, range, and operating cost.
- The inadequacy of the technology base in providing solutions to the problems of reducing the level of the noise generated, attenuating noise transmission and minimizing its impact on the environment. Noise-related research and development for civil aviation have been conducted sporadically over the last 50 years. The introduction of jet transports provided additional emphasis on noise-reduction technology. A considerable advance has been made in reducing the noise of commercial transport turbofan engines; however, technology is not yet available to provide the magnitude of reduction desired especially when economics are considered.
- The lack of long-range planning and effective zoning of land surrounding existing and proposed airports, which has resulted in the development around major airports of areas highly sensitive to noise and the disappearance of suitable sites for future airport expansion.

MAGNITUDE OF PROBLEM

- The high-noise area around the J. F. Kennedy Airport in New York includes 35,000 dwellings, 22 public schools, and several dozen churches and clubs. This area, plus that surrounding the Los Angeles and Chicago airports, estimated at 42,000 acres, is three times greater than all the land redeveloped during the 16 years of urban renewal at a cost of $5 billion dollars.

- The potential cost of damages from law suits with respect to the control of aircraft noise cannot be evaluated at this time with any confidence. However, in Los Angeles there are 34 law suits against the airport, and the Los Angeles Unified School District alone is seeking $95 million in damages.
- The reaction to noise has brought about a limitation on night operations at some airports, 11:00 p.m. to 7:00 a.m. at Washington National Airport, for example. This results in a 20% loss of capacity for these airports and is particularly important to the profitability of all-cargo planes where night operations are a distinct advantage.
- Several alternatives have been proposed for reducing the impact of aircraft noise on the community:
    - Retrofit of the current jet fleet by engine nacelle modification and acoustic lining to achieve a reduction of about 10 dB in approach noise. The cost may range from $0.5 billion to $1.2 billion depending on the extent of the retrofit and the classes of aircraft modified.
    - Establish buffer zones around existing large airports. The cost of acquiring noise easements from residents in high noise areas has been estimated at $9.4 billion.
- If the effect of noise caused an airport to be located 10 miles farther from the population area it served, the additional cost to travelers and employees could exceed $30 million annually for each major airport.
- Restrictions will limit supersonic flight over land areas because of the sonic boom. Overland operation requires a technological breakthrough to effectively eliminate the sonic boom.

CURRENT PROGRAMS

The current aircraft noise abatement program resulted largely from the efforts of the Jet Aircraft Noise Panel, an ad hoc group formed by the Office of Science and Technology in 1965. The recommendations of this panel[1] led to the introduction of legislation to provide specific FAA authority to regulate in the area of aircraft noise, and to the establishment of the Interagency Aircraft Noise Abatement Program under the leadership of DOT, and provided the stimulus for initiation of a number of key studies and R&D activities. These programs, federally sponsored with industry participation, cover all areas of noise research and promise important advances in further reducing noise levels. The programs often are small but productive (e.g., laboratory research to develop acoustical lining techniques for attenuating noise generated by engine turbomachinery). Some laboratory efforts have grown into flight demonstration programs such as the NASA acoustic nacelle project involving a 707 and a DC-8 flight demonstration of acoustic treatment technology. Other programs, for example, the NASA Quiet Engine and FAA's fan and compressor noise studies, will provide benefits in the development of specific design technology that will find applications in future engine component designs. To further assist in basic noise research, an acoustic test laboratory is being designed and built at the NASA Langley Research Center.

The support for these activities has been provided from funds of NASA, DOT, DOD, HUD, and HEW, supplemented by industry. Figure 5.1 shows the funding for FY 1969 through 1971 and the proposed budget for FY 1972. The NASA program on nacelle acoustic treatment with DC-8 and 707 aircraft accounted for the major part of the NASA expenditures in FY 1969, and was

[1] Alleviation of Jet Aircraft Noise Near Airports, March 1966, Office of Science and Technology.

completed in that time period. The FY 1970 program includes funding for the NASA Langley Acoustic Test Laboratory and the start of the NASA Quiet Engine Program. FY 1971 shows an increased expenditure in a number of areas.

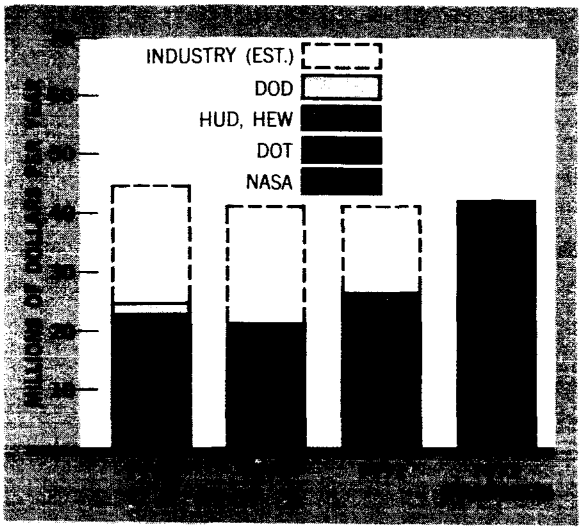


Figure 5.1. Funding for aircraft noise abatement.

The proposed FY 1972 program includes work directed toward reducing noise generation at the "source" (aircraft and engine design), optimizing procedures that can be used in controlling the aircraft "path" through steep descent and curved approaches, and work to minimize the impact on the "receiver," such as land-use planning and control. The programs of DOT and NASA proposed in FY 1972 include R&D on STOL technology, microwave instrument landing systems, and subsonic and supersonic transports. The translation of the proposed budget into appropriations at the levels submitted is considered vital to continued progress in this area.

Regulatory Actions

In 1968, the FAA received Congressional authority under Public Law 90-411 to establish standards for relief from present and future aircraft noise. In November 1969, the FAA issued the Part 36 noise rule, which was responsive to the Public Law in that it ensured in new-generation aircraft the maximum noise reduction that technology would permit within reasonable economic constraints. This rule has been adopted in concept as the basis for the International Civil Aviation Organization (ICAO) proposed noise rule.

New transport aircraft and all new subsonic turbojet aircraft must be certificated for noise as specified by Federal Air Regulation, Part 36, and shown in Figure 5.2. Also shown are the noise levels for representative aircraft of the current jet fleet. As can be seen, the noise of these aircraft is as much as 15 EPNdB higher than the levels now

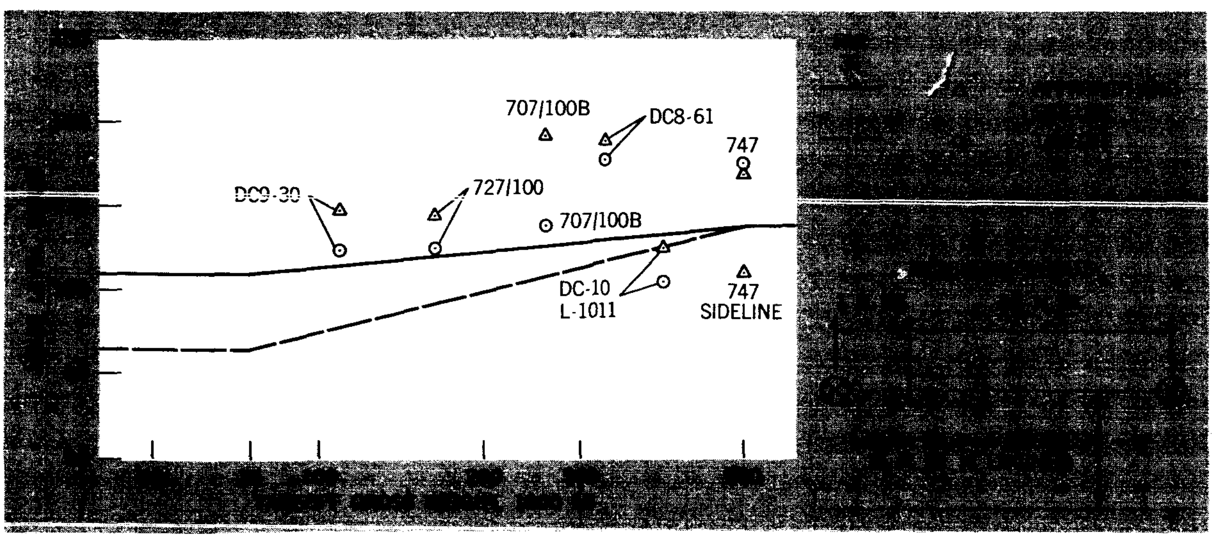


Figure 5.2. Noise levels of current aircraft.

set for approach and sideline noise, and as much as 10 EPNdB higher than the levels for takeoff. A retrofit engine nacelle modification has been tested that would significantly reduce the noise level of the 707 and DC-8 (JT3D engine), but would meet FAR 36 on approach only. The effectiveness of retrofit for other aircraft (727, 737, DC-9 using the JT8D engine) has not been tested. It is apparent, however, that a comparison of the costs and effectiveness of other approaches to noise reduction, such as steep decent and possible land acquisition, is necessary. Such a trade-off is shown in Figure 5.3. If engine noise is not reduced, it would cost roughly $17 billion to purchase the approximately 1300 square miles affected by noise levels of 30 Noise Exposure Factor (NEF) or greater. On the other hand, if engine noise could be reduced by 10 dB, the land exposed to 30 NEF or greater would cost an estimated $1.6 billion.

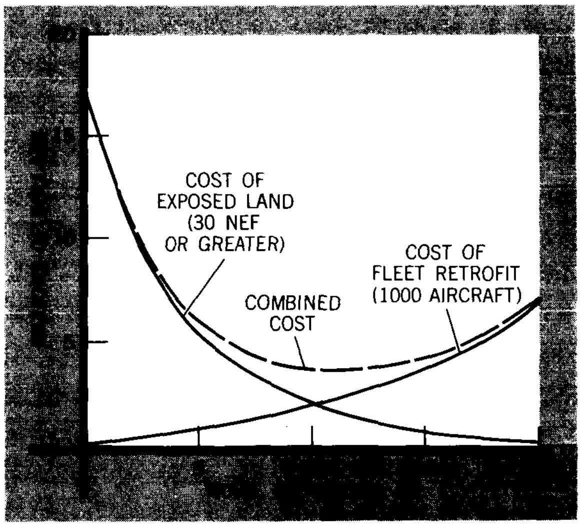


Figure 5.3. Cost of acquiring exposed land vs. retrofitting fleet (United States).

The evaluation must also include the performance and operating cost penalties of the retrofit aircraft, the expected life of the current fleet, the improvements to be gained from modified operational techniques (steep and curved approaches), and the anticipated future environmental requirements (the increasing sensitivity of the public to noise).

The noise technology developed by the aircraft and engine industry, particularly the high bypass ratio turbofan engine, has been applied successfully to the wide-body jets and significantly lower noise levels have been realized, as illustrated by the data on the DC-10 and L-1011 aircraft in Figure 5.2.

Current Policy

The current Government policy is to ensure that maximum noise-reduction techniques, consistent with the technological state of the art and reasonable economic constraints, are incorporated in future aircraft designs. The restriction will be the same for supersonic aircraft as for other aircraft. The Government's role is of necessity an aggressive one of pushing a continuing reduction of noise levels on a continuing time scale. The Government therefore finds itself in the position of sponsoring technological progress in an area where technological progress has not occurred voluntarily. This policy requires not only the establishment of acoustic standards but the promotion of the acoustic research necessary to meet these standards and to assure that the noise standards are established on a valid scientific basis.

RESEARCH AND REGULATORY GOALS

To meet the objective of acceptance of new air systems by the community and local government, and to avoid further constraints in the operation of existing systems in an era of increasing concern for the environment and the "quality of life," the most urgent need is to establish long-term research goals and regulatory standards, on a specific timetable, to attain operating noise levels that will be compatible with community and local environmental objectives.

Regulatory actions for aircraft noise abatement are governed by Public Law 90-411, which provides for applying *the results of research, development, testing, and evaluation* considering *whether any proposed regulation is economically* *reasonable, technologically practicable and appropriate.* It is important that these guidelines be projected into the future so commercial operators and manufacturers can plan future systems. It is recognized that realistic accomplishment will be a difficult task, one requiring maximum cooperation between industry and Government, and coordination with international authorities, such as ICAO. However, to delay the establishment of future regulatory goals on a time-phased basis would be to compound the current problem and severely limit the growth of commercial aviation.

Research goals should be established on the basis of the desired end result; that is, the achievement of noise levels permitting the introduction of new systems compatible with *future* environmental goals. This will require the acceptance of these systems by local communities so airports can be located, and suitable operations conducted, where they will satisfy the transportation needs in an optimum way.

At this time it appears that meeting the above criteria will require a combination of improved vehicle capability, more flexible operational procedures, and more effective land-use planning. The objectives should be aircraft operations in which the *observed noise levels, at or beyond the airport boundaries, are compatible with ambient or background levels for specified land use.* The bottom line on Figure 5.4 is the recommended maximum noise level of the aircraft perceived at the airport boundaries when operating in accordance with optimum approach and climb-out procedures; that is, 80 EPNdB for the smaller aircraft, including VTOL and STOL vehicles operating close to major activity centers, and 90 EPNdB for the larger aircraft operating at the more remote jetports. The measuring points should be at the airport boundaries with other monitoring points beyond the boundaries to make sure the background levels are not being exceeded. In the planning of future airports, where land, or land easements, may be acquired at reasonable cost, it may be possible to establish airport boundaries for this purpose several miles beyond the traditional runway and terminal area boundaries.

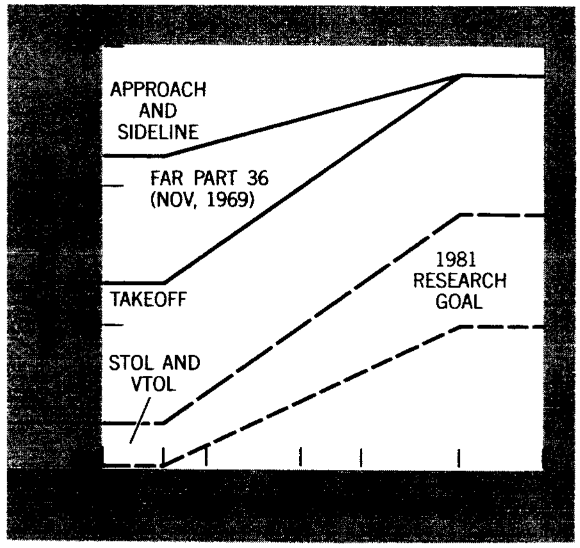


Figure 5.4. Proposed 1981 research goal.

Such ambitious research goals may be controversial, but failure to establish a low-level noise goal now could result in the use of scarce resources for R&D activities that may fail to provide the desired solution to the noise problem on a long-term basis.

The target time period to achieve the proposed research goal is dependent upon the resources made available, the effectiveness of the management of the R&D programs, and the actual rate of technological progress. A consensus of experts in the field indicates that, with appropriate funding, a reduction of about 10 dB from the current state of the art should be possible within 10 years. The upper dashed line on Figure 5.4 illustrates this objective. A more definitive evaluation of the noise-level requirements for compatibility and acceptance of new air systems should be possible as additional environmental data become available. For this reason, it is proposed that the area between the two lines be considered the broad-band objective for a 10-year research effort (i.e., the "1981 Research Goal").

Proposed regulatory standards should also be established, at least at 5-year intervals. It is important that the industry know what will be expected in 1976 and 1981 in order to proceed with confidence with new system designs. Evaluations of those standards must be projected into the future to determine the probable impact on the industry.

ACTIONS RECOMMENDED

The following actions are recommended to achieve the research goals and establish continuing future regulatory standards.

- Expand the current federally funded aircraft noise abatement program. The initial step would be a comprehensive 10-year Aircraft Noise Abatement Program Plan incorporating activities of DOT, NASA, HUD, HEW, and the Environmental Protection Agency. This plan should clearly delineate the roles and areas of responsibility of the participating agencies and require commitments from these agencies to support these activities with the appropriate resources, consistent with funding limitations. This plan should include:
  - Fundamental research on noise generation mechanisms and perception.
  - Concept definition of new vehicles, propulsion systems, and operational techniques to meet noise research goals.
  - Advanced development of vehicle and propulsion components and system demonstrations in a real environment.
  - Support of technology for traffic control and landing systems to accommodate new operating techniques.
  - Studies to define more effective methods of accomplishing long-range land-use planning, in conjunction with State and local authorities, to provide the needed sites for future airports. Strategies beneficial to the local community must be developed.
  - Compilation of a technical data base to evaluate future regulatory actions in noise abatement, taking into consideration economic, social, and environmental impacts.
- Establish monetary incentives that will encourage private industry to develop new concepts and techniques in noise reduction and control, and introduce new equipment implementing these concepts. These could include tax incentives, reduced landing and other operational fees, and loan guarantees or low-interest loans for new or retrofit equipment to meet future regulatory goals.
- Encourage personnel training and university programs in acoustics.

A DOT office to accomplish the above actions should be set up with staff drawn from NASA, DOD, and EPA. The nucleus for this office could be the participants in the current Interagency Aircraft Noise Abatement Program directed by the DOT's Office of Noise Abatement. The first objectives for this group should be:

- Agreement on 10-year research goals, such as recommended above, by the end of FY 71.
- Establishment of future regulatory goals, particularly for STOL and VTOL aircraft, projecting at least 5 to 10 years into the future. These goals should be established by the end of CY 71.
- Agreement on and approval by the NASA and EPA Administrators and DOT and DOD Secretaries, of a 10-year Aircraft Noise Abatement Program Plan. This should be completed in time for incorporation in FY 73 budget planning. The DOT–NASA funding in this area should be about $100 million per year to effectively carry out the objectives of this program.

If civil aviation is to meet the expected growth in demand for air transportation, a new approach to aircraft noise abatement is necessary. This approach must provide for research goals based not on what is technologically feasible but on what is needed to satisfy community environmental goals. These must then be implemented by coordinated action by all Government agencies, financial and program participation by industry, and concurrence by the affected public sector.

TERMINAL CONGESTION

STATEMENT OF PROBLEM

To the user of civil aviation, service is of prime concern. The tremendous growth of the commercial airlines and the user demand for services have produced serious congestion in and around airports – an undesirable by-product of success. Consequently, it is one of the key areas requiring concerted attention now if civil aviation is to meet the even greater demands forecast for the future.

Eliminating congestion in the Nation's major terminals can have great social value. Congestion at metropolitan airports indicates that the full economic potential is not being attained. Reduction of congestion will aid these metropolitan areas in meeting more fully the needs of both business and the public. In addition, with land becoming scarce and competition for remaining open space increasing, there is the need to utilize this resource more efficiently and intensively. Priority effort devoted to resolving the airport congestion problem offers the promise that civil aviation will be able to use existing airport land more effectively and to site new airports on fewer acres than at present. Attainment of these two goals will benefit the general public and will permit civil aviation to meet the demands of the users in the decades ahead.

Terminal congestion manifests itself in varying degrees at major airports in seven primary areas:

- Airport location, acquisition, and development
- Access/egress
- Parking
- Terminal processing
- Ground control of aircraft
- Runways
- Terminal area air traffic management

The extremely long time involved in acquiring and developing new airports prevents a rapid solution to the congestion problem. Since each of the remaining six elements can result in delay, the traveler or shipper must build time safety factors into access/egress, parking, and terminal processing, while the air carrier inflates his schedule to accommodate ground, runway, and air traffic control delays. The result is costly waste to the user, the air carrier, and the public. Delays in the air traffic control system alone indicate the costly effect of congestion. In 1969, vehicle delays cost the airlines an estimated $158 million in crews, fuel, and vehicle losses. More than 22 million passenger-hours were also lost in the process, accounting for another $90 million loss. In addition, 22 million pounds of air pollutants were emitted during these delays – an amount seven times in excess of all the aircraft pollution emitted in the heavily traveled New York to Washington, D.C., corridor. While an accurate aggregate measure of delay on the groundside of the terminal is not known, it would have cost the users an additional $375 million if the passengers affected by congestion in 1969 built as little as one additional hour into their schedule to accommodate unforeseen delays.

Today, four airports are subjected to restricted operations due to excessive congestion on the airside and landside of the terminal. The Report of the Air Traffic Control Advisory Committee estimates that the number of airports under restricted operations will grow to 20 to 30 by 1980 and 40 to 60 by 1995 unless the terminal congestion problem is improved substantially. If this forecast holds true, by 1980 approximate losses will amount to $610 million to the carriers,

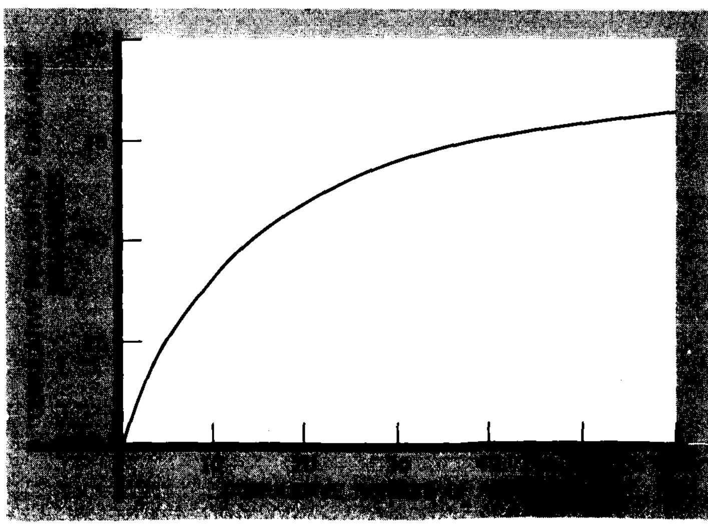
$370 million to the users on the airside plus an additional $1700 million on the landside. In addition, an emission of 86 million pounds of pollutants could be the product of the congestion induced by 600 million enplanements forecast for 1980. The present losses plus the prospect for even greater losses expected due to increased demand calls for a concerted effort to prevent the benefits of civil aviation from being seriously compromised.

Of the 817 airports certificated for air carrier service, congestion is confined to relatively few airports. Figure 5.5 shows that a small number of airports account for a very large share of the traffic. Today, 14 airports account for 50% of the enplanements, while 60 airports account for 85% of the enplanements. Therefore, a relatively few airports can profoundly affect the entire system. It is anticipated that future growth will develop proprotionately across all airports through 1980. If the 30 primary airports become congested and require restricted operations (as has been forecast), over 70% of the air passengers could be subjected to significant delays by 1980. Consequently, in the absence of concerted action over the next few years, the problem of congestion will approach staggering proportions.

One cause of congestion is the present fragmentation in responsibility and funding of the various elements comprising the terminal area. As Table 5.1 shows, no one group has sufficient authority or resources to create a more equitable balance among the systems elements. Mechanisms are needed to achieve a better balance between the funding and operational authorities. The present situation in which each group attempts to optimize one piece of the system without knowing the needs of the other elements is not tolerable. Alleviation of congestion can occur only if these problems are managed in a systematic way. Because of the large degree of fragmentation and the importance of civil aviation to the economy, it appears that only Government is capable of marshalling the forces necessary to produce a balanced system. Under current divisions of responsibility, the Federal Government would be the one to accept this leadership role; however, if the present approach of returning power to State and local governments prevails, these latter organizations might play a greater role in the future.

MAGNITUDE OF PROBLEM

Siting and construction time of airports is a major factor preventing congestion alleviation.



CUMULATIVE % OF PASSENGERS ENPLANED[a]	CUMULATIVE NUMBER OF AIRPORTS	NAME OF AIRPORT
8.1	1	O'HARE
14.2	2	LA INT'L
18.9	3	JFK
23.5	4	ATLANTA
27.1	5	S.F. INT'L
30.7	6	LA GUARDIA
33.8	7	LOVE FIELD
35.9	8	NATIONAL
39.7	9	MIAMI
42.5	10	BOSTON
49.0	13	
51.1	14	
67.0	25	
71.3	30	
77.2	40	
81.5	50	
84.5	60	

[a]*Enplaned passengers, all services total system operations, U. S. certificated route air carriers (excluding helicopters); 12 months ended June 30, 1969.*

Figure 5.5. Passenger enplanements at major airports.

TABLE 5.1. ELEMENTS COMPRISING THE TERMINAL AREA

	AUTHORITY				FUNDING SOURCE						
	FAA	CAB	AIRLINES	AIRPORT OPERATORS/LOCAL GOVT.	AIRPORT TRUST FUNDS	HIGHWAY TRUST FUNDS	UMTA	AIRLINES	FAA	HUD/DOD/EDA	BONDS AND LOCAL TAXES
AIRPORT LOCATION & DEVELOPMENT	X			X	X					X	X
ACCESS/EGRESS				X		X	X				X
PARKING				X	X[a]						X
TERMINAL PROCESSING		X	X	X				X			X
GROUND CONTROL OF AIRCRAFT	X		X	X	X			X	X		X
RUNWAYS	X			X	X						X
AIR TRAFFIC MANAGEMENT	X				X				X		

[a]*Funds for parking come indirectly from the Trust Fund through grants in land purchases.*

Ten years or longer are required to develop major airports as compared to the introduction of a new vehicle, which averages four years. Sixty-two new air-carrier airports are required by 1980 to meet expected demand while many of the existing major airports must undergo extensive expansion programs as well. More than $5 billion is required to meet these construction demands.

The amount of airport land initially purchased acts somewhat as a limiting factor in that additional land required to meet new demand is often difficult to acquire. The problem is compounded in two respects – new airports are requiring more and more land and the competition for land is forcing prices up significantly. Figure 5.6 shows the decided trend towards larger land parcels for airports. The new Toronto Airport acquired 84,000 acres – a feat difficult to duplicate in the United States in those hubs where the traffic might justify such a large acquisition. The capriciousness of local zoning ordinances causes the airport operator to seek even larger amounts of land to assure an adequate buffer zone to minimize incompatible unforeseen future uses of the land bordering an airport.

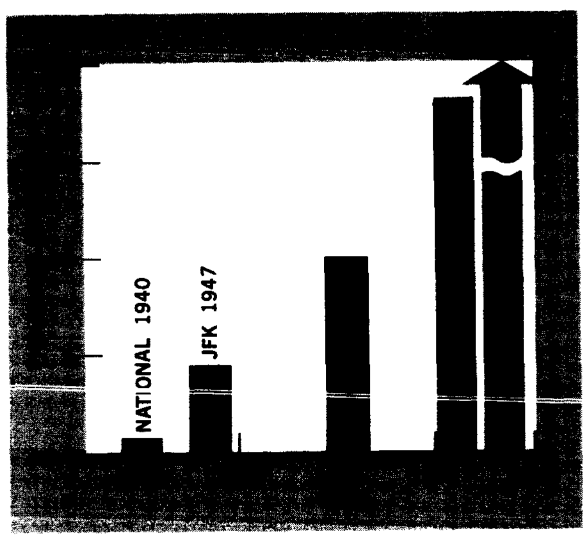


Figure 5.6. Airport size vs. year of dedication.

Despite public opposition to the noise generated by aircraft operations, land tends to increase in value around airports due to its desirability as a focus for business activity. Land costs alone can amount to $500 million for a 20,000-acre plot as acreage approaches $25,000 per acre (Fig. 5.7), while land values around the busiest airports are typically $50,000-$100,000 per acre and more.

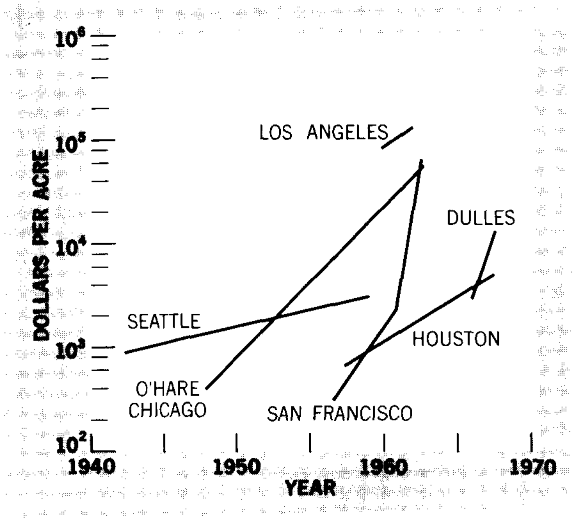


Figure 5.7. Increase in land value around U.S. airports.

Because aircraft noise is such an undesirable aspect of aviation, airports are often located far away from the points of natural demand. Noise also tends to cause airport authorities to seek one large site suitable for all types of traffic rather than to develop smaller specialized airports – the feeling being that it is easier to establish one large noise generator rather than several smaller ones.

Institutional factors are a primary cause impeding solution. The Federal Government has had little impact on airport siting. The Airport and Airway Development Act contains the provision for early land acquisition, but airport "land banking" is of low priority. The concept of "land banking" is not new, as early acquisition of park lands has been a Government practice for years. Some form of Government support seems essential to the long-term solution of congestion since the airport developer is unable to put up the money for land that will not be used for some time even though it is recognized that later acquisition will be much more costly or even impossible. Airport development is also slow since multiple jurisdictions must participate – a difficult situation to manage even in the most favorable circumstances.

Access links to the airport are a prime cause of airport congestion. Major hubs today generate 17,000 passenger movements in and out of airports per day. Coupled with another 17,000 visitors and 10,000 airport employees per day, very heavy loads can be imposed, particularly at peak rush hours when workman, traveler, and visitor all compete for the roadways. Consequently, the traveler must build large time safety factors into his schedule because of the uncertainties of road congestion.

While public transportation to the airport offers the promise of concentrating many people in fewer vehicles, it has not been a widely accepted form of travel. A recent survey of auto traffic at JFK, Los Angeles, San Francisco, and Washington National revealed that 73-85% of the people arriving at and departing from these airports do so by private car and taxi. In the absence of a suitable alternative, future prospects indicate a steadily deteriorating situation. As a result, Los Angeles faces the difficult prospect of creating facilities to handle 80 million people per year by 1975, with a highway capacity for only one-half that number.

Funding differences help influence access choices as well. The Highway Trust Fund can provide up to 90% of the revenue for interstate roadways and up to 50% for access roadways. UMTA general funds offer up to 67% Federal support.

Closely associated with access/egress is parking congestion. The large influx of traffic requires a significant amount of valuable land devoted to parking. Airport authorities are reluctant to discourage airport parking, despite the congestion it produces, since it is a substantial source of revenue. For example, in 1970, Washington National Airport received $5.1 million in parking revenues as compared to $2.3 million in landing fees. The parking and congestion problem is aggravated by the fact that about 50% of the people entering the airport are visitors.

Other policies also lead to congestion. At JFK airport, additional bus service has been denied and an American Airlines proposal for a garage to service its patrons has been refused. Whatever the reasons, such denials do not lead to congestion relief.

Within the terminal area itself, the passenger must move through a series of loosely integrated processes – ticketing, baggage, movement to the gate, seat selection, and boarding. This requires a number of airline personnel to process the patron onto his plane. Not only are these steps time-consuming to the traveler, but costly to the airline, since it costs up to $15 to get a passenger boarded. This is a fruitful area for future R&D.

Passenger and cargo processing steps lack balance. Delays often occur at the interfaces between the systems elements, which lengthen the door-to-door trip time. Many of the delays experienced in cargo-handling are due to regulatory barriers, different documentation practices, and lack of intermodal standardization of such things as cargo continers. Lack of standardization in handling baggage of travelers also results in poorer service to the patron and greater operating cost to the airlines, as the carriers are not taking full advantage of the economy of scale that standardization can offer. The terminal area is one of the most visible parts of the aviation system to the traveler – it is believed that balancing the many processing steps in the terminal will stimulate even greater use of air travel when improvements in passenger-handling efficiency become evident to the patron of the system.

Present baggage and cargo management practices on the ramp also contribute to congestion. In 1969, about 70% of the cargo capacity of U. S. airlines went unused. The 30% that was used contributed 15% of the airlines' total revenue. As wide-body jets increase in number and belly capacities correspondingly increase, there will be even greater pressure to utilize this unused capacity. Cargo-carrying surface vehicles and handling equipment will contribute to more and more congestion at the loading ramp as cargo capacities are utilized, accentuating the need for greater automation.

Control of a number of aircraft simultaneously moving across many ground intersections is now performed manually and visually. Aircraft control along taxiways can be a major task similar to the traffic problem of a small city. Repeated stops and starts necessitate restricting the speed of the aircraft to assure that adequate and safe control is maintained. This contributes to ground congestion delays. Operational practice also dictates that aircraft, once loaded, must taxi out to the runway and line up with engines running. This practice creates unnecessary noise and air pollution in addition to increasing operating costs.

Gate selections are not optimized, particularly for connecting flights, causing extra baggage handling and difficulty in people movement. Dynamic gate allocation schemes might provide better utilization from existing gates, permitting people and baggage to move shorter distances.

One of the most critical points of congestion at the airport is the runway, the main factor in determining the number of operations an airport can sustain. The 5000-foot spacing of runways for simultaneous approaches under Instrument Flight Rules (IFR) on parallel runways, which is due to safety and control requirements, does a great deal towards limiting airports from developing additional capacity. As land surrounding airports develops intensively, it becomes extremely expensive for the operator to purchase additional land. The question then becomes one of how to utilize existing land more efficiently by spacing runways closer together to reduce congestion. Close runway spacing requires more accurate approach and landing control techniques and better methods of detecting and dissipating wake turbulence. In addition, maximum utilization of runways will not be possible until aircraft are able to take off and land in all-weather conditions.

At the present time, landing fees are based on weight. This formula supports the hypothesis that a 2:00 a.m. landing has the same value as a 5:00 p.m. landing to the user and the air carrier. The patterns of travel are such that the user prefers access to the system at the two times a day that coincide with peak-hour surface travel of the working force. Consequently, the two reinforce each other to produce even greater congestion on the entire air system, including the runways. One desirable goal towards congestion alleviation would be to explore ways to equalize the load on the system throughout the day.

Of all the elements contributing to terminal congestion, the air traffic control problem is the best understood. Still, ATC capacity (enroute and airport) will not catch up with expected total operations until 1980. However, since the need for *control service* is increasing at an even faster rate than *total operations*, projections indicate that sufficient capacity will not be available until about the year 2000. This is caused by the need to provide service to aircraft under both Instrument and Visual Flight Rules in the high-density areas.

The technical challenge then becomes one of how to efficiently meter and space aircraft, creating sufficient capacity to meet demand. The varying performance characteristics and pilot proficiency on commercial, private, and military aircraft further compound the problem. Grouping of like-performance aircraft for landing and takeoff may be preferable to mixing slow and fast aircraft on a random basis. The large growth forecast for general aviation aircraft and the increased trend towards IFR will place even more serious loads on the system, causing more airports to adopt operation restrictions. The enormous penalties that will be inflicted on the air carrier, the user, and the affected regions suggest that the highest priority be given to increasing capacity to meet demand.

Improvement of air traffic control is of particular concern since the Federal Government is both operator and regulator. The expected demand cannot continue to be met by simply adding more people and reducing the size of control sectors. If this trend is allowed to continue, it will cost the Government at least an additional $0.5 billion per year by 1980. Therefore, an investment in R&D is essential so new technologies and automation methods can be explored. This R&D effort will help keep the Government's net outlay at the minimum and help keep the service sufficient to meet the needs of the users.

Certain present R&D programs offer the promise of reducing some of the points of congestion noted. The Cleveland-Hopkins Airport rapid rail link to the airport is an example of access/egress effort under way. Automatic ticketing, automated baggage handling, UMTA people movers, seat selection, and boarding systems experiments have also been demonstrated. There has also been some experimentation with time-variable landing fees for general aviation aircraft and off-site terminal processing. On the airside, R&D efforts have explored runway design with attention to high-speed turnoffs, aircraft ground traffic management, and more precise Instrument Landing Systems (ILS) such as the microwave system to permit closer runway spacing. Other R&D efforts under way that will have significant influence on congestion elimination include the DOT and NASA noise programs and STOL efforts. These two efforts offer the potential of using existing land more effectively and making aviation a better neighbor, thus making it possible to break the log-jam on airport development.

KEY ACTIONS

The multifaceted nature of congestion is such that many changes will have to be initiated if the problem is to be solved. This requires a combination of technological, institutional, and organizational changes.

Because of insufficient data on some of the problem areas causing congestion, selected demonstrations are recommended so that systems choices and their alternatives can be more clearly understood. The Federal airports (including NAFEC and Edwards AFB) and, if needed, several commercial airports should be designated demonstration airports as sites for both market and operational experiments. Such experiments would also be useful in providing data related to the FAA criteria for certification of new airports. Some recommended experiments include:

- Off-site passenger and cargo processing
- Integrated passenger processing
- Runway/taxiway design and ground control of aircraft
- Premium-rate landing fees for prime time at congested airports to level traffic load

Decentralized passenger and cargo processing centers with rapid access links to the airport offer the promise of reducing congestion at the air terminal. Since more than 50% of the people at terminals today are visitors, this demonstration experiment could generate data showing the effect on airport congestion, door-to-door time savings, relative costs of operation, and public acceptance. The off-site airport operator-owned processing centers would experiment with integrated parking, ticketing, and baggage handling, as well as seat selection techniques to guarantee the patron a seat on his flight. These sites should also be easier to purchase than the large blocks of land required to contain all the services at the airport. The land saved at the airport could then be utilized more intensively for airside activities.

Edwards AFB could be effectively utilized to demonstrate the operational feasibility of runway/taxiway layouts and automated ground control of aircraft. New configurations could be inexpensively and quickly painted on the desert floor and tried with a minimum of effort. Once perfected, the experiment could be moved to NAFEC for further validation and eventually to a full operational trial at an operating airport.

Little data are available on the effect of altering landing fees and fares to correspond to levels of demand throughout the day. A surcharge might be levied on landing fees, tickets, or both to determine if there were better techniques than the present ones to gain greater utilization of an airport throughout the entire day. There are proponents on both sides of this proposal, but neither side has satisfactory proof supporting its point of view, lending further weight to the need for such a trial. Vehicle development has utilized numerous demonstration techniques from wind tunnels, proof-of-concept, to demonstrations in a "live" environment. Consequently, their trade-offs are generally well known. Airports have not taken full advantage of such a test approach. Thus, a lack of accurate data has impeded innovations designed to relieve congestion in and around the terminal area.

Inasmuch as runway capacity is one of the key factors in terminal congestion, it is recommended that the Government increase its share of funding for airport grants from 50% to a level at least comparable with other large-scale Federal construction projects (67%) and increase the overall level of airport grants for runway expansion. With the passage of the proposed Special Revenue Sharing Program for Transportation, the responsibility for funding these areas will be shifted to State and local governments.

Projected demand may continue to outpace system capacity for years to come unless there is concerted Government action. A careful assessment of the relative merits of new concepts of ATC and the related technology alternatives is required on a continuing basis to assure the upgrading of the airways system as rapidly as resources and technology will permit. This continuing assessment would minimize the possibility of making too large an investment in capital improvements that would be prematurely obsolescent and, at the same time, guard against overoptimism about time-availability of new technology. In the past, increases in both safety and capacity have been achieved largely by adding controllers and supporting facilities to match increases in traffic volume. In the future, additional safety and capacity must be accompanied by increases in productivity of the ATC system which would provide a potentially significant benefit to the Government and to the users in terms of reduced operating costs. Furthermore, it is urged that special emphasis be placed on R&D related to closer spacing of runways, and all-weather landing and ground control.

Since general aviation, the principal user of the airspace, will continue to grow at a rapid pace, safety and better control in crowded airspace is essential to facilitate flow and reduce congestion. It is recommended, therefore, that a four-step program be initiated leading to a fully cooperative air traffic control system. The Federal Government should perform the necessary R&D to develop the standards required of avionics manufacturers by the end of 1972. By the end of 1973, all *newly* manufactured aircraft should be equipped with a cooperative device manufactured to Government standards. By 1980, all aircraft flying in the areas of the *30 primary hubs* should be required to have such a device and by 1985 *all users* in the system should meet this specification. Certain special categories of general aviation aircraft, such as crop dusters, could be exempted from this requirement at the discretion of the FAA Administrator. Many general aviation users have voluntarily purchased transponders (about 40,000), and the rate of acceptance is increasing. However, this proposed regulation is believed essential to bring the entire system up to a capability which will permit greater automation and eventual retirement of the costly primary radar system.

For the long term, a totally different approach to congestion elimination is required. The potential level of demand cannot be served with the existing air system. Moreover, the use of large aircraft and expected improvements in airports for conventional take-off and landing (CTOL) aircraft and the air traffic system will provide the capability to service only some of the anticipated demand. Additional facilities will be required in these congested areas. It is doubtful that the new CTOL facilities could be established in sufficient quantity to reduce the congestion to satisfy the potential increased demand. An alternative is to separate the short-haul system from the long-haul system. This would unload CTOL facilities by providing much smaller, less expensive facilities closer to the demand for short-haul service.

The challenge is to utilize existing airports more effectively, eventually developing smaller specialized facilities at other locations. For this effort, STOL, VTOL, or V/STOL type vehicles for *high-density markets* are all potential candidates. The ability to climb and descend at steep angles at existing airports also will reduce noise outside the airport and should receive community endorsement. Coupled with concerted quiet-engine development, it is anticipated that the public will find the system environmentally acceptable and will then permit establishment of close-in "STOLports."

It is, therefore, recommended that a short-haul system definition study for high-density markets be initiated by an aviation capacity office under the auspices of DOT and staffed by FAA, NASA, DOD, and HUD. This office, in concert with industry and local governments, also will be responsible for development of a long-range short-haul system implementation plan including provision for interfaces with ground transportation systems. The vehicle technology should be advanced to the point of reasonable risk development by industry through an experimental flight test program. Concurrently, the ATC system should be modified to take full advantage of steep-descent, curved-approach capability at existing facilities and new "STOLports." The Government should also provide incentives for the modification and use of selected existing airports for experimental short-haul operations.

This program office would be given responsibility to plan, measure, and control activities related to terminal congestion, and to insure integrated action and the best use of available resources. One of the tasks the systems capacity office should undertake is the establishment of techniques and indicators of congestion (delay) in each of the systems elements. These indicators should be used to determine where the next incremental change is required at a particular airport to bring it into reasonable balance. It is only through such continuous monitoring by the Federal Government that all of the many parties responsible for different systems elements can be made to act in concert. The great disparity in R&D expenditures between airside problems and landside problems (17:1 in FY 1970) underscores the need for a single organization responsible for insuring that corrective action is taken with respect to all aspects of congestion.

An organized effort to resolve the combination of problems constituting congestion will require increased funding. One source would be extension of the Airport and Airway Development Act of 1970 to the airport landside to the boundaries of the airport. This extension would be consistent with the user payment of taxes to provide improved transportation rather than just to improve selected elements of the system. In view of the very large acreage requirements associated with modern airports, greater emphasis should be given to early purchase of land and the establishment of airport land banks.

Today, the various transportation modes generally do not work together effectively to develop a balanced area transportation system. As an example, substantial Government funds have been allocated to mass transportation projects such as BART and the D. C. Metro, yet initial plans do not encompass links to the local airports. To facilitate this integration of modes, the Secretary of Transportation should precondition the release of the Trust Funds and UMTA general funds on adequate plans being demonstrated for access links to the airport. In addition, DOT should undertake a special effort to encourage the establishment of unified state transportation agencies to promote a better balance between modes.

R&D is required in many areas to solve the congestion problem. Over the next ten years, it is estimated that a yearly average Government R&D expenditure of $20 million is required to solve the congestion problem of the airport and $80 million to address that portion of the air traffic control system, navigation, and weather R&D that affects the airspace adjacent to the airport. In addition, a $100 million per year R&D expenditure by Government and industry is required for a STOL vehicle for high-density congested areas. It is only through a concerted effort of approximately $200 million per year in R&D in all of these areas that congestion will be eliminated, allowing civil aviation to grow and meet the needs of the Nation over the coming decades.

LOW-DENSITY, SHORT-HAUL ECONOMICS

INTRODUCTION

The preceding sections address two major problem areas currently facing civil aviation that could seriously constrain its future growth and effectiveness. This section addresses a third area – low-density, short-haul service. While the problems of this service may not be as severe as noise and congestion, civil aviation does encounter several significant difficulties in providing commercial service to cities having relatively few passengers per day and a route structure with short stage lengths. With relatively few passengers per station, it is difficult to support the indirect costs of maintaining ground facilities. With few boardings at each stop, the passenger revenues do not compensate sufficiently for the costs of takeoff, landing, and servicing. Statistics show that the cost of boarding each passenger is between about $4 and $15 depending on the airline and the type of service. These costs must be borne by the revenues from fares and although there is some correction for shorter trip lengths, fares are geared directly to the distance the passenger is carried. All of these factors make it difficult for the airlines to match expenses with fares in low-density, short-haul service. In addition, the short stage lengths result in poorer utilization of equipment and higher operating costs due to relatively more takeoffs and landings than for operations over long stage lengths. Short-haul service is also subject to severe peaking of demand near morning and evening prime times which further complicates utilization of equipment. Most of the equipment used is not satisfactory, being either old, designed primarily for long-haul service, or constrained in capacity and performance by the certification limit of 12,500 pounds gross takeoff weight. This limit affects the aircraft certification standards, and aircraft weighing less than this limit can be operated by the airlines without route certification. In low-density, short-haul service the airlines can not make effective use of large modern jet transports. It is the increased productivity of these new aircraft that has helped permit the trunk carriers to compensate for increased labor costs, an advantage mostly lost to local carriers. Progress toward the solution of these problems will assist in improving the economics of this service of civil aviation and could result in a reduced need for Federal expenditures since the local carriers are the only airlines still receiving subsidies. It is also true that low-density, short-haul service represents a market for future growth of civil aviation if it can be made economically more attractive. Most important of all, this service of civil aviation represents a positive tool for future use in regional development.

The type of air service of interest has many different characteristics. It includes the small commuter airlines and portions of the local service/regional carrier operations, wherein one end of the short-haul trip is a low-density (relatively low demand) terminal. High-density, short-haul operations (such as in the Northeast Corridor – Washington – New York, New York – Boston) also have difficulty in achieving profitable operations. A primary cause is airport and airway congestion, which results in a substantial portion of the trip time being unproductive. This problem was discussed in the previous section, and its alleviation will benefit all segments of air transport, including the low-density, short-haul operations.

RELATIVE OPERATING ECONOMICS

With today's aircraft, sharp increases in unit operating costs are experienced at the shorter trip distances (generally less than 200 miles). As suggested earlier, this characteristic affects all operators, but the trunk airlines can better offset the higher relative costs of the shorter trips with the proceeds from some of their more profitable longer routes. Fares for short trips have not been increased to a level that would meet or exceed operating costs because of the belief that the gain due to higher fares would be offset by losses in patronage, resulting from competition from other modes.

Data defining the economic difficulties of short-haul operations are not readily available, although some indications can be obtained by

TABLE 5.2. COMPARATIVE OPERATING STATISTICS, 1969

ELEMENT	LOCAL SERVICE/ REGIONAL	DOMESTIC TRUNK
AVERAGE PASSENGER TRIP LENGTH, MILES	273	769
AVERAGE STAGE LENGTH, MILES	145	505
AVERAGE NUMBER STAGES PER TRIP	1.9	1.5
AVERAGE SEATS PER AIRCRAFT	64.9	107
TOTAL OPERATING COST, CENTS/ REVENUE PASSENGER-MILE	9.96	6.11
TOTAL REVENUES, CENTS/REVENUE PASSENGER-MILE	9.70	6.44
COMMERCIAL REVENUES	9.13	6.44
FEDERAL SUBSIDIES	0.57	–

TABLE 5.3. INDIRECT OPERATING COST COMPARISON, 1969

OPERATION	CENTS PER REVENUE PASSENGER MILE		DOLLARS PER REVENUE PASSENGER	
	LOCALS	TRUNKS	LOCALS	TRUNKS
PASSENGER SERVICE	0.61	0.63	1.67	4.81
AIRCRAFT AND TRAFFIC SERVICING	2.29	1.08	6.24	8.31
PROMOTION AND SALES	0.92	0.73	2.52	5.64
ADMINISTRATIVE	0.54	0.26	1.48	2.03
TOTAL	4.36	2.70	11.90	20.80

comparing the experiences of local service/regional carriers with those of the trunk lines. A comparison of trip distances and costs between the local service and trunk lines is shown in Tables 5.2 and 5.3. These data are for 1969, a year in which the local service/regional carriers generated 6.3 billion revenue passenger-miles. The corresponding revenue (Table 5.2) was $612 million, of which $36 million was provided by subsidies. In 1969, the nine local carriers lost $62.9 million even after subsidy payments.

The data in Tables 5.2 and 5.3 show some interesting comparisons between the local/regional and domestic trunk carriers. There is almost a 3-to-1 difference in passenger trip length and the average passenger trip involves more stops for the local carriers. This difference and all of the factors discussed earlier result in the local carriers having a negative margin between revenue and costs whereas for the trunk carriers it is postive. The table of indirect operating costs shows that the local carriers do well at holding these costs at reasonable levels when they are viewed as costs per passenger; however, the shorter passenger trips result in higher costs per passenger-mile and thus a reduced ability to compensate for the indirect costs.

CURRENT ACTIONS

Attempts to alleviate some of the economic problems are reflected in recent actions such as the family of CAB decisions to provide "route strengthening" through the award of longer and more profitable routes to the local carriers, to change the fare structure, and to approve requests by the local carriers to drop service on some of their unprofitable routes.

The recent rapid growth of the air taxi and commuter airline industry reflects a trend toward the third-level carrier taking over some of the local-service airlines' short, low-density routes. These carriers, however, are restricted to operating aircraft of less than 12,500 pounds gross weight unless specifically authorized by the CAB. The CAB is investigating the liberalization of this restriction.

ADDITIONAL ACTIONS REQUIRED

Market Demonstration. Many fare and route analyses are based on market elasticities that are not accurately known. Few controlled experiments have been conducted to obtain the required data. In some cases, the market has responded to changes in service in ways the operators did not expect. A good example is Allegheny Airlines' experience when they contracted the operation of some of their low-density feeder lines to third-level carriers. The use of smaller aircraft permitted increases in frequency that stimulated significant increases in market activity. To provide better data for future market decisions, CAB, in conjunction with DOT, should select a specific region(s) of the country to conduct a carefully designed demonstration of the impact on low-density (feeder, local service) short-haul air operations of variations in fare, route structure, frequency of service, and equipment used. Fares, routes, and frequencies would be varied to determine resultant market elasticity (i.e., the demand variation with changes in the above factors). To allow a wide range of experimentation, the carriers involved would be temporarily subsidized by the Federal Government and possibly by State and local governments whose participation and support should be sought on the basis of the regional benefits possible from improved service. In fact, part of the criteria for selection of a given region might be based on the support State and local governments would provide to such a demonstration. Such a demonstration would:

- Obtain market elasticity data to assist in determining fare and service levels for economical operation.
- Provide operational data that would assist in defining economic, physical, and operating characteristics of new systems for low-density air operation.
- Provide data to assist in formulation of regulations and indicate possible areas of deregulation.

Vehicle Concepts. At present there is no aircraft well suited to the low-density, short-haul market. Operators make use of older, modified aircraft or jets designed for operations in regions of higher passenger densities. Much of the equipment is too large and is designed for ranges exceeding current use. To seek better and more economical equipment, the Government should fund studies for conceptual design and analysis of low-density, short-haul aircraft. Such a study would:

- Include gathering of market and operational data and the conceptual design of vehicles to serve the low-density markets economically.
- Provide information for possible development programs that could be initiated by manufacturers.
- Provide "seed" money that, coupled with the planned regulatory demonstrations discussed above, could provide incentive for manufacturers/operators to place increased emphasis on short-haul, low-density markets.

Funding Levels. For the market demonstrations, funding on the order of $1 million for the first year would be required to plan and organize the demonstration. Funding for future years would be on the order of $10 to $15 million per year (based on the assumptions that (1) a 4 to 5% sample size of local service operations would be involved in the demonstration and (2) the added expense for the experiment would approximate 50% of normal total operating expenses). At least five years of funding should be planned to allow steady-state experimentation and to provide for recovery from early experimentaion variation. (For example, if a large reduction in demand would result after a period of experimentation on a given route, it might require a long period to rebuild the demand to its original point.)

For the vehicle concepts effort, the vehicle R&T funding in this area is not large because much of the technology already exists. The major emphasis should be in the material and structures area to provide material and manufacturing techniques to reduce the cost of the aircraft. It is estimated that the vehicle conceptual analysis would amount to about $2 million per year and the structures and materials R&T would be about $5 million per year.

FUTURE BENEFITS

Federal Government policy has been one of continuous support for low-density air operations. These operations are the only ones still being subsidized; the total cost has been more than $1 billion through 1970 (to local-serivce carriers including those in Hawaii and Alaska). This policy has been based on the recognition of the significant benefits such service can provide to less densely populated communities throughout the country. The future potential for such service as a tool for regional development is such that current emphasis on this "neglected" segment of air transport is warranted. Judicious use of "subsidies" to support the actions recommended above could result in the reduction or elimination of future subsidy requirements while providing impetus to the low-density, short-haul segment of air transport.

6. INSTITUTIONAL CONSTRAINTS

Institutional Constraints

The areas of noise, congestion, and low-density, short-haul economics are clear manifestations of the current operating problems of the civil aviation system. They represent priority areas for future R&D activities. In many cases, however, progress toward solving these and other problems has not been as rapid as might be desired. This situation reflects the institutional constraints that impede the application of R&D results and directly affect the operations and growth of civil aviation. As discussed in the section on Policy Development, the Government has undertaken diverse activities in civil aviation that include regulation, subsidization, R&D, and operation. Thus, it has been extensively involved in creating the existing system and the institutional framework within which it operates. For this reason, Government must accept a role in removing any institutional constraints inhibiting civil aviation's growth. It is appropriate, therefore, to examine institutional constraints and their relation to the problems of civil aviation in order to set the stage for recommended policy actions and specific programs.

RELEVANCE

In the Joint Study, the institutional constraints considered important to the future of civil aviation are:

- *Regulatory and legal:* Most of the current regulations and laws governing civil aviation are at least 10 years old and many are more than 30. Most were designed to protect civil aviation in its early years; however, many now have the effect of either constraining competition or otherwise eliminating the incentive for innovation.
- *Market and financial:* In a free-enterprise system, industry is normally motivated by a search for profit. For many present needs of civil aviation (e.g., noise alleviation and improved ATC), this motivation is missing. In other cases, the possibilities for profit are unsure or distant, as is the introduction of an entirely new transportation system (e.g., a STOL system). In other cases, a profit potential may exist but for one reason or another, industry does not have the necessary resources to produce the desired product. In these latter cases, market or financial considerations constrain private industry from satisfying recognized needs.
- *Attitudinal and social:* In recent years, public attitude has changed rapidly toward technology, especially in areas that affect the environment. Public pressures can easily constrain or even prevent the introduction of new systems or can be equally effective in curtailing the use of existing systems. Noise, pollution, and congestion have created such a situation for civil aviation, especially near airports.
- *Organizational:* With the Government's pervasive involvement in civil aviation, the division of responsibilities can be an effective deterrent to progress. Major obstacles can be created in reaching a necessary decision when several levels of government (local, State, Federal) or multiple industries are involved.

EFFECTS ON PROBLEMS

These institutional constraints affect progress toward the solution of the operating problems discussed in the previous section. Some examples are:

Noise:

Noise regulations can be based on state of the art (i.e., FAR 36) or they can pace improvements, as is the case for auto pollution (regulatory and legal).

Some states and local communities are pre-empting noise regulation. This could result in varying and confused standards (regulatory and legal).

To date there is only an expense and no clear profit motive for manufacturers and airlines to reduce noise (market and financial).

The costs of retrofitting existing aircraft with acoustically treated nacelles or the imposition of highly restrictive noise regulations could be disastrous in the current financial state of the industry (market and financial).

Responsibilities for the noise problem have been passed from airline to manufacturer to airport operator to local government (attitudinal and social).

Solutions to the noise problem can involve vehicle changes, operational changes, and controlled land use. DOT, NASA, local government, and industry are all involved (organizational).

Congestion:

Some congestion is associated with modal interfaces (especially for cargo) and could be reduced by multimodal systems. Most multimodal ownerships have generally been opposed (regulatory and legal).

The profit potential for improved access/egress is not clear. Who might receive such profits is also unclear (market and financial).

Passenger preference for travel coincides with the peak rush hour traffic of the working force (attitudinal and social). The air carrier and airport operator have attempted to respond to this demand by providing sufficient capacity to meet these peak loads. The air carriers have suffered losses because of the resulting congestion in the terminal area (market and financial).

Access/egress is normally the responsibility of State and local governments. Because of other commitments, most of these governments are in a difficult financial condition (market and financial).

Airports have become known as undesirable neighbors. Proposed additions or expansions, althouth badly needed, usually arouse public opposition (attitudinal and social).

Seven elements from access/egress to air traffic control affect congestion. As many as four authorities and seven funding sources are involved (organizational).

A new short-haul system, such as STOL, may alleviate congestion. To develop and deploy such a system will require action by DOT, NASA, CAB, local governments, airlines, and manufacturers (organizational). Because of the difficulties in achieving unified action, many airlines and manufacturers have difficulty in defining markets and profits and are thus reluctant to proceed (market and financial). New facilities such as STOLports located close to populated areas will be required. These facilities will face public opposition because of noise and other problems (attitudinal and social).

Low-Density, Short-Haul:

Route, fare, and service regulatory decisions are based on uncertain market sensitivities. Market forces have not been adequately tested (regulatory and legal).

Local carriers, who represent much of the short-haul market, are losing money even with continued subsidies. Airlines tend to seek more profitable long-haul markets; thus, manufacturers tend to build long-haul equipment (market and financial).

Effective and (it is hoped) profitable short-haul service will require changes in many elements of the air transportation system. Many organizations in Government and industry will be involved (organizational).

IMPLICATIONS

The foregoing examples serve to illustrate the impact of institutional constraints on certain operating problems. Some additional and possibly broader implications of these constraints are also important.

Regulatory and Legal

An area significantly affected by regulatory policy has been air cargo. It has been the policy of the Federal Government to prohibit intermodal mergers involving an air carrier. This policy has a detrimental effect on the industry's ability to capitalize on the full advantages of air cargo. From the viewpoint of technological innovation, the inability of air carriers to engage in all the activities related to distribution – freight collection, consolidation, local transportation, handling, and distribution – and to control the economic benefits from these activities has a dampening effect on innovation. There is little incentive for carriers to sponsor R&D to create technological opportunities in multimodal transportation when separate ownership permits only a partial participation in the benefits of such opportunities.

The reluctance to approve intermodal mergers stems from two causes. First, the policy established during the early years protected the air carriers from absorption by other financially stronger modes. Second, the existence of different regulatory agencies for various transportation modes tends to create barriers between modes because of different methods of rate determination, etc.

The bases for prohibiting intermodal mergers no longer seem to be valid since air transport now represents the dominant mode of commercial transportation. Furthermore, the Ash Council on Government Reorganization recently recommended that the three transportation regulatory agencies be merged. The following quotation from the Ash Council Report discusses the relevance to R&D.

> *The existing structure for transportation regulation impedes full realization of the benefits of recent and anticipated technological and procedural innovations in transportation, particularly for intermodal shipments and cargo handling systems. Potential shipper demand for the coordinated services of more than one transportation mode – following on the heels of these innovations – is frustrated by divided regulation.*

It was also recommended that the task of promoting civil aviation be moved from the CAB (or its successor) to DOT. Both of these actions should assist in removing institutional constraints to better systems integration. If these recommendations are implemented (and even if they are not), there is a need for demonstrations to assess market characteristics and potentials. In this case, DOT and the regulatory agency could develop a joint venture with industry to explore on a limited basis the market potential for door-to-door cargo service using air as the primary mode for the long-distance leg. A better understanding of this market could influence future industrial R&D related to cargo containers, all-cargo aircraft, and airport design.

Specific actions required are:

- Consider Ash Council recommendations for single transportation regulatory agency and movement of promotion role for civil aviation to DOT.

- DOT and regulatory agency (CAB or its successor) develop demonstration programs to explore the market for intermodal cargo service.

Market and Financial

A few key figures show the growing interdependence of the aerospace and air transport industries, and the dependence of both industries on favorable financial conditions for the flow of new technology between them. In 1969, purchases other than by the U. S. Government accounted for 63% of the backlog of orders for aircraft and related equipment and parts reported by major manufacturers in the aerospace industry. Meanwhile, procurement of aerospace products and services by the U. S. Government is forecast by the Aerospace Industries Association to decrease from $21.4 billion in 1968 to $17.6 billion by 1971, the most protracted and sizable decline since 1948. Thus, if it is to maintain current levels of employment and sales and if it is to grow, the aerospace industry must increasingly look to the air transport industry as a market for its new technology.

Since 1966, the airline industry has been unable to attain a satisfactory return on investment. In 1969, the U. S. scheduled air carriers reported a net profit of only $53 million on a total investment of $8.6 billion. Two out of every three scheduled carriers reported a net loss for the year. The most recent estimates indicate that the airline industry had a net loss in 1970 of over $150 million.

The general aviation manufacturers face a somewhat different problem. To recover their development costs, although much lower than those of larger airframe manufacturers, an annual increase in sales of around 15% is needed. Sales of twin-engine and turbine-powered aircraft are very closely correlated with corporate investment in new facilities and equipment, and those of smaller general aviation aircraft with personal disposable income. Thus, general aviation sales are highly dependent on the perceived state of the general economy. The current depressed economic situation has not only arrested the growth of general aviation aircraft manufacturers but reversed it. It is also apparent that the general state of the economy also affects the airlines and transport manufacturers.

There are incentives for airlines to overequip, resulting from a competitive desire to be first in the marketplace with most of the best aircraft, and to long-standing beliefs in the industry that capacity and frequency of service stimulate traffic. Statistics have generally confirmed that this is indeed the case. Not long ago this line of reasoning was constrained by the financial limitations of the industry. Air carrier equipment purchasing power was limited by credit standing. Airline financing shifted from highly conservative bank credit sources, to insurance companies, and now to the leasing company.

These problems directly affect the aerospace industry in two ways. There is a natural incompatibility between the need of the aircraft manufacturer to achieve and maintain an economic rate of production on a large run of aircraft and the ability of the airlines to absorb new equipment, particularly now when equipment comes in increments of 350 seats and $16 to $23 million per aircraft. During progressive rounds of reequipment, the usual result has been not only overcapacity for the airlines, but also an increase in the capacity of the aircraft manufacturing industry. Second, the economic perturbations set up within the airline industry by the reequipment cycle tend to make it a less stable and receptive market for the aircraft manufacturing industry.

Today there is a growing threat to the current reequipment program as a consequence of the airline industry's severe and deepening financial problems. Cancellations of orders previously placed with airframe and engine manufacturers have already been announced. Tenuous financial arrangements for new aircraft are being jeopardized, with the possibility that the airlines will be unable to finance deliveries of aircraft for which orders are still firm.

It can be argued that these risks are inherent in the free enterprise system, and so should be accepted by the participants. However, it is also true that the aerospace industry is a national asset, is one of the largest employers in the country, is one of our principal technical resources, and is a vital factor in national defense and the balance of payments. When the scale of resources required to develop a commercial aircraft or engine approaches those needed today, and with the small margin between revenue and costs, the results of miscalculation or unforeseeable events may be catastrophic. Disruptive instabilities in this industry and in its civil market must be alleviated or mitigated in the national interest.

The solutions to the industry's financial problems are not entirely clear. A better definition of markets should reduce the tendency toward overcapacity. Toward this end, market demonstration programs can play a significant role. Broadening and diversification of markets are other possibilities to stabilize the industry. *Continued and consistent Federal funding of aeronautical research is necessary to assure the maintenance of a strong civil aviation technical base to serve as the basis for new development starts.* It may also be necessary to make use of Federally guaranteed loans for aircraft purchases. Services similar to those provided to foreign airlines by the Export-Import Bank could also be extended to domestic airlines. These approaches would help provide the stabilized finances the industry so desperately needs.

Attitudinal and Social

Civil aviation is unpopular with many. The rapid growth of civil aviation has been accompanied by increasing and severe resistance to the expansion of aviation activities. Since the advent of the jets, aircraft movements at many major airports have been increasingly restricted during certain hours of the night. At least one community has petitioned the Civil Aeronautics Board to limit further air services, because airport noise was already exceeding acceptable levels.

Aviation suffers because many people mistakenly view it as an elite travel mode. To put the situation into perspective, it is significant to note that as of 1967, almost half (45%) of the U. S. population had not made even a single intercity trip by any mode in the previous year. Of those who had made one or more domestic intercity trips, 88% of the trips were by auto, with air accounting for only 7.5% of all the trips. A relatively small fraction of the population travels by air, primarily because the overwhelming proportion of all domestic intercity travel is by auto. However, in the domestic intercity common-carrier market (which excludes auto), 64% of the common-carrier trips and 81% of the passenger miles were by air. Since air carried such a large proportion of the travelers, it is not correct to say that air travelers are an elite group. In 1967, the median income for all U. S. families and unrelated individuals was $6,889; of those who had taken a trip by any mode, the median was $8,225; of those who had taken a trip by ship, $13,764; of those who had taken an air trip, $11,922; by auto, $8,021; by train, $6,759; and by bus, $5,714. Thus, although the median income of air travelers was 73% higher than the median for the general population, the air traveler's median income of $11,922 shows that the average air traveler is not a wealthy person. (All of these figures are weighted by the number of person trips: when computed on the basis of the number of travelers, the figure for air travel drops to $9,905.)

Although the last decade has witnessed unparalleled growth in airline traffic and major improvements in aircraft, airports have not developed at an equivalent pace – in number or quality. A disproportionately large number of enplanements occur at a relatively small number of major airports: 60 airports account for 85% of current enplanements. Growth of the total civil aviation system may be impeded by the failure of airports to develop apace. Indeed social resistance to airports and associated landside development is perceptibly slowing the ability to make use of new technology.

Airports interact in many complex ways with the communities where they are located and the attitude of the community toward them is usually mixed. While the reasons for negative reactions – noise, safety, atmospheric pollution, the attraction of unwanted ground traffic – are understandable, the adverse reactions stimulated in those citizens who reside near airports are now translated into a virtual paralysis of our ability to plan airport expansion or improvement, or to build new ones. Unless airports can fit more harmoniously into their surroundings, efforts to keep airport development up with other parts of the system will continue to be frustrated.

One action is particularly pertinent to this problem. Civil aviation research and development should be redefined to include both physical and social sciences and the necessary steps taken to organize and staff R&D activities to reflect this new approach. Specifically, the Federal Government should augment its physical science staff at its various research and development agencies and centers with experts in economics, finance, government, market research, sociology, etc. These people should be encouraged to interact on a day-to-day basis with existing technical staff so that a multidisciplinary attack can be launched on the problems of civil aviation.

Organizational

DOT and NASA each have certain statutory responsibilities for research and development for the various elements of civil aviation. DOT's role is most pervasive in keeping with its statutory responsibility to stimulate technological advances in transportation and to provide general leadership in the identification and solution of transportation problems. The NASA is lead agency for research and technology related to air vehicles; industry has complementary programs in addition to developing vehicles. The NASA supports vehicle development with its test facilities. Within DOT, FAA is the lead agency for the air traffic system, and is the operator of the system as well. FAA is also the lead agency for airports, but because of the roles of the Department of Housing and Urban Development and of State and local governments in planning and development of airports, the FAA's role in this area is not so broad. The situation is similar for complementary ground transportation except that in addition to HUD and the local governments there are several modal administrations within DOT that have responsibilities in this area.

Traditionally, therefore, the responsibilities for R&D in civil aviation have been divided primarily along the lines of the system elements. Both DOT and NASA have recognized, however, that there are important interactions among elements. For example, aircraft characteristics influence the air traffic system and the airport and, conversely, the airport and air traffic system influence vehicle requirements, especially those for avionics. Accordingly, the two agencies have a number of programs that are complementary and interact.

It is also apparent that the combined resources of the two agencies will be required for the effective solution of the operating problems discussed earlier. The necessary mechanisms for a coordinated attack on the problems have been evolving for some time. For example, DOT and NASA have engaged in advanced coordination of civil aviation R&D budgets for the past several years. Another important step was the recent addition of the Secretary of Transportation to the National Aeronautics and Space Council (NASC), which already included the Administrator of NASA, the Secretary of Defense, the Secretary of State, the Chairman of the AEC, and the Vice President as chairman.

In the course of the Joint Study, options for organizational arrangements were examined for improving the climate for balanced systems research and development. Pending further organizational considerations, the following initial steps should be taken:

- For those programs where responsibilities cross organization lines, program offices should be established in DOT, staffed in part and as required by experts on loan from other agencies, to manage programs directed at priority problems, especially those involving demonstrations or hardware. Subordinate offices for individual elements of major programs could be located as appropriate within DOT or NASA, but should report to the program office. While each program office will require special analysis, some of the functions that these offices might perform are to insure that total program planning is accomplished, to perform overall systems analysis, to monitor and report progress, and to insure program coordination within Government and with industry.

- Interchange technical personnel among DOT, NASA, DOD, and possibly CAB at middle management levels. This interchange would provide a cadre of trained and experienced people with broad knowledge of the systems and elements of civil aviation.
- Use the NASC more actively as a focal point for the evolution of national policy related to civil aviation. Within NASC, a permanent mechanism should be developed to review and recommend those policies which embrace several agencies. In performing this role, the NASC should engage the cooperation of leaders of industry.

DEMONSTRATION PROGRAMS

Demonstration programs are one way to circumvent at least temporarily many of the major institutional constraints. Used in this way, carefully conceived demonstration programs can be very important to the future of civil aviation. Demonstration programs are experiments designed to embrace new concepts, procedures, regulation, or the blending of new technologies into existing systems. These programs should collect information and required data in a real-world environment involving the ultimate users of the system. Two types of demonstrations have been considered. One may be termed an "operational demonstration" and would test the effects of new elements on the operations of present systems (e.g., testing the effects of a STOL vehicle on the ATC system). The other may be termed "market demonstrations" and would test market reaction to new elements and other changes in such factors as equipment, fares, routes, and service. In either case, the demonstrations should be carefully designed to test key variables and to collect required data so that the information necessary for the guidance of R&D programs can be obtained. The role of operational demonstrations in this regard is clear but market or regulatory experiments can also be very important to the R&D process. With accurate data on price, frequency, and service elasticities available, the manufacturer can better evaluate trade-offs and requirements for new systems. Both types of demonstration programs will provide important data required for cost/benefit analyses of proposed new operational systems.

The Government has not had extensive experience in air demonstration programs. In some ways, the best examples of demonstration programs have been the CAB subsidy programs. Investments in both domestic and international carriers have successfully demonstrated the attractiveness of air travel to the public. Subsidies to the local service and helicopter carriers have not yet produced successful demonstrations. Experiments with all-cargo carriers and nonscheduled charter flights, however, have proved successful. These "experiments" (particularly helicopter and local service) would have been more valuable were there more emphasis on the gathering of data, especially market elasticity data, while conducting experiments involving orderly variations in price, frequency, and service choices.

The airlines themselves have undertaken demonstrations. Eastern and American Airlines STOL demonstrations with the Breguet aircraft were essentially operational demonstrations without marketplace effects. Several airlines, however, did consider market effects of shuttle services, suburban passenger terminals in the New York Metropolitan area, and the fostering by Allegheny Airlines, of third-level commuter passenger service.

While these examples indicate limited use of demonstrations in the past, there is an increasing need for future demonstrations because of growing market complexity and financial risk and the need to select new systems from balanced systems analyses rather than from piecemeal technological improvements.

Ample provisions have been made. The DOT Act of 1966 states the proper role for Government by saying "... the DOT should assure the *coordinated* effective administration of the transportation program of the Federal Government ... *encourage cooperation* of Federal, State, and local governments, carriers, labor and other interested parties ... provide *general leadership* in the identification and solution of transportation problems ...." Therefore, the Secretary, under existing legislation, can undertake demonstration projects in all areas of mass transportation. The acts of 1958 creating the NASA and FAA also allow for the participation of these agencies.

The question, however, is not whether the Government *can* engage in demonstration programs but rather whether it *should* participate and under what circumstances.

Government involvement in research is easily justified on the basis that the end products of research are not realized for many years and industry often cannot afford the long-term investment required. In most cases, Government involvement in development and production is justified only if the Government is the operator of the system. Examples might be air traffic con- and all military systems. Demonstration pro- lie in the area between these two extremes vernment involvement must be examined -by-case basis.

Some of the questions that should be considered in these examinations are:

- Is the service being demonstrated in the public interest?
- Does it exhibit potential for broad application?
- Is the demonstration designed to produce results pertinent to a total transportation system?
- Will the demonstration be responsive to both market and social processes?

Even with these questions answered satisfactorily, there is the important matter of whether industry could perform the demonstration without Government involvement. Some considerations might be:

- No element of private industry can perform the task because it lacks sufficient jurisdiction and opportunity because of institutional barriers or other factors. In these cases, industry cannot control enough of the environment to proceed.
- Industry is not the prime mover as is the case in most airport development programs. In these cases, there is no motive for industry to proceed.
- Private industry will not proceed because of financial reasons – either too heavy initial investment or too distant profit potential. In addition, a private firm may be reluctant to engage in an expensive demonstration when the benefits cannot be restricted to itself, but would accrue equally to its competitors.
- The Government has created an environment favorable to an industry-sponsored demonstration program but no such program has emerged.

It appears that most of these conditions can exist for civil aviation demonstrations. In this event, the Federal Government may assume any number of roles – planner, coordinator, regulator, funder, impartial evaluator, or operator.

The selected approach should be compatible with some of the criteria used to assess the advisability of Government-assisted demonstration programs in other industries. These more general criteria include:

- Industry share the risk
- No industry member be placed in a favored position
- Forces of the marketplace be recognized
- Competition be maintained

Some of the ways these criteria might be satisfied by civil aviation demonstrations are:

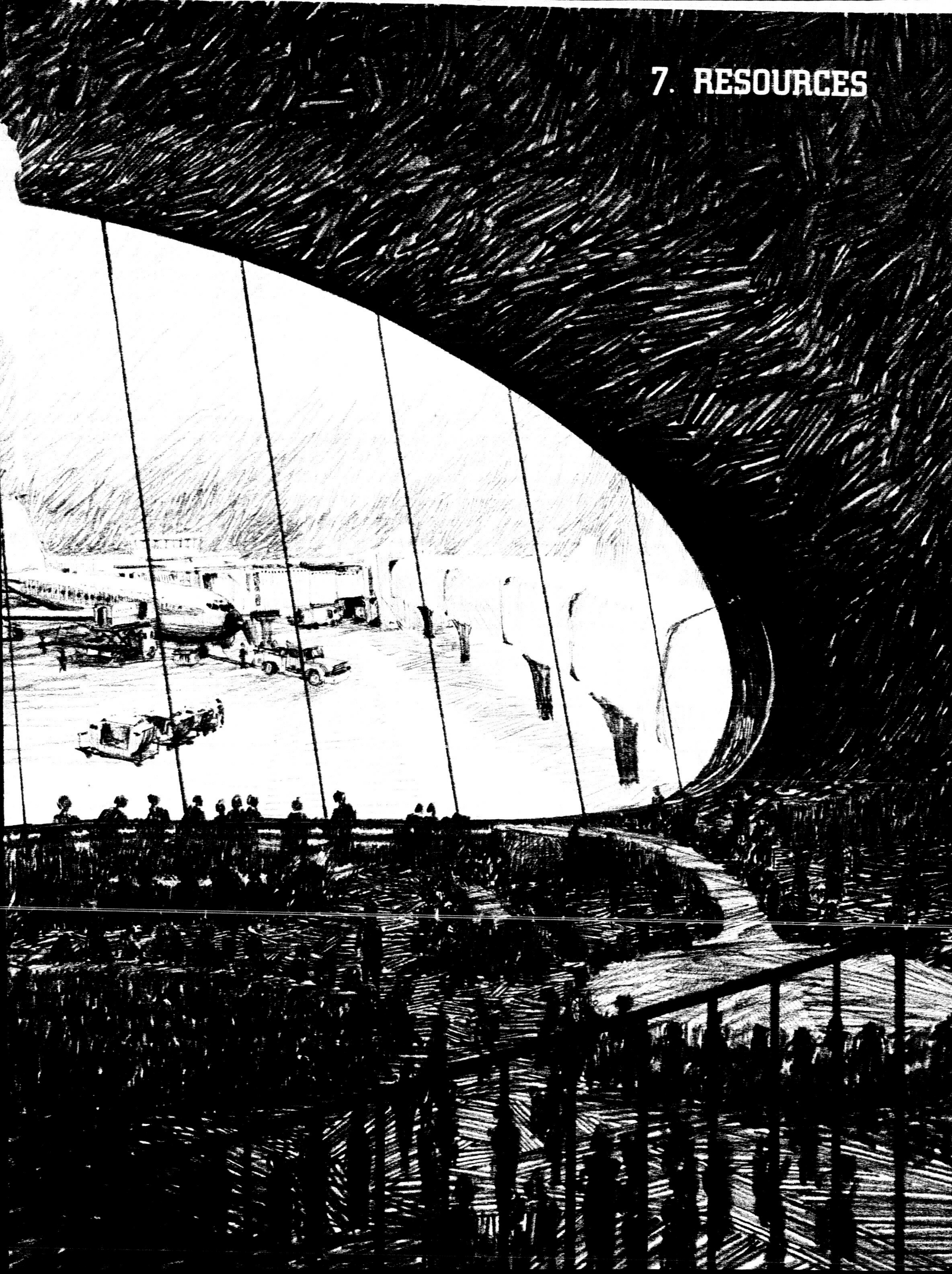
- Industry forms joint ventures with Government
- Where appropriate, both manufacturers and airlines are part of the joint ventures
- If possible, more than one industry team should participate and compete in the program

Although much remains to be learned about the feasibility and practicality of joint Government/industry demonstration programs in civil aviation, their use should be carefully explored. It is recognized, however, that these programs will present some special problems especially in the area of management arrangements. Each demonstration proposal will require a different mix of participation but emphasis should be given to the responsibilities placed on the private sector. Government roles might normally include:

- Select probable demonstration areas, set goals, and assess expected benefits
- Request proposals from private and public organizations outlining concepts for conducting demonstrations
- Award contracts with partial funding for most promising proposals
- Remain in supervisory capacity assessing progress, resolving jurisdictional problems, resolving legal and procedural restrictions, obtaining cooperation of local and regional governing agencies
- Modifying operating criteria as necessary
- Assist organizations with development of a testing and analysis plan; perform program reviews as necessary
- Issue Government report summarizing all findings and initiate Government policies (if successful) to permit implementation on broadest possible scale

Again it is emphasized that arrangements for each program will have to be considered individually. *Joint enterprises between Government and industry do present the attractive possibility of taking full advantage of the expertise and other resources in the airline and aerospace industries, which are very important to major experimental hardware and demonstration programs.*

7. RESOURCES



Resources

Aeronautical R&D funding by the Federal Government, in support of military and civil aviation since World War II, has grown from $342 million in FY 1945 to $2.8 billion in FY 1970. During the same period, annual industry funding increased from $23 million to $562 million. This substantial Government support of aeronautical R&D has been based on a national defense policy and the recognition that civil aviation provided a valuable public service and benefited the economic and social welfare of the Nation. In this Study, an effort was made to relate the level of R&D funding to these benefits and establish criteria for Government funding support of civil aviation R&D.

R&D COST/BENEFIT RELATIONSHIP

As shown in the section "Benefits," there has been a remarkable increase in the productivity of civil aircraft as a result of R&D, particularly in the last two decades. This increased *vehicle* productivity has contributed greatly to the growth and success of the aviation system and the realization of considerable benefits to the user and the general public. On the other hand, the investment in *airways and airport* R&D (only 9% of the total military and civil aeronautical R&D funding and only 3% when civil is considered alone) has been clearly insufficient and has resulted in the failure of these elements of the system to keep pace with the demand generated by the vehicle capability. Also, it is clear that noise abatement has not been properly emphasized with sufficient resources and attention by both Government and industry and has become a serious constraint on the realization of the benefits from the R&D in other areas. Such qualitative judgments regarding resources have been made, but no way was found during the Study to show an exclusive causal relationship *between a particular overall level of R&D funding (cost) and a particular level of benefits.*

Many R&D activities, particularly research and advanced technology, do not lend themselves to meaningful cost/benefit analysis. In large part, they are a process of discovery and advancement that is, to some extent, inherently unpredictable. The uncertainty of success often makes parallel approaches necessary. Research cannot be precisely "time-framed." Resource requirements sometimes have to be estimated as a "level of effort." In addition to these characteristics of R&D itself, other factors complicate the relationship of benefits to a particular level of R&D. These are the extent of duplication in the competitive R&D performed by industry, the uncertainty of market development and growth for the products of R&D, the effect of airline regulation and subsidy on R&D incentive, the impact of public attitudes toward aviation and travel in general, and changes in the economic situation.

Cost/benefit analyses can have more meaning at the project level for development and some technology activities when there are specific program plans, costs, schedules, and clearly definable applications. In many cases, data will not be available for these analyses without operational or market demonstrations. Therefore, as indicated previously, such demonstrations are an important tool of aviation R&D.

Economic analyses in connection with the planning of specific projects should address:

- The cost of doing nothing, including the existing penalty and the loss of possible benefit
- The relative cost and relative effectiveness of R&D compared to other solutions
- The relative costs and benefits of alternative R&D solutions

Although no method was developed for calculating *overall* benefits from the expenditure of various *overall* levels of aeronautical R&D, some estimates have been made of the overall *cost* of doing *no* R&D:

If no R&D were performed to introduce new technology into the air traffic control system, approximately 12,000 more air traffic controllers would have to be employed in 1980 to meet the projected demand. The annual Government cost of these addition salaries would be over $0.2 billion.

If R&D is not attempted to make low-density short-haul operations more profitable, by 1980 the Government might still be paying $75 million or more per year in subsidies.

If the proper R&D and other actions are not conducted to alleviate terminal congestion by 1980, the annual cost of delays to the airlines would be approximately $0.6 billion, and the annual cost to the user (estimated by assigning a reasonable value to his time) would be approximately $2 billion.

The eventual loss of markets to foreign competitors by 1980 because of noncompetitive products if no R&D is performed could cost $4.5 billion in lost aircraft sales and 300,000 fewer jobs.

If R&D does not make airports better neighbors by reducing aircraft noise, future airports will have to be located farther from the cities they serve at a cost by 1980 of approximately $0.3 billion annually in commuting expenses at the 62 new air-carrier airports projected by that time. If these 62 airports are not constructed, lost fares will amount to nearly $6 billion.

In addition, some costs cannot be estimated; for example, the loss of economic and social benefits related to the restricted growth of aviation and the lessening of the industry capability to fulfill defense needs.

These are only gross indicators of the potential value of R&D and do not relate to a particular level of funding, the impact of which depends on the program content. Program content is the result of annual program planning and budgeting based on up-to-date assessments of the state of the art and work progress, continuing technical trade-off analyses, and detailed consideration of program pacing and funding priorities within estimated resource availability. While program content was not the concern of this Study, there was an effort to establish Government funding criteria as a policy framework for annual program planning and budgeting.

CRITERIA FOR GOVERNMENT FUNDING

It is essential to a meaningful consideration of R&D funding criteria to distinguish the three major kinds of activities comprising the total R&D effort. There are great differences in funding requirements and in the roles performed by Government and industry in these activities. Within the broad framework of research and development, a continuum of activities takes place, beginning with a search for a basic understanding of physical processes and ending with the fabrication, testing, and evaluation of one or several articles (hardware prototypes). Funding requirements generally increase greatly as programs go from research to development. Not included are the production and operations phases. R&D activities do include nontechnological factors, such as marketing, economics, and social impact, as well as technological factors. For consideration in this study, the following categories and definitions are used:

- *Research* (sometimes referred to as basic research): discipline-oriented activity directed toward an increase in knowledge in the physical, biological, or social sciences.
- *Technology* (sometimes referred to as applied research): the application of knowledge to arrive at techniques, design data, or design criteria, or to demonstrate the feasibility of a concept with no intention of going into quantity production of operational articles.
- *Development:* The application of technology to the design and fabrication of specific components, subsystems, systems, or processes, and to the testing and

evaluation of these articles or processes with the intention of going into production. This part of the R&D is, therefore, referred to as "prototype development."

Since 1945, the Federal Government has directly funded about one-third of the total *research* activity. Another one-third has been indirectly funded by the Government as overhead on Government contracts. In FY 1970, the share of the research sponsored by the Government increased to three-fourths. The rationale for this Government research funding has been that these activities benefit both military and civil aviation, the payoff is usually unpredictable and long-term, and a large investment in people and facilities is required over a long period of time with no financial return. At the other end of the spectrum, civil vehicle prototype *development* has generally been left to the industry because of the clear profit opportunity within a reasonable time. As regulator and operator of the airways system, however, the Government has assumed the funding responsibility for the development and implementation of the traffic control system.

Technology is a gray area where there has been considerable sponsorship of effort by both Government and industry for the air vehicle. Airways and airport technology funding was largely Government sponsored, but with relatively little emphasis in the past.

Prior to FY 1971, all Government funding of R&D, as well as airways facilities and equipment, and airport assistance programs, drew on the General Fund of the U. S. Treasury. The Airport and Airway Revenue Act of 1970 established a special trust fund for aviation user tax revenues earmarked for airways and airport system development. (Vehicle R&D and the "landside" of airports are not covered by this legislation.) This legislation was a significant change in Government policy to make the user pay for the part of the system from which he directly and specifically benefits. The tax revenues are already estimated at over $0.6 billion for FY 1971 and are projected to go over $1.0 billion annually by FY 1976, and to over $1.5 billion by 1980. These revenues appear to provide a substantial share of the total airways and airport system requirements during that period, including R&D, facilities and equipment, airport development, and FAA operating costs. A detailed cost allocation study currently under way in DOT will serve as a basis for firm recommendations on the shares of the system costs to be borne by the user and the Government. A report will be made to the Congress by May 1972. (The Congress must appropriate funds annually for FAA use, even though they are earmarked in the trust fund.)

The use of Government funds for civil aviation R&D should be based on a determination that there is a significant public interest related to public safety or the general welfare (public benefit) *and* one or more of the following conditions exists:

- The Government is the primary customer, operator, or beneficiary.
- The technological risk is too high or the return on investment is too low or unpredictable for private investment, but the potential general public benefit is great.
- The size and duration of the financial risk exceeds the financial capability of any company in the private sector.
- The market opportunity is not clear to the private sector because of factors beyond its scope of activity.

Applying these criteria to the future in general warrants continued Government sponsorship of aeronautical research. Experience shows that a base of research activities is essential to the future of both military and civil aviation. The results are unpredictable and long term and the level of funding cannot be estimated precisely. For research, resource judgments must be relatively gross estimates of the funding required to employ a minimum "critical mass" of talent in all disciplines with emphasis on those where serious problems exist or large payoff appears possible.

For technology, the Government must insure the availability of the most advanced techniques and capabilities to industry for future development decisions. It is unrealistic to expect individual industrial corporations to fulfill this need. Most of the industry resources are necessarily diverted to relatively near-term applications in the most profitable markets. Also Government action is necessary to insure that all future alternative developments are kept open in the public interest to the entire industry. Furthermore, in a high technology society with the long lead times required for a proper technology base, Government sponsorship is necessary to insure a comprehensive capability for future development options in all areas.

A large part of the Government vehicle activity consists of ground-based laboratory research and technology efforts. In some cases, however, it is necessary to go further than wind-tunnel tests and ground simulations because of the lack of good engineering data on operating characteristics, unclear markets, the need for accurate cost data, the need for the demonstration of low noise levels, and other institutional problems. This is especially true if the technology has not already been demonstrated in military applications. In such cases, experimental aircraft programs may be necessary. Civil vehicle prototype development activity should still be largely a matter of industry initiative and sponsorship.

The technology and development of the airway system should remain a Government responsibility because the Government is the operator and the system serves both military and civil aviation. Since the FAA operations costs are projected to exceed a billion dollars annually and R&D offers real promise to minimize the number of air traffic controllers and to increase the productivity of the air traffic control system, there is additional Government incentive to invest in the R&D in this area. The Government should also take a strong leadership role in airport R&D where the payoff in relieving terminal congestion is high at a relatively low cost and the market opportunity is not clear to any particular segment of the industry.

RELATIONSHIP OF MILITARY AND CIVIL AVIATION

A major factor in considering future civil aviation R&D resource levels is the relationship to military aviation. In FY 1970, 84% of Federal aeronautical R&D funding was provided by the Department of Defense. As shown in Table 7.1, it has been estimated that 44% of the total funding provided by Government and industry in FY 1970 is likely to benefit civil aviation directly and indirectly, including 20% of the military R&D sponsored by the DOD. In terms of dollars, this DOD funding of work with potential civil application exceeds the combined NASA and DOT funding.

TABLE 7.1. FY 1970 CIVIL AVIATION R&D, $ MILLIONS

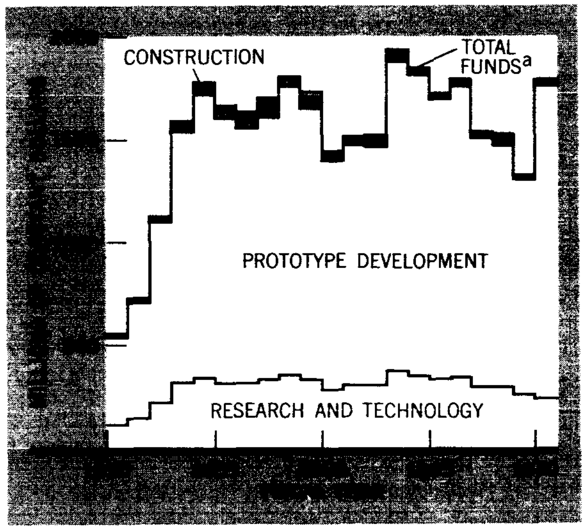
SPONSOR	DIRECT	DIRECT AND INDIRECT	TOTAL INCLUDING MILITARY
DOD	–	477	2,381[a]
NASA/DOT	384	441	441
GOVERNMENT SUBTOTAL	384	918	2,822
INDUSTRY	451	562	562
TOTAL	835	1,480	3,384

[a]*Includes allowable IR&D.*

Both military and civil aviation draw on a common technology base and rely on the same industrial capability. Therefore, the relationship of military aviation to civil aviation has been analyzed regarding the trends in military versus civil aviation technical requirements, the direct funding of R&D, and the procurement of aircraft.

There has been concern that military and civil aircraft requirements are diverging and, therefore, civil aviation will not continue to benefit from military technology to the same extent it has in the past. The Study results do indicate that the emphasis in future military requirements will be different from civil aviation in some aspects, but it appears that there will continue to be common benefit from both military and civil aeronautical research, and considerable joint benefit from technology and development efforts in the VTOL, subsonic, and supersonic aircraft areas. However, despite military interest in STOL vehicle technology, this area has relatively low priority in military program plans for the next few years. With the promise of a significant contribution to the problems of terminal congestion and better airport land use in the civil sector, STOL technology has a high civil aviation priority. The lack of military priority on STOL systems at this time underscores the need for special civil R&D funding priority in this area. This civil-oriented work would benefit future military systems.

Overall funding of R&D by the military comes to industry in two ways: (1) direct Government R&D contracts, and (2) independent R&D costs allowed by the Government as part of the overhead expenses charged to military aircraft and equipment production contracts (referred to as IR&D funds). A major reduction in either of these sources would adversely affect the Nation's civil aviation capability. Although the funding of military research and technology has declined somewhat over the last seven years, no further decline is expected (see Fig. 7.1). The funding level of military prototype development had been trending downward during the same seven-year period until a large increase in FY 1970. The dollar level of military aircraft procurement remained about the same during the three-year period 1967-69. Although sales for 1970-71 are expected to show a decline, an upturn in sales is forecast for 1972. However, there is a change in the total military versus civil aerospace sales ratio that is the basis for the Government allowance of IR&D funds to industry as overhead charges. A larger percentage of industry sales in the future will probably be non-Government; therefore, the Government share of IR&D overhead costs will be reduced. This change could result in a Government allowance for IR&D by FY 1975 that will be as much as $50 million a year lower than the FY 1970 level, even though the dollar level of military sales remains level. If the Government allowance for IR&D is reduced, and the available industry funding is channeled into the very large civil development and production cost commitments of the next few years, research and technology will suffer. Another concern is the trend toward fewer new military starts that reduces exercise of the development and production process so important to maintaining a healthy industrial capability.

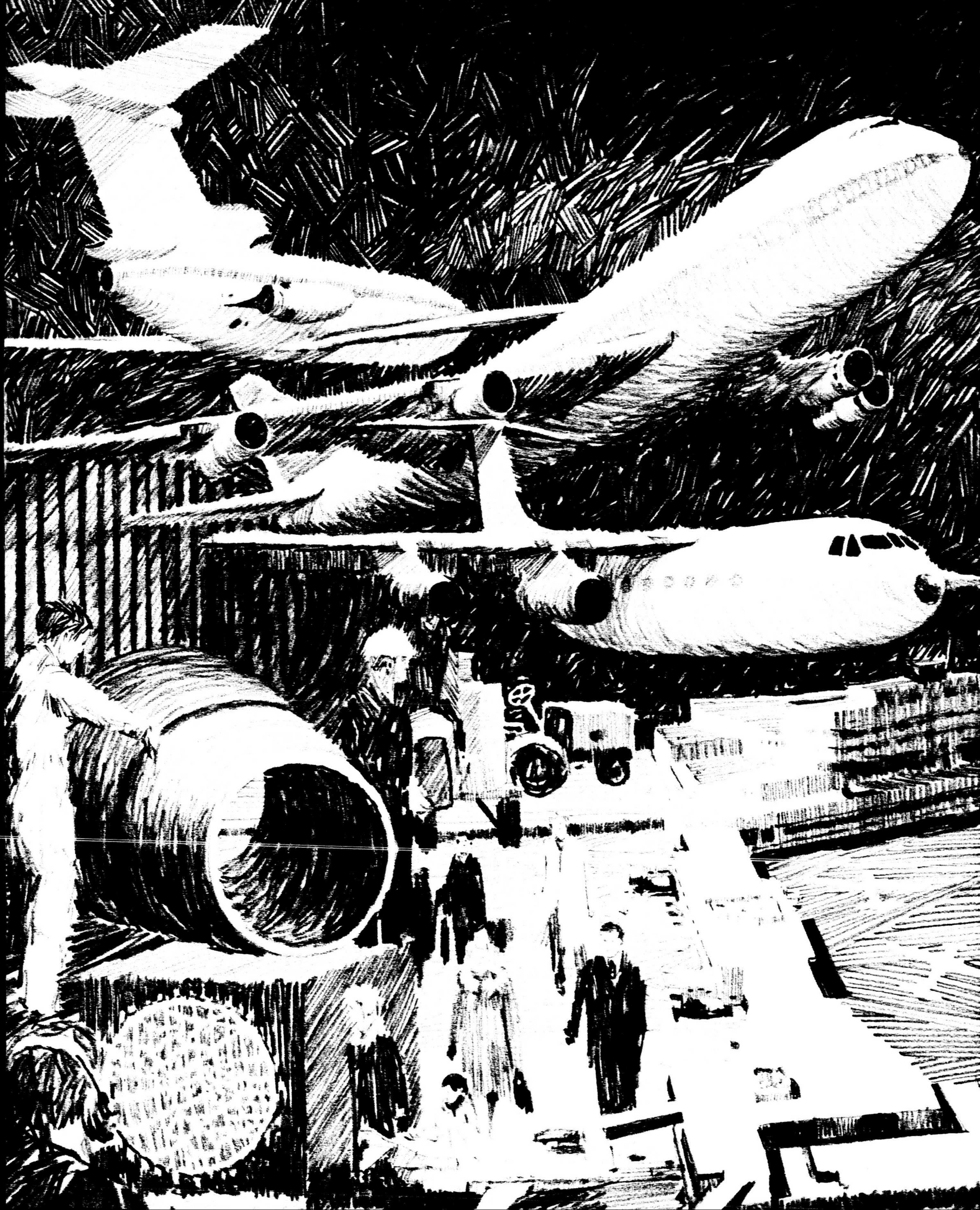


[a]*Data derived from several sources including selection of those projects considered to be aeronautics oriented from DOD RDT&E "Project List" and estimates for construction obligations for aeronautical R&D facilities. Estimates for salaries and other support costs are also added to the selected projects funding obligations (excludes allowable IR&D).*

Figure 7.1. Distribution of DOD aeronautical R&D funds.

There is a need to watch this situation carefully to assure that there is not an erosion of the National aeronautical capability for the future. The National Aeronautics and Space Council should be used for a continuing review of this situation as a matter of broad national policy concern involving the DOD, DOT, and NASA, as well as the industry.

8. SUPPORTING ANALYSES



Supporting Analyses

In the foregoing sections, some of the major problems affecting civil aviation that require additional R&D emphasis were discussed. The importance of these problems was identified from the results of numerous individual analyses carried out as part of the Joint Study. These analyses are the subjects of the family of supporting papers contained in the second volume produced in the Study, the contents of which are outlined in Appendix A. In the preparation of these supporting papers, a concerted effort was made to treat comprehensively and quantitatively all of the major factors important to the future of civil aviation. As noted earlier, these supporting papers form the foundation of this report.

The results of the supporting analyses demonstrated that civil aviation is indeed a vast and diverse industry with numerous and varied problems. When the results of the supporting analyses are viewed in combination, it becomes clear that the future problems of civil aviation will not be solved and further growth will not be realized unless there is a continuing broad based program in research and development. The combined results show that NASA should continue and broaden its work in basic disciplines such as aerodynamics, structures, propulsion, and applied mathematics. The DOT, including the FAA, should develop or expand programs in the disciplines related to airways and airport design. Some of the continuing basic programs required are:

- Development of near-term improvements for the airways system to increase automation of ATC functions, upgrade the beacon system and include data links, expand the digital communications network, and upgrade the navigation systems including an all-weather scanning-beam microwave landing system.
- Research and development for future airways systems including systems engineering, simulation, and trade-off studies of new concepts for air traffic control and optimized airspace utilization; research on both ground- and satellite-based position determination methods for navigation and surveillance; and research in communication techniques for application in the high-density aircraft environment.
- Systems engineering, simulation, and other studies of new concepts for design of airports for both CTOL and STOL vehicles.
- Continued analysis of the impact on airport and airways systems of new classes of aircraft, noise reduction advances, and improved weather and turbulence detection methods.
- Studies of aircraft configurations suitable for both the long- and short-haul markets and incorporating advanced technologies such as new VTOL and STOL concepts and supercritical aerodynamics.
- Research to improve the accuracy and to increase the applicability of aerodynamic theory.
- Advanced development of improved engine cycles to minimize noise generation, increase thrust-to-weight ratio, and reduce specific fuel consumption.
- Research and development of improved structural concepts, materials, and fabrication techniques to reduce the structural weight fraction and thereby permit greater payloads and longer ranges for advanced aircraft.

The supporting analyses also show that the long-haul market has been the backbone of the air transport system. The long-haul system has been a major factor in the impressive growth of commercial air service that now accounts for 85% of all common carrier passenger-miles for trips more than 500 miles. The productivity of individual vehicles, as measured in seat-miles per hour, has increased from about 9,000 for the DC–4, to about 70,000 for the 707, to about 180,000 for the 747, representing an increase by a factor of about 20 since World War II. This growth and the general excellence of American transport aircraft, more than any of the other factors, are responsible for the world leadership position this country enjoys in civil aviation. If this leadership is to be maintained, there is a need for continuous advances in technology to insure the excellence of U. S. commercial aircraft.

There will also be a need to give increased attention to the air pollution resulting from the emissions of aircraft engines. Currently, this pollution is small compared to that generated by the automobile; less than 1% of urban air pollution is contributed by aircraft. As auto emissions are reduced and as the number of aircraft operations increase, the reduction and control of aircraft emissions will become more important, particularly in the vicinity of airports. The development of aircraft propulsion systems and fuels designed to minimize both visible emissions and noxious exhaust constituents should be accelerated. Research is needed to assess the effect of supersonic transport operations on the upper atmosphere. In the future, time-phased standards for allowable aircraft pollution, along the lines of those established for noise abatement, should be required.

There are several areas where research and development activities funded by the Federal Government might be limited. Two of these are general aviation and air cargo. Although both of these areas are important to the future of civil aviation, the Government's roles should become primarily those of setting standards and assuring safety. In accepting the responsibility for standards and safety, it is necessary that the Government sponsor the R&D necessary to discharge this obligation effectively. It appears, therefore, that Government support for research related to safety for general aviation is justified while support for that related to improved utility of general aircraft is not at present, primarily because this area lacks a demonstrable public benefit.

These and many other areas are covered in the supporting analyses.

9. CONCLUSIONS

Conclusions

The more significant conclusions and proposed actions of the Joint Study are summarized in the following lists (the order does not indicate priorities or relative importance).

The conclusions are:

1. Research and development have produced dramatic improvements in aircraft performance, economy, reliability, and safety. Since World War II, for example, commercial-aircraft productivity has increased by a factor of about 20, while direct operating costs have been reduced by a factor of about 3. Both the industry and the public have taken advantage of these improvements. As a result, civil aviation now has a significant influence on the way of life in the United States. Aviation is vital to our society in providing mobility to people *at all economic levels.* It affects the places people live, and it has a major effect on the conduct of business by permitting wide geographic dispersal of operations and by allowing vast enlargements of markets. It has become a valuable and versatile public service and has made contributions to the social and economic welfare of the Nation. It is an important factor in employment, the gross national product, U. S. regional development, the international balance of trade, and cultural exchange.

2. Civil aviation offers the promise of increased benefits to the Nation in the future. To achieve these potential benefits, R&D will be required to improve technology and to allow continued growth; R&D is also necessary to make civil aviation more available and acceptable to society. *However, these future benefits of R&D may not be fully realized without increased attention to institutional factors such as regulatory constraints, social impacts, financial conditions, and organizational problems.* In recognition of these constraints, increased emphasis will be required on nonphysical sciences such as sociology and economics.

3. The rapid growth and widespread acceptance of civil aviation have produced a variety of problems. *The major problems of civil aviation – those of immediate importance and requiring increased R&D emphasis and high priority programs – are noise abatement and relief of congestion in areas of high traffic density.* Noise abatement is important because of public concern for the environment and because successful noise abatement will affect the solution to other problems. Congestion is a complex problem and has many elements. One important need is increased R&D for the airways system and for airports to permit full advantage to be taken of the performance and market potential of new and improved aircraft. Programs to provide solutions to these major problems must consider both technological and nontechnological factors.

4. An area important to the future of civil aviation is short-haul service in areas of low traffic density. This service has great potential to contribute to the goals of the Nation by aiding regional development and by importantly affecting population distribution. Increased R&D and other actions such as deregulation and market sensitivity experiments will permit these benefits to be more fully realized and could also permit reduced subsidy cost to the Government.

5. Broad based programs are required to produce the technology necessary to solve the varied problems of civil aviation, to allow civil aviation to achieve its full potential, and to provide options for future developments. Research and technology programs are and will continue to be required in a variety of basic disciplines including avionics, communications, aerodynamics, propulsion, structures, human factors, and applied mathematics.

6. Potential costs of *not* doing adequate R&D are high; some of these costs are:

a. Increased cost for air traffic control operations and maintenance that must be borne by the Government and ultimately by the user.

b. Decreased opportunity for eliminating operating subsidy payments by the Government.
c. Increased operating costs to airlines because of terminal and enroute delays.
d. Inability to expand operations at existing airports and to site new airports because of public concern for environmental effects.
e. Loss of economic and social benefits as a result of restricted growth of civil aviation.
f. Lessening of the industry capability to meet defense needs.
g. Loss of markets because products fail to remain competitive.
h. Eventual loss of U. S. leadership in civil aviation.

7. Federal support for civil aviation research and development will continue to be required. Government funds should be used when there is a significant public interest such as safety or general benefit. In addition, conditions should exist making it clear that private industry cannot or will not act independently. Where possible, benefits should be defined and related to costs. This relationship is normally meaningful only at the level corresponding to individual projects where specific plans, cost estimates, and clearly identified applications are available.

8. During the Joint Study, no way was found to show an exclusive causal relationship between a particular level of R&D funding (cost) and a particular set of benefits. At least four factors contribute to this conclusion: (a) the nature of the R&D process itself; (b) the inability to calculate a meaningful and accurate dollar value for the military contribution to civil aviation; (c) the unavailability of complete and precise aeronautical R&D funding data for past activities; and (d) a set of economic, market and social variables (including industry competition) that affect the achievement of benefits from R&D.

9. Military aviation R&D will continue to contribute significantly to civil aviation. The emphasis in future military requirements will be different from civil aviation in some aspects, but there will continue to be common benefit from both military and civil aeronautical research. For example, there will be considerable joint benefit from technology and development programs in the VTOL, conventional subsonic and supersonic aircraft areas. STOL aircraft and their related technologies represent one area where the military have an interest but where civilian needs are more urgent.

Some of the more significant proposed actions resulting from the Joint Study are:

ENVIRONMENT

Noise Abatement. Solution of the noise problem will require balanced R&D programs designed to reduce noise generated at the source (improved design of aircraft and engines), to optimize the flight path of aircraft through use of steep descent and curved approaches, and to develop better planning and control for use of land adjacent to airports. Incentives should be used to stimulate industry to accelerate progress in noise abatement. In addition, *research* goals should be established corresponding to a reduction in noise levels at the source of about 10 to 15 PNdB per decade. Based on the results of this research, new standards should also be set for *regulation* of aircraft noise levels. DOT and NASA should assure that R&D on all elements of the problem (aircraft engines, air traffic control, and land use) are proceeding expeditiously. A special program office located in DOT and jointly staffed as appropriate by experts from NASA, DOD, and possibly HUD and EPA should be established. This office would facilitate program integration and assure the best use of available resources.

Air Pollution. Pollution from aircraft engine exhaust emissions will require continued attention. Jet aircraft produce only about one-seventh the pollution per passenger-mile when compared with automobiles. With the growth predicted for civil aviation in the future, however, this level may not be acceptable, and intensified research in engine cycles and fuels is required to provide a basis for future Government regulation in this area.

CONGESTION

Air Traffic Control. To meet current and projected demands, the capacity of the air traffic system must be increased both in the near term and with the aid of longer term improvements. To provide the required increases, R&D must be given high priority and continuing analyses are necessary to determine the best pacing for the introduction of new technology in the future Air Traffic Control System. To permit the forecast growth in air operations for the 30 primary congested terminal areas, the Federal Government should develop a time-phased program to implement a fully cooperative air traffic control system by 1980.

Airport Development. The growing size of modern airports requires that *early* airport land acquisition be assigned higher priority among the programs supported by the Airport and Airways Trust Fund. In addition, the Act should be amended to increase the share of funding provided by the Federal Government for airport grants from 50 to 67%; the overall level of airport grants for runway expansion should also be increased. The Act should be extended to include those elements comprising the *airport landside*, and thus to provide funding for R&D related to passenger processing and baggage handling. With the passage of the proposed Special Revenue Sharing Program for Transportation, the responsibility for funding these areas will be shifted to State and local governments. The Federal Government will, however, still retain its leadership role in planning and safety regulation.

Demonstration Programs. Demonstration programs are required to serve as a controlled environment in which to examine the characteristics of proposed new air transport systems, to provide data for cost/benefit analyses, to serve as a basis for deregulation, and especially to aid in the solution of the airport congestion problem. Demonstration airports should be used as tools for R&D related to terminal congestion. Experiments should be developed in such areas as time-variable landing fees, decentralized passenger and cargo processing, aircraft loading and queuing, ground control of aircraft, and runway spacing.

High-Density Short-Haul. A new short-haul system, separate as much as possible from the long-haul system, would help alleviate terminal congestion. Presently STOL vehicles offer great promise for this application. Research and technology related to STOL aircraft is needed to develop this system and to assist the FAA in establishing criteria for STOL vehicle certification and in defining STOL system operating rules. Where major experimental and possible demonstration programs are required, Government-industry joint enterprises should be explored as a method of making best use of available expertise and resources in Government, and in the aircraft and airline industries. A demonstration program should also be considered by DOT and CAB to determine experimentally the effects of deregulation in this market.

Joint DOT–NASA Effort. Congestion is a multifaceted problem and its solution can best be approached by a joint DOT–NASA effort to plan, measure, and control activities related to terminal congestion, to insure integrated action, and to make the best use of available resources. (Joint action has already started on the technology for STOL systems as one effort designed to relieve terminal congestion.) A special program office for this purpose should be located in DOT and staffed as appropriate by personnel from NASA, DOD, and possibly CAB.

LOW–DENSITY SHORT–HAUL

Market Sensitivity Demonstrations. DOT and CAB should conduct experiments in areas of low traffic density to determine market sensitivities to changes in fares, schedule, and service and to explore the effects of deregulation. The results of these market experiments can be used to guide the planning of R&D and to establish a sounder basis for Government policies covering future regulation of air carriers.

Vehicle Definition. In concert with the market sensitivity demonstrations, the NASA should analyze the need and study possible design concepts for low-density, short-haul aircraft. The combination of vehicle studies and market experiments should lead to the definition of a short-haul aircraft which would have the capacity, economic and performance characteristics to best serve the *low-density markets.*

SYSTEM-WIDE ACTIONS

Soft-Sciences. The scope of civil aviation R&D programs should be expanded to increase emphasis on nontechnological factors. For this purpose, specialists trained in economics and the social sciences should be assigned to both DOT and NASA technical staffs.

Staff Interchange. Members of the R&D staffs of the several agencies having related responsibilities in aviation (DOT, NASA, DOD, CAB, etc.) should be interchanged to provide a cadre of personnel with broad systems backgrounds and thereby lead to more effective Government action in programs affecting civil aviation.

Intermodal Mergers. It is proposed that the CAB explore a revised policy allowing intermodal mergers involving airlines. Intermodal mergers would be conducive to expanded use of air cargo and could thereby encourage innovative R&D by industry in this area. A policy allowing intermodal mergers has not evolved under the present system of multiple regulatory agencies and the creation of a single regulatory agency, as recommended by the Ash Council, may assist in the evolution of an environment favorable to these mergers.

U. S. Leadership. The United States presently enjoys a position of comprehensive leadership in civil aviation but this position could be challenged in the future. There is a need therefore for a set of measurable indicators to chart progress and trends in the civil aviation industry. Some indicators were examined in the Joint Study and it is recommended that these indicators be refined and then monitored on a continuous basis by the Department of Commerce.

NASC Role. The National Aeronautics and Space Council should develop a permanent mechanism to review and recommend national policies guiding civil aviation which embrace several agencies. Some of these policies relate to areas such as regional development and U. S. leadership that are beyond the jurisdiction of DOT and NASA alone. In performing this policy role the NASC should engage the cooperation of leaders of industry. The NASC should also monitor the combined level of military and civil aviation R&D and production programs to insure that the aerospace industry maintains a competitive capability and the capacity needed for national defense.


10. PERSPECTIVE AND FUTURE

Perspective and the Future

For more than 50 years, both industry and Government have maintained active programs in aeronautical research and development in the United States. As a result, civil aviation has enjoyed a history of rapid change and growth. Today, commercial air travel is so widely accepted that in 1970, every man, woman, and child in the United States could have flown 500 miles and the resulting passenger-miles would still not have exceeded those actually flown. While the past growth of civil aviation has been impressive, there are indications that the industry is entering a new era, where the pattern of further growth will change. In making this change, civil aviation bears many similarities to other industries that are also strongly dependent on technology. Many of these industries go through four distinct phases in their evolution (see Fig. 10.1).

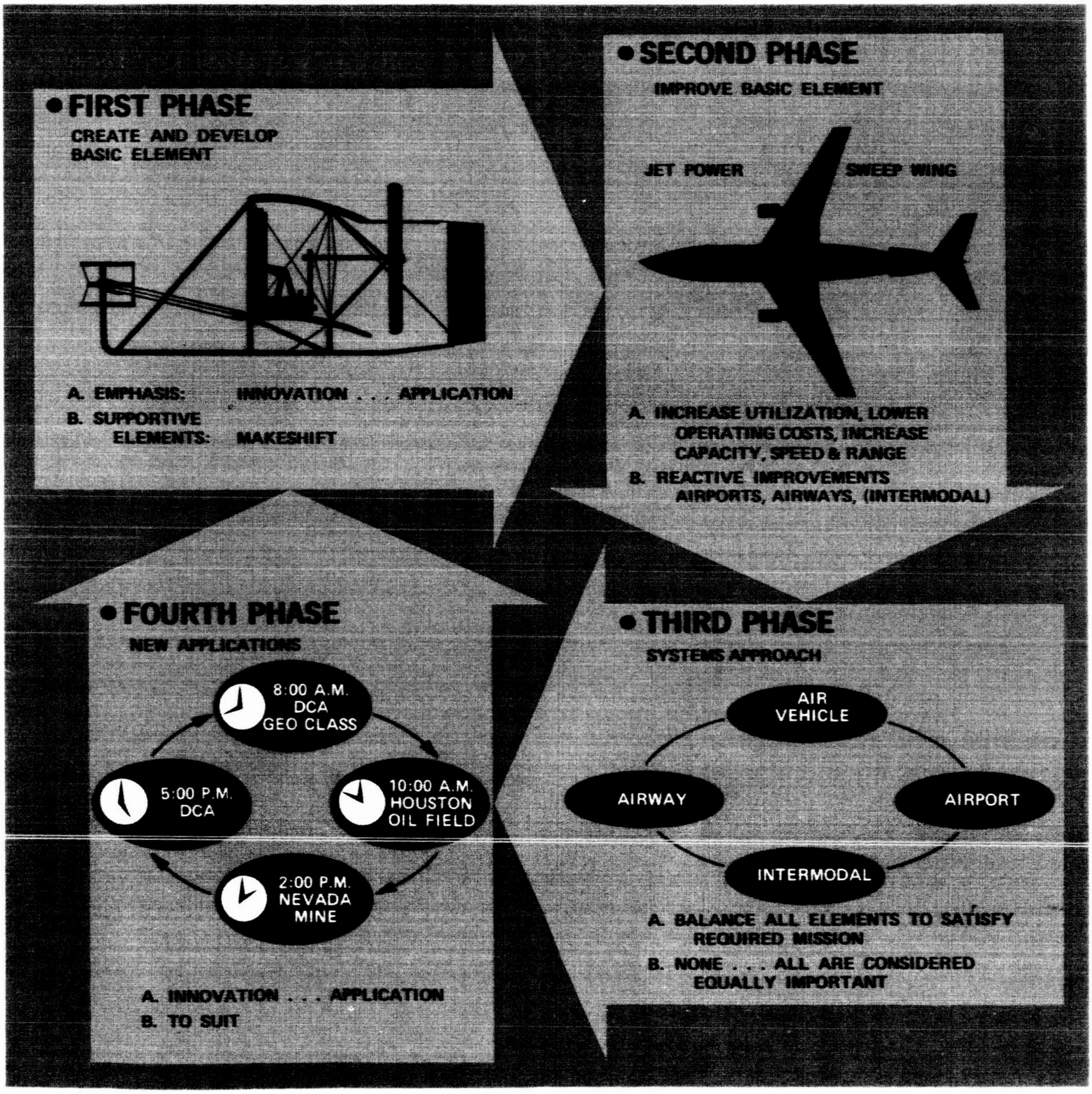


Figure 10.1. Four phases in the development of civil aviation.

In the first, or creative phase, the new idea or primary system comes into being, establishing a new industry. By the way of example, the airplane is that development for aviation; it is the central processing unit for the computer industry; it is the TV set for the television industry; and it is the car for the automobile industry.

In the second or growth phase, the product undergoes substantive change due to its acceptance by the public. At the same time, reactive improvements are made to the other elements supporting the system. Examples of this phase are the introduction of the jet with air traffic control, airports, and complementary ground transportation responding to the demand imposed by the vehicle. Similarly, the introduction of solid-state computers, color television, and automatic transmission on automobiles introduced an era of accelerated growth. Still the supporting elements of the system were not balanced one against the other. Evidence of this in the aviation industry can be seen in the congestion induced in all parts of the system but the vehicle itself.

In the third or systems phase, attempts are made to optimize the entire system. In some instances, the central element of the system is compromised in design to be more efficient in its environment. The computer industry has entered this phase with balanced performance third-generation computer systems. User-oriented devices to facilitate input and output are as important as the processing unit itself. The TV industry is also moving into the third phase. The combination of cable TV communications, the TV set, and personalized programs are today within technical reality. The automotive industry has not yet reached this phase and may not recognize its opportunity. Similarly, the aviation industry has not entered the systems phase as is evidenced by the present approach to air cargo and short-haul service. The "systems approach" means much more than analyzing technological factors of the various elements to produce a "technically perfect" system. It also takes into account aviation legislation, regulation, industry and Government institutional factors, and the impact of the approach on other modes of transportation.

In the fourth, or new application phase, the industry starts to move on a broad scale into new applications for which the original system was never intended. This change requires major product revisions. Again, aviation has not yet come to this phase. Developments are already being pursued in the television industry which will permit these communication systems to poll attitudes and opinions, to allow the housewife to do her shopping at home, and to serve as a home education system as well. The computer industry is planning for a similar revolution, whereby entire factories can be run automatically from purchasing raw materials, to designing, manufacturing, and shipping; similarly, the computer may be used to perform delicate medical operations or assist the housewife with her chores.

Previous studies, as well as the present Study, suggest that much of civil aviation's future growth will be dependent on the industry's moving into the third or systems phase. Aviation now has that opportunity, but the questions are – Is the opportunity recognized? Is the industry capable of moving into the third phase? What are the deterrents that might prevent it from doing so?

In the past, some industries have recognized the need for change while others have not. In the latter case, there was a common tendency to stay with a tried and true approach. In the case of civil aviation, the traditional approach has been to develop faster, longer-range, and bigger aircraft. Many present-day aircraft fly close to the speed of sound (the current overland limit) and have transcontinental range. While an SST will provide increased productivity for overseas flight and while further increases in size and efficiency are possible, future growth of the industry could be equally dependent on compromising vehicle performance to the overall performance of the entire system which includes not only the vehicle, but the airports, air traffic control, and ground transportation systems that feed them. Easily recognizable as representing this trend is the current interest in V/STOL systems. In general, the direct use of power to produce lift and other compromises inherent to V/STOL vehicles results in slower, shorter-range, and smaller aircraft having lower productivity and higher direct operating costs. Such compromises are justified, however, if the vehicles can provide better overall service to the traveler and if they can be made more compatible with the air traffic control, airports, and ground feeder systems.

Many considerations could affect civil aviation's implementation of a more balanced systems approach. In recognition of these effects, the present Study has examined such systems factors as areas of R&D requiring increased emphasis, policies affecting Federal Government involvement in civil aviation R&D, and regulatory constraints. If aviation can move into the third and possibly the fourth phase, it could provide greater utility to more segments of society. Response to this objective represents civil aviation's biggest challenge and opportunity for the future.

Appendix A - Supporting Papers

In addition to the present report, a complementary volume entitled "Joint DOT-NASA Civil Aviation R&D Policy Study – Supporting Papers," has been prepared and is available as Department of Transportation Report TST-10-5 and as National Aeronautics and Space Administration Report SP-266.

The sections in this complementary volume cover a variety of technical and nontechnical subjects which either comprise the elements which make up civil aviation or are factors having a bearing on civil aviation. Each of the technical sections is based on analyses which included examining characteristics and growth to date, current problems, future requirements (demand for service), potential solutions, implications for R&D, and recommendations.

The sections of this complementary volume include:

Systems Status and Potential

Missions
- Commercial Passenger Service
  - Long-Haul Systems
  - Short-Haul Systems
- Air Cargo
- General Aviation

Systems Elements
- Air Vehicles
- Air Traffic Control
- Airports
- Complementary Surface Transportation

Special Considerations
- Environmental Factors
- Financial Considerations
- Foreign Competition
- Military Contributions to Civil Aviation

Policy
- Institutional Factors
- Policy Issues

Benefits

In addition, the Joint Study produced the following contractor reports:

Institutional Factors in Civil Aviation, prepared by Arthur D. Little, Inc., Cambridge, Massachusetts, under Department of Transportation Contract OS-00083, Washington, D. C., available as DOT Report TST-10-1 and as NASA Report CR-1807, January 1971.

A Historical Study of the Benefits Derived From the Application of Technical Advances to Civil Aviation, Vol. I, Summary Report and Appendix A, prepared by Booz, Allen Applied Research, Inc., Bethesda, Maryland, under Department of Transportation Contract OS-00020, Washington, D. C., available as DOT Report TST-10-2 and as NASA Report CR-1808, February 1971.

A Historical Study of the Benefits Derived From the Application of Technical Advances to Civil Aviation, Vol. II, Appendices B Through I, prepared by Booz, Allen Applied Research, Inc., Bethesda, Maryland, under Department of Transportation Contract OS-00020, Washington, D. C., available as DOT Report TST-10-3 and as NASA Report CR-1809, February 1971.

Appendix B - Organization and Acknowledgment

ADVISORY COMMITTEE

An Advisory Committee, organized within the framework of the National Academy of Engineering, was established at the outset and provided invaluable advice and guidance in the course of the Joint Study. Members of the Advisory Committee were:

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The Joint Study was staffed with selected personnel from the following agencies:

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Department of the Air Force
Department of the Army
Department of the Navy
Department of Transportation
National Aeronautics and Space Administration

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[1] Lawrence P. Greene served as Executive Director of the Joint Study from its beginning until July 1970.

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