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ECONOMIC IMPLICATIONS OF A
UNITED STATES SUPERSONIC TRANSPORT
AIRCRAFT UPON AIRPORTS AND
ENROUTE SUPPORT SERVICES

STATEMENT NO. 1

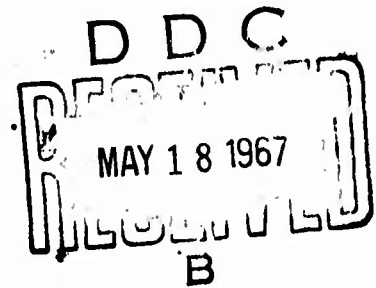
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Volume I

Executive Summary

PRC R-890

31 December 1966



Prepared for
Economics Staff
Office of Supersonic Transport Development
Federal Aviation Agency



PLANNING RESEARCH CORPORATION
LOS ANGELES, CALIFORNIA WASHINGTON, D. C.

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VOLUME I
EXECUTIVE SUMMARY

PRC R-890

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ABSTRACT

This report defines the economic implications to government and local agencies of modifications to airports, terminals, and enroute support facilities as a result of the introduction of a United States supersonic transport aircraft (SST) into scheduled commercial service by United States and foreign carriers.

Costs associated with modifications to the ground environment and enroute support services which advanced, high-capacity commercial transport aircraft may require are identified. Only those improvement programs beyond the normal planning responses to increased traffic and technology advancements are attributed to the larger, faster airliners which will fly within the next 9 years. The costs of these aircraft-sponsored modification programs are allocated among the four competing aircraft:

- stretched subsonic (DC-8-63),
- high-capacity subsonics (B-747 and L-500),
- Concorde,
- United States SST. ()

This report is divided into four parts.

Volume I presents the summary and conclusions of the study of the economic impact of a United States supersonic transport aircraft upon airports and enroute support services; Volume II describes the economic implications of the SST upon airports; Volume III relates the economic implications of the SST upon enroute support services, and Volume IV provides a discussion of the adequacy of airport pavements for the next generation of commercial aircraft.

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I. SUMMARY FINDINGS

The costs to government and local agencies for improvements required to qualify appropriate air terminals, airways, services, and facilities for supersonic transport operations in 1974 will be minimal, between zero and \$19 million.

Airports and Terminals (25 existing, potential SST)	zero to \$19 million
Enroute Support Services (Airways, Navigation, and Com- munications; Meteorology and Radiation Support Systems)	zero

Although these findings would appear to conflict with recent publicity, in fact they do not. In their jointly conducted National Airport Survey, The Airport Operators Council International, the American Association of Airport Executives, and the National Association of State Aviation Officials estimated the total cost of needed airport development from 1966 through 1969 as follows:

Estimated total costs of planned airport development	<u>\$1,956 million</u>
Total FAAP (Federal Aid-Airports Program) eligible costs	<u>\$1,197 million</u>
Land acquisition (21 percent)	
Landing area (68 percent)	
Lighting (7 percent)	
Service buildings (4 percent)	
Maximum FAAP participation ¹	\$627 million
Projected available sponsor funds	\$570 million
Additional funds required (Passenger and cargo terminals, hangars, and other service buildings)	\$ 759 million

¹ Usually limited to 50 percent federal participation

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While identifying to government and local agencies the costs of improvements required because of evolutionary growth, the FAA study was concerned only with the costs which would be incurred at existing, potential SST airports as a direct result of the introduction of succeeding aircraft types into scheduled airline service through 1975. The estimate of \$33 million for the correction of pavement deficiencies at 25 major hubs resulting from the introduction of the SST in 1974-1975 should not be compared with the National Airport Survey estimate of \$1,956 million for total necessary improvements (through 1969) at 1,799 airports and terminals.

Virtually all expenses identified in the National Airport Survey are due to growth of air travel, both passenger and cargo. Increased air traffic and the expanding jet family (707 through 727) have taxed to the limit existing pavements at the airports served and have created an immediate need for ameliorative programs. The survey estimate of \$627 million (FAAP participation) in airport development for the period 1966-69 includes the costs of strengthening runways and taxiways for present jets, but does not provide for additional pavement strengthening which might be required for future aircraft types beginning with the stretched DC-8's.¹

Investigation of the costs to government (Federal and local) for pavement improvement programs at 25 potential SST airports to adequately support the larger commercial airliners through the DC-8-63 would approximate \$14 million. Airport modifications imposed by the SST would cost an additional \$19 million. These potential improvements represent public investment only and do not include airline- and concessioner-financed facilities; nor do they include airport modifications built with locally-derived funding which is recovered in its entirety from the benefiting air carriers, private operators, and concessioners.

¹ Pavement strengthening programs at airports, to be eligible for FAAP participation, are limited to the capability to support a 350,000-pound aircraft with dual-tandem landing gear.

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Such modifications and improvements are due to increased air travel, not to aircraft type. Increased passenger demand creates a need for additional capacity which has historically been satisfied by the introduction of new aircraft. Even if it can be shown that growth rate accelerates following introduction of a new aircraft type, it may be said that the introduction of a new aircraft type does not necessarily create demand. The demand may in fact have existed but was latent because services were saturated. Capacity may have been inadequate, awaiting the availability of an improved aircraft with the characteristics required to satisfy the needs of potential air travelers. For example, the introduction of stretched DC-8's into scheduled service between the West Coast and Hawaii will no doubt contribute to an increase in commercial air travel between these locations. Advances in equipment design permit air carriers to offer service improvements more attractive than competing surface modes, thereby increasing public preference for air travel.

While a new aircraft type may contribute directly to increased air travel, it is not axiomatic that concurrent investment in facilities at airports due to greater service density can be attributed to that aircraft. Improving and enlarging airport facilities to handle increased traffic which may accompany the introduction of an improved aircraft is a sound investment--an opportunity for continued economic growth. The large number of travelers through airports should make possible an improved return on investment to local communities affected, to the airlines, and to the concessioners. Expansion of facilities to accommodate air travel growth does not constitute a cost unique to an aircraft type. It is rather a necessary expense to provide needed services to the traveler and to the shipper as well as to private and corporate aviation, thereby assuring continued growth.

Airport costs attributable to the SST are for modification programs only. New airport construction costs were not assessed against particular aircraft types because the designs of the new hubs currently under construction (Houston Intercontinental, Dallas-Fort Worth Regional, and Kansas City Mid-Continent) are based upon the total, integrated

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requirements of civil aeronautics to 1990. Many of the major and medium hubs which are beginning to exhibit characteristics similar to those which typified the recent growth experience among the 25 selected potential SST airports should qualify for SST service within the 1976-1990 period. However, most hubs now serving traffic generating centers are today obsolescent--their designs have been based upon pre-jet, pre-large-capacity aircraft criteria, thinking, and concepts. Limited with regard to size, location, and topography, the busier existing airports are constrained within an economics viability envelope which in turn depends upon community support for its integrity. For these reasons, it is difficult, in fact unrealistic, to foresee extensive modification and expansion of existing hubs beyond 1975. Only the construction of wholly new commercial airport complexes to supplement or replace the existing overtaxed, inextensible airports can provide for continuing, orderly growth of air commerce into the supersonic and V/STOL era.

Examination of enroute support services adequacy disclosed that there are no identifiable, unique costs which must be incurred to provide external support to the SST, or to any aircraft type.

The trend in airways, navigation, and communications systems design is to provide independent, accurate, and reliable avionics within the aircraft and to lessen the dependency upon externally oriented systems. The expansion and improvement of air commerce support activities to keep pace with traffic growth are evolutionary technological advances which increase civil aeronautics capabilities.

The experience of supersonic military aircraft at SST altitudes has established that existing meteorological systems are adequate to permit commercial flights at these altitudes without undue risk to passengers and crew. Considerable improvement to existing meteorological systems, however, is planned throughout the free world prior to introduction of the Concorde and SST. These improvements will contribute to the realization of more economical, efficient, and safe flights by supersonic, high-altitude aircraft.

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Suggested systems and associated costs have been estimated in studies for the Department of Commerce over the past 3 years. A recent study by the Environmental Science Services Administration, Weather Bureau (ESSA) explored the concept of a "World Weather Watch" to include total operational meteorological requirements into the foreseeable future. Should the systems envisioned become operational on schedule, the meteorological needs of the Concorde and SST would be essentially satisfied. The associated costs would be borne by the participating nations with the Department of Commerce acting as the focal agency for the United States. Since no concurrent requirement exists which is unique to civil aeronautics, the FAA would not share in the costs of this program.

NASA is completing the ground-based Apollo Space Radiation Warning Network which, together with onboard monitoring devices, should ensure safe operation throughout the flight regime of the SST. Capable of providing a precautionary safety measure in support of SST, the Apollo Network will consist of both optical and radio observatories continuously monitoring solar activity, so as to detect the onset of intense solar flares in time to provide adequate warning to all subscribers.

Meteorological and radiation systems thought to be required for safe and efficient flight of the SST are already planned and programmed to be in operation prior to the SST entering commercial service. Any unique requirements which might evolve out of future studies in these areas (for example, the need for clear air turbulence detection systems) would probably result in airborne systems to satisfy these requirements rather than in external enroute support services. Such airborne systems as an integral part of the aircraft would become an airline expense.

Environmental enroute support systems requirements are essentially the same for both the Concorde and the SST. Utilizing a cost allocation technique whereby the first aircraft type to need a service is assigned the entire investment as well as operation and maintenance costs, the Concorde would be allocated all costs, since it is scheduled for commercial airline service approximately 3 years prior to the SST.

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Exhibit 1 summarizes estimates of costs to satisfy the requirements of the SST and identifies the organizations which are sponsoring present efforts to provide needed facilities or services.

Exhibit 2 presents the expenses identifiable only with the field of aviation and which would be financed by local, state, or Federal funds. This chart allocates these costs by aircraft type according to forecast entry into commercial service.

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EXHIBIT 1 - SUMMARY OF COSTS OF SST REQUIREMENTS
THROUGH 1975

<u>Category</u>	<u>Costs Through 1975</u>	<u>Costs Sponsor</u> (Millions of Dollars)	<u>SST Unique</u>
Airports and Terminals	<u>\$ 33</u>	\$16.5 FAA (1/2) ⁽¹⁾ \$16.5 Local and state Gov'ts. (1/2)	\$19
Enroute Support Services	\$ 650		zero
Airways	-		
Navigation	-		
Communications	-		
Meteorology (Operational 1970)	\$ 88 invest. \$ 93 O&M	U.S. (through De- partment of Com- merce) and partic- ipating foreign nations for World Weather Watch system	
Radiation (Operational 1967)	\$ 2 invest. 0.6 O&M	NASA - for Apollo Space Radiation Warning Network	

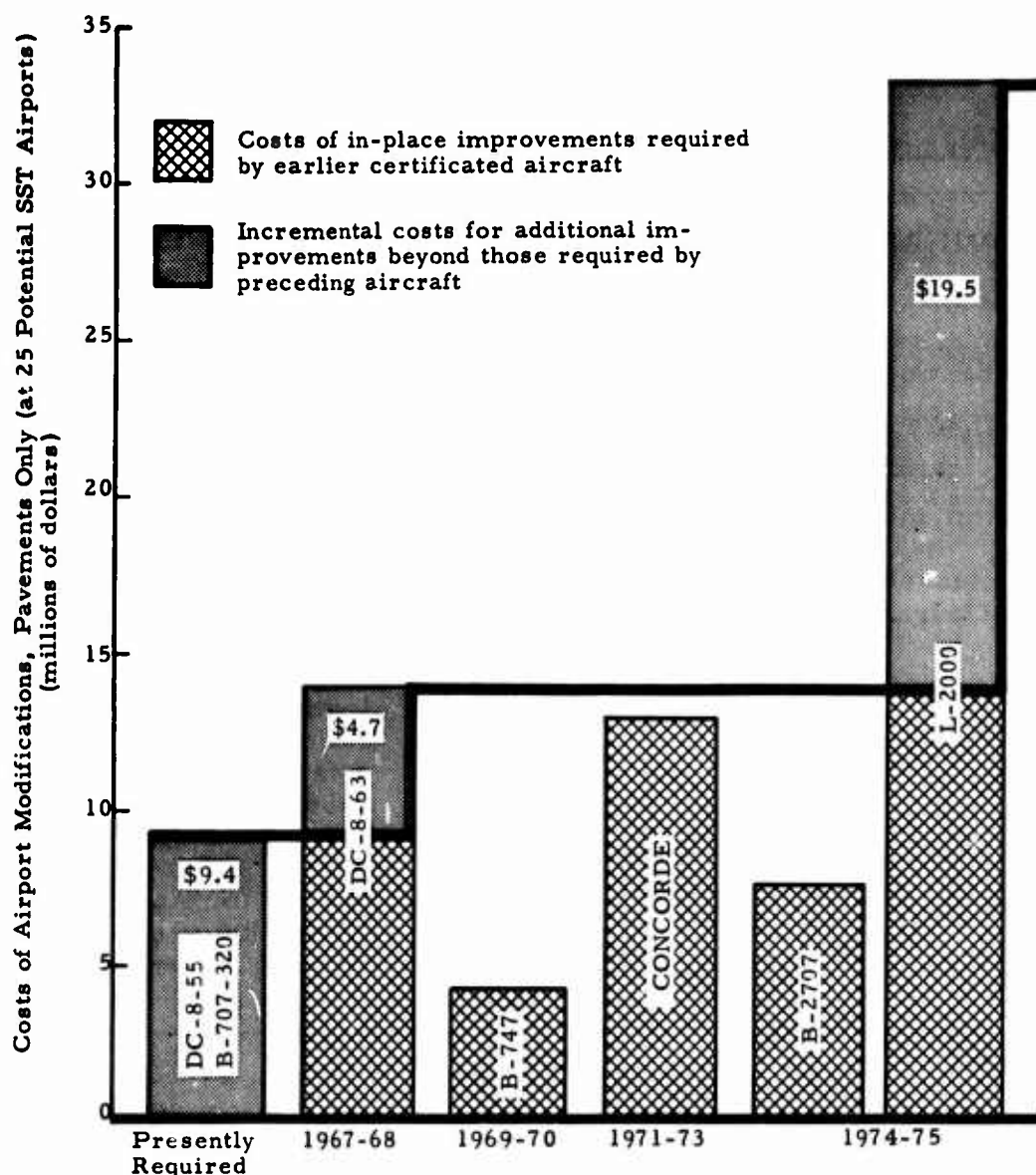
Note: (1) FAAP provides for up to 50 percent federal participation
for pavement improvements.

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Note: Highest point of vertical bar indicates total cost of pavements (runway and taxiway strengthening and fillet enlargements) for an airliner if that aircraft had entered commercial service during 1966.

EXHIBIT 2 - INCREMENTAL PAVEMENT IMPROVEMENT (PUBLIC)
COSTS AT 25 POTENTIAL SST AIRPORTS

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II. COST ALLOCATION TECHNIQUE

Because the SST will not join airline fleets until 1974-1975, it was necessary also to investigate and identify the impacts to airports and airways of those aircraft types which will probably precede an SST into commercial airline service. The total study effort was directed toward allocating--for each ground facility and enroute support service improvement which may be required by an SST and/or by other advanced high-capacity aircraft--the U.S. supersonic transport's appropriate share of the estimated public costs, attributing proportionate shares among the:

- current subsonic family
- stretched subsonics (DC-8-63)
- high-capacity subsonics (B-747)
- Concorde

A. Cost Allocation

The cost allocation methodology employed is applicable only to commercial aviation, i. e., to the common carriers, and deliberately excludes general aviation and national defense activities. Where national defense programs were identified which also benefit any of the above-mentioned aircraft, costs associated therewith were separately accounted for. An example of such a defense program is research into radiation effects upon aircrews of very high-altitude aircraft, such as the U-2, RB-57F, and XB-70. Costs identified in this study are those for research and development and for procurement and construction.

The technique for cost allocation is straightforward. Modifications which would be required because of increased air passenger traffic, normal programmed maintenance, and obsolescence and exhaustion of existing facilities and systems (if only those aircraft now in commercial service were to be considered) were made the cost baseline.

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Incremental improvements and modifications beyond this cost datum were identified with one of the four advanced aircraft types which are expected to join airline fleets by 1975. This effort to identify public costs focused on two areas of investigation: airports and terminals--the ground environment, and enroute support services--the airborne aspect.

1. The Ground Environment

Allocation was a function of time. Costs were allocated by order of precedence among the five potential modifications sponsors (DC-8-55, Boeing 707-320; DC-8-63; Boeing 747; Concorde; SST). This approach is historically self-sustaining. Current Department of Defense practice for cost analyses of weapons systems assumes all prior investments to be "sunk cost", i.e., costs which were incurred at a point in time which antedates the current program. It follows, then, that if aircraft Y requires facilities or service modifications in 1970 which are beyond the normal planning baseline, but less than those required by aircraft X in 1968, X would be assigned the total costs of the incremental modifications beyond the cost datum. These would be considered "sunk costs" for aircraft Y, and Y would enjoy the benefit of the improvements without sharing the investment costs. It is not intended to infer, however, that in reality the actual recovery of costs would be so straightforward. Improvements at airports are usually financed by a revenue bond issue. The bonds then are retired with airport revenues; e.g., concessioner-shared earnings, property utilization and rental income, and landing fees imposed upon all user aircraft. Landing fees are based upon aircraft takeoff or landing weight and frequency of operation.

2. The Airborne Aspect

The advanced, high-capacity airliners might each have required some modifications to enroute services. Intensive investigation disclosed, however, that only for the supersonic commercial jets is this the case. The Federal Government, having the responsibility for

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safety of flight, provides whatever enroute support services are necessary. The SST and the Concorde will require enroute support services to 70,000 feet, such as radiation measurements, prediction, and observation; weather reporting and forecasting; and a continuous communications capability between the aircraft and ground control.

B. Cost Recovery

Cost allocation is a management tool for guiding the decision maker in choosing among available alternatives:

- whether to construct "system" A, B, C, or D
- whether a mix or combination of "systems" would be preferable
- whether to construct any of the proposed "systems."

Intended and developed solely as one of many predecision guides for weighing opportunities for action, cost allocation attempts to predict and approximate the investment (the resources commitment) which each of the feasible options would require. Cost allocation is not a plan for recovering the resources commitment once the (selected) system becomes fully operational. That process is called "cost recovery." Cost allocation occurs before the fact--prior to the decision. It is a management tool. Cost recovery occurs after the fact--after a new system becomes operational. It is the product of a management decision. In the real world, cost recovery defines precisely and according to sound accounting principles the contract between landlord and tenant in economic terms.

Within the aviation community, the rationale and procedures which are actually observed for determining "how to pay" for an improvement are quite different from those followed in predecision cost allocation.

1. Ground Environment

Once the requirement for a particular airport improvement program has been successfully demonstrated and the probable capital investment estimated, it is necessary to develop a detailed plan for recovering all costs, including financing charges. Public approval of a

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revenue bond issue is essential, together with support of the financial community and the ability and willingness of concessioners, air carriers, general aviation, and other benefitting users to support the required financing program within the structure of appropriate user charges. An airport cannot commit itself or its operating authority to a capital investment program without first having devised a sound cost recovery plan. Almost without exception, cost recovery capabilities exercise a controlling influence upon the size and scheduling of an improvement program on the airport.

The SST will bear its fair share within the cost recovery plan for capital improvements at the airports it will serve even if such modifications are completed prior to the SST entry into airline service. An improvement to the landing area would be paid for jointly by all benefitting aircraft. The SST, together with other using commercial and general aviation aircraft, will pay landing fees based on aircraft weight and flight frequency. Further, if the SST requires that planned improvements at an airport be accomplished earlier than scheduled, the costs thereof would be allocated as described previously, but actually recovered as user-charges from all aircraft using that airport. Improvements to the terminal complex are not formally paid for within the landing fee structure. Instead, tenants (airlines and concessioners) within the terminal area defray the costs through readjustment of lease and rental agreements and pass on these costs to the customers and air travelers in fares and services and commodities prices.

2. The Airborne Aspect

In actual practice, the recovery of system improvement costs within the airborne aspect would probably take the form of government-imposed user-charges, such as passenger fares and fuel taxes. Where such a scheme appears practicable, the recovery assessment might be charged only to benefitting aircraft.

III. SST IMPOSED PUBLIC COSTS UPON THE GROUND ENVIRONMENT

A. Objectives and Methodology

The goal of this aspect of the study was to determine the public costs of improvements which United States airports might be required to make to qualify for future commercial passenger aircraft service. To achieve that objective, it was first necessary to select those centers of population which are now or have the potential to become gateway terminals by 1974, when the SST is expected to enter commercial service (see Exhibit 3: Potential SST Airports Seen Against Population Density).

Two approaches were available to determine the economic impact (potential public investment) of an SST upon airports. The first would be to sample gateway airports and to suggest, from the study results, an average cost to qualify an international air terminal for commercial SST service. Essentially, this was the method used by the FAA in sponsoring the Phase II (SST Development Program) airport compatibility studies by the two airframe design competitors. This philosophy was discarded because the Boeing and Lockheed airport surveys had as their primary purposes measurement of the "degree of fit" between each SST design and specified gateway airports. Further, 1975 (the first full year of SST commercial operation) is only 9 years into the future. This permits valid selection of potential SST airports because of the short time frame. It should be noted that this effort was primarily directed toward assessing modification costs (public investment) associated with a United States SST, not toward providing a basis for source selection. Having discarded the sampling concept as inadequate to the study goals, the following criteria were established for selection of potential SST airports up to the year 1975:

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- Inclusion of all 15 gateway airports studied by Boeing and Lockheed.
- Inclusion of those major airports, medium or large hubs, which serve principal centers of population and which by 1975 should be able to originate or attract international air traffic: passenger, business, and tourist travel as well as air cargo.
- Consideration of those airports recommended by the Airport Operators Council International.
- Consideration of those airports suggested by the FAA.

Exercising these criteria, 28 airports were selected for evaluation. Of these, 3 were new construction: Dallas-Fort Worth Regional Airport, Houston Intercontinental Airport, and Mid-Continent International Airport (Kansas City, Missouri). Construction of an entirely new terminal complex at Tampa International Airport was scheduled to begin during calendar 1966. Fifteen of the airports had been previously examined in detail by each of the competing SST airframe manufacturers during Phase II of the FAA supersonic transport development program. These airports are identified by an asterisk in the following listing.

Anchorage International Airport*
Atlanta Airport
Cleveland Hopkins International Airport
Dallas-Fort Worth Regional Airport
Detroit Metropolitan Wayne County Airport*
Dulles International Airport (Washington, D.C.)*
Friendship International Airport (Baltimore, Md.)*
Greater Pittsburgh Airport
Honolulu International Airport*
Houston Intercontinental Airport
John F. Kennedy International Airport (New York City)*
Lambert-St. Louis Municipal Airport
Logan International Airport (Boston, Mass.)*
Los Angeles International Airport*

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Metropolitan Oakland International Airport
Miami International Airport*
Mid-Continent International Airport (Kansas City, Mo.)
Minneapolis-St. Paul International Airport
New Orleans International Airport
O'Hare International Airport (Chicago, Ill.)*
Philadelphia International Airport*
Portland International Airport*
Puerto Rico International Airport
San Francisco International Airport*
Seattle-Tacoma International Airport*
Sky Harbor Municipal Airport (Phoenix, Ariz.)
Stapleton International Airport (Denver, Colo.)
Tampa International Airport

The selected airports are depicted in relation to population density in Exhibit 3.

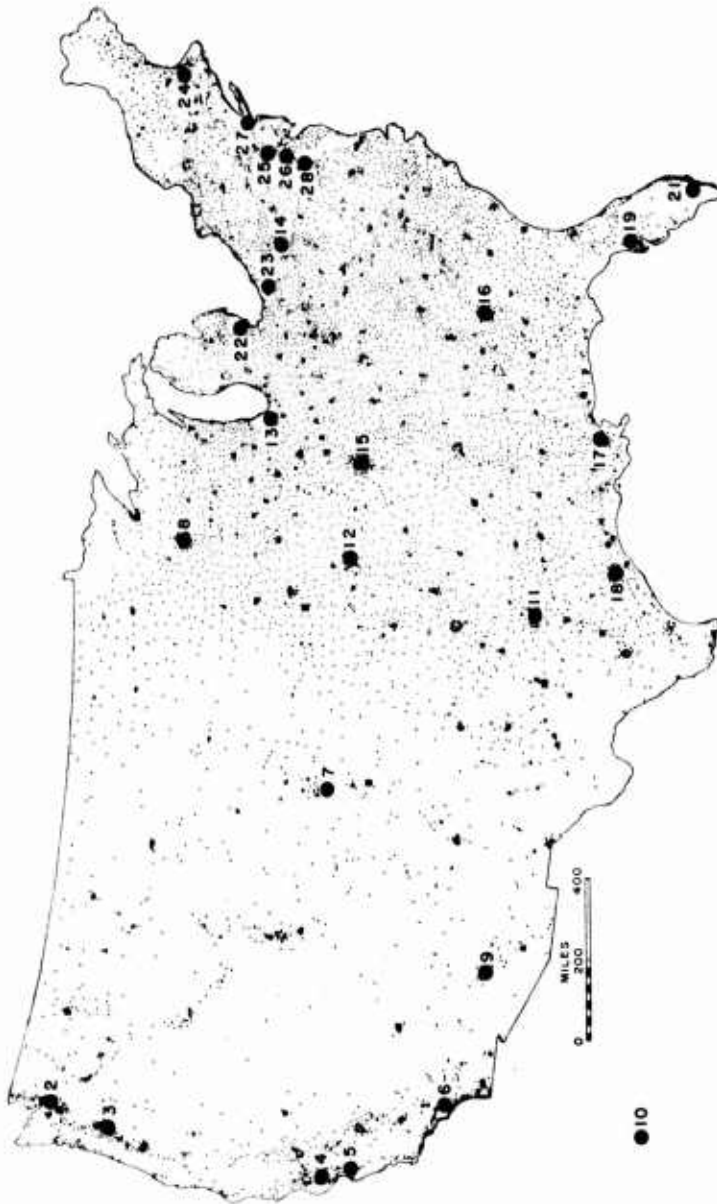
After selection of potential SST airports for examination, those features of an airport which might be affected by aircraft design were isolated. The adequacy of the existing structure, configuration, or capability could be described for each feature, and improvements identified which might be required by advanced, high-capacity commercial airliners.

The criteria chosen for a compatibility assessment of potential SST airports were as follows:

- Adequacy for flight operations (including jet runway information: dimensions, instrumentation, lighting)
- Pavement adequacy (considerations of strength, area, geometry, and underground structure integrity)
- Gate facilities (considerations of adequacy of gate positions, aircraft parking, passenger loading, and baggage loading)
- Aircraft fueling
- Ground safety
- Noise
- Cargo handling
- Aircraft maintenance facilities

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1 ANCHORAGE International	7 STAPLETON International (Denver)	13 CHICAGO O'HARE International	19 TAMPA International	25 PHILADELPHIA International
2 SEATTLE-TACOMA International	8 MINNEAPOLIS- ST. PAUL International	14 GREATER PITTSBURGH	20 PUERTO RICO International	26 BALTIMORE FRIENDSHIP International
3 PORTLAND International	9 SKY HARBOR Municipal (Phoenix)	15 LAMBERT-ST. LOUIS Municipal	21 MIAMI International	27 JFK International
4 METROPOLITAN OAKLAND International	10 HONOLULU International	16 ATLANTA	22 DETROIT Metropolitan	28 DULLES International
5 SAN FRANCISCO International	11 DALLAS-Ft. WORT Regional	17 NEW ORLEANS International	23 CLEVELAND HOPKINS International	
6 LOS ANGELES International	12 MID-CONTINENT International (Kansas City)	18 HOUSTON Intercontinental	24 LOGAN International	

EXHIBIT 3 - POTENTIAL SST AIRPORTS SEEN AGAINST POPULATION DENSITY

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- Passenger services
- Enplaning: ticketing, baggage handling, in-terminal movement, departure rooms, boarding methods
- Deplaning: in-terminal traffic flow, baggage claim, movement to and adequacy of local transportation and airport parking.

B. Approach

Adequacy of the selected airports for operation of an SST was examined within the context of the environment predicted to exist at the introduction of an SST into scheduled commercial service--about 1974-1975. Competing aircraft types considered were:

- current subsonics (B-707-320, DC-8-55) (baseline)
- stretched subsonics (DC-8-63)
- high-capacity subsonics (B-747)
- Concorde

Appropriate airport authorities were interviewed, in addition to vice presidents for property and facilities of the major carriers and/or their staff. In this manner, the airport study benefitted from the comments and valued judgments of both the landlords and their tenants. A questionnaire was developed from the airport/aircraft assessment criteria as the control vehicle for collecting uniform data concerning the physical facilities at each potential SST airport. This technique provided the substance--consistent, valid, and unambiguous information--for an economic analysis of the impact of advanced design, commercial aircraft upon airports and terminals.

C. Pavement Improvement Costs at Potential SST Airports

Of those airport features which had been isolated as being potentially affected by aircraft design, pavement is the only feature constructed, maintained, or modified by public funds which requires modification because of the SST. Analysis of potential SST airports pavements identified the requirements, in many cases, for additional pavement. In actual practice, paving programs for strengthening purposes may or may not follow theoretical analysis, and when they do, it may take the

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form of concrete or bituminous overlays, concrete inlays, or other alternatives. Recommended action in the present study has taken the form of a bituminous overlay in all cases, for the following reasons:

- Installation of bituminous material in the range of thicknesses being treated here is generally less expensive than concrete.
- Even in cases where concrete overlays might be preferred, bituminous requirements were estimated because the minimum recommended concrete overlay thickness is 5 inches. Better cost distribution was felt available by using bituminous overlays with a 2-inch minimum.
- Adoption of a ground rule regarding choice of overlay material ensures consistency of presentation. It is in no way intended to reflect on the relative merits of either concrete or asphalt.

In the determination of the costs for pavement improvement an effort was made to use local prevailing, installed costs of bituminous overlays at each airport (where such information was available) because natural resources of the locale and proximity of the airport to major processing plants obviously influence both materials and labor costs.

The areas to be overlaid were calculated by use of exact dimensions wherever possible. It was necessary to estimate dimensions in those instances in which only a portion of a runway, taxiway, or apron was in need of strengthening. While it was recognized that overlays of various thicknesses would be problematical on a surface with an existing level grade, costs associated with feathering edges or removing present pavement for replacement were not considered. The allocation of such costs to a specific aircraft would be difficult and, even if accomplished, would contribute little to the comparative analysis. It was further assumed in cost calculations that critical runway areas consisted of 1,000 feet at each end of the runway, unless available data indicated otherwise.

Exhibit 4: Pavement Strengthening Costs, illustrates the overlay costs by aircraft and potential SST airport. Special attention was given to each area in need of strengthening at each of the airports. The pavement area costed is described. Overlay thicknesses in inches together

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EXHIBIT 4 - PAVEMENT STRENGTHENING COSTS

AIRPORTS	DC-8-55	B-707	DC-8-63	B-747	L-500	CONCORDE	B-2707	L-2000
Anchorage	0	0	0	0	0	0	0	0
Atlanta	505	505	564	423	292	564	491	718
Cleveland	132	132	176	0	0	176	88	360
Detroit	1376	1376	1665	824	0	1665	1376	2651
Dulles, Washington	0	0	0	0	0	0	0	0
Friendship, Baltimore	0	0	0	0	0	0	0	0
Greater Pittsburgh	112	112	246	70	0	246	84	499
Honolulu	175	140	210	0	0	210	140	924 (420)
John F. Kennedy, New York	0	0	1725	0	760	1533	0	4850
Lambert-St. Louis	0	0	0	0	0	0	0	545
Logan, Boston	0	0	0	0	0	0	0	0
Los Angeles	1603 (0)	1603 (0)	2509 (675)	1122 (0)	2055 (0)	2278 (675)	1393 (0)	5342 (1210)
Metropolitan Oakland	3	3	4	0	0	4	0	278
Miami	612	459	725	306	0	725	422	997
Minneapolis	958	785	1226	228	0	1226	685	1860
New Orleans	741	741	874	646	494	874	741	1178
O'Hare, Chicago	712	212	818	0	0	712	0	2386
Philadelphia	1140	985	1210	757	379	1210	985	1820
Portland	0	0	0	0	0	0	0	256 (0)
Puerto Rico	0	0	0	0	0	0	0	360
San Francisco	92	92	138	0	0	138	0	3057 (253)
Seattle-Tacoma	300	300	408	188	0	408	225	683
St. ; Harbor, Phoenix	536 (216)	536 (216)	723 (288)	234 (144)	320 (0)	723 (288)	316 (181)	1590 (504)
Stapleton, Denver	421	421	815	0	0	683	337	2373
Tampa	27	0	113	0	0	135	0	326
TOTAL	\$9445 (7522)	\$8402 (6479)	\$14149 (11880)	\$4798 (3586)	\$4300 (1925)	\$13506 (11468)	\$7283 (5755)	\$33456 (24674)

Notes: (1) Costs are in thousands of dollars.
 (2) For rigid pavements, the Westergaard analysis was used. For flexible pavement, both Corps of Engineers and FAA procedures were used, according to the availability of subgrade test results. If both were available at a single airport, the Corps of Engineers requirement was included in the cost analysis, and the cost results via the FAA method (usually lower) were placed in parentheses.

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with the costs are enumerated by aircraft type. Only the areas necessary for the operation of the large jets being studied were considered. This usually included only the main runway, adjacent holding areas and taxiways, and applicable apron areas. The costs for overlaying existing flexible pavement were based on thicknesses determined by the Corps of Engineers method wherever possible, and on the FAA method in cases where no CBR data were obtainable. Wherever the Corps of Engineers method was used, footnotes indicate the costs derived by the FAA.

In addition to the strengthening of existing pavements (the requirement for which is occasioned by the great weight of future aircraft), certain new pavement costs can be allocated to future aircraft as a consequence of their increased length and wingspan. These include the widening of fillet radii at runway and taxiway intersections to accommodate larger airplanes.

The inside portion of a turn being executed by a large jet aircraft is important in that the landing gear must not be permitted to run off the pavement. This is normally avoided by paving the area within the angle formed by the intersecting runways or taxiways. The area enclosed by this curve is called a fillet. FAA standards currently call for fillets with a radius of 100 feet at a 90° intersection. Some airport pavements have been improved to these standards while others are still in the planning stage. It should be noted that this standard is far in excess of requirements (including appropriate margins for pilot error) for current subsonics. However, some of the large aircraft considered in this study could not negotiate a 90° turn within such standards unless dangerously small margins were permitted between landing gear tires and pavement edges. Considering the extreme forward seating position of future SST pilots in relation to the landing gear (one SST version measures 82 feet from the tip of the nose to the nose gear), it is concluded that greater margins of safety are warranted for the larger aircraft than for present jets. The requirements set forth here for fillet radii are therefore considered to be an absolute minimum for safe operation.

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Costs of the fillet enlargements at the various airports were allocated to each aircraft according to its dimensional characteristics. In computing these costs, only those intersections associated with the major runways and taxiways likely to be used by the larger jets were considered. These were also the areas analyzed for pavement strengthening. Most likely routes from runway to terminal apron were assumed and fillets of insufficient radius along those routes were evaluated. When a fillet is enlarged it is necessary to move the edge lights. For costing purposes the expense of moving these lights was considered a constant \$1,300 for each fillet altered. An additional expense associated with each fillet is the removal and renewal of the shoulders. While this cost varies according to local conditions, it was considered appropriate to this costing effort to base shoulder repair costs on the fillet paving cost at a rate equal to 30 percent of the new fillet pavement cost.

Exhibit 4 indicates the costs for each aircraft under the assumption that no modifications have been accomplished for any previous aircraft, in other words, as though each aircraft were to be put into service on existing pavements. Exhibit 5 presents these results graphically. Results are in accordance with present knowledge concerning the commercial jets now in service (i.e., that some present airport pavements require immediate strengthening). Also, the similar configurations of the Boeing and Douglas models result in closely parallel costs, with the DC-8-55 requiring slightly thicker overlays than the B-707-320. The stretched jets (DC-8-60 series) will stress all pavements to a greater extent than current models.

The results of the analysis regarding the high-capacity jets (B-747, L-500) are paradoxical in a sense because they require (comparatively) less modification than present jets despite their great size and weight. This is because of favorable flotation characteristics which more than offset the weight differential. Tire loading is low: one aircraft has 28 tires and the other has 18.

The Concorde, which is being built by the British and French as a potential SST competitor, is similar in weight and landing gear configuration to the DC-8-63. Dual-tandem spacings are somewhat more narrow,

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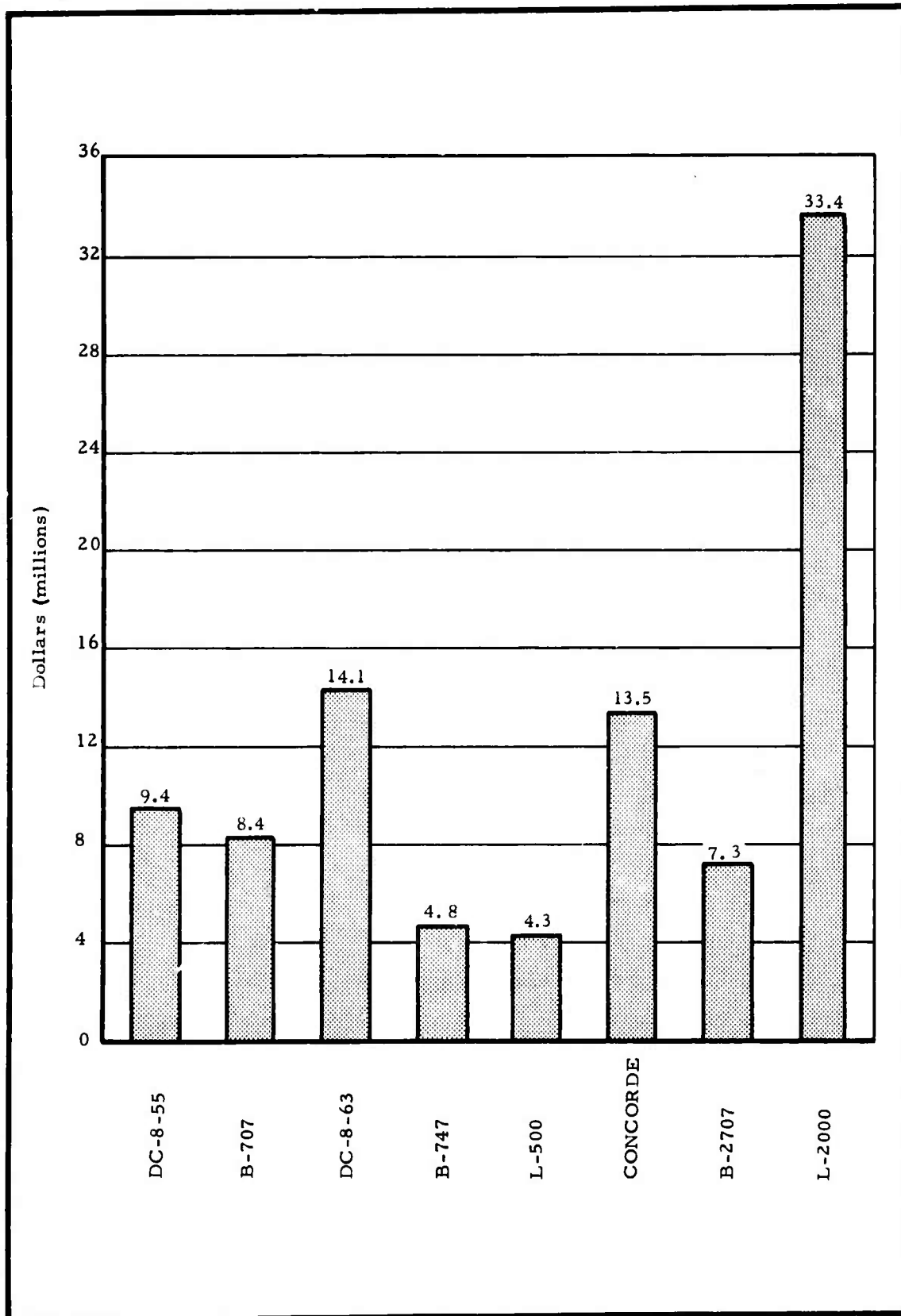


EXHIBIT 5 - PAVEMENT STRENGTHENING COSTS (BY AIRCRAFT)
FOR POTENTIAL SST AIRPORTS AS THEY EXIST IN 1966

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but are also slightly longer. Modification costs attributable to this aircraft are somewhat less than those of the Douglas stretched jet. The SST models in the American competition vary widely in their configurations and in the costs of required pavement strengthening.

Exhibit 2 shows the time-phased incremental costs for pavement improvement programs required by the aircraft. The assumption here is that pavements have been upgraded for each aircraft during the initial period of its operation.

It should be noted that present jet aircraft (DC-8-55 and B-707) are now operating in some cases on pavements which engineering analysis indicates to be deficient. Actual experience corroborates this finding at many airports where pavement deterioration and distress occur. The current subsonics require immediate airport pavement improvement programs to meet analytical standards for unlimited stress repetitions. If expenditures are now made for needed pavement strengthening, future aircraft will require materially less public investment at airports. In addition to the costs for current jets, the stretched version of the DC-8 requires pavement modification approximating \$5 million. No further costs are incurred until the introduction of the supersonic transport about 1974.

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IV. IMPACT UPON ENROUTE SUPPORT AREAS

Each of the three enroute support areas was examined separately to identify the systems improvements needed to fulfill SST requirements. The respective areas are:

- Airways, Navigation, and Communications
- Meteorology
- Radiation Monitoring

Each system was examined and compared with SST requirements to indicate deficient areas. Planned and conceptual systems were investigated and compared with SST requirements. The modifications required to satisfy commercial aviation needs in the particular enroute support areas were identified and, where appropriate, costs allocated to the aircraft types in the manner described in the "Cost Allocation Technique."

A. Airways, Navigation, and Communications

Air traffic congestion is having an increasingly deleterious impact upon commercial air transportation. To the passenger, congestion manifests itself in the form of departure delays, late arrivals, missed connections, and unplanned stopovers. To the airline, congestion means increased direct operating costs and inefficient usage of personnel and equipment. Continued, increasing preference for air travel, together with the introduction of stretched and high-capacity subsonic aircraft, and in the 1970's the SST, will compound this problem. Approximately 300 flights per day were scheduled during the peak summer period over the North Atlantic in 1965. Probably by 1975 an instantaneous maximum of 230 flights per hour will be experienced during peak season in the North Atlantic Region. The next eight years will see the introduction of both advanced subsonic aircraft and supersonic equipment. Following the stretched DC-8's into commercial service will be the Boeing 747, designed to carry nearly 500 passengers. Supersonic transport aircraft

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(SST and Concorde) will multiply the present jet aircraft speed by a factor of three and increase cruising altitude to a level almost twice today's commercial experience.

As a result of Project Beacon, the National Airspace Utilization System (NAS) was developed and is now being systematically implemented to provide safe, efficient handling of air traffic through 1975. Modifications are continually being made to the overall design to reflect advances in technology and procedures. In 1966 the air traffic control system was in a period of technological transition. Various parts of the future, fully automated systems are being introduced (usually) on a center rather than a system-wide basis, constructing a strong foundation upon which could be built a control system adequate to control the traffic predicted for the 1970's.

A joint NASA-FAA simulation program has been in effect since 1963 for the purpose of evaluating the problems associated with introduction of an SST into the air traffic control environment. Early studies were limited to operating problems in terminal areas and did not consider the enroute segment. Later tests have extended the simulation to include an exchange between air route traffic control centers during transcontinental service. Results indicate that the enroute segment is not a potential source of difficulty for the SST because of that aircraft's ability to cruise above the congested subsonic airways. The terminal control system is equally capable of controlling the SST in the terminal environment, where no distinction will be made between subsonic aircraft and the SST. Airport surveillance radar will provide the necessary information to maintain the established ATC separation standards. Terminal radar beacons will be used which are capable of detecting and identifying properly equipped aircraft within a range of 200 nautical miles and throughout the approach leg.

Present airborne navigational equipment aboard intercontinental airliners range from inertial devices to celestial optics. The most recent intercontinental aircraft are factory-equipped with both doppler and inertial navigation systems which to a large extent eliminate air crew dependence upon external electronic signals, thereby obviating the

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need for new ground facilities or modifications to existing installations. Several airlines are considering retrofitting their entire fleets with inertial systems in order to realize the potential savings associated with the more efficient flight profiles (reduced time aloft and fuel consumption) that should be possible because of more precise navigation. Any improvement in fuel consumption on a range-payload sensitive aircraft could be converted into additional revenue passengers. Particularly attractive as external systems for transoceanic flights support are the navigation and communications satellites which possess an ability to provide information to aircraft operating over extensive areas where no surface aid is available. Radio is essentially the only long-range communication system now available but cannot be considered a reliable, all-weather system because of propagation anomalies. Large communication gaps exist over heavily traveled North Atlantic routes where it is possible for aircraft to lose contact with control facilities for periods up to half an hour under certain atmospheric conditions. The same is true of navigation over areas where no positive radar control exists. Lateral separation standards in the North Atlantic Region are based on the possible exceptions from accuracy to which an aircraft is subject, employing present navigational methods. If a more reliable and accurate position determination capability existed (such as would be possible with navigational satellites), significant reductions in separation standards could be effected.

B. Meteorology

The increasing number of aircraft in the skies, and the high speed and altitude capabilities of the proposed supersonic transport place additional burdens on the various devices which collect, process, communicate, and forecast meteorological phenomena data. These devices must be improved to meet the more stringent demands for faster, more accurate, and more detailed weather forecasting imposed by the increasing numbers of flight operations and the introduction of high-capacity, faster and higher-flying aircraft.

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Because the stretched and high-capacity subsonics will operate near the altitudes and speeds of current commercial airliners, they present no unique demands on the present meteorological system. Normal planning and improvements will benefit these new aircraft, as well as the existing aircraft. However, the advanced design configuration of the SST involves a number of revolutionary concepts. The cruise portion of SST flight will require more accurate and more frequent coverage of the meteorological phenomena within its flight profile, particularly data at high altitudes. Economic considerations, such as fuel consumption, demand accurate environmental parameter prediction for the transonic region. The high-speed capability of the SST makes preflight forecasting accuracy necessary because of the advance warning needed to safely execute an unscheduled maneuver.

The U.S. Weather Bureau has enlisted the cooperation of other government agencies, military and civil, together with private organizations to define the weather service requirements of a rapidly expanding aviation community. Principal U.S. government agencies cooperating with the Weather Bureau in carrying out its responsibilities to aviation are:

- Federal Aviation Agency
- Air Force
- National Aeronautics and Space Administration
- Coast Guard
- Navy

The meteorological satellite program presents the most promising means to a solution of the problem of rapid, comprehensive observation and reporting of meteorological phenomena. Experimental balloons have successfully transmitted atmospheric temperature to the degree that mean temperatures have been computed for each of five 2-mile layer segments of the atmosphere. Current temperature-sensing devices have been used only in balloons to date.

Present technology can detect precipitation and measure temperature with precision, but the cost of such observations is prohibitive at this time. Current stations receive cloud cover photos, radiation data,

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and temperatures of cloud tops. Plans to refine temperature data collection will be implemented by the end of 1967. The gathering of precipitation data from satellites is still experimental.

The following methods of improving the current subsonic weather system were suggested by the Borg-Warner Corporation. First, the meteorological products of the aviation weather service should be of a nature that can be immediately used for operational decisions without further interpretation. This suggestion evolves from findings that objective weather observations were not always received by the processing subsystem, and that methods for processing these observations could not always provide operationally sound products. Secondly, the observation grid should be reduced, particularly in the Pacific Ocean, to ensure that all phenomena (including such local occurrences as squalls, icing, and severe to extreme turbulence) are reported for immediate use. Third, smaller airports that frequently lack instrumented weather observations should be provided with instrumentation. Approximately 800 civil airfields currently make and disseminate terminal observations. No instrumentation is available at some 3,000 smaller airports used by general aviation pilots. Finally, objective methods of measuring icing and turbulence should be developed to eliminate inaccuracy or inconsistency because of differing types and speeds of aircraft and varying pilot experiences which usually result in a lack of standardized reports. Improvements in methods of measuring wind speed and direction, cloud heights, and visibility should be sought.

Existing FAA Weather Communications Networks are deficient with respect to selectivity, capacity, and speed of data transmission. The present meteorological network is inadequate for SST operation whose unique requirements include detailed upper-air observations and speed of communications, along with detailed terminal area forecasts. The two Borg-Warner recommendations applicable to Concorde and SST operations would provide improved detail and increased altitude for the parameters observed.

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As previously discussed, the ambient temperature profile through which the SST passes while in its transonic flight phase is a critical factor influencing SST performance during this portion of the flight. Increase in the detail and accuracy of forecasts, particularly in and around terminal areas, is a requirement for Concorde and SST flight.

The last improvement necessitated by high-altitude flights is the collection of high-altitude data. Preliminary Weather Bureau cost estimates of meteorological support for SST operation, utilizing any configuration of ocean station vessels, approach a prohibitively high figure. Therefore, an alternative means for providing meteorological support must be investigated. One method might be airborne support in the form of satellites, rocketsondes, or independent avionics. This, together with increased data from land-based upper-air stations and with the provision of several ocean station vessels reporting from the expansive areas, would considerably lower the capital requirements as well as the operating costs.

To help meet the need for rapid communications exchange, the FAA has proposed a teletypewriter communications system. This system design centralizes, consolidates, and automates the message switching functions of the existing weather teletypewriter services within the Weather Message Switching Center.

The existing system has 300 circuits and is 30 percent overloaded, which means that 390 circuits are needed. If the proposed computerized system becomes operational in 1968, it will provide 150 percent of the present requirements, or 585 circuits. The proposed system has a design potential for expansion to twice its 1968 capacity, or 1,170 circuits. Comparison of the possibility of 1,170 circuits with the present capability of 300 circuits yields approximately a 400 percent increase in service networks.

The Air Force maintains its own circuits (COMET) and receives information over FAA circuits, as well. The computer would eliminate the redundancy of receiving their own reports back.

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"World Weather Watch" is the name given to a new world weather system which the World Meteorological Organization (WMO) is now planning. Recent developments in technology such as computers and satellites require more than simple readjustments to the existing world-wide systems. The various components of the system must be analyzed so that it will utilize the scientific advances in the most efficient manner.

Plans for the World Weather Watch which are now being prepared may be divided into three broad categories: Global Observational System, Global Telecommunications System, and World Weather Watch centers of various kinds.

The development of a Global Observational System will be approached in several ways. Conventional ocean observations will be increased in number and their altitude coverage will be expanded by the introduction of radiosonde observations. Satellite coverage, special aircraft reconnaissance flights, and the use of dropsondes--radiosondes which transmit observations as they parachute after release from an aircraft--will further add to global observations. Many techniques are still experimental, and the final working mixture of the devices will depend on the cost and efficiency of each type in different parts of the world. Current developments in satellite technology will result in significant improvements, of which one will be satellite interrogation of unmanned weather stations, buoys, and floating balloons. These will in turn be read out to selected ground command stations or broadcast for reception by a number of stations. Although these new techniques will not be available during the initial stages of the World Weather Watch, they will undoubtedly take their place once their full potential has been established.

To collect and process the wealth of material obtained from the new system, complex and costly equipment will be needed. A logical solution to this problem is the establishment of a small number of centers to serve the world. This plan has begun with the establishment of world meteorological centers (WMC's) in Moscow, Washington, and Melbourne. They receive and distribute conventional as well as satellite data from all over the world. In addition to the foregoing functions,

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the WMC's will prepare analyses of prevailing weather conditions and prognoses. They can also promote research and training and serve as archives for the quantities of data passing through them.

The planned global telecommunication system is based on a high-speed circuit called the "main trunk circuit" which will connect the three world meteorological centers. A number of regional and national meteorological centers will be linked directly to the main trunk circuit. In designing the system, the fullest possible use will be made of cable and land-line circuits together with other telecommunication methods with similar technical and operational characteristics.

A system of regional meteorological centers (RMC's) will provide a link between world and national centers. The practical responsibilities of the RMC's will vary with the countries served and the physical and climatic characteristics of the region. In spite of this probable variety of responsibilities, raw data for the whole of the hemisphere in which an RMC is located is likely to be channelled through it. It will work in close association with the NMC's in their sphere of operation, by providing them with the material needed and by serving as centers through which incoming observations are fed to the world centers.

The planning of a world system of the kind described is a task of great magnitude and complexity. In order to ensure the orderly and systematic development of the plans, the work has been divided into three phases. Phase one, which concerned the establishment of the broad lines of World Weather Watch, was completed in the middle of 1965. Phase two calls for the preparation of a world plan in a more or less complete form and will be finished in 1966. Phase three involves the completion in full detail of the plan which must be ready for submission to the representatives of the countries of the world at the Fifth World Meteorological Congress in 1967. The completion of phase three of the Worldwide Weather Watch will essentially satisfy the meteorological requirements of the SST. Its costs will be borne by the participating nations.

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The provision of research facilities at the regional meteorological centers and the growing awareness of future aviation requirements offer excellent opportunity for development of techniques to most efficiently and adequately record, transmit, and analyze meteorological data. The satellite program, and the increase in horizontal sounding balloons, radiosondes, and dropsondes provided in the World Weather Watch System will have the capability to provide upper-air observations which are adequate both in number and in geographical distribution.

C. Radiation Monitoring

Introduction of the Concorde and the SST into scheduled commercial aviation service by 1975 will necessitate the development and implementation of radiation forecasting, detection, warning, and measuring systems prior to the aircraft's respective scheduled commercial operation dates, 1971 and 1974. This development is necessary because of expressed potential radiation hazards at the Concorde and SST cruising altitudes of 50,000 to 80,000 feet.

On the basis of present estimates of radiation levels at these altitudes, safety considerations indicate the need for adequate warning systems to prevent unnecessary radiation exposure to passengers and crew. Through 1975, commercial aviation requires a national space environment monitoring and forecasting system which can provide daily radiation information and forecasts as a routine operation, and a pilot advisory warning service to direct enroute SST's to descend to safer altitudes or to advise rescheduling of subsequent flights.

There is presently no operational system to continuously monitor and detect radiation levels as required to provide adequate information for the SST program. However, a number of individual and joint programs and activities have been undertaken by various agencies to assist in solving their specific problems.

1. ITSA¹ - Space Disturbance Forecast Center

Under the Environmental Science Service Administration, the Space Disturbance Forecast Center currently has a tentative three-fold mission:

¹ Institute for Telecommunication Sciences and Aeronomy

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- a. To determine whether space radiation is a hazard.
- b. If so, to indicate what services are necessary for human beings flying at very high altitudes
- c. To set up necessary services.

These efforts are performed in conjunction with the Air Weather Service, NASA, and FAA. Planned ESSA facilities should be adequate for forecasting flares which might necessitate grounding of an SST, warning aircraft in flight to descend to lower altitudes, and ex post facto reporting.

2. NASA Apollo Space Radiation Warning System

NASA is developing a worldwide solar flare monitoring system to support the manned space program. The system is designed to provide real-time data to the Manned Spacecraft Center in Houston and ESSA's Space Disturbance Forecast Center in Boulder and will consist of seven optical flare patrol stations and three radio telescope stations.

3. USAF/FAA/NASA High Altitude Radiation Environment Study

The joint USAF/FAA/NASA High-Altitude Radiation Environment Study which began in the summer of 1966 and will terminate in July 1968, gathers appropriate data during high-altitude RB-57 flights. Some of the objectives of the program are the measurement of direct radiation doses received by human tissue, measurement of linear energy transfer (LET), correlation of data with balloon-gathered data, and measurement of neutron and proton spectra. Results from this program will be extremely helpful in developing specifications for SST radiation instrumentation. These flights will help determine the need for systems to give dose profile, accumulated dose, and danger warning. Such data may also contribute significantly to the knowledge of the biological effects of various particles.

The two competing SST airframe manufacturers have devoted considerable effort to investigating the potential radiation hazard problem at altitude and to determining adequate safety measures for air crew

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and air travelers. The Boeing report, Some Radiation Problems in the Supersonic Environment, concludes that the radiobiological problem for supersonic aircraft is not serious and that neither passengers nor crew will experience doses in excess of recommended tolerance levels¹ in normal flying schedules. In Lockheed's Horizon magazine, Dr. Charles I. Barron, Medical Director for the Lockheed California Company, concludes that "the findings are most encouraging in indicating a low-level hazard, which was safely tolerated by man."²

The panel on Space Environmental Forecasting of the Interdepartmental Committee for Atmospheric Sciences, Federal Council of Science and Technology, has summarized the common needs for space radiation information which exists or are anticipated to exist. There are common needs for:

- Optical observation of solar events
- Radio observation of solar events
- Monitoring of solar X-ray emission
- Monitoring of solar proton flux
- Monitoring of trapped particle flux
- Measurements of atmospheric structure.

A joint program to satisfy these needs would aid³ the FAA in providing adequate information relative to SST flights at the high altitudes of 50,000 to 80,000 feet. Many other programs are planned and in progress which will contribute to increased knowledge of the upper-atmosphere radiation environment. None of the costs of these programs can be attributed to SST requirements, but the knowledge gained from them will be of benefit to SST high-altitude operations.

¹The Boeing Company, Boeing D2-90391, Some Radiation Problems in the Supersonic Environment, Sheldon, W.R. and Dye, D.L., November 1963

²Barron, Charles I., "Of Airmen Exposed to Supersonic Transport Altitudes", Horizon, Summer, 1965

³Federal Council of Science and Technology, Final Report of the Panel on Space Environmental Forecasting of the Interdepartmental Committee for Atmospheric Sciences, December 1964

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The numerous investigations sponsored by several government agencies are increasing knowledge of the radiation environment at high altitudes and are contributing to the subsequent development of systems adequate to permit routine use of this space for commercial aviation. Even with the conclusions reached by scientists as to maximum expected dose rates based on relatively conservative and pessimistic assumptions, the future radiation systems expected to operate before the first scheduled high-altitude commercial flights seem adequate to prevent undue radiation exposure to passengers and crews. High-altitude flights would probably not be affected more than three or four times a year, and then only during one or two solar maximum years. The consequences would be to reroute flights to lower cruising altitudes or to reschedule flights during the brief periods of maximum solar activity. The periods of solar activity affecting high-altitude flights plans would last no more than several hours each, and each event could be detected and observed by onboard radiation warning systems as well as ground observatories.

The worldwide radiation detection and warning system scheduled for operation by 1974 will adequately meet SST requirements for support of the radiation warning system onboard the aircraft. This worldwide system is being financed by NASA and will require no capital outlays to permit use of the data for SST flight planning.

Many programs and systems, however, may ultimately contribute to increased understanding and better definition of the high-altitude radiation hazard as well as to refinements and improvements in radiation detection and forecasting techniques. Some of these programs or systems and their estimated costs are listed below:

NASA Apollo Space Radiation Warning
System (10 stations)

Procurement and Construction	\$1,650,000
Annual Operation and Maintenance at \$60,000 per station	\$600,000

HARES Program

FAA Instrumentation	\$100,000
FAA Data Reduction (3 years)	\$50,000

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SST Airborne Radiation Detection
Equipment per Aircraft

Dose Profile \$5,000

Accumulated Dose \$2,000

Danger Warning (may have to
measure LET) Not yet available

NASA Balloon Flights \$350,000 per year

Continuing NASA Space Radiation Studies
from the Office of Advanced Research
and Technology Indeterminate

Solar Proton Monitors on TOS Satellite
(2 years of continuous observation) \$300,000

Riometers (Proton Bombardment Detection)
(ESSA has about 12 in operation) \$20,000 each

VHF Forward Scatter
(three links now in Artic, three in Antartic) \$20,000 per link

In addition ESSA is developing a satellite plan to satisfy its future
needs in space disturbance detection and forecasting. The plan is sche-
duled to be fully developed in about 1 year.

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V. IMPLICATIONS

An SST compatibility survey of 15 gateway airports conducted by the competing airframe designers during Phase II of the SST Development Program was followed (in this study) by a Planning Research Corporation evaluation of those same 15 airports plus 13 similarly qualified potential SST airports. The Boeing Company measured airport compatibility at each of the 15 facilities in relation to its SST design. The Lockheed California Company did the same for its competing entry. Each of these three distinct and separate studies concluded that existing and planned facilities can, with minimal modifications, accept scheduled, commercial operation of an SST. As a result of their separate studies, Boeing and Lockheed indicated that modifications in certain areas will be necessary. Cost estimates of each of these opportunities for improvement for the 15 airports were also developed.

Unlike the two above-mentioned studies, the Planning Research Corporation effort did not sample gateway airports to determine expected SST impact upon the ground environment. PRC instead selected those major United States hubs which are now gateway airports (including the 15 sites studied by Boeing and Lockheed) for compatibility with their respective SST designs, in addition to others with the traffic-generating potential to become international air terminals by 1975, the scheduled first full year of SST commercial operation.

While Boeing and Lockheed in their Phase II studies considered the SST as the next generation of commercial jets to join airline fleets, the Planning Research Corporation study assessed SST-airport compatibility in the context of a more realistic environment; PRC examined the serial airport modifications sponsored by (1) continuing preference for air traffic over competing surface transportation modes; (2) increased capacity, stretched DC-8 subsonic airliners; (3) the commercial, high-capacity subsonic, Boeing 747; (4) the foreign, free world

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Concorde; and (5) the United States supersonic transport, the SST. As a consequence, the capital investment costs to qualify major hub airports for SST operation developed by PRC are less than those derived by applying data from the Boeing and Lockheed airport compatibility studies.

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VI. CONCLUSIONS

The summary conclusions reached by Planning Research Corporation as a result of the evaluation of potential SST airports and an examination of unique requirements of an SST for enroute support services are listed below.

1. Only minor modifications are required to qualify appropriate air terminals for SST operation. All necessary improvements fall in the pavements area; e.g., thicker concrete and larger fillets will be required. Alteration or replacement of buildings in the terminal complex cannot be attributed to the SST, but rather to continually increasing air traffic volume. Independent analysis of pavement adequacy at each of the potential SST airports considered for the two competing SST designs concludes that the SST could require improvement programs which would range from \$15 million down to zero dollars, depending on which aircraft design is selected.

2. The SST will impose no significant additional requirements on airways, navigation, and communications systems. Operational requirements imposed upon the SST designers dictate that the SST will perform within the limitations and capabilities of the air traffic control system programmed through the 1970's. SST avionics will incorporate highly accurate onboard inertial navigation systems, thereby negating the need for more sophisticated externally dependent navigational aids. No unique SST costs are identifiable.

3. Although meteorological systems improvements are not operational necessities, they are highly desirable for reasons of improved safety and economy. While the experience of supersonic military aircraft at SST altitudes has established that current meteorological technology is adequate to permit safe, programmed operations above 40,000 feet without undue risk to air crew members, inauguration of

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scheduled, commercial supersonic service will--for reasons of passenger confidence and operational and economic efficiency--impose requirements for an improved meteorological forecasting capability. There will be a need for better terminal area forecasts; more complete high-altitude data on such phenomena as temperature, turbulence, jet streams, wind shear, and particulate matter; and more rapid communication of meteorological data.

Indeed, there presently exists the desirability for these flight planning and operating improvements. Study and research into these aspects are being intensively pursued, and systems to alleviate existing deficiencies in these areas should be operational prior to the first scheduled commercial flights of the Concorde. However, these costs would not be primarily attributable to high-altitude supersonic commercial aviation needs.

4. The extent and exact nature of the radiation hazard at SST cruising altitudes is yet to be determined. Current knowledge indicates a need for both onboard radiation warning systems and ground-based solar observatories. The warning system is considered a necessary and integral part of the aircraft. The cost of the installation of ground-based solar observatories is being borne completely by NASA as part of the Apollo Space Program and is expected to fulfill SST requirements. No unique SST costs can be identified.

VII. RECOMMENDATIONS

During the course of the SST economic impact study, related areas which warrant further comprehensive investigation were identified. The more prominent areas are described briefly in this section.

A. Identification of Potential Gateway Airports

As part of its long-range planning, the Federal Aviation Agency should predict 10 years in advance which major airports (both large and medium hubs) have the potential to become international air terminals. These long-range projections should be reviewed and updated on an annual basis with a 5-year firm plan as an implementing directive.

The short-range, 5-year projection should be the basis for FAA-sponsored coordinating seminars among interested and concerned parties; e.g., federal inspection agencies, the Post Office Department, U.S. air carriers (both scheduled and supplementary), foreign carriers, freight forwarders, and local and regional commerce, industry, and planning representatives.

B. New Airport Construction Programming

In a manner similar to that described above, the FAA should establish a continuing capability to predict airport saturation and replacement schedules. As an instrument for oversight of United States air commerce, the FAA should annually assess for each of the major hubs:

- Responsiveness to air commerce requirements in a national context
- Capability for continued growth as required by increasing passenger and freight volumes

The FAA should further project the status of those airports for a period of 10 years into the future.

Where the requirement for a new airport is identified, the FAA should sponsor coordinating discussions with the affected communities within the region to be served. In this manner, a smooth and orderly transition would be ensured from the situation wherein an airport approaches the condition of becoming saturated or unmanageably large to the implementation of acceptable remedies such as phase-out of the existing airport or transfer to the status of a general aviation terminal, supplementation of the existing airport(s) by the construction of an additional facility, or replacement of the existing airport(s) with a new, regional service airport.

C. General Acceptance of a Universal, Standardized Pavement Analysis Method

The FAA should sponsor the development of single standard methodology for determining pavement requirements at airports which would receive general acceptance within the aviation community. The several evaluation techniques currently employed by airport engineers resist correlation and separately provide an unacceptable margin for error. A uniform, scientific method of measuring pavement stress capability is essential as a basis for national (and international) comparison of airport abilities to accept future aircraft.

D. Airport Adequacy Survey

An airport adequacy survey of foreign air terminals should be undertaken as soon as practicable after FAA adoption of a uniform airport pavement evaluation system. Potential SST airports should be examined first. These would include all major European airports, most Asian airports and principal African, Australian, and Oceania airports. Central and South American airports would present a particularly attractive situation because this survey would provide an opportunity for the United States to assist its southern neighbors in a demonstrably pragmatic manner. Central and South American citizens appreciate engineering assistance which, as in the case of the inter-continental jet airliner, promises technological and economic progress to the regions surveyed.

VIII. OBSERVATIONS ON AIR COMMERCE
INTO THE SST ERA

Analysis of the potential impact of an SST upon the ground and flight environments could properly be performed only within the context of the total air commerce situation. Therefore, in addition to determining the economic implications which might accrue to government (Federal, state, and local), a number of observations were made concerning non-SST aspects of the commercial aviation community. These grew out of the research and experience of the participating consultants and were catalyzed by the opinions and observations of airport planners and administrators and representatives of the major carriers.

Because such discussion is outside the realm of the primary direction of this SST economic impact analysis, it was felt that these indirectly related observations should be presented separately to interested users of this report.

A. Air Cargo

By 1975, air cargo will exert an influence upon airport design at least equal to that of passenger air travel. The increasing preference of producers and consumers of high-value and time-sensitive goods for air shipment should continue to expand. As a result, larger air freighter fleets among scheduled and supplementary carriers and local service airline-owned jet freighters and quick-change aircraft will be necessary. Because primary points of origin and destination are not limited to the immediate proximity of major hubs, an attendant growth appears inevitable in air cargo handling by feeder lines and in freight distribution activities at medium-hub airports, both in air-reassigned routings and transmodal handlings.

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B. Pavements

Pavements at airports served by the heavier and medium-to-long-range jet airliners continue to break up at a rate which was not experienced or predicted prior to 1958. The experience at most of the airports analyzed was that pavement distress has been accelerated since jet aircraft joined airline fleets. As a result, replacement cycles have been shortened and associated costs increased. This problem, which is widespread at airports served by commercial jets, is restricted neither to the transoceanic, very long range airliners, or even to domestic long-range versions. The medium-haul Boeing 727 was repeatedly cited by airport authorities and their consultant engineers as causing deterioration in specified pavement sections which had previously evidenced only normal wear.

C. Costs of Airport Improvements

The costs of airport improvements are usually borne by a combination of the following:

- The airport authority as a public agency, or through the administering municipal or regional government. Financing is generally through the issuance of revenue or general obligation bonds.
- The airlines, which utilize their own capital resources and borrowing powers
- The concessioners in the same manner as the airlines
- Federal financial assistance under The Federal Aid-Airport Act (FAAP) in the form of grants-in-aid

Terminal and other physical plant improvements are usually financed by a bond issue. Financing costs are usually recovered through user-charges to tenants (airlines and concessioners). Although this is the most popular method of financing airport modification programs, it is the least fair because it restricts the borrowing capability and flexibility of the proximate communities. Perhaps a reasonable remedy would be a new Federal assistance program to sponsor the unhampered growth of air commerce in the United States. Such a program might

make low-interest loans available to airports for progressive and orderly growth. The application of such monies should not be restricted as in the FAAP grants, but should include terminal improvements. Such funds should also be available for planning studies to measure the adequacy of existing airports, to forecast the saturation potential, and to examine, where appropriate, the feasibility of expanding the existing airport or constructing an additional (replacement) airport. A Federal air commerce support activity as described above would be an adjunct to the Federal Aid-Airports Program.

The Federal Government should be involved because beneficiaries to airport improvements are not only local residents traveling by air. They include other Americans and often foreign nationals who either have chosen to visit the locale served or are passing through that area. Equally important are business travelers; business travel exerts a definable impact upon national and regional economics. The positive effect of business air travel is diffused among the general public.

D. Ground Travel

Ground travel to and from airports in the United States is unsatisfactory in nearly all instances. As air travel becomes faster (e. g., with the B-747, Concorde, and SST), ground travel time consumed in reaching the airport becomes a larger portion of the total trip time.

To the business community, time means money. To the business traveler, excessive ground time means fatigue, restrictive scheduling of business appointments, and an abnormally structured workday. To the tourist, ground delays and inconveniences detract from air travel as the preferred mode of transportation where competitive commercial surface service is available.

Public acceptance of an SST may well depend upon the availability of improved local transportation facilities--facilities which are faster, more comfortable, moderately priced, and conveniently and frequently scheduled.

ERRATA

Planning Research Corporation

Economic Implications of a United States Supersonic Transport Aircraft Upon Airports and Enroute Support Services

- 1) Replace pp. 7-8 in Volume I with attached revised pp. 7-8.

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EXHIBIT 1 - SUMMARY OF COSTS OF SST REQUIREMENTS THROUGH 1975

Category	Costs Through 1975	Costs Sponsor (Millions of Dollars)	SST Unique
Airports and Terminals attributable to Boeing design ^{1/}	\$ 14	\$7 FAA (1/2) ^{2/} \$7 Local and state Gov'ts. (1/2)	minimal
Enroute Support Services	<u>\$650</u> ^{3/}		zero
Airways	-		
Navigation	-		
Communications	-		
Meteorology (Operational 1970)	\$ 88 invest. \$555 O&M (111/yr.) ^{4/}	U.S. (through De- partment of Com- merce) and partic- ipating foreign nations for World Weather Watch system	
Radiation (Operational 1967)	\$ 2 invest. \$ 4.8 O&M (0.6/yr.) ^{4/}	NASA - for Apollo Space Radiation Warning Network	

Notes: ^{1/} Attributable to Lockheed design - \$19 million costs thru 1975, \$19 million SST unique.

^{2/} FAAP provides for up to 50 percent federal participation for pavement improvements.

^{3/} \$650 M represents total Enroute Support Services Costs from respective estimated systems operational dates through 1975

^{4/} A rule-of-thumb has been applied stating that the first two years' O&M costs are approximately equivalent to one year's normal O&M costs.

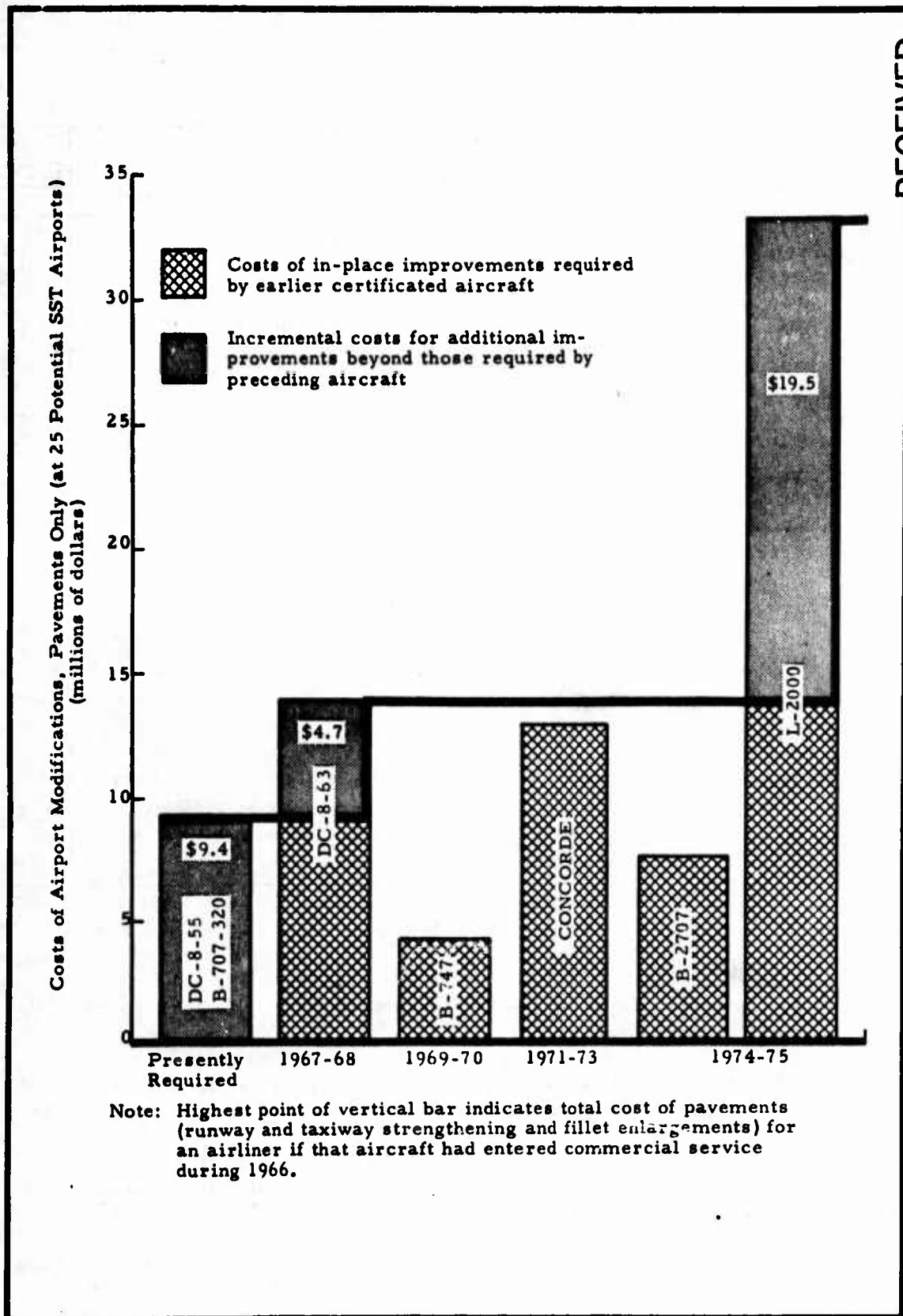


EXHIBIT 2 - INCREMENTAL PAVEMENT IMPROVEMENT (PUBLIC)
COSTS AT 25 POTENTIAL SST AIRPORTS

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