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Symposium on the United States Commercial Supersonic Aircraft Development Program

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SYMPOSIUM ON THE UNITED STATES COMMERCIAL SUPERSONIC AIRCRAFT DEVELOPMENT PROGRAM

INTRODUCTION

LUCILE S. KEYES, ASSOCIATE EDITOR

THE articles in this issue were originally submitted as statements to the Aviation Subcommittee of the United States Senate Commerce Committee in October, 1963, during hearings¹ concerning the government's program for development of a supersonic commercial aircraft. Manufacturers' proposals for the design and development of such an aircraft are now being evaluated by a governmental committee. As the articles show, the planning of this program has involved important political and organizational issues, relating to the distribution of functions both among governmental agencies and between government on the one hand and private industry on the other. The history of the program also brings out the major influence of foreign government policies in setting limits to the freedom of the United States to choose its own course in matters affecting international air transportation. This country's initiation of the present program was prompted by foreign government actions, and, whether or not the United States program succeeds, the decision of these governments to produce the Concorde may well have a profound effect on the institutional framework and economic performance of international civic aviation in the 1970s.

Although the technical problems involved in the design of the supersonic transport have been under active study by United States government agencies since 1956, it was not until mid-1963 that the President announced his decision to proceed at once to explore possibilities for development of this aircraft by United States manufacturers. This decision resulted directly from the progress of the British-French Concorde development program, which had at that time been under way for more than two years and which had reached the point where conditional orders were being solicited and accepted from United States air carriers.

The Concorde, which is designed to fly at a speed of Mach 2.2, carry a maximum of one hundred persons, and have a range of 3,700 miles, is expected to be available in 1969 or 1970, and will be sold for approximately ten million dollars, a price which includes none of the estimated 500 million dollars in development costs contributed by the participating governments. Even at this price, as CAB Chairman Alan Boyd notes in his statement, the aircraft may well not be able to compete on a cost-covering basis with the subsonic jets, and may therefore give rise to a need for operating subsidies not only for European airliners but for United States carriers who may be forced to buy these planes in order to attract traffic.

¹ *United States Commercial Supersonic Aircraft Development Program*, Hearings before the Aviation Subcommittee of the Committee on Commerce, U. S. Senate, 88th Congress, First Session (October, 1963). The articles have been selected with a view to presenting a variety of points of view. All have been extensively edited. For the sake of ease of reading deletions of material have not been indicated in the text of the articles as presented in this issue.

Prospects for earnings apparently did not affect the European decision to build this plane, which was regarded primarily as a make-work project for aircraft manufacturing concerns.

The program now under consideration in this country does not, however, envisage production of an uneconomic aircraft. The government is offering to furnish three-quarters of the funds necessary to cover development costs of up to one billion dollars; but these funds are to be repaid during the operating life of the planes. The requirement that manufacturers take twenty-five per cent of the risk is intended to insure realistic bidding. In its *Request for Proposals for the Development of a Commercial Supersonic Transport* issued on August 15, 1963, the FAA specified not only a speed of Mach 2.2 or better, as well as "operational characteristics which will ensure maximum safety and adaptability to airport communities and air routes of the world," but also "economic characteristics equal to, or better than, current subsonic jet transports now engaged in transcontinental and international operations." Both range and payload are expected to be superior to the Concorde, but the price is expected to be perhaps twice as high.

The preponderance of United States expert opinion has been that effort should be concentrated on a pioneering venture into titanium-steel construction, and speeds of Mach 3 and over, rather than on the production of an aluminum aircraft, of the Concorde type, operating at or near the top speed for a plane built of that material. As Dr. Jerome B. Wiesner, former Director of the Office of Science and Technology, has said, the second type of effort utilizes "the end of the old technology," whereas the first would offer "maximum opportunities for growth."² It is still doubtful whether the more advanced technology can at the present time be incorporated in a commercially viable aircraft; but even if this should prove possible, the effort will presumably be based on a less thorough research background than would have been the case had the program not been forcibly accelerated.

Certainly the statements before the Committee contain ample justification for intensive exploration of possibilities for developing a self-supporting supersonic transport in time to compete with the Concorde for the business of the world's airlines. Unless this feat can be accomplished, United States-flag carriers will in all probability face reduced earnings and possible losses whether or not they buy the Concorde; a significant adverse effect on this country's balance of payments will be experienced as the world's airlines buy long-range aircraft abroad rather than here; and our aircraft manufacturers will be excluded from a large market, possibly for several years.

On the other hand, the successful development of the self-supporting supersonic transport cannot be expected to solve all the problems raised by the Concorde, which is unlikely to be abandoned at this stage of the game and may be thrust upon European airlines regardless of their management's preferences. In addition to the temporary over-capacity which may well accompany the introduction of the new type of plane, as it has accompanied the introduction of the first generation of jets, the presumably high cost of operating the European aircraft may well intensify differences between European and United States positions on matters of

² *Hearings*, p. 205.

international air transport policy and hinder progress toward a more competitive way of life in that field. In the past, governmental pressures for high and rigid fare agreements and for other restrictive measures have arisen from identification of national interest with the financial interest of the nation's own flag carrier. Such pressures can only be strengthened if these carriers are subjected to financial strain because of governmental decisions as to the aircraft they must operate. These prospective difficulties serve to emphasize that the discouragement of uneconomic and subsidized competition should be a major long-range objective of United States international air transport policy, and to suggest that much more attention should be devoted to the development of means for furthering this aim.

VIEWS OF THE GOVERNMENT

FROM THE REMARKS OF PRESIDENT JOHN F. KENNEDY DELIVERED AT
THE UNITED STATES AIR FORCE ACADEMY, JUNE 5, 1963

[I]t is my judgment that this government should immediately commence a new program in partnership with private industry to develop at the earliest practical date the prototype of a supersonic transport superior to that being built in any other country of the world. An open preliminary design competition will be initiated immediately among American air frame and powerplant manufacturers with a more detailed phase to follow. If these initial phases do not produce an aircraft capable of transporting people and goods safely, swiftly and at prices the traveler can afford and the airlines find profitable, we shall not go further. But if we can build the best operational plane of this type, and I believe we can, then the Congress and the country shall be prepared to invest the funds and efforts necessary to maintain this nation's lead in long-range aircraft, a lead we have held since the end of the Second World War, a lead we should make every responsible effort to maintain.

Spurred by competition from across the Atlantic and by the productivity of our own companies, the Federal government must pledge funds to supplement the risk capital to be contributed by private companies. It must then rely heavily on the flexibility and ingenuity of private enterprise to make the detailed decisions and to introduce successfully this new jet transport into worldwide service—and we are talking about a plane in the end of the sixties that will move ahead at a speed faster than Mach 2 to all corners of the globe.

This commitment, I believe, is essential to a strong and forward-looking nation and indicates the future of the manned aircraft as we move into a missile age as well.

N. E. HALABY

ADMINISTRATOR, FEDERAL AVIATION AGENCY

When viewed in the light of aviation's history, the development of a supersonic transport is consistent with the primary mission of commercial aviation to provide safe and fast transportation, and is, in fact, an inevitable

step forward. If for any reason the United States should not produce a sound commercial supersonic transport, we will have defaulted the leadership in commercial aviation to the British and French or to the Russians. If the Concorde is the only SST available to the airlines of the free world, and if for any reason it does not possess the requisite economic characteristics to permit our airlines to operate at a profit, we will have contributed to weakening this valuable national asset. We would not seriously entertain the thought that we should rely solely on British-French efforts to produce ships or buses for the free world, and no more can we avoid our responsibility to meet our obligation to maintain United States leadership in the field of commercial aviation.

President Kennedy in his letter to the Congress of June 14, advised that our national aviation objectives as formulated by the Congress in the Federal Aviation Act of 1958, clearly require that the United States undertake the development of a commercial supersonic aircraft. This aircraft must be safe, economically sound, and operationally superior to any comparable aircraft. The President's identification of this requirement emphasizes the policy of the Congress for the development of an air transport system that will further our domestic and international commerce and national defense.

Our commitment to this program is consistent also with United States pre-eminence in science and technology. We propose to construct the safest, most commercially efficient, and perhaps the fastest passenger aircraft at the earliest possible date. Its introduction into passenger service will illustrate this nation's capability of producing the logical successor to America's famous family of transport aircraft which has found acceptance among all nations. We have the opportunity and the capability to demonstrate our dedication as a nation to the perfection of a vehicle operating at such speed as to revolutionize travel among nations. As an instrument of international communications and commerce, its impact will be immeasurable. The supersonic passenger aircraft has an even more immediate significance to this country. It will signal a new growth of aviation. It will energize and invigorate the United States aircraft and engine manufacturing industries and American air carriers, and will enable these valuable resources to maintain and strengthen their skills in the national interest.

Even though the British-French program to develop the Concorde holds promise of one type of commercial supersonic transport, the realization of the United States program objective will, in our opinion, result in a superior transport. We confidently anticipate the development of an entirely new market attracting new travelers to air transportation, in addition to the equally important market for the sale of the aircraft itself.

A. Market Potential

On the basis of comprehensive studies by the Stanford Research Institute, after consulting with many of the major airlines of the world, they estimated that airline passenger miles will increase 150 per cent by ten years from now and the 1962 free world figures of approximately eighty-one billion revenue passenger miles should grow to almost 200 billion in 1973. Forty-three per cent of the total world market anticipated for 1973, or approximately eighty-seven billion passenger miles, is expected to be potentially available to the supersonic transport. In anticipation of such

expansion and travel there should be a potential for 250 United States Mach 2 aircraft and 128 Concordes, or 216 United States Mach 3 as compared with 125 Concordes. We regard these estimates as conservative in some respects, since the Stanford Research Institute study was based on a hypothetical aircraft which is less commercially attractive than we believe will be possible to attain through the development program.

I think those who have to sell airplanes may say that these figures look optimistic. However, in my opinion the Stanford Research estimates were carefully determined. They were tested by two different approaches. They estimated that eighty-seven billion passenger miles would be available to the SST in 1973 and divided this figure by the average passenger mile productivity of the SST thus determining total aircraft requirements.

In the second approach, Stanford Research reviewed the operations of all free world airlines currently using subsonic jets and estimated their requirements for the SST in the 1970's. In many instances they confirmed their estimates through interviews with the airlines themselves. As a result of these two approaches, Stanford Research estimated that the first round orders would approximate 378 transports. If the SST is as effective as we think it will be, the follow-on orders by the airlines of the world could substantially increase this number.

There is, of course, the question whether airlines will have the financial resources to purchase the SST in the 1970 time period. Because of the mounting prosperity of the carriers we are convinced that they will, and I believe that the Chairman of the Civil Aeronautics Board will confirm that at least the United States airlines will have the resources required.

There will be at least a twelve-year period between the introduction of the current subsonic jets and the introduction of the supersonic transport. This is a substantially longer period of time than has elapsed in the past between availability of new generations of transport aircraft.

The potential market for an American SST is, of course, a significant factor in the balance of payments problem. In view of our continuing unfavorable balance of payments position, the effects of the purchase or sale of the SST on foreign trade becomes an important consideration. While economic forecasting is risky under any circumstances, we have made a projection based on the Stanford Research Institute's market forecast of first-round orders. We estimate the impact upon the aeronautical segment of the balance of payments for the period 1970-79 to be as follows:

1. Assuming no United States SST program, there would be a deficit of 1.07 billion dollars.
2. Assuming a superior United States Mach 2 aircraft, there would be an export balance of 1.23 billion dollars.
3. Assuming a successful United States Mach 2.5-3.0 SST, there would be an export balance of 2.75 billion dollars.

B. Characteristics Of The Aircraft

I would like to turn now to the more difficult questions—What kind of aircraft are we seeking and how do we propose to get it? What are the required characteristics of the SST as we view them? First, it should serve the major markets of the world on a non-stop basis. Thus, we seek a range of approximately 4,000 statute miles, which will accommodate eighty-five per cent of the potential traffic. The aircraft should have a gross weight in the order of 350,000 to 400,000 pounds with a payload of from 30,000

to 40,000 pounds, and should carry from 125 to 160 passengers and 2,000 pounds of cargo and mail.

The aircraft must accelerate through the transonic speed regimes at altitudes above 40,000 feet, and cruise at altitudes which will reduce the sonic boom, and, thus, the adverse reaction from people on the ground. It must be capable of operating at airports designed to accommodate today's larger subsonic jets and should produce no more noise on arriving and departing than today's jets create for the area surrounding the airport. Its handling characteristics should be equal to or better than those of today's large jets.

To the extent compatible with structural, safety and economic features, we have an open end objective on speed. We feel more than reasonably confident that we will achieve speeds in excess of those known to be the objective of any comparable commercial transport. We should have an aircraft ready for passenger service within a year after the planned introduction date of the Concorde in 1970.

It has been generally assumed that the United States SST development program is seriously behind the British-French effort. This assumption does not take into consideration that the United States has spent billions of dollars during the last decade developing supersonic aircraft such as the X-1, X-15 research vehicles and military aircraft; B-58, F-4H, F-104, and B-70. In addition, for the last several years, major manufacturers have been devoting intensive study to the problems of the SST as well as cooperating with the FAA-funded research program which was approved for the past two years by the Congress.

There have been at least ten aircraft companies in the United States that have successfully developed and produced aircraft capable of supersonic flight. These companies include Boeing, Douglas, General Dynamics, Lockheed, North American, McDonnell, Northrop, Republic, Ling-Temco-Vought, and Grumman. The period of time that these companies have been studying and conquering problems associated with supersonic flight represents an aggregate of more than one hundred company years. These ten companies have developed approximately twenty different supersonic systems and their aircraft have accumulated more than 100,000 hours of flight time at speeds in excess of Mach 1. We have accumulated more than 2,000 hours of flight time at Mach 2 or better, which is in excess of 1,400 miles an hour. With this technological background, we are very much in the game right now, although many problems remain to be solved.

Beyond the actual supersonic experience itself, the fact that the United States aircraft companies have built and sold more than 600 successful large commercial transport jet aircraft is of considerable significance. Experience in solving problems associated with airline operation is of major importance. As a result of these programs, DOD and NASA have been intensively engaged in dealing with the technology of supersonic flight. Both of these agencies, therefore, constitute rich technical resources which we plan to utilize in the program.

The intensive and extensive tests required of a modern prototype aircraft are sometimes overlooked—the dynamic tests in the air and static tests on the ground. These supersonic experimental aircraft will be subject to more ground simulation and flight testing than any in the history of aeronautics. From these tests will follow redesign and modifications of the

prototype before it becomes a production model; then the production model will require full testing leading to certification of its airworthiness. There will also be a very substantial program of simulation and actual training of crews and maintenance personnel in the course of which much more will be learned and fed back into the airplane. This whole cycle will take more time than ever before and it is during this period that the wider and deeper United States experience will give this country a very important edge over others.

The real payoff of a sound technological background preceding actual development of an aircraft is not related to the beginning date of detailed design. It is rather in reducing the time lost in correcting mistakes in the preproduction prototype. We believe that we have established a solid foundation for the United States supersonic transport from experimental and military aircraft as well as the research programs which have been going on for the past several years. The value of this effort will be reflected in the quality of the first aircraft fabricated. This then will be the true test of whether the British-French effort is ahead of the United States development program. We are confident that the so-called lag of the United States effort to the British-French effort will prove to be non-existent or minimal.

The knowledge gained through this research, development, and production program will assist the manufacturers in developing the transport through the use of advanced techniques and within a reasonable time period. Our sound foundation in supersonic technology is one of the reasons we have such high confidence in the capability of the United States industry to more than match the efforts of the British-French industry.

C. The Development Program

The development program under which we are proceeding consists of three phases. Phase I is an initial design competition among three airframe and three engine companies. Out of that competition may emerge a clearly superior and obviously "winning combination" of airframe and engine. If so, the government in consultation with the airlines, would be able to make an award and proceed without further competition. However, if no clearly "winning combination" emerges, Phase II involves a detailed design competition, for a twelve month period, at a cost to the government of approximately sixty million dollars. Phase III is scheduled to begin July 1, 1965, and will see the development of the transport through proof of its airworthiness for passenger use. The cost of Phase III may range from 700 to 940 million dollars depending on the design characteristics ultimately determined.

The program's initial design competition phase was inaugurated on August 15, 1963, by the issuance of our Request for Proposals. This is somewhat unusual in the procurement field. Its publication was preceded by extensive consultation with interested persons and groups to insure that the objectives stated were realistic and fully understood. Before the proposal was finalized, meetings were held with the airframe and engine manufacturers, the airlines, interested government agencies, and other groups including the Air Line Pilots Association, Air Line Dispatchers Association, Flight Engineers' International Association, National Association of Noise Abatement Council, AFL-CIO, American Association of Airport Executives, Transport Workers Union of America, Aerospace Department of United Automobile Workers, International Association of Machinists,

and Airport Operators Council. We had the benefit of the cumulative judgment of all these organizations in putting the Request for Proposals in final form. The formal release of the Request was followed by a period in which manufacturers were invited to submit questions.

Our timetable called for manufacturers to indicate by September 10, 1963, whether they intended to submit proposals. By that date, three major airframe manufacturers and three major engine manufacturers had notified us that they intended to submit proposals in the design competition. The airframe manufacturers are the Boeing Company, Lockheed Aircraft Corporation, and North American Aviation. The engine manufacturers are Pratt and Whitney, General Electric, and Curtiss-Wright. These concerns represent immense reservoirs of talent and experience in development and production of airframes and engines, both for military and civil application. These companies have already turned their very considerable capabilities to intensive study of supersonic transport development in its many facets.

In the important task of evaluation, we intend to draw freely on the technical experience of DOD, NASA, and the CAB. Detailed evaluation of the proposals will also be submitted by the potential purchasers of the aircraft—the air carriers. In addition, engine manufacturers proposals will be submitted to selected airframe manufacturers for review and evaluation. We will, by May 1, 1964, be in a position to award contracts to one or more airframe and engine manufacturers.

According to our schedule, we should know, by April 1964, precisely what type of an airplane we will produce within very reasonable limits. We believe that it will be possible to produce a Mach 2.5 to 3 steel-titanium transport for commercial service before June 1970.

It may even be possible to complete the program at an earlier date depending upon the design characteristics finally determined, or if unforeseen technological difficulties emerge it may take longer. On the other hand, a Mach 2.2 aluminum transport, for example, could be available in 1969. Of course if we are indecisive, if we change our minds repeatedly under various kinds of pressures and preferences, we could extend the development time by years and we could increase the cost very substantially.

D. Industry Financial Participation

Our objective is that the airframe and engine manufacturers will participate in twenty-five per cent of the total program requirements. We consider financial participation an eminently reasonable requirement, since the only justification for government support of the development program is that the risks and costs associated with it are beyond the financial capability of manufacturers. Unless manufacturers demonstrate faith in the program by undertaking to share substantially, there will be doubt of the justification for funding by the government. This is an important point and should be emphasized, because it indicates very clearly that this is not to be an unrestricted subsidy, a give-away program, or a handout in any respect.

Costs in excess of the manufacturers' development contracts are proposed to be prorated as follows:

1. Of the first one hundred million dollars in excess of contract price, the manufacturer to pay seventy-five per cent, the government to pay twenty-five per cent.

2. All costs over one hundred million dollars in excess of the contract price to be paid by the manufacturers.

This, of course, contrasts very sharply with the space and military procurements where many contracts are cost plus fixed fees, and where overruns are frequent, and are funded by the government. That is not what we have in mind here.

In Phase II, the detailed design competition, the government will reimburse unsuccessful contractors for all development cost after delivery of all design information, hardware, patents, and rights to the government. In other words, if we go on to Phase III and one manufacturer is selected over another, the unsuccessful company is entitled to its investment, and the government is entitled to the fruits of its work. We do not yet know the development cost and will not know until we see proposals which will determine what manufacturers propose to build and have carefully investigated the cost estimates. On our estimated range of costs, 700 to 940 million for Phase III, the manufacturers' twenty-five per cent participation would require a contribution of 175 to 235 million dollars of which the engine manufacturers' share would be approximately forty per cent and the airframe manufacturers' sixty per cent.

I would like to emphasize that until we receive the proposals, we will not know the amount of the financial participation which will be required by the manufacturers. To the extent that two or more manufacturers collaborate with each other, the risk will be shared and the impact on each will be reduced. It is also possible that prime manufacturers might require participation by sub-contractors in meeting the financial commitment, as has apparently been done with both courage and apparent success by Douglas, in proceeding with the DC-9.

The financial participation requirement itself constitutes a very important check and sanction on the manufacturer. It not only enables us to have a method of evaluating the soundness of proposals to be made by the manufacturers, but will ensure realistically costed estimates because the manufacturers will know that a solid amount out of every dollar is theirs. The financial participation requirement will also reflect the manufacturers' confidence in their ability to deliver a sound commercial transport. It is, of course, evident that the manufacturers will have to assume the additional financial requirement associated with production of the transport. These costs, which include production tooling and "work-in-process" will, during the early stages of the production program, amount to several hundred million dollars. The exact amount will be determined by the required production rate of aircraft per month among other factors.

We have from the beginning stated that during this period manufacturers would probably require government assistance in the form of guaranteed loans. It is evident, therefore, that the financial participation of the manufacturers in this program will be substantial, but the manufacturers tend to overlook the obvious fact that the successful manufacturers will have a monopoly in the United States for the production of the supersonic transport. Assuming a sound commercial transport, they will be assured of a production run in the order of ten years and will, of course, be expected to make a profit.

E. Air Carrier Financial Participation

The air carriers, because they are direct beneficiaries of such a program,

will also be required to demonstrate their confidence. Without this confidence the government expenditures cannot be justified. Since the economic and operational performance of the aircraft should be reasonably predictable at the end of Phase II, air carriers who wish to place orders for aircraft within six months after Phase II completion, will be required to make payments in the order of 200,000 dollars per aircraft. This payment is in the nature of a royalty to defray a portion of development costs.

Those air carriers who desire to ensure delivery positions may do so at this time by making a payment of 100,000 dollars for each aircraft to the government. Our contract with manufacturers will require that these delivery position commitments be honored. These delivery positions will be non-transferrable. Two major United States airlines have formally proposed arrangements assuring delivery of twenty-one aircraft and backed them with partial royalty payments of 2,100,000 dollars. Another air carrier has telegraphed a comparable proposal for six additional aircraft.

All aircraft ordered after the initial period will require a royalty of 500,000 dollars. Additionally, carriers will be required to repay the government's development contribution through a royalty in the order of 1.5 per cent of revenues generated by the aircraft over a twelve-year period. These royalties will be terminated as soon as the government's share of the development program has been recovered, and no interest will be charged. The government does not plan to pay operating subsidies to airlines for operation of the supersonic transport.

As President Kennedy indicated in his letter to Congress, we must be prepared to postpone, terminate, or substantially redirect this program whenever it fails to achieve its objective. These primary decision points, these D-days, will be:

1. After completion of the Phase I competition if it is clear that requisite aircraft characteristics or program costs will not be achieved.
2. After completion of the Phase II competition if it is clear that requisite aircraft characteristics or program costs will not be achieved.
3. If manufacturers are unwilling to meet the financial participation requirement.
4. If airlines do not order a significant number of transports within six months after the completion of Phase II.
5. If the production prototype aircraft does not demonstrate the required characteristics after one hundred hours of flight test.

I cannot over-emphasize our determination to stop the program if and when it is clear that a commercially sound aircraft is not feasible. We will not continue from that point and compromise on a research aircraft. Our objective is a sound commercial supersonic transport. We neither want nor will settle for less.

F. The Government's Role

An understanding of the government's role in this program is very important. The major factors and related weights to be used in determining winners of the design competition were made public prior to initiation of the competition. Every effort will be made to preserve the normal relations between manufacturer and air carriers and, to the maximum practicable extent, leaving the designing and developing, producing, servicing and operating of the aircraft in the hands of our competent United States industry. We will limit the role of the government to the degree required

to meet international competition and to protect public investment.

The President designated the Federal Aviation Agency to supervise the program and has instructed me to ensure that this country produces this aircraft as a highly productive new part of our transportation system and our economy, and as a demonstration of our ability to maintain a position of technological pre-eminence. FAA, of course, will also have the additional responsibility to plan and provide for the navigation, communication, traffic control, airport and operating environment in which the supersonic transport will operate. FAA will vigorously enforce airworthiness standards for United States and for competitive foreign aircraft. It should, therefore, continue the work thus begun and see that this craft is engineered into the national aviation system with greatest safety and economy.

For its part, the FAA will organize a management staff of less than one hundred administrative and technical personnel. They will function as an independent unit within the Agency under the direct supervision of the Deputy Administrator for Supersonic Transport Development, Mr. Gordon Bain, a man of wide and deep experience in government and the aviation industry. Fortunately, he is the right man in the right place at the right time and can bring to bear his experience as Executive Vice President of Slick Airways, and more recently as Vice President of Northwest Airlines.

Mr. Bain's group will make use of all resources within the government to the maximum extent feasible and concentrate their efforts on direct supervision and evaluation of the progress of the program. The cost of the administration and development of the program will be budgeted for separately from the regular FAA budget, so as to be able to more particularly identify the cost of this program and isolate it from the regular FAA budget.

Contracts let in the course of the program will include the recovery of development costs clause, standard in FAA procurement regulations, under which the government reserves the right to charge royalties on any commercial exploitation of products developed with Federal funds. The Agency's patent rights clause will be employed, under which patent rights will be retained in proportion to the Federal investment. The larger the share of the government's contribution, the larger the share of the patent rights. Thus, patents will inure to the benefit of the United States and a contractual basis will be provided for recovering development costs through royalties.

There is a definite need for full public understanding of this program and its consequences. Essential to such an understanding is a clear endorsement and expression of support from the Congress. The FAA authorizes the undertaking in which we are now engaged. In appropriating funds for this activity in fiscal years 1962 and 1963, the Congress has recognized this authority.

G. The Risks

The principal risk is found in the technical problems inherent in producing a transport that can operate continuously at supersonic speeds. These problems are substantial. To date, most of our supersonic flight experience has been at burst speeds, five to fifteen minutes, for example, at Mach 2. I have had two Mach 2 flights, one in the B-58 and one in the

F-4H and, in each case, due to fuel and other considerations, we were flying at approximately 50,000 feet at Mach 2.1 or Mach 2.2 for only five minutes at a time, and that is in general the kind of experience we have had to date. But in a supersonic transport we will be dealing with three hour flights at 60,000 to 70,000 feet. Maximum temperatures in the order of 306 degrees F. will be encountered at Mach 2.2, the design point for the Concorde, and can range to 620 degrees, should the competition disclose that we should cruise at Mach 3. Of course, our astronauts encounter temperatures much higher than this, but again for very brief periods.

The risk also exists that a supersonic transport might be developed which would not have requisite economic characteristics to permit it to operate profitably in commercial service. We feel confident we have the resources to meet this challenge and we must proceed with faith that the cost barrier can be pierced. There is little question but that the manufacturers, to succeed in this project, will have to exercise extraordinary management techniques to assure attainment of a high degree of productivity. The delivery price of the United States supersonic transport must be in relation to that of the Concorde, with higher costs justified only by design features which render the aircraft more productive.

Informally and on a general basis, I have said to the manufacturers, "Here is an opportunity for you to demonstrate your capability. Here is an opportunity to go to work and show that with reduced overheads, with tight cost controls, that you can estimate, that you can build, in a free enterprise economy, with minimum government assistance, a superior article." I have gotten a variety of responses from the manufacturers. A few say, "It is tough, but we can do it." Some say, "We are just now taking the bandages off the burns suffered our last try at such a task."

It is no secret that the manufacturers have been through what might be called a financial trauma. The manufacturer of the DC-8, Douglas, has recorded in its annual reports very substantial losses (over 200 million dollars) to its stockholders. The manufacturer of the 880/990 series, the Convair Division of General Dynamics, has recorded in its annual reports losses to its stockholders amounting to almost 400 million dollars. Lockheed on its turboprop electra and the Jet Star has recorded substantial losses, between fifty and one hundred million dollars, and Boeing says it has barely broken even on the 707/720 series. Therefore, they look with great concern and anxiety, and will calculate with enormous caution whether or not to accept the challenge that we are posing here to an industry that must remain enterprising, and at least as free as it is today. Because of these considerations and others, General Dynamics and Douglas have indicated that they will not be able to be prime contractors. These two companies have their hands full with the TFX and the DC-9. On the other hand, both have indicated a willingness to assume associate or sub-contractor roles.

I feel that the law of supply and demand should continue to operate in the civil transport aircraft industry. Unfortunately, the development costs for so complex a technological accomplishment are so high that the government must, in my judgment, step in and provide this kind of assistance. But it should not design and build an airplane as though we were a nationalized industry or a socialized country.

Another risk which we must recognize is sonic boom. This is a problem of major magnitude which if not resolved could seriously restrict domestic operations. Very briefly, sonic boom is the pressure exerted by a release of energy occurring when a moving object such as a wing or fuselage of an airplane exceeds the speed of sound. Shock waves are formed on the airplane surfaces which extend to the ground and are heard by the observer as mild explosions. This is called overpressure and is measured in pounds per square foot. The formation of shock wave and resulting sonic boom is an inescapable physical phenomenon.

An overpressure of 1.5 pounds per square foot is similar to a clap of thunder. Lower than 1.5 it is like distant thunder. High overpressures—over two pounds per square foot—are very disturbing and may break windows.

As with all noise, the best antidote is distance. Therefore, the altitude at which this airplane climbs and accelerates through the transonic range of Mach 1.1 to 1.2 and the aircraft attitude (the climb angle) and the weight, all require this airplane to have a powerplant that will permit high altitude acceleration. Initiation of acceleration at over 40,000 feet will permit partial dissipation of the energy in the shock wave and therefore the irritation to the recipient. And then, secondly, the aircraft must cruise at a very high altitude, we believe, in the order of 60,000 to 70,000 feet, which is twice the average altitude that our current jets fly. We believe the problem can be alleviated to some degree through aircraft design characteristics and aircraft routings.

ALAN S. BOYD

CHAIRMAN, CIVIL AERONAUTICS BOARD

The Civil Aeronautics Board supports the Federal Aviation Agency's program objectives of the development of a United States commercial supersonic transport that has,

- (a) Operational characteristics which will insure maximum safety and adaptability to airport communities and air routes of the world.
- (b) Economic characteristics equal to, or better than, current subsonic jet transports now engaged in transcontinental and international operations.¹

The CAB is charged with both the promotion of economical and efficient service by the air carriers and also the promotion of safety in air commerce. The Board has kept abreast of airline, manufacturer and government activity in the supersonic commercial air transport program through its Bureau of Safety, Planning Office and other staff sections. We expect to participate more fully in the future months as the program comes down to the wire and probative economic and technical data become available.

As is indicated by the wide-ranging declaration of policy for the Board in the Federal Aviation Act, we have a great interest and responsibility for practically all economic aspects of SST or any other airline operations. The primary economic considerations may be most conveniently grouped as they affect revenues, costs, competition, physical prerequisites, and arrangements affecting the over-all economics of air transportation.

¹ FAA, Request For Proposals For The Development Of A Commercial Supersonic Transport, p. 3 (1963).

The government sponsored program for the design and production of the aircraft is going forward in accordance with the FAA's Request for Proposal. The RFP contains a detailed program and certain design specifications based on current knowledge of the art. The Board is aware of the many economic trade-offs which have to be examined in designing an aircraft which will minimize community noise and sonic boom overpressures and maximize range, payload and operating cost characteristics. The Board is in essential agreement with the physical characteristics proposed in the RFP as reflecting a good initially attainable supersonic commercial air transport. However, paralleling the technological problems there are operating and economic problems which will continue to require our attention as the program goes forward.

We think it is generally recognized that the airplane contemplated by the FAA's RFP will meet the general criteria of a commercial supersonic aircraft better than others being proposed today.

Promotion of safety—Section 102(e) of the Federal Aviation Act of 1958, as amended, provides the Board shall consider the promotion of safety in air commerce as being in the public interest and in accordance with the public convenience and necessity. In discharging our obligations under this legislative directive we list a few of the technical problems which could have a major effect on safety, both on the ground and in the air. These items have become evident as a result of our experience in the investigation of incidents and accidents, our review of various technical considerations in the design, construction, certification, and operation of a supersonic transport and our evaluation of the XB-70 Experimental Vehicle.

Sonic boom—The RFP calls for a maximum overpressure during acceleration to supersonic cruise speeds at less than two pounds per square foot, and overpressure at maximum cruise and deceleration at one and a half pounds per square foot.

Excessive sonic boom, if the design of the SST did not prevent it, could provide a practical veto over the economic use of the aircraft.

In cruising, the sonic boom spreads out in a wide path beneath the aircraft. If this shock wave were excessive, and if the public reaction is such as to prohibit flights over certain portions of this country, practical flight paths across the country would be impossible, and detours over uninhabited or water areas would be so widely circuitous as to make the flight extremely uneconomic in mileage traversed as well as the additional time taken which would reduce the time advantage of the SST.

At airports, the sonic boom over the approach paths would also have to conform to local authority problems on sonic boom and community reactions. If these were too restrictive, it might be impossible to get an SST in and out of many airports. In addition, foreign countries might likewise restrict or prohibit SST.

Noise—In addition to sonic boom, the RFP also calls for limitations on takeoff noise, landing noise, and ground noise. These, in a manner similar to sonic boom problems near the airport, could be limiting on the use and economic results of the SST. If noise is greater there may be more limitations placed on the SST than on our present jets.

Propulsion considerations—At present there are no powerplants available with sufficient thrust to fly at the supersonic speeds which are out-

lined as being the speed for economic feasibility. It should be noted that General Electric, Curtiss-Wright, and Pratt & Whitney are taking part in the initial design competition.

Fuel Problems—Fuel containment (leakage) and fuel pressures at high and low altitude under varying temperatures and pressures appear to be a real problem in the construction and preparation for flight of the XB-70. Revision of Civil Air Regulation relative to fuel reserve requirements will probably need to be considered.

Hydraulic systems—Because of the tremendous variations in outside air temperatures, the high operating hydraulic pressures contemplated, and the extremely high skin temperatures expected, the hydraulic system in the SST must be much more dependable and reliable than in present jet transports. The system must be so designed that no single failure will cause the interruption of any operable mechanism.

Electrical system—New problems will be encountered in assuring a positive fail-safe electrical system because of the wide variance in operating pressures, temperatures, and rapid changes in altitude which will be encountered. Because of the size, speed, and rapid temperature and pressure variations encountered, an electrical system with the maximum amount of flexibility, redundancy, and reliability will be indicated.

Structural integrity—Present Civil Air Regulations are based on the concept that rough air turbulence and gust intensity decrease with altitude. Experience with the operation of swept-wing jet transports in clear air turbulence and the effects of "G" forces encountered in extreme rough air has demonstrated that gust-load-factors as presently defined in the Civil Air Regulations will probably need revision.

Passenger protection—Because the SST is scheduled to fly at altitudes up to seventy, seventy-five, eighty thousand feet at speeds of three to four times the speed of our present jet transports, positive protection must be afforded the passengers and crew. This will require more reliable systems-worthiness, and positive fail-safe passenger pressurization and oxygen systems.

Controllability, stability, maneuverability—There must be a decided improvement in positive controllability as to feel and control force gradients. Control forces must be positive at all times and there must be a gradual increase in control forces from any trim condition up to the maximum movement of control deflection.

The aircraft must demonstrate positive stability about all axes.

Visibility from pilot's cockpit—The visibility afforded to the crew must be as good or better than presently accepted on jet transports, particularly for takeoff, climb, approach, and landing.

Instrument panel readability—Sufficient dampening of crew instrument panels should be provided so that engine, flight, and navigational instruments will be readable under the most severe rough air turbulent conditions likely to be encountered.

Simulated training—Investigation of incidents and accidents has revealed that little or no simulated training is provided the crews of present jet transports by some air carriers. It is believed that an important facet in the development, certification, and operation of an SST is the simultaneous design, construction, and use of a highly sophisticated flight simulator with a visual attachment and realistic "G" force capabilities so

that a continuous training program can be conducted under all anticipated flight conditions. This is especially important since there may be more frequent intervals between flights and possible loss of crew proficiency.

Flight recorders—Accident investigations involving turbine-powered transports where flight recorders are installed have served to prove the need for the recording of several additional parameters. Altitude, air-speed, acceleration, and magnetic heading are the four parameters presently required. Consideration should be given to requiring additional parameters such as (1) engine performance, (2) component temperatures, (3) cabin pressures, (4) engine vibration, (5) degree of movement of controls, slats, spoilers, etc., (6) position of controls, (7) time, (8) angle of attack, etc.

Miscellaneous—In addition to the above there are many other important considerations which will need to be solved before passenger operation at supersonic speeds can be realized. These include, (1) the accomplishment of wing warp to improve supersonic performance, (2) reduction in skin friction, (3) axisymmetric supersonic inlet interference, (4) exhaust nozzle design efficiency, (5) improvement in material selection, (6) configuration effects on sonic boom and community acceptance of same, (7) engine and boundary layer noise, (8) improved handling qualities, (9) piloting techniques, (10) navigational systems, (11) communication problems, and (12) positive airways traffic control.

It is heartening to know that NASA, FAA, and DOD are aware of these problems and are optimistic that they will be resolved in a satisfactory manner.

Recognition is taken of the many strides made to date in the construction and operation of experimental vehicles and military aircraft. It is believed that the flight testing of the three XB-70 aircraft should materially contribute to the solution of many unknowns in flying large vehicles at supersonic speeds.

Up to now, the economic results of the SST have been based almost entirely upon assumptions rather than upon real estimates. This is not a criticism. As of the present, this is probably the only way in which we can proceed. As one illustration, the payload of the plane has not yet been fixed within even a fairly wide range of values; for example a desirable payload has been stated as between 125 and 160 passengers. With such a range of over twenty-five per cent in the potential revenue producing ability of this plane, it is quite obvious that any estimate of the economic consequences will contain at least a possibility of a twenty-five per cent variation in this primary element of how many dollars such a plane will be able to take in.

Since the economics depend so closely upon the engineering, and since the engineering is still in a very early stage, the economic consequences cannot realistically be estimated other than a presentation of various assumed levels of performance. This is not to say that work should not proceed on the SST until we have a closer economic fix on its results. Quite the contrary. Until considerable time and effort have been devoted to solving some of the engineering problems, and until closer estimates are available on which to base economic estimates, using the lack of economic consequences as a reason to defer engineering progress on the project can only result in indefinite delay.

We therefore recommend that work go ahead on the SST. However, as the engineering problems are worked out, we should continually close in on the payload consequences. In addition, in any of the engineering work, there are usually fairly wide choices in the operating characteristics to be designed into the ultimate plans.

During this engineering and developmental process we hope there will be breakthroughs on new lightweight materials so more of gross operating weight can go into payload. Improvement in specific fuel consumption would also contribute to improved payload. In addition, any engineering design normally requires compromise to produce an optimum between a variety of design objectives which are in many cases at least partially in conflict with each other. The object of producing an SST is not to overcome technical difficulties, but to produce a final product which will serve the public most economically and conveniently. Therefore, the guidelines given by progressively closer economic estimates of the consequences of sacrificing some design objectives for others should be the key, rather than purely engineering judgments.

Date of first commercial flight—The potential sale of the aircraft and its continuing value to the airline operating it are affected by the relative date of delivery of the United States SST as compared to a foreign made SST. These planes represent large expenditures, and will have long depreciable lives. Once a carrier is committed and has purchased a type of SST, his financial ability to purchase and profitably operate more is considerably lessened.

For this reason, the relative timing of the production of the United States SST as compared to the Concorde may be critical. To the extent that a portion of the total potential market is supplied with Concorde if they should be delivered first, the potential for a United States SST will be correspondingly decreased. For example, if a foreign airline begins operating Concorde across the North Atlantic, the United States airlines then have a choice of purchasing an SST or running the grave risk of losing most of their market for the passenger service if the SST should prove to be competitively superior for potential passengers. The United States airlines could then buy a foreign SST, or wait for whatever the period was before a United States SST was delivered. An additional problem would be to what extent the United States SST would be superior to the foreign one, and its consequent effect on the division of traffic after both were operating.

Many of our carriers as well as those in other parts of the world have not rushed in and placed orders for the Concorde. Their actions seem to indicate belief in the adage "if a better mousetrap is built the United States will build it." We hope their confidence is well placed. The next six to nine months will be devoted to the manufacturers coming up with their proposals. A number of airlines have already put down their cash as indication of good faith in success of a United States supersonic transport program.

At this future time we will have a much better picture of the United States program and how our carriers view it. When a company's owned or borrowed resources are involved it may well be a matter of survival if an uneconomic capital acquisition is made.

Airline financial considerations—While financing the acquisition of SST aircraft will involve substantial sums of money, it is doubtful that this

aspect alone will prove a significant obstacle to carrying out the program if the economic characteristics of the aircraft are such as to provide a favorable outlook for earnings. It is believed that a variety of sources of funds would be available for the financing of the supersonic expansion program. With the anticipated improvement in the financial condition of the air carriers during the intervening years, substantial additional funds could be raised from commercial loans, additional equity financing may well be feasible, internally generated funds from operations and depreciation throw-off would provide substantial additional resources, and various forms of indirect government assistance could be extended through loan guarantees, tax relief or postponement, or other forms of assistance to fit the particular set of circumstances.

If the United States transport will not be available soon after the Concorde, competitive pressures may not permit the carriers to wait for the United States version to be produced. This is particularly critical if the delay causes loss of aircraft sales so that each remaining purchaser must absorb a greater share of the development costs. In passing it may be noted that the present program is silent as to how the United States will collect the development costs from a foreign purchaser, especially if a competitive aircraft is available at a price which does not include development costs.

Preliminary staff studies indicate that by 1968, when the first heavy outlays for supersonic aircraft would presumably have to be met, the industry will have attained a relatively strong financial condition. If the general economic conditions remain favorable and traffic growth meets reasonable expectations of 7.4 per cent per year for domestic trunklines and 10.1 per cent per year for international carriers, the earnings position of the industry in the intervening years should progressively improve. Based on internally generated funds alone resulting from earnings and depreciation throw-off, it is anticipated that the present relatively unfavorable ratio of debt to total capital of sixty-seven per cent will be reduced to a very favorable ratio of approximately forty per cent by 1968 after allowing for the financing of all needed additional aircraft during the interim period. This result would be achieved through a retirement of approximately one-third of the total present debt, and an increase of around one hundred per cent in the present net worth of the air carriers. On the basis of this anticipated improvement in the financial condition of the industry, approximately 2.5 billion dollars of new money could be raised through commercial loans without exceeding the relatively high debt-capital ratio of sixty-seven per cent at the present time. Assuming a cost of twenty-five million dollars for each supersonic aircraft a loan of this magnitude would finance the purchase of approximately one hundred aircraft.

In addition to commercial loans which will be available to the air carriers, substantial cash funds will be generated through depreciation throw-off from the large investments in the jet aircraft which will continue to be operated. By 1968, it is estimated that the depreciation charges for these aircraft will approximate 436,800,000 dollars annually. These funds alone would be adequate to finance the acquisition of seventeen supersonic aircraft per year at a unit price of twenty-five million dollars each. In addition to the depreciation throw-off, relatively favorable earnings for

the carriers from 1968 to 1970 or such time as the supersonic aircraft are actually introduced into service, should generate substantial additional funds with which to meet current financial needs and provide adequate support to the supersonic expansion program.

On the basis of these preliminary staff studies, the problem of financing the new supersonic aircraft would not turn so much on the financial resources then available to the air carriers as on the impact of the introduction of these aircraft upon the prospects for earnings by the industry in the future. Favorable prospects for earnings from the introduction of the supersonic aircraft will enhance the industry's ability to finance them, while unfavorable prospects could seriously complicate the problem of financing. Whether the earnings prospects are favorable or not will turn first of all upon the economic characteristics of the aircraft as well as its widespread acceptance by both passengers and ground populations which may be affected by its operation. The favorable prospects for earnings may be materially affected also by the generation of excess capacity in such magnitude as to undermine the prospects for profits over an extended period of years. Moreover, should it develop that either the economic or other operating characteristics of the subsonic jet aircraft prove to have competitive advantages over the supersonic aircraft, serious financial consequences would result from the introduction of the supersonic aircraft. Since the economic characteristics of the projected SST are not sufficiently defined at the present time to permit the economic and financial operating results to be measured with any degree of reliability, these financial projections of necessity involve a considerable degree of conjecture.

Range—The RFP calls for a range of 4,000 statute miles with adequate payload. This seems to be a desirable design objective for the initial SST's. However, it is not clear whether this is maximum range based on fuel load or maximum range at supersonic speeds. For example, today our excellent subsonic jets will fly nonstop from New York to Rome. Similar nonstop routings are available over the Pacific and South American routes. We think it would be a step backward if these nonstop services could not be maintained with supersonic transport. It does not seem reasonable to schedule a stop at Paris enroute from Rome to the United States because of design limitations when we believe our forward planning can provide for subsonic operations over the European land area followed by supersonic over the Atlantic.

We hope this range objective is attainable so present nonstop services can be continued with a reasonable degree of certainty. We think it would be unfortunate indeed to create a system of supersonic transport which caused a condition of "hurry up and wait" because of need for frequent lengthy fuel stops.

On the other hand we have the problem of designing SST's for shorter ranges from 1,700 miles up to 3,000 miles for our domestic long-haul routes.

Payload—The RFP calls for a payload of 30,000-40,000 pounds with provision for 125-160 passengers and baggage plus 5,000 pounds of cargo and mail. The present family of long range jets can carry 53,000 pounds of payload including 180 passengers and baggage and 17,000 pounds of cargo and mail.

The potential loss of the excellent payload characteristics of present jets must be overcome in some manner if we are not to lose valuable ground in the economic gains achieved thus far in commercial air transport. Up to now the transport industry and the aircraft manufacturers have been able to achieve increased speed and increased payload. In any event they did not sacrifice payload for speed. We believe that the early British built Comets were too small for commercial success; as a result, for this reason and because of safety considerations, not many were acquired, and none for self-supporting commercial ventures. Not until the United States manufacturer developed a powerplant with sufficient thrust to power an economical vehicle did the airlines of the United States and the world acquire jet aircraft for their long-haul major traffic markets. We are hopeful that payload provisions can be improved to at least equal those of our existing efficient subsonic jets.

If additional frequencies are required to accommodate 1970 and subsequent traffic demands because of limited payload capabilities there would likely be a serious effect on unit costs not to mention problems of saturation of air space and navigational aids. We are not seeking the impossible, but we are hoping for payload provisions which will not cause undue economic penalty for our airlines and for the passengers and shippers who will provide the revenue to make the supersonic transport service a profitable venture.

Speed—The cruising speed for the United States SST is to be Mach 2.2 or faster.

The cruising speed of the SST will have two primary economic effects: first, as it affects the revenue producing capacity of the plane in competition with foreign SST's and/or subsonic aircraft; second, on the cost side.

Cruising speed as such is of some value to the traveler since normally he prefers a shorter flight to a longer one between the same two points. However, particularly for the person traveling for pleasure or personal business, the monetary value for each elapsed hour in flight is not very high. For example, if a flight that takes six hours by subsonic jet can be accomplished in two and a half hours in a supersonic transport, some price differential can be charged because of the saving of three and a half hours. However, the percentage differential in total time elapsed to the traveller is considerably less than this would seem to indicate; to the actual time in the plane must be added the time to get from the point of departure to the airport, ticketing, boarding, allowances for delays in order not to miss the flight, and at the terminal airport, collecting the baggage, and getting transportation to the ultimate destination from the airport. We are hopeful there will be parallel improvements in this area.

A United States built SST designed to cruise at Mach 2.2 will probably match or better the speed objective set for the British-French Concorde. The two versions will probably have comparable lift/drag factors. The ability of the United States built transport to exceed Mach 2.2 will be related to more powerful fanjet engines yet to be developed. The cost of acquiring the additional thrust in the price of the aircraft and reduced payload because of added fuel requirements must be carefully weighed along with other potential economic trade-offs evaluated during design of powerplants.

Operating characteristics—The RFP calls for a number of flight opera-

tional characteristics in the way of flying quality and compatibility with the air traffic control system, the operational life of the SST, its maintainability, its reliability, and the fuel characteristics required.

These provide a large number of requirements which primarily affect cost but which also affect to some extent the passenger preference of an SST compared to other aircraft.

If operating characteristics are not all above a certain level, they can result in a high proportion of flight delays, flight cancellations, and closely associated new construction of airports of different size and airports usually further from the city requiring greater ground time for SST flights from initial origination to ultimate destination than for other aircraft.

On the cost side, the operational life of the aircraft has a direct relation to the period of depreciation and therefore the unit charges for depreciation per mile flown. The maintainability is also reflected in the unit cost for maintenance and overhaul. Reliability shows up both in the utilization rate—that is, the number of hours the plane can be effectively used in revenue service during the year—as well as in the additional costs which would be incurred during periods when the plane was not operated because of nonscheduled failures with continuing fixed and depreciation costs and additional expenses to take care of passengers requiring special handling.

In addition, the operating characteristics influence cost through the size of the flight crew and consequently payroll costs, the air traffic control problem and associated possible user charges to pay for them, the fuel characteristics required and their relative costs, and a variety of other consequent costs.

Direct operating costs—The RFP also calls for estimates on direct operating costs. Of course, we will be interested in such estimates as flight crew costs, fuel and oil, insurance, specified utilization, depreciation of airframe and spares, depreciation of engines and spares, depreciation of electronics and spares, maintenance costs, and all other such costs.

Fares and rates—It is bothersome to hear discussion of the possibility of operating costs which will require surcharge or fares higher than present first-class fares applicable to subsonic jets. This seems to be questionable progress particularly since we are presently experiencing a shift from first class to coach and economy because the passenger is seeking to minimize his transportation expense. Further, demand for low cost transatlantic air transportation has created need for fares even below jet economy. The scheduled and supplemental carriers continue to offer group fares and charters. In some markets, *i.e.*, Scandinavia, low fare scheduled propeller flights are continuing to operate.

We are interested in developing a realistic fare and rate level for SST services. We think it desirable the prices paid by passengers and shippers using the SST reflect the cost and value of the service. The more efficient subsonic jets should not be burdened with costs incurred by the carriers for the account of SST's. This consideration will be particularly important because a substantial portion of the traffic will continue to move on subsonic aircraft. We believe this to be a realistic appraisal because the SST's will be operated on long stage lengths of 1,700 miles or more. It seems unlikely many SST's will be scheduled in markets with shorter stage lengths because of the apparent inefficient use of the block speed of 1,550

miles per hour. We believe the carriers will be cautious in trebling their investment in a single aircraft merely to reduce the travel time from midtown Manhattan to midtown Miami less than one-third, particularly when it appears unit costs will not be reduced below those of the jets.

A commercial supersonic transport aircraft should be what its nomenclature implies, a commercial transport. There is no doubt our technicians can design and produce supersonic aircraft. The concern of those of us charged with economical, safe air transport is with the integration of a vehicle designed to carry man faster than the speed of sound into our air transport common carrier system. The United States commercial operation will probably be the only one in the world conducted by private enterprises. The British-French venture is heavily government supported and Air France and BOAC probably expect continued government assistance. It may be necessary for our government to help out. Unlike the present jets the possibility of supersonic aircraft achieving important economies over predecessor types is dubious. Based on achieving commercial air transport goals of expanded markets, reasonable fares, minimum of social problems, and reasonable profits, it appears to those of us working on achieving these goals a substantial doubt exists the supersonic will carry us in this direction. However, the supersonic transport aircraft is in production. Our carriers have ordered them. Our task is to work with them to achieve reasonable integration and avoid, if possible, economic and social consequences of a severe nature.

We have heard about the productivity of the supersonic because of increase in speed compared with subsonic jets. This prediction of productivity improvement is based on the assumption there will be no onerous restrictions on payload or hours of operation and that passengers will be available at hours other than the "magic times" heretofore thought mandatory. We know the present jet is more productive than its piston predecessors. A large element of this improvement, however, can be attributed to additional capacity as well as increase in speed. We cannot foresee more capacity per unit for the SST; in fact the capacity may very well be less.

The productivity increase of the subsonic jet can be quantified and measured as real economic gain because the increase in productive capability was at a greater rate than the increase in unit cost. In 1958, the last year before the major introduction of domestic jet service, the largest domestic carriers operated at a cost of 27.44 cents per available ton mile. In 1962, this figure was 27.36 cents. The carriers did a fine job of absorbing increased labor and material costs. The Board is hopeful a similar result can be forthcoming four years after the introduction of a commercial supersonic transport. However, we realize this objective will not happen unless those responsible for the program maintain a close surveillance over the economic implications of design and production as the program goes forward.

Route problems—Additional problems of competition might be generated by the SST. Normal manufacturing process allows for the assembly line to be left open for a relatively short period of years at a relatively high production rate. This then requires that the airlines take delivery of the aircraft in groups highly concentrated in time. This produces a high degree of potential excess capacity during the early years before the traffic growth has time to catch up with the capacity purchased.

On international routes, the problem of competition is heightened by the large number of foreign nation flag airlines. In addition to any economic considerations, there are problems of international pride and prestige and standby military desire.

Even further complications may be incurred where the ability of foreign nations to purchase SST is not as great or is not as soon as that by United States carriers. In such cases, the tendency would be present to keep fares on the SST unduly high on the part of the foreign nation. In addition, considerable difficulty might be encountered in some countries in securing landing rights for the SST, particularly in the dates of inauguration and in frequency of scheduling.

Simulation—We are hopeful the major carriers or the ATA will undertake an SST schedule simulation program similar to that conducted by United Air Lines prior to the introduction of jet service. In this manner operational, scheduling, traffic handling and other problems can be planned for based on results of simulated flights, including effect on departures at intermediate stations when supersonic overflight is causing sonic boom overpressures. For years the airlines worked together to handle airport saturation by controlling number of frequencies and spacing of flights. There may be a requirement for similar cooperation to avoid saturation of airspace and thus forestall excessive sonic boom overpressures and noise in general.

Conclusion—The Civil Aeronautics Board supports the Administration's SST program.

We believe that the primary aim of the new vehicle is to meet the future needs of travelers and the public interest.

We believe that the design and engineering of the SST are essential to attain this aim; the CAB's role in anticipating and developing policies to deal with safety, public service, operating cost, and financial feasibility of the operation.

We expect that as the technical development of the SST and simulation of the total system operation proceed, we will make progress in forecasting the travelers' demand for SST service as evidenced by their willingness to pay its cost, the operational costs of the new air transport system, the financial profitability for the airlines, and the net economic value to the United States.

JEROME B. WIESNER

DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY

The suggestions I would like to make about the general need for the supersonic transport (SST) program, are principally related to the overall technological well being of our country in the near and distant future.

Even if we were not faced with imminent international competition, I believe that the development of a commercial SST is a step that we would wish to take sooner or later in a logical advance of our long-distance transport capability. In fact, most of the technical problems that now exist are the kind for which we anticipate solutions but which we could not expect to actually solve except under the stress of necessity in a well defined system development program.

For example, a basic problem in SST development appears to be the fact

that the payload, for any given aircraft and mission profile, is such a small proportion of the gross takeoff weight; the payload is about fourteen per cent of the gross takeoff weight in the subsonic jet but is estimated to be only about seven per cent of the SST. Obviously this condition sets a premium on favorable structural strength to weight ratios. Improvement in this area will come about primarily through the development of better fabrication techniques with aluminum, steel, titanium and other known materials. But these, in turn, can best be accomplished in a program designed to meet the rigorous requirements set by commercial objectives.

A similar situation exists in propulsion technology, since important improvements must be made in currently attainable specific fuel consumption rates over the broader speed range of the commercial supersonic mission profile, and in the use of high temperature materials required for high speed, long endurance engines. These improvements are necessary steps in our general technological advance in aviation although they would probably be long in coming without the requirements exerted by an SST development. There is every reason to believe that these improvements can be realized for the SST. They suggest that the program represents not only a logical step in our overall technological development, but one we are most likely to take in any case in the future, if not now.

Also, it is enlightening to consider the consequences of not beginning the development *now*. In view of the avowed intention of the British and French to complete the job they have already started, the probable intent of the U.S.S.R. not to abate in its effort to demonstrate to the world community that its technology leads the world and the likelihood that real demands for an aircraft to replace subsonic jets should appear in the early 1970's, it appears virtually certain that a foreign version of a supersonic vehicle will enter international airways sometime in 1969 or 1970. Furthermore, in view of sharp competition among airlines for international traffic, it would be extremely difficult, if not impossible, for American international carriers not to purchase supersonic vehicles of foreign origin if such aircraft began to be used by foreign carriers and equivalent ones of American manufacture were not available. Then, with no domestic supersonic craft in early prospect, it would not be long before even a barely acceptable SST of foreign origin would begin to take over our internal long-line airline market. The unavoidable consequences of pursuing a national policy leading to this situation would then become quickly evident:

First, the United States' previously dominant position in the commercial aircraft field would tend to deteriorate, probably irretrievably, because skilled engineering and scientific personnel would have abandoned the field.

Second, the military potential of the United States would be lessened to the degree that these skills were no longer available for military aircraft design.

Third, the United States' international balance of payments position would become seriously aggravated since, in addition to diminishing gold inflow because of lower aircraft exports, gold outflow would increase to pay for imported aircraft.

Finally, the United States' overall position as the dominant technical and industrial world leader would also deteriorate, with further obvious, but incalculable, losses of prestige on the international political scene.

In summary, then, I would like to emphasize these points:

In the first place, from a technical standpoint the development of a supersonic transport is a logical step in the evolution of advanced aircraft of the future, and one that we should undertake sooner or later.

Next, the competition which is assured by the British-French Concorde makes it imperative that we undertake such a development now if we are ever going to do so.

And finally, our future technological health, and therefore our general economic progress and our military strength in this area, is strongly dependent on our maintaining a continuously vigorous program of transport aircraft development. In my opinion, the supersonic transport program meets a vital national need along these lines.

VIEWS OF THE AIRLINES

CHARLES C. TILLINGHAST, JR.

PRESIDENT, TRANS WORLD AIRLINES

We at Trans World Airlines fully and enthusiastically support the timely development of an economically and operationally satisfactory supersonic transport by United States industry. We have felt a sense of urgency for some time. It motivated us, in fact, to make a commitment for the first supersonic aircraft to be built in the United States. On October 14, 1963, TWA made a down payment of 600,000 dollars to the Federal Aviation Agency, coordinator of this country's SST program, on the purchase of six vehicles. Subsequently we increased our order to ten and our down payment to one million dollars.

To be sure, serious doubt exists as to whether supersonic transport will represent an advance to the airline industry from an economic standpoint. But the British and French have forced our hand. The British Aircraft Corporation (BAC) and Sud Aviation, the French aircraft manufacturer, are now building the prototype of what stands to be the world's first commercial supersonic transport, to be known as the Concorde. Its design and development are being financed fully by the British and French governments to the tune of 450 million dollars, none of which will be reflected in the purchase price of the aircraft. They expect, rather, to realize a return on investment by stimulating an industry and capturing a world market for England and France, by dominating international air commerce and by enhancing national prestige.

The purchase price of the Concorde will not exceed ten million dollars, plus price escalation to adjust for price inflation. It is expected to be ready for test flight in 1966 and for commercial service in late 1969 or early 1970.

This challenge requires that we act now—and that we do so boldly, decisively and enthusiastically. Our objective must be a resounding success, not a carefully controlled failure. The consequences of doing too little too late are unthinkable: they would embrace the loss of our historic leadership in aircraft manufacture and export. The rewards of success, on the other hand, would be eminently worthwhile: the opportunity to compete in the world market place for SST sales which are expected to exceed ten billion dollars in the 1970s.

The United States has been far ahead of foreign competition at almost every step of aircraft development. We dominated the twin-engine monoplane market in the 1930s, the four-engine piston aircraft market in the 1940s and 1950s and the four-engine jet transport market since the late 1950s.

This leadership has provided work for some 5,000 aircraft, engine, and supply manufacturers and jobs for many tens of thousands of people. It has provided America a prime source of export. Production and sale of commercial transport aircraft have pumped close to seven billion dollars into the American economy just since the advent of the civil jet age in 1958—some twenty per cent of which accrued from sales abroad.

Thus our failure to pursue our SST program vigorously will cost us our global leadership and deny us, perhaps for all time, the potential for becoming the world's prime producer and exporter of supersonic transports. The consequences of such a setback are grave and many-sided, ranging from the loss of production and payrolls and taxes to aggravation of our already-precarious international balance-of-payments problem.

We must emphasize, furthermore, the threat to the United States airlines of being dependent on a single foreign supersonic transport produced under the auspices of two governments whose government-owned airlines are among our largest competitors. Already the manufacturers of the Concorde have mentioned their backers' intent to use this aircraft as a tool to strengthen the position of the European carriers in air transportation during the 1970's and beyond. Obviously, the United States airlines cannot play their appointed roles if they are dependent upon the grace of their competitors for the sinews of competition.

In pleading for an effective United States program, I hasten to point out that I wish our British and French friends no ill. The world of air transport will be better off if they, too, enjoy a measure of success in their supersonic effort. For as strongly as I feel about the vital importance of an effective United States program, I think that the interests of air transportation would be poorly served if any country, or pair of countries, obtained a monopoly in SST manufacture.

By the same token, we must recognize that the British and French have both the competence and the purpose to produce a supersonic transport of substantially the type and on the timetable they contemplate. Our technical people have studied the Concorde design, within the limits of the security imposed by the French and English governments, and we have no reason to believe that the Concorde will not, as claimed by SUD/BAC, fly at approximately Mach 2.2 in regular nonstop service across the Atlantic with roughly 20,000 pounds of pay-load. Thus, we should not assess the United States program on the basis of any belief that the French-English combine is incapable of producing a reasonably good airplane, even though we hold reservations as to some of its characteristics from economic and other standpoints.

In our opinion, therefore, the correct United States program objective must be to present the world a technically better product competitively priced within the customer's reasonable ability to pay. What are the important criteria of superiority from an airline's standpoint? We would stress safety, economics, public acceptance and timeliness.

Everyone involved shares the same high concern for the safety aspects

of any SST. Our objective is an overall standard which represents an advance even over the high standards of safety built into our subsonic jets. It is imperative, therefore, that, as in other technical matters, the manufacturers be given a free hand in working with airlines and other appropriate groups to achieve the best solutions to this objective. Obviously, safety is not just a matter of the aircraft itself; it embodies as well the whole system of air traffic control, communications, navigation and ground facilities.

Profitability will be essential. We should fully recognize that United States prestige and perhaps the survival of the United States international airlines as private enterprises may well rest on the economic acceptability of the United States product. Therefore, to be fully acceptable it must be capable of generating a reasonable return on investment to the airline operators, and it must be economically competitive in the world market place. It would be disappointing, indeed, if the United States produced a technically superior airplane which no one could buy.

The airline industry could ill afford a plane which proved to be highly marginal from an economic standpoint, but a Pied Piper competitively, for some carriers would surely buy it and the balance of the industry would feel it necessary reluctantly to follow. Possibly, the Concorde may be in this class. In any event, industry adoption of an economically inferior product would precipitate the return to operating subsidies, whether or not through government ownership.

Operating economies will, of course, be importantly influenced by the purchase price of the aircraft as well as by the existence of any royalty obligation on the operator. Here the Concorde will have a great advantage. Its basic price will be only one-third that of the anticipated price for the United States version. Moreover, it will not carry with it any royalty obligation imposed by the French and British governments to recover their 450 million dollar developmental investment.

These factors might well make the Concorde too serious a competitor to a United States SST in world markets. Without the burden of development costs, and aided by sharply lower labor rates, the Concorde's price advantage will materially offset the expectedly superior performance of the United States craft. Indeed, considering what the experts have to say as to possible advances in the state of the art, we are forced reluctantly to conclude that the technical superiority of the United States plane may not be sufficient to counter-balance, economically, the tremendous difference in price.

In considering the superiority of public acceptance of a United States supersonic transport, one must keep in mind both the public who fly and those who remain on the ground. Acceptance by the latter will concern itself principally with noise, including the oft-discussed problem of overpressure, or sonic boom. The smaller size and probably lighter weight of the Concorde may give it an advantage with respect to sonic boom.

The United States program will need to have as a major objective utilization of advanced technology to be no worse than the Concorde in the matter of sonic boom and better than the Concorde with respect to noise in and about airports.

From the passenger's standpoint, speed will be most important. Airline history has shown that, other things being equal, the passenger will choose

the faster airplane. Thus, it seems important that the United States SST have a significant speed advantage over the smaller and less costly Concorde. While we are not sure that it would be wise to aim at Mach 3 immediately, we would hope for a plane holding the potential for evolving to such a speed.

The fourth important competitive factor from the standpoint of airline acceptance will be timeliness. Unless our SST enjoys an overwhelming superiority in terms of safety, economics and passenger acceptance, the purchasing decisions of many airlines will be strongly influenced by the availability of the plane within a reasonable period of time. There may be those who, from the security of highly favorable Concorde delivery positions, argue that production of a United States SST should be delayed until the "ultimate" has been achieved in size, power and speed. In our judgment, this would involve a delay of years. If the United States program is delayed this long, the resources of too many airlines already will have been committed to the Concorde, and the remaining market will be so small as to assure failure from the manufacturer's standpoint.

All these competitive factors bring us to the conclusion that the United States supersonic transport should be the minimum size that can safely and regularly fly year-round in nonstop service between Paris and London, on one hand, and New York and Washington on the other with an economic payload. I emphasize minimum size to do this job on an economic basis. It is essential that we not price the product out of the domestic and international market by sheer size alone. The FAA's design range of 4,000 statute miles with adequate reserves is about correct. To achieve further range or to build a plane of maximum size might consume too much time, cost too much, and result in a vehicle unacceptable from the sonic boom standpoint.

If the supersonic transport and related required power-plant developments are amply funded, there will be no reasonable question but that the United States aviation industry, working with the government, can produce the world's finest design. Unfortunately, several significant new factors have been injected which must be coped with if our program is to be a success.

The first new factor involves the great size and uncertainty of the program from a manufacturer's standpoint. Huge expenditures and huge uncertainties, too great for a private company to assume, are involved. Recent experience in the development and manufacture of subsonic jets, which has seen but one manufacturer do as well as to break even, is not likely to move a prudent board of directors readily to assume the risks inherent in an SST program. Government help is essential.

In recent years, transport aircraft development has benefited substantially from government-supported work on similar military types. To this extent, the development of civic transports has thus been the beneficiary of government subsidies. But this will be much less true in the case of the SST. Although a significant amount of military supersonic development will be drawn upon, it will be much less substantial in relation to the total job than has been the case with the subsonic jets.

In contrast, the British and French are subsidizing directly the development of the Concorde. As a matter of fact, the two prime manufacturers have asserted that they will establish the final airplane purchase price on

the premise that recurring costs only will be recovered, with the fixed engineering, development, and tooling costs being absorbed by their governments. As against this, the United States program is grounded on the theory that in time it will be fully self-liquidating.

In our judgment, the burden of engineering, development and tooling costs, on top of labor rates at least twice as high as those prevailing in Britain and France, will prove too great to permit the United States SST to be sold on a competitive basis with the Concorde. We must face frankly the need for giving our manufacturers financial support of the type being extended by the British and French.

Critics may question the respective roles of private enterprise and government subsidy in the development of a new product or industry. As businessmen, we pride ourselves on our independence, and we respect the private initiative which made our country the industrial leader of the world. Were it feasible, we would prefer to see supersonic transport developed solely by private capital. We find, however, that circumstances have taken SST development out of private hands.

First, the tremendous financial risk, and second—the one that forces our hand in this issue—the action of the British and French governments. So one cannot realistically discuss SST in terms of private enterprise, for when he does, he is suggesting that our private sector (with its markedly higher labor costs) compete with the combined financial resources of the British and French governments. This our private sector simply cannot do.

Nor will sloganeering about the ability of free enterprise to outdo nationalized enterprise change the hard facts of economic life. The British have twice proved in recent years their ability to sell transport aircraft in this country in competition with the best we have had to offer. Likewise, France has proved her competitive ability with the Caravelle, a number of which fly in scheduled service in the United States.

Surely a nation which subsidizes its Merchant Marine, which thinks of spending twenty billion dollars to forty billion dollars to get to the moon, which spends five billion dollars annually on the civilian space effort, and many billions for farm aid and other programs can afford substantial contribution to stay in the race for leadership in the field of supersonic transport, a market which should top ten billion dollars during the 1970s. A very great deal is at stake, and I am talking about economics—dollars and cents, world markets, international trade and commerce, and our American balance of payments.

We all want our government to be prudent and to avoid ill-advised expenditures, but the United States government dare not risk forfeiture of its stake in this great market by following an overly cautious, overly prudent policy of underwriting too little of the program—and insisting that it get all its money back through royalties. Surely it is worth the effort to make certain that the United States is the seller, not the buyer of these huge flying machines.

HAROLD GRAY

EXECUTIVE VICE PRESIDENT, PAN AMERICAN WORLD AIRWAYS

Pan American's objectives by necessity encompass National Interest objectives. We are in fact a tool of the United States government for achiev-

ing their objectives and recognize that this has been, and will continue to be, the basic reason for our existence.

The tools we have to work with in achieving these objectives are three-fold: (1) our Certificates of Convenience and Necessity; (2) our personnel; and (3) our equipment.

Aircraft is a major and very important tool. Here we find that no country has been able to achieve a permanent advantage over any other, since aircraft built in one country are normally made available for sale to all others. However, in spite of this fact it is possible to greatly enhance or diminish the achievement of the objectives I referred to earlier by decisions made or not made with respect to aircraft equipment. For example, a decision to purchase an aircraft which turns out to be a mistake can be corrected by subsequent replacement, but this is a very costly process which could make the operation temporarily a serious burden on the stockholder or the government, worsen temporarily the gold flow problem, and decrease the prestige and respect for the airline involved. On the other hand, a bad decision which results in unnecessary delay in acquiring substantially superior equipment can have the same adverse effect.

When we made the original purchase of the Boeing 314 in 1939 and the Boeing 377 Stratocruiser in 1945, the British were forced to do likewise. The last thing the British wanted to do was to spend scarce dollars on an American-made aircraft. However, they had no choice. Similarly, when Pan American equipped itself with Boeing 707 and DC-8 jets, the British had to follow suit even though dollar exchange was difficult to obtain and even though the British were pushing aircraft of their own manufacture, such as the Comet IV, capable of flying the Atlantic.

These experiences and others demonstrated the fact that a nation's airline is compelled to purchase the best airplane available if its primary competitor is equipped with it.

The compulsion behind these purchases is easily demonstrated in terms of the gold flow objectives mentioned earlier when I tell you that the Boeing 707 jet in transatlantic service was capable of earning more than eleven million dollars in foreign exchange, or about twice the purchase price, in the first year of operation.

You will recall that the British first flew the Comet I in 1949. Its range was not suitable for our operations but it was a real potential threat on sectors of our routes beyond the primary gateways of Europe. The British started service with the Comet in 1952. At the same time Boeing announced a jet prototype program. The British were then going ahead with the longer range Comet III design. This was a serious threat on all routes and Pan American committed itself to the purchase of three of these aircraft and obtained an option on several more. In 1955, three years later, we signed contracts with Boeing and Douglas with firm specifications for a vastly superior aircraft. The British changed from the Comet III to the Comet IV which by reason of limited speed, range and economy was still inferior to the Boeing 707 and DC-8 on long range, high density international routes. We ended up not buying any of these Comets and BOAC consequently beat us to the gun in inaugurating token transatlantic jet service in 1958, a few weeks before we inaugurated jet service with the Boeing.

Today there are about sixty Comet IV's in operation as compared with over 500 Boeing and Douglas jets in service. The Comet IV still serves a useful purpose on certain short range, low density routes such as London-Madrid and other routes which represent a relatively small percentage of the world's international air transport system. The point is that although the United States sacrificed the earliest jet starting date it ended up with by far the best jet aircraft and the largest part of the market.

Another interesting historical fact which bears on this problem is that the first United States jet effort was pointed at the international market. In other words, Boeing and Douglas did not spend years making a small jet for domestic operations while someone else captured the international field. They did the opposite and as a result have earned a billion or so in foreign exchange for the United States.

All of the national interest objectives I have referred to receive maximum input if we have a superior aircraft of United States manufacturers placed in international service. The placing of an improved United States built aircraft on any of our domestic operations such as New York-San Juan does comparatively little for the national interest. We firmly believe that the benefits accruing from sponsoring a United States built supersonic aircraft will be greatly enhanced if its design is initially directed toward the international field, and that based on the know-how thus developed manufacturers will be better able to satisfy specific domestic needs thereafter, possibly through modifications requiring no added government support.

We should not delay but at the same time we should not be panicked into building something which is simply just a little bit better than the Concorde. The Concorde will be available about a year or more earlier but the world's airlines can afford to wait even longer for the substantial economic or performance improvements which we believe the United States product will provide. Once an airline has purchased one or more Concorde the economic penalty of expanding by adding another type rather than a similar one, will outweigh minor but not major improvements.

If we can design an aircraft with vastly superior qualities, and let the world's airlines know what these qualities are before they have equipped themselves with too many Concorde, as happened in the case of the B-707 and DC-8, we can be sure of success.

In order to build a vastly superior airplane we must achieve the following:

Variety—It must fit a wider variety of the world's present and potential operations than does the Concorde. This requirement means that it should have greater range than New York-Paris; in fact, it should if at all possible have a range of New York-Rome or New York-Moscow—4293 and 4660 statute miles, respectively. If Pan American has a supersonic aircraft capable of flying New York-Rome nonstop, how can Alitalia—for example—avoid the necessity of buying one and becoming competitive; or, in reverse, should the Soviet Union have a Moscow-New York nonstop aircraft, how can Pan American compete without it? This, among other things, calls for a large aircraft—not a small one. It also calls for the lightest possible airframe and engine weight through extensive use of titanium.

The requirement of fitting a wider variety of operations also means

that it must have substantially better subsonic performance than the Concorde. Every trunk airline will have to operate over certain short segments and densely populated areas where subsonic cruise will be essential. In fact, there may be whole countries where supersonic flight will be restricted for one reason or another, particularly in the early years of supersonic air transport. This capability would be a tremendous sales stimulus, worth a lot of money and if necessary worth waiting for. This requirement, subject to some more research by the manufacturers, may or may not involve variable sweep.

Safety—It must be a safer and more reliable airplane. This means that the airframe, all of its systems and in particular the engines, must be operating well within their limits, not on the edge of destruction or failure. Air frame materials must not be operating at temperatures close to their limits. Engines in particular must not be hurriedly beefed-up versions of subsonic engines, but be specifically designed for supersonic flight environment with prospects of over 4,000 hours between overhauls. Our current JT-4 engines on our Boeings and DC-8's are now operating 4,600 hours between overhauls! This is the kind of reliability we need. Enhanced safety also requires that our supersonic aircraft have maximum maneuverability and control at low speeds around airports.

Economical—Our supersonic aircraft must be substantially more economical to operate. The economics of airplane operation are greatly affected by built-in reliability and safety, price, and direct operating costs such as fuel, crew salaries, maintenance, and landing fees. However, one of the most important elements in determining cost per seat mile is size of aircraft. Historically, almost every significant reduction in operating cost per ton mile has been associated with increased capacity. The practical economic limit to size is a function of average route density and to some extent runway strength. I say "to some extent" by available runway strength because experience has shown that the advantages of the B-707 and DC-8 were so great that runways have become available for their use throughout the world.

As for route density, I remember when there was considerable resistance to the capacity of the Boeing-321 (the largest of the 707 series). Yet its size has made great economies possible in international air transport. Unfortunately, the concept of how big an aircraft should be is too often influenced unduly by the size of today's market rather than the market that will exist in the midpoint of the life of the aircraft under construction. We have to think in terms of a fifteen to twenty year life for our supersonic aircraft. The mid-point in its life will be perhaps as late as 1980. It is not unreasonable to assume that traffic will more than quadruple by 1980. This says that at twice the frequency of today's operation, our aircraft could be built for twice as many passengers as today's aircraft. This dictates that we should have the largest aircraft that the most ingenious manufacturer can build without exceeding sonic boom limitations and without imposing severe costs in airport modifications. Possibly this could be a 200 or 220 passenger aircraft, the more the better.

An economic advantage in large capacity often overlooked is that airports and traffic control facilities at major cities are or soon will be completely saturated. A small SST can only intensify these problems. To achieve maximum capacity as well as range within the sonic boom

criteria will require every development known, and hopefully some still to be discovered, for keeping the total weight to a minimum. Based on what we have learned from talking to manufacturers, this probably indicates extensive use of titanium.

Speed—This is probably the least important of all criteria for creating an aircraft that will take over the world market. It should, however, be superior to the Concorde. As far as the public is concerned, any increase in speed is desirable, but a small one is not of overwhelming significance. However, there are certain advantages in more speed that may be very important and lead to greatly increased utilization of aircraft, and improved range. Since extensive use of titanium is indicated for other reasons, there seems to be no question but what speeds close to Mach 3 can be obtained or at least provided for in the basic structure.

I could conclude by saying that we feel very strongly that the over-all interest in the United States requires that it give its manufacturers an opportunity to produce the tremendously improved product which we believe they can. Our present position in air transportation was built with United States aircraft, manufactured in a competitive private enterprise system. We like them and the results they have produced for Pan American as well as the United States.

C. R. SMITH

PRESIDENT, AMERICAN AIRLINES

A. Economic Risks

It is clear to all parties concerned that the effort to build a supersonic transport, if it is to succeed at all, will inevitably impose a new pattern of obligations among the government, the plane builder and the airlines.

For one thing, the state of the art (the extent of our specific knowledge) does not now permit an airplane designer to be certain that he can produce an airplane that will make a living for its operator, without government subsidy.

The government, through the President, and the airlines both are agreed that the supersonic airliner should be brought along on the premise that it will be able to fly and to work without government subsidy. How do we find out whether self-sustaining, profitable operation is possible? The computation is not difficult but first the producer of the airplane should be prepared to give the users, the airline operators, firm, unequivocal answers to the fundamental questions the operators have to ask if they are to stay in business:

1. How much will the airplane carry, in number of passengers or tons of freight, or a mix of both?
2. How far will the airplane carry a useful load; what is its effective economic range with a full payload?
3. What will be the made-good speed, the average speed from the time the airplane departs from the runway until it lands again?
4. What will the airplane cost?
5. How long will it be useful before technical obsolescence overtakes it?

As of today, not a single one of these basic specifications is available to the airlines. There are some who are willing to guess what they might be; but no one is willing to guarantee that the guesses will be fulfilled.

And without a suitable guarantee of specifications, the airlines will be unable to buy. They cannot buy until they are reasonably sure that the airplane will be profitable in operation.

I am confident that all in good time the essential technical and economic questions will be resolved. And I am no less certain that much remains to be learned about this project and that the learning will be extremely expensive. In hindsight, the transition from piston-engined airplanes to jet airplanes appears to have been surprisingly smooth, a successful business undertaking. Yet even so, the financial integrity of two highly experienced manufacturers was endangered by the heavy losses they had to absorb in the course of the transition. The airlines were able to make the transition only because they were willing to risk several billions of new money, nearly all of which they had to borrow, and most of which has not yet been repaid. The risks inherent in subsonic air transportation were high; they will be very much higher in supersonic aviation.

B. Development Costs Beyond Capacity Of Manufacturers

A wise government will not ask a business man to assume a project of such monumental size that if it fails of success his business enterprise will be left bankrupt. The costs which the supersonic transport is certain to run up during its course of development are far beyond the financial resources of any one manufacturer, or any possible combination of manufacturers. Even after the machine has been developed, tested and put into production, the probability is appallingly high that no profit from sales will flow back to the manufacturer for a long time. No single manufacturer or group of manufacturers has the means to assume so high a financial risk; it is plainly beyond the resources of all.

It is much the same with the airlines. For all of their public prominence, they have had little in the way of earnings in the post-war period, and less than average earnings during the long and difficult introduction of the subsonic jets.

So the airlines cannot be expected to advance substantial capital sums, in advance, for the development of the supersonic airplane. Even with the best of intentions, their resources are insufficient for that.

C. Airlines Will Buy Proven Supersonic Transports

The airlines will buy, and pay for, supersonic airplanes when they are ready for the market. Have no doubt about that—competitive factors will make customers of them. There will be airline orders, firm orders, quantity orders when there is reasonable proof that:

1. The airplane will operate with safety;
2. Its operation will be acceptable, to those who live near the airport and along the air routes;
3. The airplane can operate with profit.

When such proof is available, the airlines will not hesitate to take new risks, to raise new capital and to introduce the new kind of air transportation. But don't count on them for a substantial contribution of capital, in advance, for the supersonic program—they just don't have that kind of money.

Obviously, this leaves the government as the last possible provider of the capital needed for the development of this extraordinary airplane. In my judgment, the government in good conscience could assume all of

the costs incidental to the development, testing and certification of the first model. The specific point thereafter at which private risk-taking and private financing should properly take over can be debated during the several years that will be required for developing the machine itself. At worst, the total outlay on behalf of the government will be a fraction of the sums being committed to rather minor space projects. In fact, the full development costs could, in my opinion, be justified as a charge against the national defense. Additionally, there is, having in mind the national interest, that intangible called world prestige to be taken into account.

I am not suggesting, however that the government pick up the whole tab. Should a good airplane result from the development phase, a substantial part of the Federal investment will no doubt be recovered, in time, from sales of the production airplane. For, in the natural order of things, the manufacturer and the airlines would logically be expected to share in the risks associated with the production of the plane for commercial use.

It makes me uncomfortable to say this. My life has been spent in a regulated industry, an industry that began with and could not have taken root without a Federal subsidy. Most of us in the industry long ago became successful enough to break away from the Federal umbilical. This is not to say that the others and I are ungrateful for past help. We prefer, nevertheless, the estate of self-sustaining, independent, tax-paying citizens, along with the rest of American business. As much as we would like to do so, it is impossible for us to finance the supersonic airplane on our own. If the government is not willing to take on the development cost, then the project will fail. And should there be doubt about the wisdom of a decisive Federal investment, then, I suggest, it would be better not to start at all; for anything short of a full resolute commitment in terms of capital and purpose is certain to wind up as an all but total financial loss, and there will be frustration, disappointment and loss of prestige as well.

D. Suggestions For A Federal Program

For the purposes of this discussion, I am assuming that the government is preparing to do for the supersonic transport program what it alone has the financial resources to do at all and to take on the general responsibility for seeing to it that the job serves the national interest. In this context, I would like to propose two possible lines of action. One relates to how the development job might best be organized under Federal auspices. The other is concerned with the question of the kind of supersonic vehicle that might most usefully serve the American purpose, at home and abroad.

There is one thing that we should be able to make up our minds about at the outset. The design of this airplane is much too important to be entrusted to a committee. Obviously the government must see to it that the money it puts up for development is properly spent. But the watchdog function should not include close and detailed supervision of the actual design and manufacturing process. If the design specifications are made the responsibility of a government committee, the airplane will be a colossal failure. The government will never recover its investment, and the plane will not be profitable for the operators.

E. The Sensible Way To Build The SST

The sensible way to produce this airplane would be to give the most competent manufacturer, or possibly a partnership of two experienced manufacturers, a contract to design, build and test fly the machine. The contractor or contractors should have maximum responsibility for the design and the one or both should be free from interference by a body of overseers.

One need not worry about how a responsible manufacturer will conduct himself. The requirement binding upon him is to produce an airplane capable of self-sustaining operation, one that the operators will buy because it will improve their service and promise them a reasonable return on investment. Meeting that requirement will provide the manufacturer with all necessary incentive. If he misses the target, he will be the loser.

The Federal Aviation Agency has done a fine job in arousing public interest in this job. Its people have been diligent, imaginative and persevering. I admire them and so do others in my business. Nevertheless, as an operator and as an intended purchaser of the supersonic airplane, I am strongly of the opinion that the Agency is trying to settle too many hard issues too soon.

This is no time for the Agency to be worrying about the kind of tooling to be used in the factory, or the share of the fares to be recaptured by the government. Too many other important matters have to be solved before we can even be sure that an economical machine can be designed. For example, we are not at all certain at this stage that operations in the likely speed range are possible with a tolerable sonic boom level. If the sonic effect should be severe, then the use of the plane will be at least partially restricted, and that will probably add to the operators' cost. In any case, it makes no sense to haggle over how the government will get back its money from the users when the specifications for the plane have not even been drawn, and the selling price is altogether hypothetical.

Let us concentrate on first things first. Government and industry can debate about percentages after it has been established that the airplane will be built, that it will be sold, and that it will be economically self-sustaining in operation.

F. The Case For A Prototype

The supersonic concept has been described as a "billion dollar" project. I have no way of determining to my own satisfaction whether that estimate is too high or too low. But I would not want to see the government commit itself to a billion dollar investment. Instead, the government should start off by allocating a much smaller sum, perhaps less than half that amount, for financing a sensible prototype program.

The great advantage of the prototype approach is that one learns as one moves along. In this project all of us—the government, the manufacturer, the operators—are likely to change many of our initial assumptions and conclusions as we learn more. Once the prototype has progressed to a point where a sensible evaluation of the plane's technical and economic prospects becomes possible, then the parties at interest will be in a much better position to decide how best to move to the production plane.

There are many good reasons for starting off on this project with a prototype. The case for this approach is well set forth in a study done by the Rand Corporation for the Air Force. I believe, quite strongly, that

the design, construction and testing of a prototype is the right starting method for this program, and that any other approach will almost certainly waste time and money. We will be on a sounder foundation if the prototype is first developed and tested. And we may escape crushing disappointments on the way.

G. The Need For A Superior Airplane

With regard to the broad requirements that be imposed upon the designer, I would like to make one general recommendation. It is that the United States should not content itself merely with duplicating the British-French supersonic machine. Our fundamental objective should be to reach for a plane that will be substantially superior to the European one in all respects. It should be safer if possible, at least as fast, and it should have a growth potential beyond its initial speed. In all important categories, technical and economic, it should be superior.

ROBERT F. SIX

PRESIDENT, CONTINENTAL AIR LINES

The supersonic needs and requirements of the smaller United States trunklines should be considered along with the needs and requirements of the big national and international carriers. Continental Air Lines long has been in favor of supersonic transport development. While we have ordered three British-French Mach 2.2 Concorde to protect our future competitive position, we have participated fully in the United States program whenever given the opportunity. We hope to be able to order a limited number of United States-built SSTs to fill out our presently forecast supersonic needs.

I believe it is obvious to all that supersonic transports will revolutionize the travel patterns of the world; I feel, for the better. The impact of the planes will be tremendous—both on the manufacturers and on the airlines. If the planes are successfully produced, reasonably priced and profitable to operate, the early operators will make great competitive gains and the late operators will fall seriously behind. Everyone in the industry realizes these potentials and these pitfalls and it has been this realization which has caused the early orders for the British-French Concorde and the proffers of money to try to block out the early United States production positions. With limited initial production on any new aircraft, the first twenty to forty orders can take as much as two years to fill, leaving late comers disastrously behind.

Unless the industry is to be forced to reshape itself to meet the competitive impact of a few dominant SST operators, the government will have to take the necessary steps to insure equitable and timely distribution of our supersonic transports as they come off the production line. And, since production and sale of passenger aircraft really is a world-wide business with a universal market crossing over all national boundaries, proper consideration will have to be given to the needs of our foreign competitors as well as of our own flag carriers—unless we choose to write off half the world's potential market and run the risk of incurring operating restrictions against our own airlines flying abroad.

If subsonic jets had been unprofitable, I think we would have been

less enthusiastic about supersonics, but we look upon supersonic transports as potentially profitable supplement to subsonic jet operations. Since SSTs would supplement, not replace, the industry's subsonic jets, almost all the nation's airlines would be able to make this next step with far less financial strain than they went through in moving from piston equipment to subsonic jets. I use the term "supplement" because the industry's fully depreciated subsonic jets will have many profitable years ahead of them in lower fare and cargo services after SSTs are in operation.

We purchased the Concorde because it can be produced sooner than a larger, faster plane; because its physical size and flying characteristics will make it acceptable at the airports we now serve; because its capacity seems adequate for our present markets.

The slower, smaller plane had considerable appeal for us because we felt we could operate it profitably over Continental's present limited domestic system. In fact, with our present system, a larger, faster plane would not necessarily represent much improvement for us. We estimate that our block-to-block time between Chicago and Los Angeles with the Mach 2.2 Concorde will be one hour and forty-five minutes. A Mach 3 aircraft would only cut the trip to one hour and thirty minutes, or a saving of fifteen minutes. A Mach 2.5 supersonic transport would save only eight minutes.

The price of approximately ten million dollars per copy is higher than a subsonic jet, while the passenger carrying capacity is slightly lower, but the increased speed will boost productivity enough to overcome these factors. We believe we'll be able to operate our Concordes at seat mile costs no greater than our current subsonic jet costs.

When we first began flying subsonic jets, many people forecast that they would only be profitable in long-haul operations, but we have found that we can operate profitably over many shorter-stage lengths as well. We think the same thing will be true of supersonic schedules.

Obviously, it would cost less to only use the supersonic jets on the longest routes, but to obtain the greater utilization it would make sense to operate the SSTs over the shorter-stage lengths as well, even though this would entail some subsonic flying.

Our initial planning shows that with the three Mach 2.2 aircraft operating ten hours and twenty-eight minutes a day, we could, for example, operate four round trips a day between Los Angeles and Chicago, two round trips between Los Angeles and Houston, two round trips between Los Angeles and Kansas City, one round trip Los Angeles-Chicago and one additional round trip between Denver and Chicago. The morning flights would depart no earlier than 7 a.m. and all flights would terminate in the evening no later than 11 p.m. to minimize potential noise problems. All maintenance would be done at night on the same perpetual basis we now use for our subsonic jets.

While we forecasted a 1970-1971 need for six Mach 2.2 to Mach 2.5 supersonic transports for our present system, we ordered only three Concordes. Once our initial competitive position was protected, we felt we could afford to hold off the additional orders until we could properly evaluate the American SST in relation to our requirements. We would prefer, of course, to buy the additional transports here, but before we can make a decision, we will need to know the speed, size and price and the

economics of the American SST—and we will have to know what delivery positions will be available.

I'd like to list a few of the things we would like to see in the American program:

1. The plane should have the ability to grow to greater speeds and greater ranges than the aluminum Concorde will be capable of achieving. Aircraft noise should be no greater and, if possible, less than that of our present subsonic jets. Handling characteristics should be better. The SST should be able to operate safely from any airport now handling subsonic jets. The plane should be designed for a three-man cockpit crew for domestic operation.

2. The SST should be able to operate profitably at subsonic as well as at supersonic speeds. Affecting profitability, of course, will be initial price, royalty payments and actual cost of operating the airplane. Together, these figures should produce a seat-mile cost no greater than that of our present jets. I'd like to point out there is little margin for error in this program. For example, if a tax is imposed on supersonic fuel, a profitable aircraft might become an economically impossible aircraft.

3. There must be equitable distribution of production positions to all domestic and foreign operators to insure maximum sales and to avoid dislocation of present competitive relationships within the airline industry.

4. The time for the FAA to accept orders should be in accord with the FAA's own Request for Proposals which was issued last August 15, and which said: "Air carriers may place orders for the commercial supersonic transport within a period ending six months after completion of Phase II." Adhering to this timetable would enable the airlines to evaluate the product being offered by the winner of the design competition and would allow each company to determine its needs in relation to its system *before* being forced to order.

The industry also will save hundreds of thousands of dollars in lost interest which will be forfeited if interest-free royalty payments must be made in advance of this date.

5. Our air traffic control system must be improved to match the improved performance of the SST, preferably by automating the system. The SST should be designed for all-weather operation and the nation's airports and air traffic control system also should be capable of all-weather operation. Diversions or cancellations with supersonic transports will be so expensive that such an all-weather operation, in my opinion, will be mandatory.

6. Passenger ground handling and ground transportation must be improved to match the improvement in the air.

7. The manufacturers, the FAA and the airlines all should review their rules, regulations and traditional ways of doing things to make sure that the economic potential of the SST is not hamstrung by procedures which were designed for piston or subsonic jet operation. Everything we do or require should be geared to the potential of the plane, not to habit or past custom.

8. We believe that two competing experimental prototypes or at least a single prototype ultimately would produce a more successful program than would the present plan of jumping directly to production models from the winning design.

STUART G. TIPTON

PRESIDENT, AIR TRANSPORT ASSOCIATION OF AMERICA

The airlines endorse the United States supersonic transport effort and the Administration's recommendation that we proceed with a national program to "support the development of a commercial supersonic transport aircraft which is safe for the passenger, economically sound for the world's airlines, and whose operating performance is superior to that of any comparable aircraft."

The SST effort calls for a new and very complex concept, however, and it is important to examine the issues involved.

The first thing that must be considered is the United States objective—what are we trying to do? It seems to me that this is what we are trying to do: In about 1970 there should be offered for sale to the airlines of the United States and the world a supersonic airplane built by a United States manufacturer. This airplane should have a potential speed of more than Mach 2.2. In other words, the airplane should be so designed, and built of such materials, as to be able to operate ultimately at a speed of more than Mach 2.2.

It should be capable of being operated by the airlines at a reasonable profit. The airplane must be operated without undue annoyance to persons on the ground. It must fit efficiently into the total air transportation pattern without excessive restrictions on the other parts. And last, and probably most important, the airlines should be able to operate the airplane while continuing to improve their safety record as they have in the past. These, it seems to us, are the basic considerations which should go into its design and construction—the United States objective.

It would be good, of course, if the first commercial supersonic aircraft were of United States manufacture. But history demonstrates that the acclaim for such an accomplishment is often short-lived. Far more important in our view is that the United States supersonic aircraft be the best and most saleable. That is where the lasting prestige will lie.

In the course of the discussion of this program we have all been asked the question many times—why should not the United States permit foreign manufacturers to build this airplane if they are willing to do so? If such an airplane is built, United States carriers will always be able to buy the products of these factories.

We have little trouble in answering that question. It is not necessary to review much of our history to understand the crucial necessity in the national interest of maintaining our aircraft manufacturing industry. Our industry has taken the lead for many years in the production of the most advanced aircraft, and those aircraft have been crucial in maintaining our national security. In addition, our manufacturers have led the world in building transport aircraft, and this ability has not only maintained our national security, but has yielded to our economy almost untold benefits. One small example—our foreign trade was augmented by a billion dollars or more, simply because our manufacturers were able to build the finest of the world's jet transports. Our country cannot afford to bow out of the supersonic transport program. That would begin the erosion of our manufacturing industry's strength which is so essential to our future manned aircraft needs.

That is the heart of the matter, but we further believe that the design

and construction of this airplane which has been described is equally as significant to the maintenance of the United States lead in air transportation. The far-flung routes of able, successful United States air transport operators are unquestionably a prime essential to the interests of the United States, not only with respect to its commerce, but to its national security. The Congress declared that to be the fact in the Federal Aviation Act of 1958, and it obviously is the fact. One answer to that, of course, is that American construction of this airplane is unnecessary to serve our air transport operators. They can acquire the aircraft abroad. It is really not that simple, though. The airlines of the world are in bitter, vigorous competition. Our competitors in many cases are government-owned and operated. They are arms of their governments. I do not believe that the United States can expect its air transport operators to maintain their successful positions if procurement and maintenance of their most advanced equipment is dependent upon the goodwill of their competitors.

We believe there is yet another national security interest involved. For the present the Department of Defense has stated no firm requirement for a supersonic intercontinental transport in support of its global commitments. However, by the time a United States supersonic airplane is successfully developed, the military establishment will find that they need it and will be grateful for its availability.

The question whether Federal funds should be invested in an advanced aircraft has great similarity to the one dealt with years ago in connection with our merchant marine. It was decided then that it was in the national interest to invest Federal funds in the United States design and construction of merchant ships. Since that time hundreds of millions of dollars have been spent in that effort. Indeed, in 1958 the Maritime Administration looked forward to an extensive replacement program by the year 1972. At the present rate, the construction cost for that program would require over two billion dollars in government aid. Basically, the reason for this expenditure is to make sure of the maintenance of our ship construction capability and the effectiveness of our merchant marine. The need for a United States supersonic program is similarly justified and just as critical.

Having concluded that we need a supersonic airplane of great capability and that the airplane must be built by a United States manufacturer, we have an obligation to make recommendations as to how this should be done.

Our manufacturers, in cooperation with the airlines of the United States, have been building the finest air transports in the world for more than twenty-five years. In seeking to determine how to get the world's finest supersonic transport built we should review the essence of these past arrangements to see what made them so successful. Right at the beginning we have to recognize that an important—possibly all-important—factor in that success was millions upon millions of dollars of military research, development, and aircraft construction. That formed the basis upon which manufacturers and airlines were able to begin. Thereafter, the process was a perfectly normal free enterprise undertaking. Long periods of interchange between airlines seeking to outdo their competitors and manufacturers seeking to do the same thing resulted in aircraft designs. With airlines demanding that the aircraft meet the needs of transportation to the extent that the state of the art permitted and be capable of operating

with great economy, and the manufacturers seeking to best each other in designing and building such aircraft, the airplanes finally came on the line. It is not surprising, with that background of intensive and expensive research and development, and the competitive spur among both airlines and manufacturers, that the product was excellent.

In the best of all possible worlds that would be the way to build a supersonic transport. Unfortunately, it cannot be quite like that. In the first place, military expenditures have not carried the state of the art to the point where it must be carried now. For the first time it is necessary for civilian products to carry the burden of major advancements in the state of the art. Primarily for that reason, neither the manufacturers nor the airlines are able to carry on this project with their own resources. The risk is too great, and the solution of the problems too expensive. If we are to achieve the objectives we have set out, the government must undertake substantial financial risks. In doing so, however, we think that the government should come as close as it can to maintaining the traditional relationship between airline and manufacturer which, as we have said, has resulted in the development of the world's finest transports. We believe that this should be a really cardinal principle governing this program.

The program which has been designated by the Federal Aviation Agency, and approved by the President's Cabinet Committee, is off to a good start. The Request for Proposals has been issued, and the manufacturers have submitted their proposals. We now have reached the point when, in our judgement, the program laid out by the Federal Aviation Agency should be changed. If things go as planned, it is expected that, on the basis of the proposals submitted, two manufacturers will be chosen. Those manufacturers will be asked to provide more specific designs, and will be paid to do so out of the appropriation which has been passed by Congress. Thereafter, a single manufacturer will be chosen, and production of the aircraft will begin.

We believe that the program must proceed otherwise, because, as planned, it involves too many steps, and postpones for too long, the time when a realistic appraisal can be made by either government, manufacturer, or airline as to whether the agreed design objectives are being met.

We would suggest a simplification. We believe the United States should enter into a contract now with a manufacturer or a group of manufacturers to build a prototype supersonic airplane, and that during the period of its construction the manufacturers should be given the utmost leeway, in combination with prospective buyers, to design and produce the best possible airplane. The government should not seek to supervise design decisions. This prototype should be built with low cost, flexible, low-rate tooling. As is well known, the cost of permanent tooling is enormously expensive and based upon our past experience we can be sure that the prototype which is produced will differ very substantially from the ultimate production aircraft. There will be an urgent need to alter the production design for reasons of basic safety, efficiency or economy.

If efforts are made to move directly from design to production aircraft, we feel sure that time and money will be wasted. This feeling is underscored by the Rand Corporation report of last February to the Air Force entitled "The Role of Prototypes in Development" which concludes that development of prototypes before commitment to production

"should be more widely applied to aircraft development programs, particularly where large technological advances are being sought." When the prototype is completed, it should be tested and evaluated to the point where the government, the airlines, and the manufacturers have confidence that their objectives can be achieved.

As far as the airlines are concerned, the FAA's proposed financial arrangements must be considered only as suggestions at this time. The FAA proposal may well be impractical since it is now premised on full recovery from the airlines of the entire cost of the program. No consideration is apparently given to the essential national security and international trade interests involved nor the fact that the Concorde is being developed at the expense of the British and French governments.

The FAA proposals do not give adequate weight to the fact that airlines are private businesses, with limited resources and that they must make a profit to survive. The carriers will have to have reasonably clear information on the economics of the airplane before they can judge whether it can be operated profitably. All cost factors are involved in this economic evaluation, including purchase price, any operating royalties, and performance characteristics of the airplane.

If the carriers judge the economics to be sound, along with all other factors, they can finalize their contracts from their supersonic fleets. They will be able to finance them, providing the presently improving profit picture can be further consolidated and expanded and not cancelled by new burdens in the years ahead. But prognostications cannot be made now as to the ultimate number of aircraft to be taken and the details of their financing.

We are now brought to the question as to how much this project is going to cost the United States government. We have every confidence, based upon our own capabilities and those of our aircraft manufacturing industry, that a highly successful supersonic transport will be produced, and that it will be operated with profit to the carriers and credit to the United States. Estimates can be made but it is quite impossible today to say how much this project will ultimately cost. We can say this—that in designing, building, and introducing into operation a supersonic transport there are risks enough for everyone. For well established national interest reasons, the United States should risk money. Our manufacturing industry has already risked substantial funds, and will risk some more—as well as their reputations. The ultimate risk is that of the airlines. Even with the most careful of appraisals, any airline buying an advanced piece of equipment lays its financial future and its business reputation on the line. That has been true in the past, and will always be true.

The supersonic transport will be the most difficult of our advances. It can also be one of the most rewarding.

VIEWS OF THE AIRCRAFT MANUFACTURERS

J. L. ATWOOD

PRESIDENT, NORTH AMERICAN AVIATION

There are three basic areas of concern, from the manufacturer's point of view, in the proposed United States supersonic transport program. These are:

(1) The technical risks in designing and producing a supersonic transport that will meet the performance objectives established for the proposed United States program.

(2) The operating economics of the airplane to be developed under the United States program.

(3) The financial risks facing a manufacturer undertaking the United States program.

As to the technical risks, the proposed SST program is basically a development program. This means that anyone undertaking the design and manufacture of an SST at this time must recognize that there are a number of technical problems that must be solved before an airplane with the desired performance characteristics can be produced.

Complex development programs are familiar to our industry. Although the technical development problems are difficult and pose a significant technical risk, it is my opinion that these problems can and will be solved. We believe that the existing and reasonably predictable capability of our industry is such that we can produce an SST of the desired performance.

As to the second area of concern, namely, the operating economics of the SST, more uncertainty exists. At this time we do not know how much effort will be required to solve the technical problems ahead, and this uncertainty has a significant effect on the cost of the SST. This in turn creates a corollary uncertainty with respect to the operating economics.

The financial risks facing the manufacturer constitute the fundamental problem. While these risks arise from a number of interrelated factors, the essential concern is not the principle of risk but the sheer magnitude of the dollar amounts at stake. I do not believe that the full implications of this have been completely recognized.

I would like to turn first to some of the technical considerations in the SST program. Meeting the general system requirements specified for the SST is feasible in terms of operating speeds, altitudes and range—and they are reasonably predictable in an engineering sense.

Superimposed on these basic requirements are the requirements concerning noise—both residential noise near an airport and the tolerance to sonic booms in the line of the plane's flight path. Furthermore, a single supersonic transport will, in its twelve year predicted life, be expected to make some 26,000 landings and takeoffs and to fly at least 36,000 hours, two-thirds of which would be at or near its design temperature. This means that the SST requirements amount to an increase of nearly ten times the life at high temperature of the most advanced aircraft that exists today. The cost and manner in which the solutions to these potential problems are developed can have a sizable effect on the plane's operating economics.

A. *Critical Airplane Characteristics*

Let's take a closer look at the SST's critical characteristics. A plane's aerodynamic efficiency, propulsion efficiency, and weight efficiency can mean the difference between red ink and black on the airlines' books.

Aerodynamic efficiency can be expressed mathematically as the lift/drag ratio. The more efficient the aircraft, the less thrust it needs from its engines—and the less fuel—in order to carry a revenue-producing payload at an efficient altitude and fly a given distance. The less fuel it needs, the lower the operating cost and the larger the payload of passengers and cargo it can carry. Thus the potential revenue of every flight is directly

affected by the performance designed and built into the plane.

Let me cite an example. If the plane were to need about 200,000 pounds of fuel for a long-range flight (4,000 statute miles), and if this fuel load could be reduced ten per cent (20,000 pounds) by increased efficiency, the plane's revenue-producing payload (35,000-40,000 pounds) could be increased about fifty per cent.

Furthermore, a long-range plane must add several thousand pounds to its weight for each one hundred miles it adds to its maximum potential range. The added weight has an adverse effect on the airplane's economic efficiency when it does not operate at its maximum range. In other words, the kind of airframe, structural materials, engine, fuel, and the weight of the aircraft are all inseparably interrelated—and all heavily influence an airline's profit-and-loss statement.

Now consider some additional factors to be taken into account in developing a supersonic airliner. Some of the plane's skin will be heated to the vicinity of 250 degrees Fahrenheit when it flies steadily at a speed around Mach 2.2. At this temperature aluminum has lost much of its strength. Therefore, the heat resistance of metals is an important consideration in designing the SST.

The longevity of the structural materials is important, too. If they lose strength from continuous exposure to flight at high temperature, the structure is subject to fatigue, and the airplane will not have a good service life. The SST's service life must be at least 36,000 flying hours according to the FAA design objectives, and the airlines would prefer considerably more.

When the service life of an airplane must be long, and when the temperatures it must endure are high, its structural weight will undoubtedly be increased. This means that the SST structure must almost surely be relatively heavier or made of material that is costlier than that of subsonic aircraft.

However, by sufficient design, development, and testing effort, we can whittle down the weight—and the costs of production and operation—while building in the necessary longevity. Achieving the necessary service life for a commercial SST will require a very substantial test period to determine engine life, structural and material fatigue characteristics, subsystem reliability, and a host of other factors.

There are two other requirements to consider for the SST. The sonic boom, and the noise made by the SST while leaving airport areas, must be held to acceptable levels.

B. *Sonic Boom*

Sonic boom occurs when a plane speeds up past Mach 1, the speed of sound, and flies supersonically. The effect of the boom on the ground can be minimized if a plane is high enough when it operates at supersonic speeds.

Therefore, to avoid creating unacceptable sonic booms in populated areas the SST must stay subsonic until it climbs considerably higher than would be necessary if efficiency were the only consideration. This necessity to climb to high altitudes for acceleration is one of the important reasons why the SST must have larger and more powerful engines than are now available. Larger engines mean a heavier, bigger, and more expensive SST because of the interrelated factors mentioned earlier. If the estimated

public tolerance level for sonic boom were lowered five per cent (from 2.0 to 1.9 pounds per square foot) it could require an increase in aircraft weight as much as twenty per cent or more for the same payload.

Another factor is the effect of engine noise on nearby residential areas during takeoff and landing. Because the plane's acceleration at high altitudes will be more critical and will determine the size of its engines, we believe that residential noise control need not be any more of a problem than it is for present subsonic jets. These points are mentioned, however, because no engine now available can enable the SST to comply with standards of acceptable noise level and sonic boom pressure. We believe that development of an appropriate engine will be a pacing item in this country's SST program.

C. Effect Of Turbine Temperature

While North American does not produce engines of the type needed for the SST and therefore cannot speak for the engine manufacturer, let me indicate the impact of engine technology on the airplane as a whole. Turbine inlet temperature refers to the hot gas temperature as it comes out of the combustion chamber and produces the power. Present commercial jet engines operate between 1,500 and 1,800 degrees Fahrenheit, and current military engines between 1,800 and 2,200 degrees.

It is generally accepted that a turbine inlet temperature of 1,900 degrees is attainable for a commercial SST; but if that temperature can be raised to 2,200 degrees then greater use can be made of the chemical energy of the fuel. Engine efficiency is increased; fuel consumption is decreased; and the airplane weight needed to carry the engine and its fuel is decreased.

The result would be a reduction of approximately twenty per cent in takeoff weight to do a given job. However, higher temperatures could mean a potentially shorter service life, a more difficult development effort, and greater risk for both the engine manufacturer and the airframe manufacturer.

To round out this brief sketch of technical problems, I might offer the generality that the ultimate success of the plane will depend on small differences between large variables. Relatively small improvements in the SST configuration, its weight, its engines, or its fuel requirements could give a dramatic boost to its revenue capabilities. This is why the development schedule should allow time to seek out those small but significant improvements that will optimize the aircraft from the standpoint of practical operating economics.

There are numerous benefits that the XB-70 program will make available to the SST program. The XB-70 has made use of the same kind of research, development, and engineering required for supersonic-cruising aircraft like the SST.

Building the XB-70 necessitated the invention of numerous new tools, production methods, and inspection methods; the exploration of unknown areas of aerodynamics, thermodynamics, metallurgy, hydraulics, and several other fields; and the development of entirely new kinds of subsystems to meet the unprecedented requirements of a plane cruising at three times the speed of sound at a height of thirteen miles.

Even though North American had extensive experience with supersonic planes, we knew we would have to solve major new problems in building an airplane to cruise at Mach 3. Because we were exploring entirely new

fields of technology, it was very difficult to foresee the magnitude of many engineering problems or to estimate how long it would take to find the solutions.

Much of what we and our team of suppliers and subcontractors have discovered and developed will be applicable to SST. For example, the XB-70 crews will not have to wear oxygen masks nor pressure suits even when the plane is at 70,000 feet. The outside of the plane will be fiercely hot because of friction, yet the inside will be not only livable but comfortable. To make this possible we had to solve problems very similar to those that will confront designers of the SST passenger cabin.

Of course, there is no thought that the XB-70 can be modified or slightly redesigned to become an airliner. Military requirements for the XB-70 call for a relatively short service life of about 5,000 hours, as compared with at least 36,000 for the SST. The longer life calls for important differences in design. Moreover, the fuselage of a supersonic passenger airliner will have to be much larger than that of the XB-70. And the SST will need subsonic performance characteristics not required of the XB-70. Because of the interrelationships of materials, configuration, fuel, and the other technical factors mentioned earlier, our design concepts for the SST are different in many respects from the XB-70 design.

Nevertheless, many of the major technical problems associated with development of the world's fastest SST are being solved, or have already been solved, through the development of the XB-70. The basic technical advances to provide continuous supersonic operation have been made. The development for the SST will concentrate on extending this capability to longer service use.

D. XB-70 Flight Test Tasks

The XB-70 flight test program will be the first means of obtaining flight data under extended supersonic cruise conditions. No other plane in existence is designed to cruise continuously over transcontinental distances faster than sound. All existing supersonic planes are confined to comparatively short supersonic runs. The XB-70 is designed to cruise at Mach 3 for intercontinental distances.

Data from XB-70 flight tests will expedite the design of an SST with much greater assurance of success than could possibly be hoped for if we were to start from scratch. These data will help assess the fatigue resistance and heat resistance of the airframe and its subsystem; stability and control characteristics at cruising speeds not yet explored; flight efficiencies and other aspects of operating economy; sonic boom characteristics and the internal noise generated at these speeds by the flow of air over the fuselage, which is very important to passenger comfort. As valuable as its contributions are to the SST program, the XB-70 experience, of course, does not provide all the answers vital to development and production of the SST.

The effectiveness of the solutions to the technical problems is in good part determined by the amount of development time available. As the development schedule is compressed the technical uncertainties are heightened. The consequences of these uncertainties are magnified by the requirement for the initiation of the production program well before completion of the development program.

The more time available for research, development, and test, the lighter and more efficient the airplane is likely to be and the more favorable its

operating economics. The experience of the industry has always been that significant improvements are made as a result of development and flight tests. In the development and flight test stages, an airplane representing as great a technical stride as the SST is bound to need many modifications before it is ready for airline operation. To the extent that we enter the production phase early, we may sacrifice efficiency in the airplane. However, if production is deferred too long, it can have a serious impact on the market for the SST.

In discussing the design of the United States supersonic transport, I might comment on the issue of an aluminum versus a steel and titanium airplane. We think it would be undesirable to design a plane that leaves little opportunity for development of improved versions in future years. This is what a manufacturer will be doing if he designs an SST out of aluminum with a speed very close to the maximum at which an aluminum alloy can be used.

Historically, growth in transport aircraft has been predominantly through increased range, which for the SST means greater distances covered at its optimum cruising speed. A unique characteristic of supersonic cruising aircraft is that flight efficiency is increased as speed is increased, particularly between Mach 2 and Mach 3. This increased flight efficiency can be directly translated into increased range.

I think our country should have an SST with a significant growth potential. Since the technology is available to produce advanced steel and titanium aircraft with potentialities far beyond those of aluminum, the future of air transportation would seem better served if we take the necessary time and give ourselves room to grow.

While we expect that the technical problems we now foresee will be solved, it is too early to estimate with a high level of confidence the costs required to solve these problems. This leads to our second area of concern—the present uncertainty regarding the operating economics of the SST. Besides the technical factors discussed, another important influence on operating economics is the price of the airplane. The difficulty in estimating the costs of the development and production programs makes the sale price of the airplanes most difficult to establish. The size of the market will also affect the airplane price.

E. Price Quantity

Variations in the numbers of aircraft planned can have a significant influence on the unit sales price, and hence on the economic soundness of the program. For purposes of analysis, let us assume an American airplane that would be designed for a range of 4,000 statute miles, a seating capacity of 130, and a speed of Mach 2.5. By comparison, the Concorde unit price has been estimated to be about ten million dollars for a 3,750-statute mile, 104-seat airplane. With the support now planned by the United States government, and on the basis of 1963 dollars excluding interest and warranty costs, the American SST might cost about twenty-two million dollars per unit, based on a 200-aircraft market.

F. Direct Operating Cost

Let us now compare the estimated direct operating costs per seat mile of the Concorde and the American SST. Such costs are based on airplane utilization of 3,000 hours per year, a depreciation life of twelve years,

insurance rates of five per cent per year, and an average international stage length of 3,450 statute miles. For the assumptions used the Concorde would have a higher direct operating cost of about 1.7 cents per seat mile, while the American SST would have a cost of about 1.5 cents a seat mile; both would have higher costs than the current subsonic jets.

Direct operating cost is only one of the economic factors affecting the air lines. Among the other factors are the indirect operating cost, the purchase price, and the productivity of the aircraft. The productivity of the United States airplane will be higher because of its increased seating capacity and speed.

Despite the lower direct operating cost and the higher productivity of the United States SST, our analysis indicates that the airline operating return on investment, for equal load factors, is probably higher for the Concorde than for the United States airplane. This is primarily because of the substantially higher price of the United States airplane. In order for the American SST to be economically competitive with the Concorde, it would have to show a comparable return on investment.

The relative airline operating return on investment of the United States SST is, of course, sensitive to changes in the price of the Concorde. Because the price of the United States SST will be substantially higher than that of the Concorde, any reduction in the Concorde price will call for a much larger reduction in the price of the United States SST if the return on investment of the two airplanes is to be kept in the same relation. If the price of the United States SST is twenty-two million dollars, a reduction in the Concorde price of ten per cent, from ten million dollars to nine million dollars, would require a reduction of about two million dollars in the price of each United States SST to maintain the same relative return on investment. In a 200-airplane program this would represent about 400 million dollars. If the United States price is not reduced, the market for the United States SST could, under these circumstances, be seriously jeopardized.

This startling result illustrates the problem facing the United States manufacturers. It is essential to realize that the manufacturers may find themselves in this kind of contest with the British and French governments.

All of these uncertainties—that is, the technical, market, and operating economic uncertainties—lead to the fundamental problem which must be faced in the SST program. This is that the dollar magnitude involved is so vast that a failure to achieve the predicted goals could result in not merely a setback but in financial disaster for the manufacturers. The offer by the government to participate in the development program in the amount of 750 million dollars—in absolute terms a most substantial proposal—is in itself a recognition of the financial risks involved. However, without in the least desiring to minimize the government's offer, the financial risk remaining is still immense.

The manufacturer faces these financial risks in both the development program and the production program. I have already discussed the technical risks and the pricing uncertainties, together with their effects on operating economics and market potential. The problem is compounded by the fact that the production program must be commenced while the development program is in progress. At present the government program establishes a limited support ceiling. Our preliminary estimates of the air-

frame manufacturer's program expenditures by the date of airplane certification—including the development program and that portion of the production program which will have been undertaken by then—indicate that such expenditures could approximate 1.5 billion dollars. If upon completion of the development program it appears that a full commercial program is not feasible, the manufacturer will be faced with a loss in the area of 950 million dollars, even after a portion of his expenditures have been reimbursed by the government to the extent permitted by the 750 million dollar ceiling.

Taking another condition, the government has stated in the request for proposal that it may terminate this program if the prototype aircraft does not indicate the required characteristics after one hundred hours of flight test—one of the government's major decision points. If this should occur, the manufacturer would face a loss in the area of 500 million dollars, even after a portion of his expenditures has been reimbursed by the government to the extent permitted by the 750 million dollar ceiling.

These prospects are illustrative only; others could be enumerated. For example, the figures I have cited assume that the manufacturer's actual costs do not exceed his original estimates. Yet the manufacturer must commit his original cost estimate for the development program in early 1964. Since this figure must be accurate for a period of about five years, the chance of experiencing cost overruns becomes a real possibility. Another significance of these figures is that, for example, at the end of the development program, the manufacturer's share of costs is on the order of seventy per cent of the total program expenditures.

Besides the development risks thus outlined, other risks of equal or greater magnitude can be visualized in the production program.

For example, an estimating error of ten per cent in a 200-airplane program could cost the manufacturer about 500 million dollars. The possibility of such an error cannot be completely discounted when it is considered that commitment to firm prices will have to be made before the development program is completed. Even if the cost estimates prove to be accurate, experience has shown that there are other risks associated with the introduction of technically complex products which could involve large sums of money. Among these are warranty obligations, schedule slippages, major technical problems resulting in extensive redesign after a number of units are in service, and other factors which could result in additional costs running into hundreds of millions of dollars.

If we assume that the technical and cost uncertainties are satisfactorily resolved, the manufacturer still faces the possibility that the market will not materialize to the extent predicted. If the aircraft are accurately priced on the basis of a 200-aircraft market and that market does not materialize, the airframe manufacturer would be faced with very formidable losses, depending on the degree of market reduction. For example, a reduction of the market to one hundred aircraft would produce a loss of 800 million dollars. The predicted market might fail to materialize for a variety of reasons over which the manufacturer has no control. One of these would be a timely reduction in the price of the Concorde which would have a marked effect on the relative operating economics of the two airplanes.

In summarizing, I should reemphasize the following points:

1. Although the technical development problems are difficult and pose

a significant technical risk, we believe that our industry can produce an SST of the desired performance.

2. The XB-70 has made, and will continue to make, a basic and essential contribution to the technology of the SST.

3. There is considerable uncertainty as to the operating economics of the SST, primarily because of the uncertainty as to the airplane price.

4. Even with the substantial financial support proposed by the government, the dollar magnitude of the risks faced by the manufacturer, which are amplified by the necessity of commencing the production program during the development program, are immense.

In closing there is one point I should like to stress. We at North American certainly do not anticipate that disaster would befall a United States SST program; quite the contrary. I have felt it important to point out, however, that in a program of the size and complexity of the SST program, even a remote possibility that an important goal would not be met cannot be disregarded. Our analysis to date points to immense consequences which a company might not survive if there should be a significant setback in one or more of the principal factors which will determine success. It is this, and not that risks have to be taken by the manufacturer, that is our fundamental concern.

CORTLANDT S. GROSS

CHAIRMAN, LOCKHEED AIRCRAFT CORPORATION

Lockheed, with others in the industry, has been intensely interested in the development of a supersonic transport for many years. We have been seriously pursuing the questions of supersonic passenger flight since 1956, and have done a very substantial amount of research and development work targeted in this direction. Our interest has also included a substantial investment in advanced research facilities and cost-sharing in government-funded research tasks initiated by the FAA and NASA.

A. National Benefit

The British-French Concorde project has removed any doubt about the evolution of the supersonic transport, regardless of any decision our country makes. British and French government leaders already have demonstrated their faith in the future of the SST and their two countries have joined forces under a dual government-funded program aimed at having an SST operating on the world's airlines in the 1970s.

The Russians, too, have acknowledged the importance of the supersonic transport. Their views have been interpreted in a study prepared by Browne and Shaw for the Stanford Research Institute, "Supersonic Transport Development in the USSR," March 1963.

1. *The Development of the Supersonic Transport by the United States Will Contribute Substantially to Alleviation of the Gold Flow Problem*
Airline aircraft export sales in the 1958-1962 period totaled 1.18 billion dollars. This most certainly was an important factor in our country's foreign trade picture and these exports materially aided gold flow.

United States built jet transports have been sold to twenty-nine foreign countries. Foreign sales accounted for 231 of a total of 678 United States jet transports. It is significant that aircraft built abroad, such as the

Viscount, CL-44, Caravelle, and the BAC 111, have made inroads on the United States' airline market in recent years. Purchases of European aircraft amounted to fourteen per cent of the total sales to United States airlines during 1961 and 1962.

United States airlines already have placed orders for the Concorde. There can be no doubt that the supersonic transport potential in the balance of payments looms large. If the United States does not build a supersonic transport, our airlines will be forced to buy the Concorde and the United States will forfeit the export market in this field.

2. *Development of an SST by the United States Will Directly Benefit Our Military System*

The United States Air Force has undertaken study programs on Strategic Systems that most certainly will be able to utilize the technology and possibly even the hardware developed for the supersonic transport.

It is in the national interest to coordinate the SST and Strategic Systems programs in such a manner that the maximum practical mutual benefit results from the development of engines and systems and the solutions found to other technological problems.

In the broad sense, it seems reasonable to assume that virtually every technical and production invention and development for the supersonic transport will have important military applications. This would include engines, metals, lubricants, seals, fuels, and electrical, hydraulic, cooling, and pneumatic systems.

Here are some examples:

a. *Engines*—A more powerful engine than is now available must be developed for the supersonic transport. This engine undoubtedly will have application to many military vehicles for high Mach number operations.

b. *Inlet and Exhaust Controls*—To promote efficient flight characteristics at both subsonic and supersonic flight, inlet and exhaust control systems must be designed and developed. These would be applicable to future military systems which fly at supersonic speeds.

c. *Cockpit Arrangements*—To reduce the drag of the supersonic transport, new concepts in pilots' windshields must be developed. These concepts also will be applicable to high performance military vehicles.

d. *Systems*—The systems developed for the supersonic transport, including hydraulic, electrical, and environmental, are of prime importance under high-temperature conditions that will be experienced. The knowledge gained here will make the task of developing high Mach number military aircraft easier. The commercial SST will require systems of minimum weight and greater capacity than currently exist.

e. *Seals*—The work to be done on sealing devices for the supersonic transport will be more extensive than thus far has been accomplished on airplanes for high temperature flight and will be useful to future military programs.

f. *Fabrication Techniques for Titanium*—We believe the SST will be built principally of titanium. This will give a tremendous acceleration to the development of techniques for reducing the cost of the titanium alloys and titanium structures. We believe titanium is a superior metal for aircraft structure and, as its price is reduced, it will come into wider use in new military aircraft.

The titanium industry today is relatively small, having had a gross pro-

duct in 1962 of approximately one hundred million dollars.

Currently anticipated growth of this industry, plus substantially increased output for the SST, can be expected to result in a price decline similar to that experienced with aluminum. This could mean the utilization of titanium for applications presently considered uneconomical.

3. *There is Ample Precedent for Government Support for Transportation*

The government has long pursued a policy of fostering the development of rail, water, highway, and air transportation. For example, our Maritime program, our annual Federal payments for highways, and United States Army navigation projects. Current annual Federal payments for highways amount to three billion dollars. These expenditures have helped to produce our well developed surface transportation systems. The support of the Congress in aviation matters such as our air traffic control systems and aeronautical research has contributed greatly to aviation development in this country. These sums have paid off in the general welfare of the United States. In the case of the supersonic transport, government funds advanced constitute a continuation of this far-sighted policy.

Unlike the case of surface transportation where there has been no direct recovery, there is the possibility of recovery of the SST expenditures from profitable operation of these airplanes by the airlines.

4. *The United States SST Will Provide a Valuable National Asset Which Will Enhance United States International Prestige*

It is not for us to say whether the maintenance of international prestige alone warrants production of the supersonic transport; however, public reaction to the launching of the first Sputnik by the Russians demonstrated that the prestige factor cannot be ignored.

Technologically, United States industry is more advanced than any in the world. We have the capability of producing a superior supersonic transport. If we fail to do so, it will be a reflection on the American industrial system and give an impression of lack of vitality.

Traditionally, the United States has been the world leader in commercial aviation. We do not want to surrender that leadership. We want our government and industrial leaders to travel to foreign countries on a United States supersonic transport—not the Concorde. We want American-built SST's to be operating in and out of foreign airports as visible evidence of United States capability.

5. *The SST Program Will Preserve Skills Vital to Future Needs*

Lack of a United States supersonic transport program means a declining skilled aerospace work force in all areas of activity—scientists, designers, and skilled laborers.

Retention and preservation of these skills are as important to our national defense as are the weapons of defense. Once lost, these skills will be very difficult to regain.

B. *Concorde Development Program*

There have been some suggestions that United States industry team up with the British and the French and produce the Concorde in the United States. We do not believe that this is a practical or wise suggestion, even if the idea was acceptable to the British and French governments and their manufacturers.

It would be time-consuming and costly to attempt to manage and coordinate the technical development under a program involving split

management responsibilities. We believe minimum time and cost objectives can be achieved only if one organization is in charge of the program.

Our studies lead us to conclude that an aluminum SST will be too limited in range and passenger capacity. It will be limited to a speed of Mach 2.2 with no growth potential, because of the sharp reduction in strength of aluminum at the temperatures experienced at high Mach numbers.

We concur in the design objectives of the FAA's Request for Proposal for greater range, passenger capacity and speed than afforded by the Mach 2.2 concept.

A United States-British-French Concorde Program would reduce by about half the beneficial effect on balance of payments that would result from a superior airplane designed and built in the United States. Some of the other benefits of the United States SST Program previously discussed would be cancelled out or greatly reduced and, an airplane in the Mach 2.2 range would not be a sufficient step forward in the state-of-the-art to be of significant benefit to advance military programs.

A. CARL KOTCHIAN

VICE PRESIDENT, LOCKHEED AIRCRAFT CORPORATION

Lockheed believes unequivocally that the United States should move forward now with a supersonic transport program. We have already backed that belief with substantial investment in research and development work in the field, in advanced facilities, and in substantial cost-sharing in government-funded research.

We find most of the requirements of the Federal Aviation Agency's Request for Proposal to be reasonable. However, it is clear to Lockheed that the cost sharing provisions constitute an obstacle most difficult, certainly for us, and in our opinion, (although it is only an opinion) for any airframe manufacturer to handle.

The funding arrangements set forth would result in financial risks to the manufacturer which cannot prudently be accepted. These risks are associated not only with the development cost-sharing phases of the program, but with the proposed commercial production phase as well.

We believe it to be extremely important that these financial risks be reviewed in some detail.

A. *Development Cost-Sharing Phase*

1. *The Amount and Duration of Annual Write-Offs Are Excessive*

To illustrate the magnitude of the risks and financial problems, we have made a study of a representative one hundred-airplane SST program under the FAA's ground rules and assuming a normal manufacturer-airline relationship for the production program. We believe this study quite graphically demonstrates the magnitude of risks the manufacturer is being asked to take.

The Federal Aviation Agency assumes an estimated requirement of one billion dollars for funding of engine and airframe development, with the engine and airframe manufacturers cost sharing twenty-five per cent of that amount. For the purposes of our study we assumed that half of the one billion dollar cost was for engine development, and the remaining half

for airframe development. A twenty-five per cent cost sharing would burden each with 125 million dollars of unrecovered costs.

To illustrate the impact under conditions specified by the FAA of unforeseeable cost increases, we added one hundred million dollars to the cost of the 500 million dollar airframe program. The airframe manufacturer would have to absorb seventy-five per cent of that increase, or seventy-five million dollars. The manufacturer's cost-sharing obligation, therefore, would amount to 200 million dollars.

Spreading this total cost-sharing over the development years of the SST, annual write-offs would average out at more than thirty million dollars a year before taxes. These annual write-offs reach a peak of more than fifty million dollars in the year of maximum effort and they would continue over a period of six to seven years.

Financing of these annual write-offs would represent a cost of doing business in terms of the cost of the capital invested and not recovered. Interest charges on this unrecovered investment—using a rate of five per cent per year—would add another ten million dollars.

During this period, the airframe manufacturer also would be financing commercial work-in-process for the production airplanes. Assuming normal commercial payment terms for the airlines, an additional interest expense of approximately thirty-five million dollars would be incurred.

Our study indicates, therefore, the airframe manufacturer's profit and loss statement would show a net loss before taxes of approximately 245 million dollars. Conceding that these losses might be reduced to some degree by extending them to subcontractors, it still appears the annual write-offs would place the airframe manufacturer in a total net loss position during most of the development years of the program—before delivery of a single airplane.

His ability to pay dividends and to invest profits in research and new facilities would either be seriously impaired or non-existent during this period. Indeed, it would virtually prevent him from raising the funds required to finance the program.

2. *Liability for Cost Overruns on the Development Program is Unlimited*

We assume a development cost overrun of one hundred million dollars in our study, with the manufacturer bearing the required seventy-five per cent. Under the present ground rules, the manufacturer's liability for subsequent overruns would be one hundred per cent and in a program such as this one—which pushes the state-of-the-art—this liability extends to the unknown.

Summing up our study of the development phases of the program, it appears that if a manufacturer could survive the amount and duration of the twenty-five per cent cost-sharing—and this is by no means a certainty—the liability for overruns could very well bankrupt him. The threat of such consequences could force development short-cuts as unforeseen problems arise and could jeopardize the entire program. Such risks in a development program of this importance should not be taken.

3. *The Contemplated Recovery of Development Costs Would Handicap the United States Airlines*

The Concorde is being offered to the world's airlines at prices excluding development costs which are being assumed by the British and French governments. The present course of the United States program calls for

the recovery of these costs from the airlines in the price they would pay and from a royalty on revenues.

The United States supersonic transport would have to be substantially more efficient to overcome this handicap. It is too early to determine whether this can be achieved and what other operating handicaps might be imposed. For example, if consideration of the matter were to result in the imposition of a tax on jet fuel, a large disadvantage would loom up, as we recognize that more than one-third of direct operating costs on the SST will be in fuel.

While certainly every effort will be made by all concerned to achieve the utmost in efficiency in the United States transport, only the experience gained from operating experience will determine the airlines' ability to bear these costs at competitive fares in the 1970-1980 time period.

B. *Commercial Production Phase*

1. *The Impact of Over-Estimating the Market Exceeds Normal Commercial Risks*

Our first consideration is the matter of estimating the market. Here—with the high unit price anticipated for the supersonic transport—the manufacturer's risk most assuredly will be much greater than he has ever before assumed on a commercial program. For example, a program priced to break even on the basis of 150 units, but resulting in the sale of one hundred, would produce a loss before taxes to the airframe manufacturer of approximately 175 million dollars.

It is fairly well known that United States manufacturers lost at least one billion dollars in turbine transport programs, due, as we analyzed it, primarily to over-estimating the market. These costs were not reflected in the airplane prices. In addition, the estimated value to these commercial programs of prior government-funded military engine development amounted to something like 600 million dollars.

2. *Financing of Work-In-Progress Will Require Special Government Assistance Not Now Available*

Using normal commercial terms whereby airlines make advance payments to the manufacturer of ten per cent of the sales price three years in advance of delivery, fifty per cent two years in advance, and five per cent one year in advance, we estimate the manufacturer's investment in cost-sharing plus his outlay in commercial work-in-process would total a peak requirement for cash of more than 500 million dollars. Cash disbursements would exceed cash receipts for more than ten years.

This investment could be reduced some by imposing deferred payment terms on subcontractors, but it still remains beyond credit maximums available to the manufacturer. Guaranteed government loan arrangements have been mentioned in the RFP, but these will require special legislation before they can be made available.

3. *Timing of Orders Could Result in Excessive Costs*

On any large program an unbroken continuity of production is required to achieve production efficiency and the learning curve necessary to hold costs in line. The timing of orders is critical and lack of seasonable receipt of orders could result in excessive costs. An interruption in production because orders are not available or a stretch out in the production line to compensate for a slowdown in the receipt of follow-on orders would in-

crease costs in the form of displaced labor, excessive setup charges, reduced efficiency, excessive rate tooling and higher overhead.

Of course these are risks the manufacturer has historically accepted on commercial programs, but the size of the SST program magnifies them many times and puts them beyond his capacity.

4. *Warranty Liability Has the Potential of Great Risk*

There are other factors that must be given serious consideration. The size of the program and the advance in the state-of-the-art carries the liability of warranty of design into an unpredictable regime. The trend of recent liability decisions with respect to even purchased components of an airframe accentuates this risk.

5. *There Is a Major Problem in Insuring the Commercial SST Program*

The securing of insurance for the various risks on the SST program presents a major problem because (1) the normal risk base extending over several manufacturers would not apply, and (2) the insurance companies may not have the financial capacity to cover the high unit values.

Our investigation to date of products liability and hull insurance reveals a reasonable doubt that there are enough financially qualified insurance carriers who would be willing and able to write sufficient amounts of insurance for a commercial SST program. There is a similar problem in being able to obtain the required fire and business interruption insurance on work-in-process because of the high value of the units which are subject to loss.

6. *There Are Unforeseeable Risks in a Long Term Program*

There are other risks that cannot be entirely ignored. The length of the program—extending from development through commercial production—carries it into future political and economic environments and the unpredictable. For example, it will be difficult today to forecast realistic production costs for the 1970-1980 time period. Armed conflict could result in reduction or cancellation of the program.

Introduction of a subsidized foreign Mach 3 transport at some future date could result in failure to meet the market goal. The default of a major airline could mean the difference between profit and loss in the whole program.

We have reviewed these financial problems and risks in some detail because we feel that they constitute the greatest obstacle to the successful launching of the United States supersonic transport program. The most urgent need is for solutions to the cost-sharing and liability risks of the development phase in order that the development program may go forward promptly to sustain this country's leadership in commercial aviation.

JEROME F. MCBREARTY

VICE PRESIDENT, LOCKHEED CALIFORNIA COMPANY

A. *Technical Background*

1. *There Is an Adequate Background of Technical Information and Experience Today to Proceed with the Program*

A natural concern regarding an aircraft as advanced in concept as the supersonic transport relates to its technical feasibility and the degree of technical risk involved in its development.

We have now reached a point in time when a vast amount of fundamental research and development is behind us and we can confidently state that we are ready to proceed with the supersonic transport. The problems we will face during the development cycle will be no greater, in relative magnitude, than the problems we have faced at this point on any other advanced program we have ever undertaken.

2. The Principles for the Realization of Long Range Supersonic Flight Are Not New

We determined as far back as 1956 that a practical, economical SST could be designed if certain technical advances could be realized. It was quite natural for us to consider the feasibility of such an aircraft at that time because, historically, commercial applications of aviation technology had trailed military applications by about ten years and, at that time we were well into military supersonic flying experience with test vehicles such as the F-104 fighter at Mach 2 and the X-7 drone at Mach 4. In addition, increased transport speed capability was attractive, as always, because of its favorable effect on airplane productivity and economy.

The technical advances that had to occur before a practical SST could be produced were those associated with achieving efficiencies in supersonic flight that were high enough to permit the airplane to cruise supersonically for great distances. The accomplishments associated with supersonic fighters did not provide this capability. This requirement called for the development of airplane configurations that would have unusually high lift/drag ratios at supersonic speeds to minimize fuel requirements and airplane size. Further, it called for the development of engines and the associated inlet and exhaust systems that were designed to operate efficiently, and consume a minimum of fuel, at supersonic speeds.

An analysis to determine the proper cruising speed regime for the SST, expressed in terms of flight efficiency based on lift/drag ratios, speed and fuel consumption believed achievable, revealed that the aircraft should cruise at a Mach number of 2.5 or more to have the same range efficiency, which means the same miles per pound at a selected airplane weight, as subsonic jet transports have today. The selection of a lower supersonic cruising speed would result in a lower range efficiency than that of present subsonic jets.

This requirement to cruise in the Mach 2.5 to 3.0 speed regime introduced additional problems that required solution. For example, at these speeds aerodynamic heating makes the use of aluminum structures impractical, and many mechanical, electrical, and hydraulic components are exposed to an extremely high temperature environment.

Finally, supersonic airline operation can introduce operating problems such as excessive noise from high thrust engines, the sonic boom, and take-off, landing and other flight problems associated with a supersonic configuration.

3. Industry Has Invested in Research Facilities in Anticipation of this SST Program

Throughout this time span, Lockheed has been building and equipping its research facilities to handle the tasks inherent in the development of the supersonic transport. The Lockheed-California Company's Research Center at Rye Canyon, California, currently consists of a completely integrated complex of supersonic and hypersonic wind tunnels, structural and ma-

terial laboratories, altitude environmental chambers, antenna laboratories and systems development laboratories to handle the research and development effort. Investment in this advanced research facility presently amounts to more than twenty-two million dollars and, prior to the first flight of the SST, this amount will increase to approximately thirty-three million dollars.

B. Solutions To Principal Problems

Solutions to the principal problems associated with the development of a practical SST have been found. I would like to cite the following examples:

1. Research in the supersonic wind tunnel has produced airplane configurations with lift/drag ratios high enough to insure intercontinental range capability at supersonic cruising speeds.

2. The engine state-of-the-art has advanced to the point where the capability of high thrust engines to operate continuously at high speeds and elevated temperatures, with acceptable fuel consumption, is assured.

3. Analytical and experimental research on the very difficult problem of engine air inlet design, to create an inlet system that will provide proper air flow to the engines under all flight conditions, has been successful.

4. Low speed wind tunnel tests of supersonic transport configurations have demonstrated that highly satisfactory low speed flight characteristics can be provided in airplanes with either fixed wing geometry or variable sweep wings.

5. Materials and structural tests have proceeded to the point where the practicality of designing and fabricating light weight titanium and steel aircraft structures is established.

6. The physical characteristics of the sonic boom, and the effects of the airplane configuration on the strength of the shock wave, are understood to the point where configurations can be designed to minimize the sonic boom problem.

The preceding were examples of the accomplishments that we believe to be especially significant. In addition to our own efforts, we have been fortunate enough to have been selected as one of two contractors to perform a Supersonic Commercial Air Transport study for NASA. The purpose of the study was to evaluate for NASA configuration concepts in sufficient depth to assure confidence in gross weight and range-payload characteristics. Many aspects of detail design, passenger accommodations, airline requirements, structure and materials, equipment and aircraft systems, and compliance with FAA regulations were integrated in accomplishing the study objectives.

In addition, we are performing several contractual tasks for the FAA, under the administration of the Air Force Aeronautical Systems Division. Three of these tasks are concerned with high temperature structural problems. For example, Lockheed is designing and fabricating wing box beam specimens of titanium for testing by the Air Force. We are also conducting analytical and experimental work on engine inlet and exhaust systems under another contract. We are firmly convinced that United States industry is technically capable today of developing the supersonic transport in accordance with the objectives of the FAA.

H. M. HORNER

CHAIRMAN, UNITED AIRCRAFT CORPORATION

In conducting design studies of engines for the supersonic transport, Pratt & Whitney Aircraft has worked closely with the airframe industry to insure that the requirements of the various aircraft designs were recognized and met to the maximum possible degree. The true worth of a given engine design can only be judged in terms of what gains in aircraft performance are achieved. The engine design studies have covered turbojet and turbofan engines with a wide range of cycle characteristics, such as bypass ratio, compression ratio, gas temperature, thrust augmentation, and various mechanical design arrangements. We believe that the results of these studies, which have been supplied to the various aircraft manufacturers, will permit valid evaluations of the performance of possible airframe-engine combinations.

We can design a turbine engine which will meet the requirements of the supersonic transport Request for Proposal and also the special detailed requirements of the three competing aircraft manufacturers. We believe we can develop this engine and successfully complete the existing FAA requirements for prototype engine tentative flight test status qualification and production engine type certification. But while we are confident of our ability to successfully develop a satisfactory powerplant for the supersonic transport, this confidence should not be construed as diminishing the magnitude of the job to be accomplished. The supersonic transport program represents the largest single step ever attempted in the commercial air transport field. The performance and weight requirements imposed on the engine for a safe and economically satisfactory airplane represents sizable steps in technology.

Historically, the commercial aircraft engine requirements of this country have been fulfilled by the use of engine types which were originally conceived and developed for military aircraft. This has resulted in the selection for commercial aircraft of engine types which had already proven their excellence in military use, thus eliminating many possible problem areas prior to commercial operation.

In the supersonic transport program this advantage is not available, and thus all of the usual technical problems normally present in such new projects must, in the case of the supersonic transport, be borne within the SST program. The use of engines adapted from military aircraft has also had a considerable effect in the past in reducing the development cost and development time of commercial engines and has provided essential service experience prior to carrying passengers.

We believe that the tentative flight test status qualifications and type certification programs for the supersonic transport engine can be successfully completed within the calendar of events established for these phases by the FAA and as needed to meet the aircraft manufacturers' requirements. The magnitude of the supersonic transport development problems, coupled with the required long development period, indicates that the engine development costs will be substantially greater than any prior engine program undertaken by Pratt & Whitney Aircraft. Our experience in the field leaves us with a serious concern that the amount of engine development money envisaged for this program is adequate.

A review of costs for prior engine development programs has shown that

the expenditure of funds for continued engineering and development during its service life is more than equal to the development funds which are required to bring the engine to its initial qualification or certification status.

The Request for Proposal on the supersonic transport makes no acknowledgement of this situation which obviously has a very great impact on the total development funds. The FAA Request for Proposal requires a substantial financial contribution toward the development program by the manufacturer and, in addition, indicates that full repayment of government advances is anticipated. The British and the French governments are taking a different and, in our opinion, a more realistic approach in supporting and financing the Concorde. Insofar as we can determine, the British and the French governments are financing the development, tooling, and introduction costs without requiring repayment. In our opinion, the development cost of the supersonic aircraft will be of such size that it will need substantial government support and that a twenty-five per cent participation by the industry is not financially feasible.

THE SST: AN EDITOR'S POSTSCRIPT

On March 2, 1964, after copies of the document had been circulated among industry representatives and a number of newspapers and trade organs, the White House released a special report on the SST program prepared at the late President Kennedy's invitation by Eugene Black, retired president of the World Bank, and Stanley Osborne, former chairman of the Olin Mathieson Corporation. Although they support the development of an SST by the United States, Black and Osborne differ at many key points with the program contemplated by the administration. Among other things they propose that the government advance not only ninety per cent of the price asked by the successful bidder for building the prototype but also eighty per cent of any additional costs incurred (up to a limit of twenty-five per cent over the bid price) and ninety per cent of the cost of the flight tests and tooling costs. This means that if the asking price for a prototype were three billion dollars and additional costs amounted to another one billion dollars, the government would end up paying 3.45 billion dollars, without allowing for flight tests and tooling expenses. Little wonder that the aircraft manufacturers and the airlines are reported to have received the Black-Osborne document "with great glee."

Certain other features of the special report deserve mention. Development of the SST, urge the authors, should be supervised, not by the FAA, but by some sort of mysterious "independent authority" reporting directly to the President. While no one should be surprised that Black and Osborne, distinguished businessmen, urge that it be headed by "a man of stature and of broad industrial experience," certainly some will be puzzled at their desire to create an additional independent government agency.

Although removing the financial ceiling from the government's contribution to the SST development and recommending an increase in the share of the burden to be assumed out of public funds the Black-Osborne report admonishes that the program should not be viewed as one of "subsidy, but as a necessary element in our overall national economic panorama." And with that lofty enunciation the authors conclude their study, cautioning that the government may be able to recover some portion of its outlay—if "it turns out to be economically feasible." R.J.B.