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BOEING SUPERSONIC TRANSPORT DIVISION



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THE **BOEING** COMPANY
COMMERCIAL AIRPLANE DIVISION
RENTON, WASHINGTON

⑥ DOCUMENT NO. D6A10582-1
TITLE: Airport Suitability Report.
Fifteen Major Domestic U. S. Airports

MODEL 2707-1

ISSUE NO. 5 TO: Faa

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ABSTRACT

This document was prepared by The Boeing Company as a part of the Supersonic Transport (SST) contract awarded by the Federal Aviation Administration of the United States.

The objective was to evaluate the suitability of fifteen selected domestic U. S. airports to accommodate the Boeing 2707. The various compatibility aspects of the study were calculated and results superimposed over aerial photographs of the various airports and their terminals. Cost estimates necessary to upgrade the airports to a state of minimum compatibility with the SST are also displayed.

Results and conclusions are summarized in Section 4.0 of this document.

KEY WORDS

Supersonic Transport
Airport Suitability
Airfield Compatibility
Pavement
Runways
Taxiways
Holding Aprons
Terminals
Fueling and Services

Maneuvering & Parking
Passenger Loading
Evaluation or Analysis Criteria
Characteristics of SST
Structures
Engine Blast
Costs
Filletts

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1.0 INTRODUCTION

In the overall objective of developing an operational supersonic transport aircraft, major consideration must be given to the environment within which it must operate. The airport suitability aspects of the program are a significant link in the functional purpose of the production airplane. In order to operate safely and profitably the aircraft and the airport must be as compatible as possible.

In accordance with contractual requirements, this document has been prepared for the purpose of evaluating the fifteen selected major domestic airports from which the 2707 supersonic transport will operate. The documents will be maintained through Phase III of the program as the configuration of the production aircraft emerges. It may serve to keep the airport planners and operators abreast of the latest aircraft design status and its direct relationships with the airports involved.

It is not the intent of the document to speculate upon intangible effects such as overall airport size, internal terminal sizes and requirements, total number of gate positions, etc. The document is one effort to reduce the gap between aircraft and airport development and present a preview of some of the items that will reduce operational difficulties at the airport when the 2707 arrives.

This report is based on the present configuration of the aircraft as shown herein. It is possible that the production aircraft may change in some respects. The document will be revised periodically to incorporate the effects of design changes upon airport compatibility.

Following is a list of items which have been evaluated and for which some recommendations and estimates have been presented:

- a. Pavements - Runways, taxiways, ramps, aprons, and holding aprons

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- b. Traffic, utility, and drainage structures; underground pipes and conduits
- c. Terminal areas - maneuvering and docking; passenger loading
- d. Fueling and servicing of aircraft
- e. Engine exhaust considerations
- f. Fire and rescue equipment
- g. Runway length requirements
- h. Economics and costs

The following airports have been studied:

<u>Airport</u>	<u>Location</u>
ANC - Anchorage International	Anchorage, Alaska
BAL - Baltimore Friendship International	Baltimore, Maryland
BOS - Boston Logan International	Boston, Massachusetts
DIA - Dulles International	Washington, D. C.
DTW - Detroit Metropolitan/Wayne County	Detroit, Michigan
HNL - Honolulu International	Honolulu, Hawaii
HOU - Houston Intercontinental	Houston, Texas
JFK - John F. Kennedy International	New York, New York
LAX - Los Angeles International	Los Angeles, California
MIA - Miami International	Miami, Florida
ORD - O'Hare International	Chicago, Illinois
PIK - Portland International	Portland, Oregon
PHL - Philadelphia International	Philadelphia, Pennsylvania
SEA - Seattle-Tacoma International	Seattle & Tacoma, Washington
SFO - San Francisco International	San Francisco, California

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2.0 EVALUATION BASIS AND CRITERIA

In order to properly determine the suitability of airports, certain parameters were established. Pertinent characteristics of the aircraft were established which were used to check the various compatibility aspects of the airports. The most significant of these criteria which were used as a basis of comparison are displayed below.

2.1 Characteristics of the Boeing 2707-200

The various characteristics of the aircraft which were considered applicable to this study are shown below. A general description of the SST is followed by pertinent data, dimension drawings, and other material as found appropriate. This information will be updated as the aircraft design approaches the final production model.

General Description - The Boeing 2707 Supersonic Transport is an aircraft employing the principle of variable-wing geometry. During takeoffs, approaches, landings, and ground operations, the 2707 will operate with its wings in the forward position. In the forward position, the leading edges of the wings have a sweep of 30° from a line perpendicular to the fuselage centerline. During supersonic cruise, the wings are swept rearward so that their trailing edges fair into the leading edges of the horizontal stabilizer. As a result, the aircraft exhibits a delta planform, with the sweep of the leading edges of the wings at 72° .

For purposes of optimizing the pilot's range of vision on takeoff, landing approaches, and while taxiing, the SST has been designed so that its nose can be articulated downward approximately eight feet.

The main landing gear comprises two pairs of dual-tandem trucks. The forward pair of trucks is spaced outboard of the rear pair. The rear pair is steerable in conjunction with the nose gear.

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The 2707 is powered by four G.E. 4/J5P jet engines. The four jet engines are affixed beneath the horizontal stabilizer. They are so mounted as to have an upward cant from the inlet of about 5° when the aircraft is standing on a horizontal surface. Owing to the geometry of the engines, however, the centerline of the efflux at the exhaust is upward from the horizontal by only slightly more than 1° . Jet wakes of the power plants are shown in the sketches included.

The fueling of the 2707 is accomplished through four ports located on the underside of the wings about 173.5 feet aft of the nose and about 22 feet outboard of the centerline of fuselage. Their height above ground is about 12 feet. The fueling rate is to be 2,000 gpm at a maximum pressure of 50 psi. The fuels used by the 2707 will be the same as those used by subsonic jet aircraft.

Details Pertinent to Airport Compatibility - The principal dimensions and data of the Boeing 2707 which are used in the airport suitability studies are shown in the data in Figures I through IV. Comparison data for the DC-8 main landing gear is also displayed.

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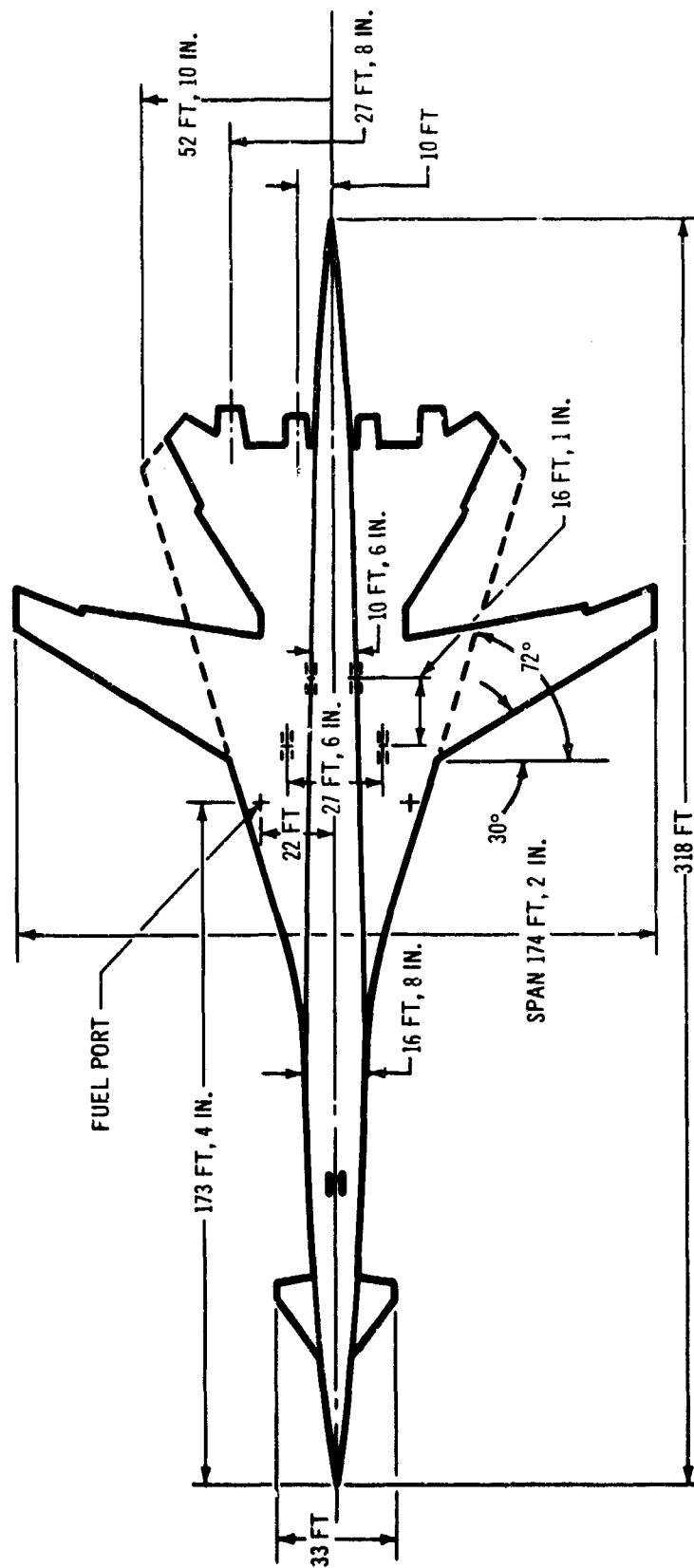
2707 CHARACTERISTICS USED IN AIRPORT EVALUATIONS

Maximum Gross Weight, Lb.	675,000
Flight Crew Size	3
Cabin Attendants	8
Passengers	
10/90 International Mix	292
All Tourist Configuration	310
Cargo Capacity, Cubic Feet (Using Containers)	2,431
Cargo Capacity, Lb. (Based on 10 Lb./Cu.Ft. Using Containers)	24,310
Fuel Rate	2,000 GPM @ 50 psi
Number of Landing Gears	1 Nose 4 Main
Structural Materials	Titanium 6Al-4V High Strength Steel

Figure I

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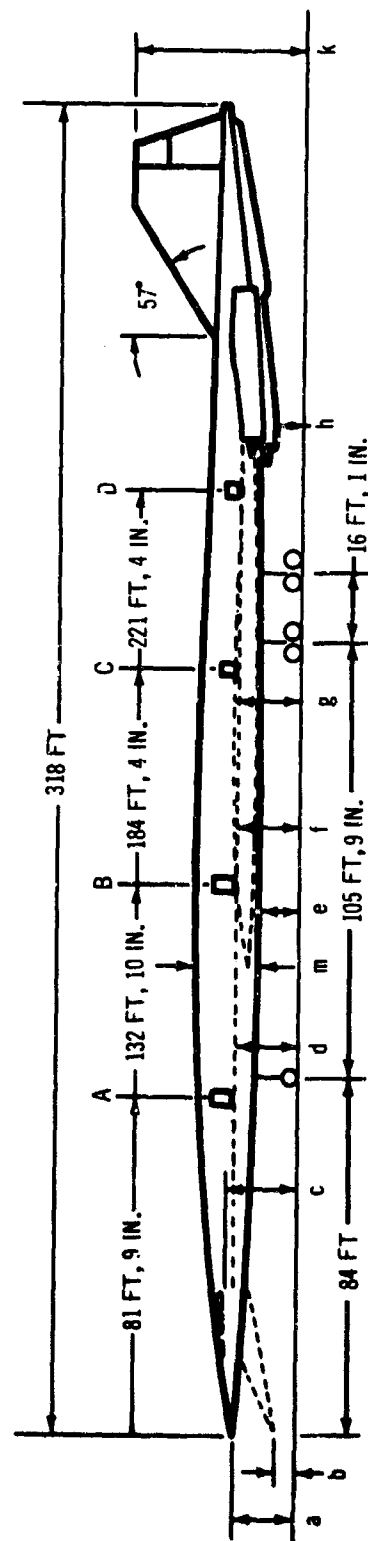


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Figure II. Principle Dimensions, Model 2707-200 - Plan View

MAIN DOORS	STATION		SIZE (INCHES)	
	RH	LH	RH	LH
A	1,181	1,181	42 X 72	42 X 72
B	1,794	1,794	42 X 72	42 X 72

EMERGENCY EXIT DOORS	STATION		SIZE (INCHES)	
	RH	LH	RH	LH
C	2,412	2,412	24 X 48	24 X 48
D	2,856	2,856	24 X 48	24 X 48

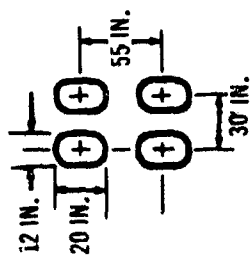


DIMENSIONS	FEET - INCHES
a	12 FT, 2 IN.
b	4 FT, 0 IN.
c	16 FT, 0 IN.
d	15 FT, 0 IN.
e	9 FT, 9 IN.
f	15 FT, 9 IN.
g	16 FT, 6 IN.
h	6 FT, 10 IN.
k	45 FT, 3 IN.
m	15 FT, 7 IN.

Figure III. Heights and Clearances, Model 2707-200 - Side View

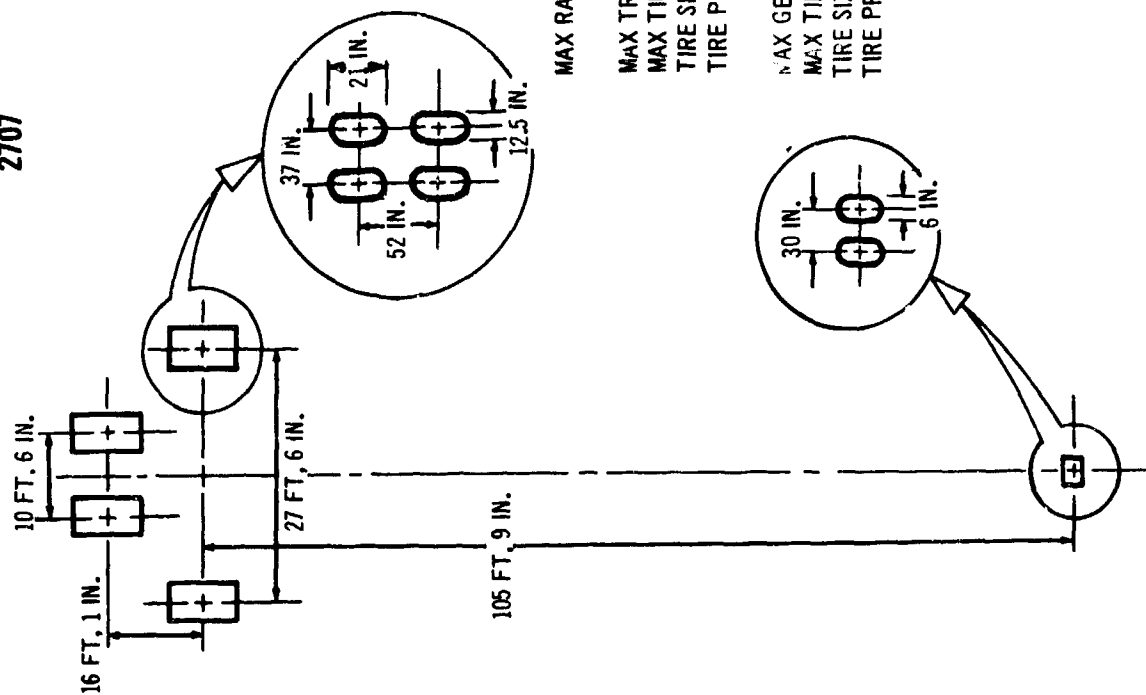
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DC-8-55



MAX GR WT 328,000
TIRE SIZE 44 X 16 IN.
TIRE PRESS. 187 PSI
WT ON NOSE 5%
TRUCK SPACING 20 FT. 10 IN.

2707



MAX RAMP WT 675,000 LB
MAIN GEAR
MAX TRUCK LOAD 164,000 LB
MAX TIRE LOAD 41,000 LB
TIRE SIZE 44 X 16-18
TIRE PRESSURE 205 PSI
NOSE GEAR
MAX GEAR LOAD 61,400 LB
MAX TIRE LOAD 30,700 LB
TIRE SIZE 37 X 15.5-15
TIRE PRESSURE 195 PSI

Figure IV. Landing Gear Truck Data

2.2 Criteria and Evaluation Data

In addition to the aircraft characteristics themselves, certain other material was necessary as a basis for which to evaluate the airports. These criteria cover the pavement, underground structures, terminal maneuvering and parking space, passenger handling capabilities, fueling and servicing aspects, engine blast considerations, fire protection equipment, and cost data.

2.2.1 Evaluation of Pavements

Evaluation of pavements required for the supersonic transport is one of the very significant items in the consideration of SST airport compatibility. Pavement compatibility is important to the airport operator because the pavements represent one of his major facilities investments and the strengthening or refurbishing of existing pavements can represent a large additional capital investment. On the other hand, pavement compatibility is of high import to the airplane operator because without it he must bypass the airport, or at the least, operate there under reduced weight conditions.

Because of the magnitude and import of pavement compatibility, a separate document has been prepared and is maintained on the subject. This document, D6A10317-1, "Airport Pavement Requirements for the Boeing Supersonic Transport," discusses the assumptions and analytical methods used in pavement analysis and presents comparative data for the Boeing Supersonic Transport and the Douglas DC-8-55 jet transport. The "Pavement Requirements" document appendix utilizes this data in combination with pavement and subgrade data acquired from 15 domestic airports. These data are displayed as a tabulation of SST and DC-8-55 requirements versus presently existing pavements and subgrades.

As a part of pavement evaluation, it should be emphasized that many of the pavements at an airport would never be used by a fully loaded SST or other commercial transport. Thus, there would be no requirement for these pavements to be capable of supporting the full gross weights of these airplanes. Examples of these pavements are high-speed exit taxiways, maintenance and over-haul area access taxiways, and maintenance aprons.

The DC-8-55 at 328,000 pounds gross weight was selected as the SST airport compatibility airplane by agreement between the Airport Operators' Council, the Supersonic Transport Development Office of the FAA, and the two airframe contractors then engaged in the supersonic transport program competition. At the time of its selection, this airplane had the highest pavement requirements of any commercial jet transport in regular service. The SST designer's goal was then to develop landing gear on the SST that would be compatible with any pavements or pavement structures extant which were compatible with the DC-8-55.

2.2.2 Requirements for New Pavements

The determination of pavement design is based in a large part on the judgment and experience of the designer. There is no universal design method and at the 15 major domestic airports studied, two completely different methods of flexible pavement design are in use. Because of these different design method approaches, two complete flexible pavement comparison studies were prepared for the SST and DC-8-55.

2.2.2.1 Flexible Pavement

Using the FAA flexible pavement procedure, it was shown that for the entire range of subgrades (Fa to F10 as defined by the procedure) the

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Boeing SST required less pavement thickness than the DC-8. For that reason, at those airports that use the FAA flexible pavement method, no penalty for additional pavements was assessed against the SST. In recent revisions of the FAA "Airport Paving" advisory circular (AC 150/5320-6A), flexible pavement requirements are determined on the basis of airplane gear type and airplane gross weight. For airplanes with twin tandem main gear as proposed for the SST, the pavement design curves are limited to a maximum airplane gross weight of 400,000 pounds. As these design charts are generalizations of those shown in the November, 1962, "Airport Paving" circular, it was assumed proper that those base charts be used for both airplanes in this comparative study.

In the pavement evaluation of those airports that presented their flexible pavement subgrade data in the form of CBR, the Corps of Engineers pavement analysis method was employed. In those cases where existing pavements were judged inadequate by this method, engineering judgment and rationalization were necessary to establish the overlay requirement attributable to the SST. These rational are described individually where those situations occur.

2.2.2.2 Rigid Pavement

In the evaluation of rigid pavements, the combination of pavement thickness and subgrade strength result generally in lower induced flexural stresses by the SST than the DC-8-55. In those few instances where the reverse is true, the existing pavements are overstressed by both airplanes and only slightly more by the SST.

Where existing rigid pavements are inadequate, the deficiency would normally be corrected with a bituminous overlay. Owing to the difference in pavement flotation characteristics of the two airplanes, a thicker corrective overlay would be required for the DC-8-55 than for the SST.

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2.2.2.3 Fillets

The adequacy of existing fillets at pavement intersections was evaluated by studies performed with the gear assembly configuration of the 2707 reduced to a scale of 1" = 30'. Rolling turns were used to obtain the best possible approximation of actual operating conditions.

Studies made in this manner indicate that the critical requirement for the smooth negotiation of intersection turns is starting them at the right point. In recognition of this finding, the criteria adopted for normal operations of the 2707 provide adequate margins for misjudgment by the pilot of the optimum turning point. These margins are achieved by limiting the maximum nose-wheel steering angle to 50° and by maintaining 18 feet as the minimum clearance from edge of full-strength pavement to centerline of nose gear and 20 feet from edge of pavement to centerline of outside truck. In addition, it was assumed that weaving away from a turn prior to actually starting it would not be a normal piloting practice. Figures V, VI, and VII illustrate the paths followed in the model studies of typical intersections.

Within the limits adopted for routine operations, it was found that the 2707 can be maneuvered smoothly around any runway-runway intersection and any runway-taxiway intersection paved with fillets of the radii recommended by the FAA and its Advisory Circular 150/5335-1. At certain taxiway-taxiway intersections, however, the fillet radii recommended by the FAA are inadequate, in terms of the adopted study criteria, for 2707 taxiing operations.

At almost any airport pavement intersection, a situation can be conceived in which an airline aircraft is required to perform an awkward taxiing maneuver (e.g., turning the acute angle of a high-speed exit taxiway). In day-to-day operations, however, many such maneuvers are performed only rarely, if at all. In recognition of this fact, a less rigorous set of

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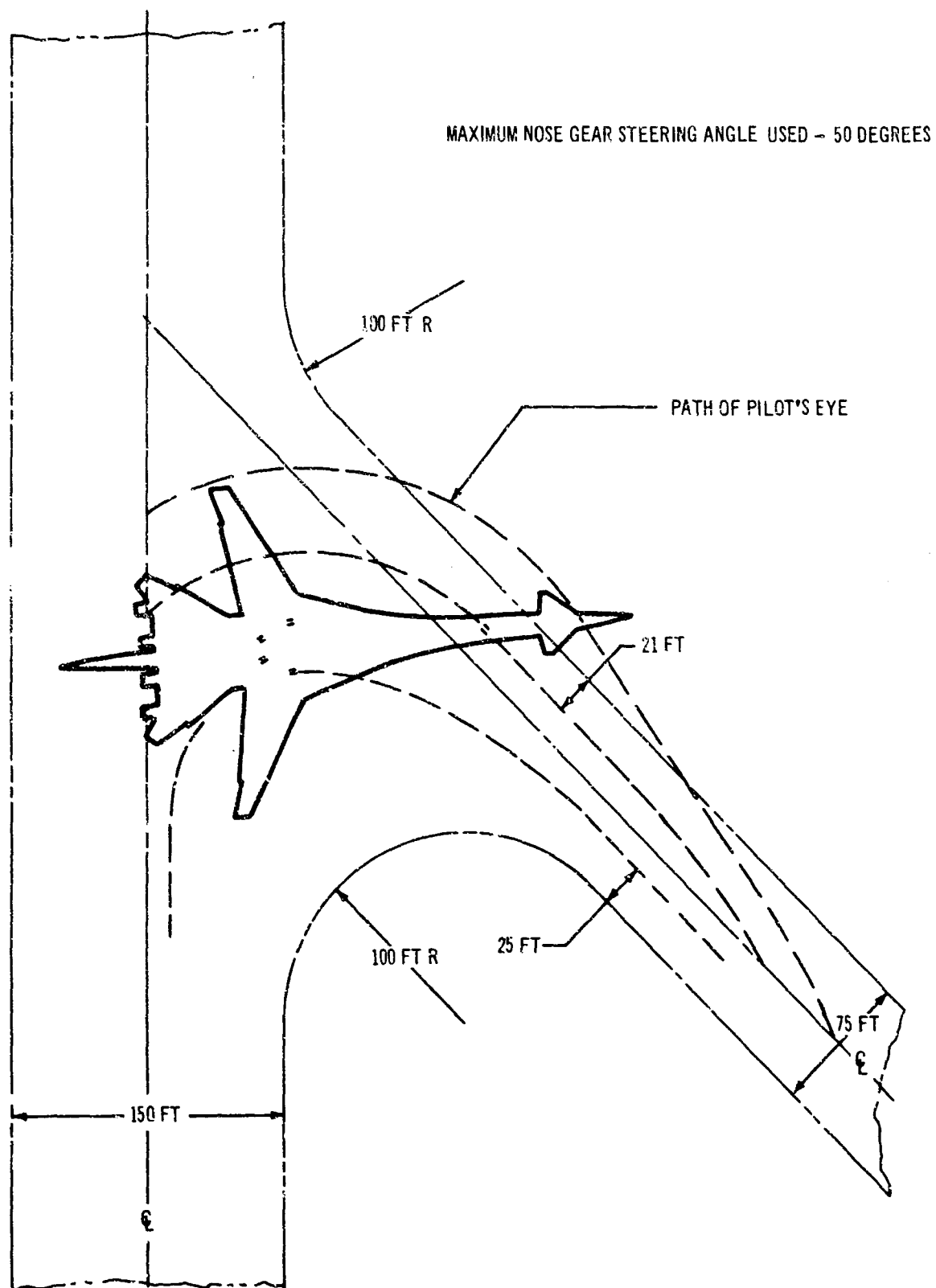


Figure V. Maneuvering Data, 2707-200 - Runway-to-Taxiway Turn

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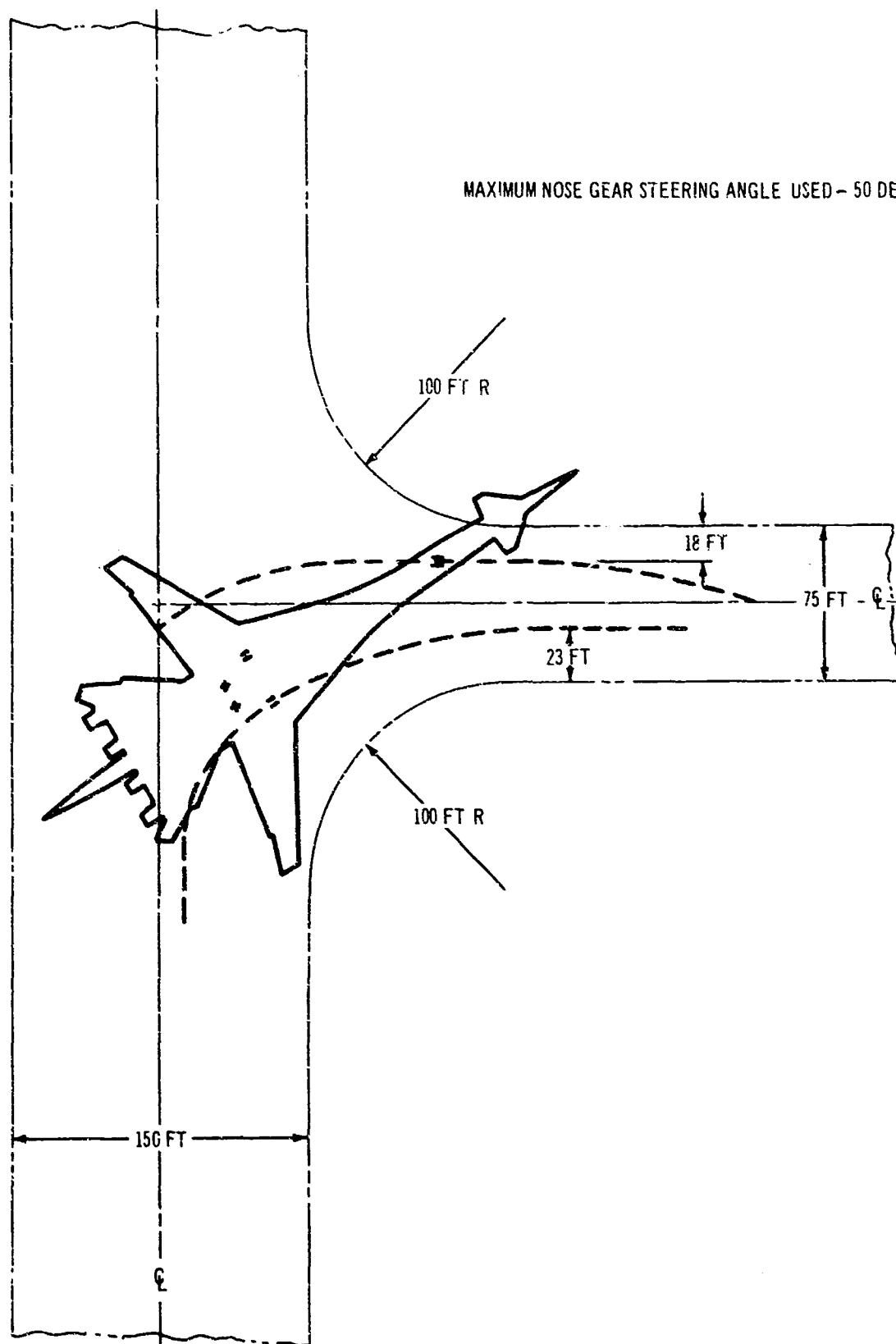


Figure VI. 90-Degree Runway-to-Taxiway Turn

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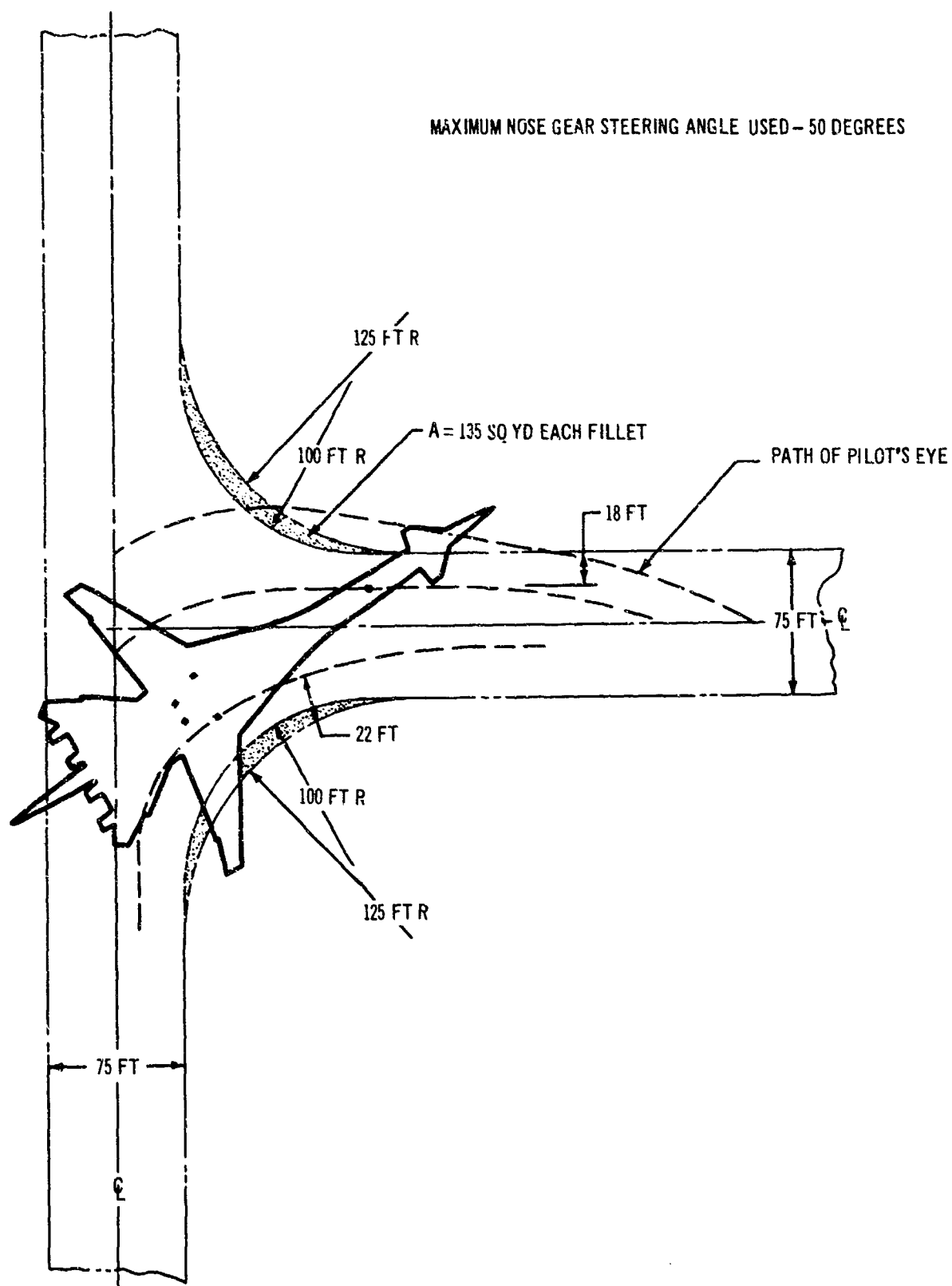


Figure VII. 90-Degree Taxiway-to-Taxiway Turn

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criteria was adopted during the study for determining the adequacy of the pavement geometry confronting the pilot forced to make an unusual maneuver. Basic to the establishment of these criteria is the assumption that pilots in such circumstances will maneuver slowly and with due caution.

The operating limits adopted for rarely-made intersection maneuvers permit the use of the maximum nose-wheel steering angle (75°), veering away from the direction of turn prior to starting it, and a reduction to a 5-foot clearance between the edge of pavement and the centerlines of nose-wheels and the main-gear truck.

Minimum fillet radii for a wide range of turning angles were determined for various combinations of widths of intersecting pavements in accordance with each set of criteria. Tables of study standards, Figures VIII and IX were then prepared for the investigation of pavement geometrics at the study airports.

Curved taxiways of constant radius and width are also encountered. Studies show that the 2707 can readily negotiate 75-foot-wide taxiways having radii of curvature of the centerline of 230 feet or more. Where the SST would use such taxiways only rarely, the radius of centerline curvature can be as little as 100 feet. (These and other findings are contained in Table 4, Figure IX.)

Several important assumptions were made prior to the investigation of individual airports.

- (1) The SST will not be required to taxi to existing air cargo areas. (This is the only limitation placed on the operational flexibility of this plane.)
- (2) No preferential ground routing clearances will be issued to pilots of SST's.
- (3) Turnoffs made from the landing roll will not be initiated

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PAVEMENT GEOMETRY REQUIREMENTS BOEING MODEL 2707

NOTE: Criteria for taxiing through "normal usage" intersections:

- (1) Maximum nose-wheel steering angle equals 50° .
- (2) Minimum clearances 18 feet from edge of pavement to centerline of nose-gear and 20 feet from edge of pavement to centerline of critical main-gear truck.
- (3) No weaving away from direction of turn prior to starting turn. Aircraft centered on taxiway/runway prior to starting turn.
- (4) Required fillet radii to next largest 25 feet.

TABLE 1
RUNWAY-TAXIWAY FILLETS

Angle of Turn	Minimum Edge-of-Fillet Radius Required			
	150-ft R/W to 75-ft T/W	150-ft R/W to 100-ft T/W	200-ft R/W to 75-ft T/W	200-ft R/W to 100-ft T/W
30	0	0	0	0
45	0	0	0	0
60	50'	0	0	0
75	75'	0	50'	0
90	75'	0	50'	0
105	75'	25'	50'	0
120	75'	25'	50'	0
135	75'	50'	75'	25'
150	75'	50'	50'	50'

TABLE 2
TAXIWAY-TAXIWAY FILLETS

Angle of Turn	Minimum Edge-of-Fillet Radius Required	
	75-ft Taxiways	100-ft Taxiways
30	100'	0
45	150'	0
60	150'	0
75	150'	25'
90	125'	50'
105	125'	50'
120	100'	50'
135	100'	50'
150	100'	50'

Figure VIII

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PAVEMENT GEOMETRY REQUIREMENTS BOEING MODEL 2707

Note: Criteria for taxiing through "rare usage" intersections:

- (1) Maximum nose-wheel steering angle equals 75° .
- (2) Minimum clearance, edge-of-pavement to centerline of nose-gear and to centerline of critical main-gear truck equals 5 feet.
- (3) Weaving away from direction of turn prior to starting turn permitted.

Runway-taxiway intersections turned according to the above criteria do not require fillets.

TABLE 3
TAXIWAY-TAXIWAY FILLETS: RARE USAGE

Angle of Turn	Minimum Edge-of-Fillet Radius Required	
	75-Ft. Taxiway to 75-Ft. Taxiway	
30	0	
45	0	
60	0	
75	0	
90	25	
105	25	
120	25	
135	25	

TABLE 4
CURVED TAXIWAYS

Usage	Taxiway Width	Minimum Centerline Radius Required
Normal	75	230
Normal	100	135
Rare	75	145
Rare	100	100

Figure IX

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closer than 4,000 feet from the marked landing threshold of the runway.

- (4) Reverse turns from a runway to a parallel taxiway will only rarely be made via the acute side of a 30° high-speed exit taxiway. (The layout of such an exit is commonly characterized by a taxiway throat width of 100 feet and a fillet radius of 25 feet on the acute side. The 2707 can make the 150° turn around the acute angle without exceeding the 18-foot edge-of-pavement clearance criterion; however, the maneuver must be started with the aircraft offset toward the opposite side of the runway.)

The first step in the study of intersection fillets at the individual airports was the elimination of those pavements that the SST would never use, such as entrances to cargo areas, etc. Next, each remaining fillet was classified either as "rare usage" or "normal usage." In marginal cases, the fillets were conservatively classified as "normal usage" pavements.

Where applicable, the standards developed for the study were used to determine the adequacy of the existing construction (which was taken to include any proposed future construction for which the airport operator had prepared engineering plans, as well as pavement now in place or under construction). A separate model study was performed for each intersection to which the study standards were found inapplicable.

Quantities were determined for the improvements required to bring each inadequate fillet up to the set of study standards by which it had been classified, except where the rare usage classified fillets require improvement. For these it was determined to show quantities which would bring them to normal usage standards. Included were grading, full-strength pavement, shoulder

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pavement, marking, sign relocations, edge-lighting relocations, and (where required) new edge lighting. At all airports, signs and lights were assumed to be in existence at all pavement intersections, whether or not they are currently installed. It was assumed that the minor shifting of the points of curvature and tangency resulting from the fillet modifications would not in turn require the relocation to uniform spacings of all edge lighting between intersections. Although the realization of such an assumption would not be in accord with the current FAA recommendations for edge-lighting, it is believed that, as a matter of practical economics, the airlines will not press airport operators to embark on expensive edge-relighting projects for the relatively minor improvements to be gained.

Current unit prices for materials and labor were applied to the estimated quantities to determine the costs of improvements. All such costs have been allocated to the SST. They are reported in the summary of costs found at the end of each airport evaluation.

2.2.2.4 Holding Aprons

Holding aprons at the ends of runways are of less importance to turbine-powered aircraft than to piston-engine aircraft, whose pilots require them for engine runups. By the time the SST is in use, there will be very few or no piston-engine aircraft in the inventories of the scheduled airlines. Nevertheless, the holding apron will continue to serve as an area in which aircraft lacking departure clearance or requiring additional last-minute functional checking can wait while those behind them pass.

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The combination selected as critical for this study was a Boeing 747 with a wing-span of 196 feet and the 2707, which has a 174-foot span with wings extended. Depending upon the geometry and size of the apron, the SST (assumed to be the holding aircraft) was parked either parallel to the long edge of the apron or at an angle to it, with the main gear no closer than 18 feet from the edge of pavement. In maneuvering into its parked position, the criteria of maximum nose-wheel and minimum gear-to-edge-of-pavement equals 18 feet were observed.

The subsonic aircraft was required to pass on the taxiway centerline while clearing the SST by at least 40 feet.

Where necessary, the widenings and lengthenings required by these criteria have been designed and all costs associated therewith have been estimated, including the resetting or addition of edge lights.

2.2.2.5 Terminal Aprons

At some terminal areas, the layout of concourses and satellites is such that aircraft parked at the outermost gate positions are too close to the periphery of the apron to permit the passage of a 2707. Although other large aircraft placed in service prior to the SST will probably necessitate the widening of aprons in such terminal areas, the costs of appropriate widenings have been estimated and allocated to the SST. FAA minimum spacing will not be exceeded.

2.2.2.6 Terminal Area Inlays

At some of the study airports, certain terminal area pavements have been inlaid with concrete pads at the gate positions. These serve a two-fold purpose: (1) the prevention of rutting, which frequently occurs when flexible pavements are subjected to static or highly channelized loads; and (2) the prevention of pavement deterioration caused by fuel spillage.

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At those airports where the management or tenant airlines have installed an appreciable amount of rigid-pavement inlay, it has been assumed that inlays would be required at the SST gate positions.

An inlay 75' x 130' would provide an ample margin around the fueling stations, main gear, and engines, and inlays of this size have been assumed for estimating purposes. It is not believed that the nose-gear, which is relatively lightly loaded, would require inlays; and it is quite possible, besides, that at most SST parking positions the nose-wheels would be standing on inlays constructed for present-day aircraft.

2.2.3 Evaluations of Structures

At every airport investigated, it has been found that pavements subjected to aircraft loadings are underlain in many places and at various depths by several types of structures. These may be pipes, culverts, utility conduits or passenger and baggage channels. A few airports have pit covers or drainage grates of sizes sufficient to warrant investigation for the effects of 2707 gear loads.

2.2.3.1 Bridges and Culverts

At five airports, there are or will be overpass structures or vehicular subways carrying aircraft live loadings. The assumptions and criteria employed in the investigation of all such structures are given below:

- a. Aircraft Loads - Static 2707 loads and their arrangement are the same as those used for the evaluation of pavements. (Refer to the above discussion and to Figure IV.

Rolling impact loads have been neglected for all structures except overpasses and culverts with less than three feet of cover. The rolling impact factors used in the investigations of overpasses, subways, and culverts were the same ones used by their designers.

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- b. Strength of Materials - The properties of all structural materials were assumed to be those required by the specifications to which they were built or fabricated. Assumed soil bearing values are those used by the original designers.
- c. Methods of Analyses - Overpass deck slabs and the top slabs of box culverts and other underground structures having less than two feet of fill cover have been analyzed for a live load distribution based on orthotropic plate theory, which accounts for the relative stiffness of the slab parallel and normal to the span length. The top slabs of box culverts and underground structures having a fill cover of greater than two feet have been analyzed for a live load distribution in accordance with American Association of State Highway Officials (A.A.S.H.O) data exhibited in paragraph 2.2.3.3. The bottom slabs of box culverts and the footings of underground structures have been analyzed for a live load distribution in accordance with the same A.A.S.H.O. item, except that the loads have been distributed longitudinally by the walls. The box culverts and underground structures have been analyzed as rigid frames for stresses caused by dead load, live load, and earth pressure.

Grates and their supporting beams have been analyzed for the wheel loads distributed over the tire contact areas shown in Figure IV.

2.2.3.2 Pipes and Conduits

At each of the airports studied, there are extensive and complex installations of pipe and circular conduit. Complete and up-to-date underground

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survey maps are seldom available, and the specifications and field reports on materials actually used and construction practices followed are also difficult to obtain. For these reasons, investigations of many individual conduits could not be made.

It was decided, therefore, to use the same approach as that used in the analysis of the 2707's compatibility with airport pavements, and the DC-8-55 was again used as the criterion aircraft.. (See Figure IV.) A full explanation of the method of analysis and the results thereof are given in paragraph 2.2.3.3. The results may be summarized as follows:

- (1) For depths of cover of 1 to 2 feet, the 2707 imposes loads 5 per cent greater than those imposed by the DC-8-55;
- (2) For depths of cover of 2 feet to about 5 feet, the DC-8-55 imposes the greater load;
- (3) The depth of cover at which maximum relative over-stress on the pipe occurs is about 8 feet, and for this depth the loads imposed by the 2707 are about 8 per cent greater than those imposed by the DC-8-55.

The DC-8 and other aircraft exerting similar loads have been operating at most of the airports studied for over five years. That no damage to pipe or conduit has been reported is indicative of proper selection of materials and good construction practice.

Since it would serve little useful purpose to remove and replace undamaged pipe in anticipation of imposed loads only 8 per cent greater at most than those currently being borne without evidence of distress, it has been assumed that no costs will be incurred by the 2707 for improvements to pipe and conduit.

2.2.3.3 Vertical Loads on Underground Conduits - A Comparative Analysis of
The Douglas DC-8-55 and The Boeing 2707

Basically, the main-gear truck of the DC-8 and the Boeing 2707 are quite similar. The DC-8 has four tires spaced 30 inches center-to-center transversely and 55 inches center-to-center in the longitudinal direction. The corresponding dimensions of the 2707 are only slightly larger. (See Figure IV)

The DC-8 has two trucks, while the 2707 has four trucks. Those of primary concern are the rear trucks, which are the most closely spaced.

The investigation of the loads on any underground pipes by any precise method is practically impossible. The distribution of the tire load through pavement directly over and adjacent to the pipes, the method of bedding the pipe, and the method of placing the backfill are quite variable. Because of the similarity of the trucks being compared, the procedure used to determine the live load transmitted to pipes was that described in Article 1.3.3, "Distribution of Wheel Loads Through Earth Fills," of the Standard Specifications for Highway Bridges of the American Association of State Highway Officials. Eighth Edition, 1961.

It is known that the dead loads imposed by fills over large pipes placed in trenches can be somewhat greater, by up to 25 per cent, than the weight of fill directly over the horizontal projection of the pipe. On small pipe, the fill dead loads can be as much as two to three times the weight of the fill directly over the pipe. Accordingly, two cases were investigated: Case A, in which a factor of unity is applied to the fill dead load; and Case B, in which a factor of two is applied.

The combined dead and live loads on pipe to which aircraft loads are

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transmitted are tabulated below as ratios of the loads caused by the 2707 divided by those caused by the DC-8-55.

<u>Depth (Ft.)</u>	<u>Case A</u>	<u>Case B</u>
2	0.94	0.94
4	0.98	0.98
6	1.06	1.04
8	1.08	1.05
10	1.08	1.04

For very shallow depths of cover, the loads on pipe are proportional to the tire loads, and the 2707 imposes loads about 5 per cent greater than does the DC-8-55. For covers from 2 feet to about 5 feet, the closer spacing of the tires of a single truck of the DC-8-55, despite the slightly lighter load per tire, results in greater loads on the pipe than those caused by the 2707. Above a cover of about 5 feet the closer truck spacing of the 2707 produces a greater load on the pipe, but the dead load of the fill over the pipe becomes a greater percentage of the total load. The 2707, therefore, produces maximum loads on pipe no more than about 108 per cent of those produced by the DC-8-55.

2.2.4 Terminal Area Considerations

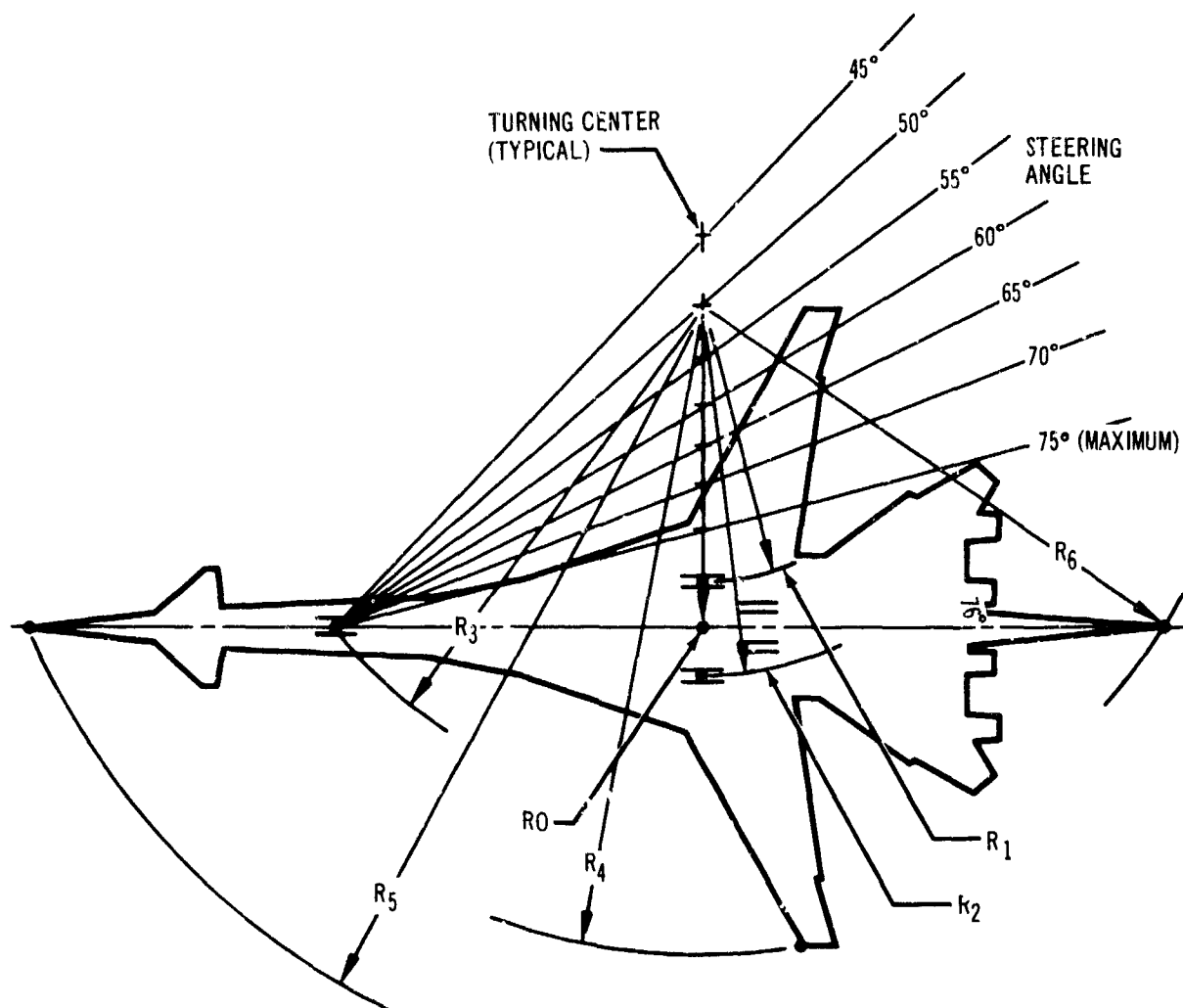
Three major areas of study were made in regard to the terminal:

- a. Aircraft Maneuvering, Docking and Parking
- b. Passenger Loading
- c. Fueling and Servicing

All of the above items are applied as external functions, as they are related to the aircraft. No internal terminal functions have been considered.

2.2.4.1 Maneuvering and Docking

The studies of the terminal area have been to examine the degree of flexibility open to the airlines for maneuvering and docking the 2707 by conventional techniques. (Turning radius data used in Figure X.) The operating



STEERING ANGLE (DEGREES)	CENTER POINT	NEAR STRUT	FAR STRUT	NOSE STRUT	WINGTIP	NOSE	TAIL
	R ₀	R ₁	R ₂	R ₃	R ₄	R ₅	R ₆
	FT	FT	FT	FT	FT	FT	FT
30	183	170	196	212	272	263	224
45	106	92	120	149	196	217	167
50	90	75	102	138	181	209	157
55	74	60	88	129	166	204	149
60	61	47	75	123	153	199	143
65	49	36	63	117	142	196	138
70	39	25	52	112	131	193	134
75 (MAX)	28	15	42	109	120	191	132

Figure X. Turning Radii - No Slip Angle, Model 2707

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criteria employed in studying the feasibility of maneuvering into and from a specific position were as follows:

- (1) Allowance is to be made for a forward roll of 10 feet prior to stopping and a 10-foot forward roll prior to taxiing out. (Where taxi-out is possible.)
- (2) A minimum of 25 feet clear from all fixed objects, retracted loading devices, and other aircraft will be maintained while maneuvering and when docked except that a minimum of 10 feet from nose to building will be permitted for nose-in parking.
- (3) Retraction of the wings shall not be necessary to gain required clearances.
- (4) The maximum nose-wheel steering angle of 75° may be employed for maneuvering.
- (5) The nose, which is normally down for ground maneuvering, may be raised as required to clear low obstructions to maneuvering.
- (6) When docked, the 2707 shall not interfere with vehicular travelways adjacent to terminal buildings and concourses.
- (7) All other considerations being equal, the most feasible gate positions for the SST would be those to (and in some cases from) which it can be maneuvered under its own power. The conservative assumption was made that criteria in this regard is as follows where jet wakes are incurred.

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JET WAKES DISTANCES

<u>Item</u>	<u>Typical Velocity</u>	<u>Corresponding Temperature</u>	<u>Distance Behind A/P</u>
Personal Comfort, Loose Objects, Equipment Location (Including Extended Loaders)	30 MPH	Ambient	360'
Cross Gusts on Moving Vehicles	20 MPH	Ambient	470'
Building Design	75 MPH* 30#/Ft. ²	130°F.	150'

*Normal to Surface

- (8) Allowance has been made for taxiway clearances for the larger subsonic jets (Boeing 747) in areas where they will be passing the 2707. No consideration, however, has been given to situations where 2707's must pass parked "jumbo" jets, since it is not known how or where they will be parked.

2.2.4.2 Passenger Loading

Passenger loading evaluation must consider the imminent changes to be introduced by proposed airplanes and traffic growth. Since the Boeing Model 747 and stretched versions of the DC-8 are being placed in service prior to the introduction of the 2707, it is highly likely that many existing terminal facilities will have undergone extensive architectural remodeling. Hold rooms in concourses, for example, may require enlargement, and the concourses themselves may have to be widened. Also, mobile loading ramp heights will have to be increased. Since such alterations would probably be made even if the 2707 were not developed, the costs involved are not properly attributable to it.

It is foreseen that passengers will normally be transferred between the 2707 and the terminal building via second-story loaders. Alternate parking positions have been studied to determine the optimum mode of gate positioning for passenger handling. Final gate positions selected and shown in the report have been chosen to ensure taxiing clearance, and usage of existing loading

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bridges, while maintaining the capability of two-door loading. (Except where indicated as one door loading.)

Representative costs of alteration or replacement have been estimated for the various loaders in use at gate positions where the 2707 can be readily parked. The costs of new loaders at new locations on the terminal face have also been estimated. Such costs are greater than those of a replacement loader by the amount required to provide power and an opening in the terminal face.

A wide variety of passenger-loading practices was observed at the airports included in the study. At some, all loading and unloading of large, subsonic jets is performed by movable ramps. More commonly, however, a mixture of practices is found. Typical of such situations is the one in which each airline has exclusive gates assigned to it and has been permitted to install loaders of its own choice at locations of its own choice. To achieve consistency in the allocation of costs per gate position, the following criteria have been adopted for the purposes of this report:

- (1) At existing terminal facilities where there are now no loaders and where no equipment has as yet been selected for future installation, no passenger-loading costs are attributable to the 2707. The basis for this reasoning is that future installations will, for the most part, be compatible with large subsonic jets and, therefore, with the 2707 as well.
- (2) The same reasoning holds true for proposed terminal buildings and for proposed extensions to existing terminal buildings.
- (3) If at a particular concourse, satellite, or unit terminal building it is the current practice of a particular airline to perform all or most passenger loading by means of second-level loaders, then all costs incurred by providing the same capability

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at each 2707 gate position shown for that airline are attributable to the 2707.

- (4) At concourses, satellites, or unit terminals where the airport operator or the airlines have installed loaders at only a few of many positions, second-level loading is not considered to be normal practice. Therefore, at those terminals, no loader costs are attributed to the 2707. If an existing loader can be used, the costs of any required modifications to it, plus the costs of a second new loader are allocated to the 2707.

From the foregoing criteria, it can be appreciated that, for a particular airport, passenger-loading costs might be charged to some SST positions and not to others. To prevent any misunderstanding of the average costs reported per position, the summary of costs given in each airport evaluation report shows both the total number of 2707 gate positions investigated and found to be feasible and the number of such positions for which passenger-loading costs are considered attributable to this airplane.

The costs are necessarily approximate, and perhaps somewhat conservative. The data obtained on existing passenger-loading installations at some terminal facilities were incomplete, and for some makes and models there are no cost histories for the kinds of modifications required to make the loaders compatible with the 2707.

Where no data were obtained on the maximum vertical adjustability of existing or firmly-planned loaders, it was conservatively assumed that, if retained for use at SST gate positions, such equipment would require modification to enable their cabs to match the sill heights of either the forward or second door of the 2707. It was further assumed that the longer telescoping models, after being modified, would remain compatible with current

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aircraft. On the other hand, it was assumed that the replacement, resetting, or modification of existing short nose-loaders would result in a gate position's becoming exclusively an SST facility.

2.2.4.3 Fuel System

2707 fuel will be a standard commercial kerosene of the same grade as that used by subsonic jet airplanes. Thus, the existing fuel storage and distribution systems may be used for both supersonic and subsonic airplanes.

Fuel will be loaded through two under-wing fueling stations having two hose receptacles each. The fueling ports are located under each wing stub (see Figure II for dimensions). The aircraft is designed to accept 2,000 gpm at a maximum pressure of 50 psi.

At those airports where underground fuel supply lines are not installed, it will be practical to refuel the 2707 from tenders, although a means will have to be provided to reach the fuel hose receptacles, which are about 12 feet above the ground. A modification providing a platform on the tender itself would satisfy this requirement.

The designs of most existing underground systems have been based upon a maximum fueling rate of 1,200 gpm per aircraft. In general, the 2707 will occupy two current gate positions. Since the maximum flow rate of 2,000 gpm for the Model 2707 is less than twice the design flow rates of 1,200 - 1,600 gpm of current jet aircraft, it is judged that increases in the numbers and sizes of the trunk and loop pipe lines of existing underground fuel systems will not be required.

In the future, some airport operators, tenant airlines, or fuel suppliers may install additional trunk or loop capacity. They may in addition, or as an alternative, increase the pumping capacities and line pressures of existing underground systems. Certain of such modifications will be necessary in the normal course of converting the airline fleets from piston- to turbine-

engine equipment. Others will be necessitated by increases in peak-hour traffic, which will place on some systems instantaneous demands in excess of those assumed in their designs. Modifications made for these reasons are not considered to be attributable to the 2707. Because its schedule patterns will probably differ from those of subsonic aircraft, the 2707 may, in fact, alleviate the peak-hour instantaneous demand problem.

Existing fuel hydrants may not prove to be suitable for fueling the 2707 at the maximum rate specified. If so, a larger (possibly four-inch) connection may be necessary to satisfy the requirement of 1,000 gpm per ground fueling station. Accordingly, the costs of providing new hydrants and laterals have been estimated and attributed to the 2707.

Similarly, it is evident that existing fueling carts would not be suitable to service the SST. However, carts capable of serving supersonic transports as well as current, large subsonic transports can be anticipated to be in use before the 2707 is introduced. Inasmuch as the proportion of the unit cost of such carts fairly attributable to the 2707, as well as the number of them required per compatible gate position, cannot be ascertained at this time, no expenditures will be expected for the modification of current models, or for incremental costs of new ones.

At most airports, bulk fuel supply systems and bulk and satellite storage systems will have to be increased for the rapidly increasing rate of traffic growth and the conversion to an all-turbine fleet of airline aircraft. Such improvements may be expected to provide for a much greater daily demand than those anticipated when the systems were designed. For the reasons previously cited in connection with distribution and loop pipelines, the costs of such expansions are not considered to be specifically chargeable to the 2707.

For airports having underground fuel systems, the costs attributable to the 2707 for modifications are reported on a per-gate-position basis.

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Modification costs were determined for each feasible SST gate position at concourses, satellites, and unit terminals now served, or soon to be served, by such a system. These costs were totalled and averaged. The number of gate positions for which costs were estimated is reported with the average cost.

2.2.5 Blast Effects

Figures XI and XII show the profiles of engine blast velocity and temperature contours for two different levels of thrust - maximum augmented power and breakaway power. The first, associated with takeoff, is applicable to areas to the rear of runway thresholds. Breakaway power is of interest primarily in terminal areas and at holding aprons where the efflux velocities shown would be developed at the start of taxiing.

The engines of the 2707 will be capable of developing thrusts considerably greater than those developed by current airline jet engines. They will do this primarily by accelerating correspondingly larger masses of air. While their jet wake velocities will be somewhat higher for ground maneuvering than those of present-day turbo-fan engines, they will differ little from those of the most powerful subsonic turbojet engines now in airline use. The greater height of the 2707 engines, as compared to those of current underwing engines, tends to offset the effects of higher velocities as related to vehicles and personnel on the ground.

In terminal areas, the principal operational difference anticipated is that the 2707 will be towed or pushed somewhat farther from terminal faces and other aircraft more frequently than is the present practice; this difference will be minor and will not significantly alter terminal operations.

The 2707 engine exhaust velocity and temperature impingement on the runway during takeoff rotation, although greater than present subsonic jets, is not anticipated to have any adverse effects.

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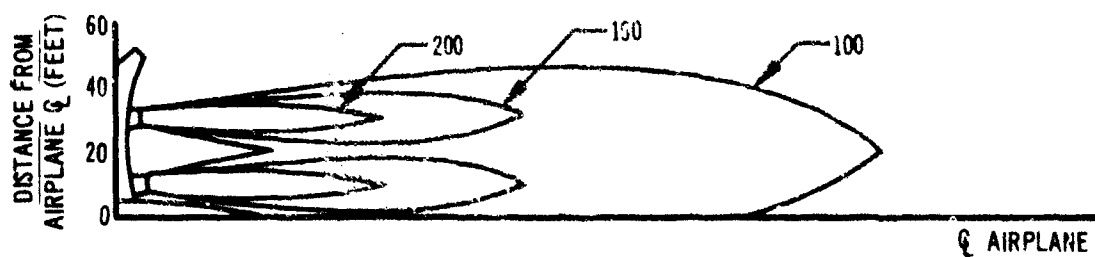
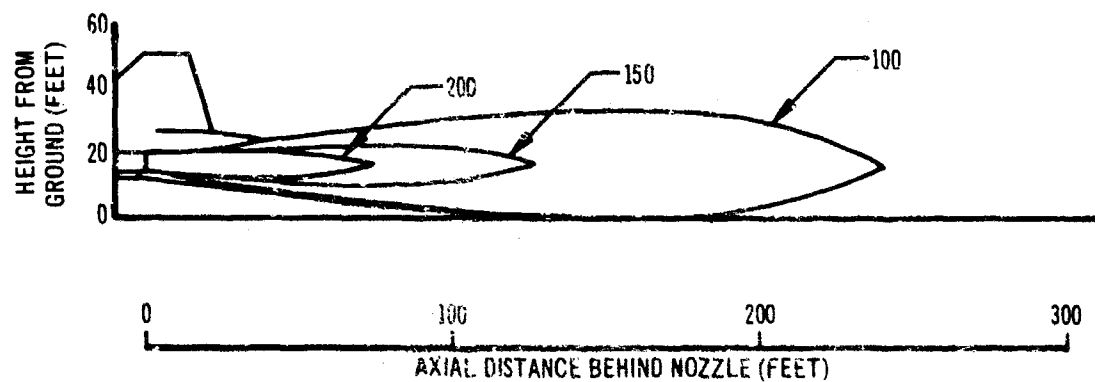
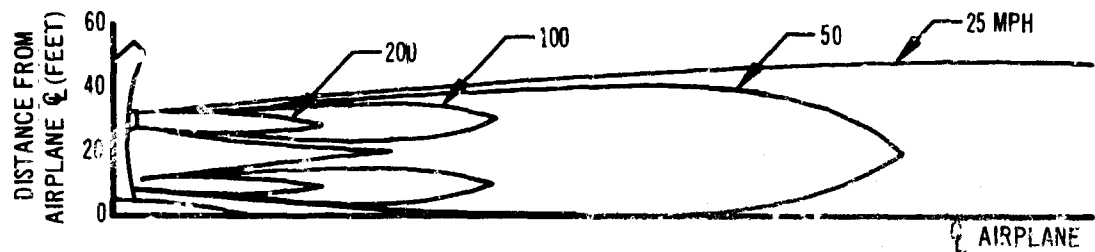
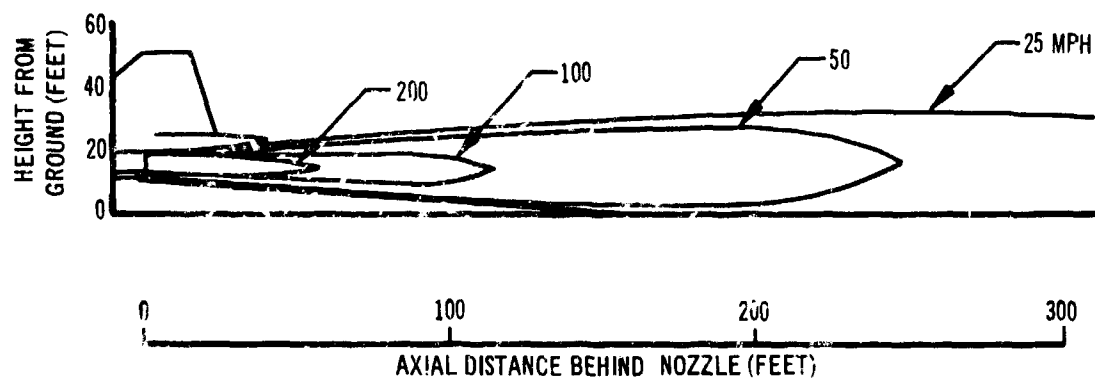


Figure XI. Velocity and Temperature Profile, Breakaway Power - Boeing 2707 (GE4-J5P Engine)

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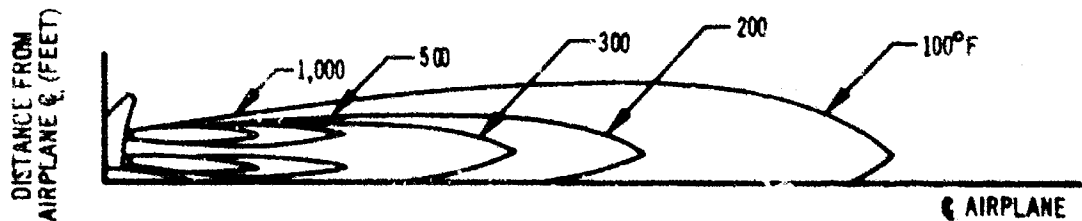
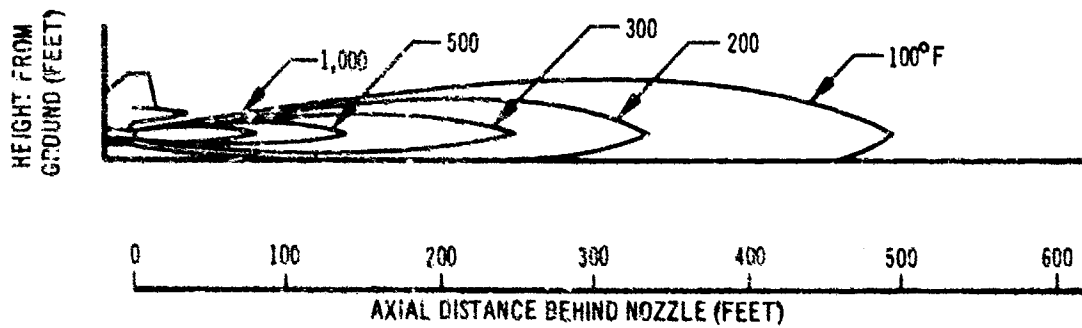
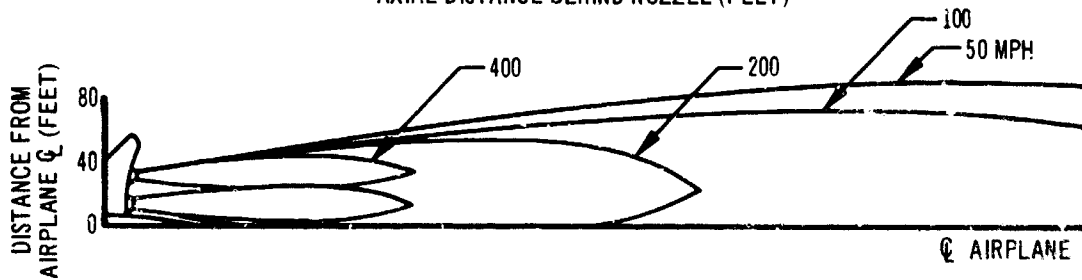
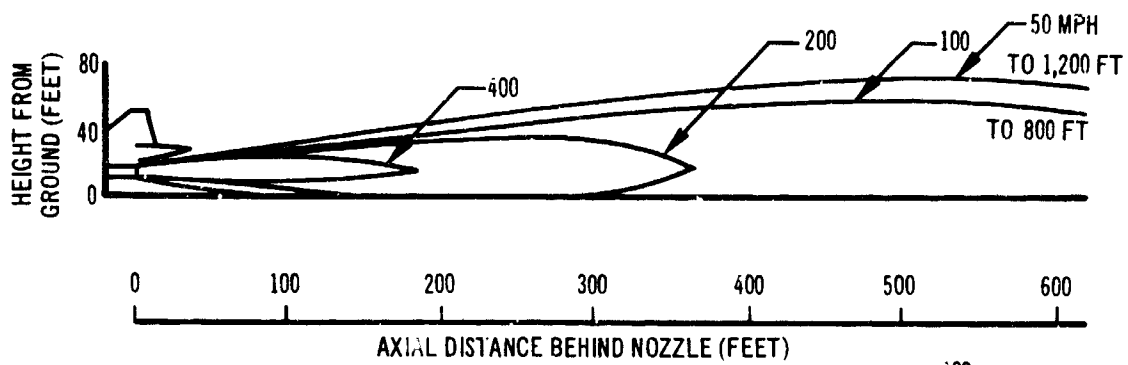


Figure XII. Velocity and Temperature Profile, Maximum Augmented Power - Boeing 2707 (GE4-J5P Engine)

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Generally there is no incompatibility of the 2707 with the airports studied in the area of blast effects, except where blast fences must be lengthened to be effective for the SST.

2.2.6 Fire Rescue Equipment

Considerable research and development in aircraft fire rescue technology is in progress. The FAA and the military are engaged in studies and experimental programs designed to improve equipment response time and fire-fighting materials, capabilities, and techniques.

With the advent of the stretched versions of today's jets and the larger subsonic jets the aviation industry will be faced with the problems of achieving the capability to rescue larger numbers of passengers from individual aircraft fires. Since these planes precede the 2707 and the passenger carrying capacities are comparable, the capabilities developed will serve for the 2707 requirements also.

The temperature-resistant titanium fuselage of the 2707 will add extra minutes of protection for the occupants. The arrangement and size of the exits permit evacuation of passengers on the ground in 90 seconds with all exits blocked on one side. It is therefore, not anticipated that new or additional types of rescue equipment will be required for the SST.

2.2.7 Runway Lengths

Takeoff and landing runway length requirements for various performance conditions of the 2707 are shown in Figures XIII and XIV. It is apparent from these figures that the runway lengths required are less than those at all the airports evaluated in this report.

All the airports are therefore considered compatible, and will not be discussed further in the evaluations.

The usable runways are shown as unshaded on Plate 1 of each of the airports.

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W_a = 633 LB/SEC

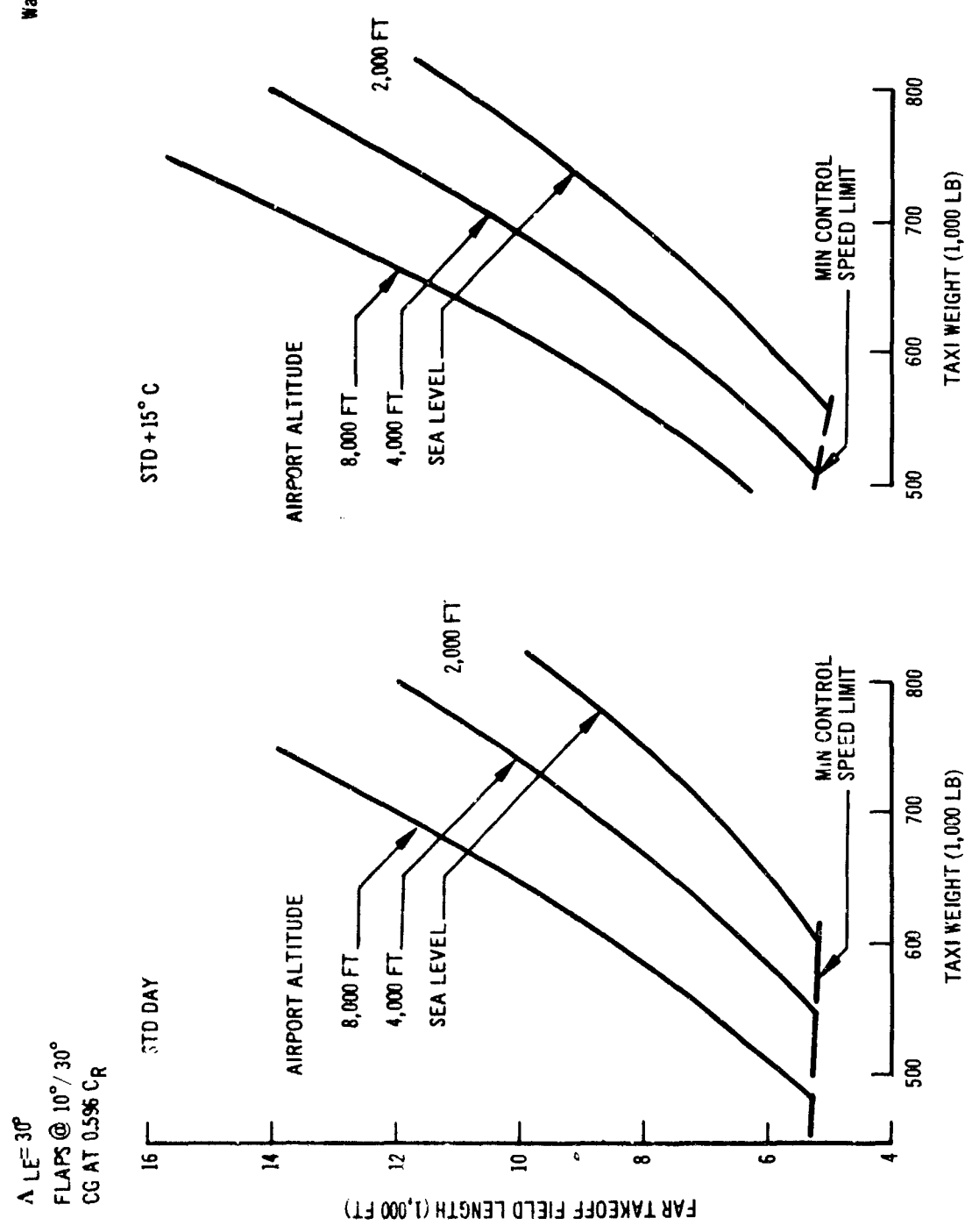


Figure XIII. Runway Requirements, 2707-200 Takeoff, Maximum Augmented Power

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$\Delta_{LE} = 30^\circ$
CG @ 0.576 C_R

3° GLIDE SLOPE

30°/50° FLAP SETTINGS
 $V_{APP} = 1.3 V_{SFAR}$ (DRY FIELD)
 $V_{APP} = 1.4 V_{SFAR}$ (WET FIELD)

FAA RULE 121.195 USED FOR
WET RUNWAY ONLY

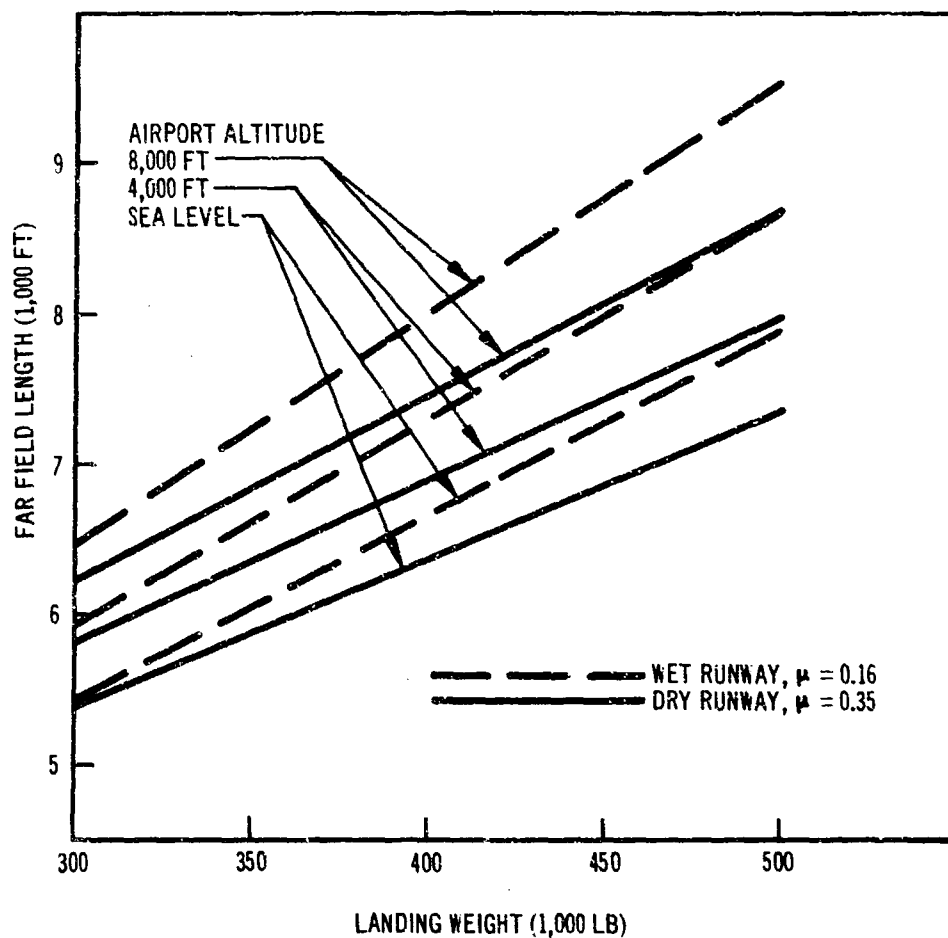


Figure XIV. Runway Requirements, FAR Landing, 2707-200, Std Day

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2.3 Economics and Costs

One of the functions of this report was to evaluate existing incompatibilities between the proposed SST and the study airports. Where an incompatibility was determined to exist, it was defined as well as possible and a logical solution projected. Using cost histories for similar projects at the airport where the incompatibility was found, the cost of resolving the problem was estimated.

In most cases, the existence and magnitude of any incompatibility were plainly defined to the degree of significance warranted by this report. However, at three airports (New York, Los Angeles, and San Francisco) this definition was not readily apparent. In these cases, engineering judgment suggested alternate solutions and cost estimates were included for both a "best" estimate and a "high" estimate.

Cost items are presented as a total figure except items involving gate positions. Since the exact number of gate positions were not established, those costs were presented on a "per gate position" basis. To prevent presenting excessive detail, the costs of the gates at each airport were averaged and the average cost presented. The gate position costs covered various factors such as loaders, fueling facilities, and apron inlays.

All estimates are based on best available 1966 "in place" cost information applicable to the local areas involved.

Items which are peculiarly applicable to individual airports are explained in the evaluations and will not be covered in the general criteria.

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3.1 Airport Evaluation - Anchorage International Airport - ANC

3.1.1 Structural Evaluation of Pavements

All of Anchorage's pavements are of flexible construction and are supported by a sand filter course up to two feet thick. Although subgrade construction of this kind is nonplastic, conditions at Anchorage are reported such that extensive areas of the subgrade hold water and are susceptible to frost. Hence, the Airport's operator recommends the use of an FAA subgrade classification no higher than F6. No CBR data have been obtained.

Runway 6-24, now 10,600 feet long, was extended 2,200 feet in 1961. The original runway construction comprised a number of different pavement cross sections, none less than 35 inches in total thickness. The extension itself was constructed to this minimum thickness. Most terminal area and taxiway pavements are 37 inches thick.

The existing pavement is in good condition except for some longitudinal sags in the runway and taxiways, which are judged to be the results of frost action.

Use of the FAA method of pavement design with the F6 subgrade classification results in a required flexible pavement thickness for the DC-8 of 34 inches; for the SST the requirement is 32 inches. Both aircraft, therefore, appear to be compatible with Anchorage's pavements.

3.1.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Anchorage International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the Airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in Paragraph 2.2.2.3 of this report. The

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specific assumptions made for the investigation of the fillets at Anchorage are as follows:

- (1) Runway 13-31 will be extended as shown on Plate ANC-1 prior to the introduction of the SST. As a result, its exit taxiways would be used routinely by the 2707.
- (2) The Airport's operator has in the past improved the maneuverability of intersection fillets; and it may be expected that additional improvements will be made from time to time in the future. Nevertheless, the cost estimates given in this report have been based upon the conservative assumption that existing fillets of inadequate radii will be improved solely because of the higher maneuvering requirements of the 2707.
- (3) The terminal apron expansion proposed on the Airport Master Plan will have been accomplished prior to the introduction of SST operations. As a result, improvements to the fillets at the periphery of the existing terminal apron need not be considered.

In view of the foregoing, it is believed that the following assessment of required fillet modifications is reasonable and conservative.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	3	5
Rare usage	4	0
Runway-taxiway		
Normal usage	8	4
Rare usage	9	0
Taxiway-terminal apron	See Paragraph 3 above	
At holding aprons		
Normal usage	2	2
On maintenance area routes		
Rare usage	2	0
TOTAL number of fillets investigated	28	11

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate ANC-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this Section.

Holding Aprons - At Anchorage International Airport, there are three holding aprons: one near the threshold of runway 13 and one at each end of runway 6-24, the primary runway.

Runway 6: The holding apron at the southwest end of the primary runway does not meet the criteria stated in paragraph 2.2.2.4. Therefore, the costs of paving it to an adequate width have been estimated and allocated to the 2707. It should be noted that the north edge of the apron (an extension of the parallel taxiway) cuts into the slope of a hill about 30 ft. high, but that its west

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side has been built on a shallow fill. The assumption has been made in the present study that the apron would be widened to the west. Such a widening would incur only minor costs for grading work.

Runway 24: According to the criteria set in paragraph 2.2.2.4, the apron dimensions are more than adequate.

Runway 13: At the present time, this runway is only 5,000 feet in length. It appears extremely unlikely that the SST would ever use the holding area at the existing Runway 13 threshold.

3.1.3 Evaluation of Structures

Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3 and therefore may be considered compatible with the 2707.

3.1.4 Terminal Area

Anchorage International Airport is in the process of a complete revision of its terminal area. A hexagonal satellite located southwest of the central terminal building has been built. This new satellite is currently being served through the existing finger pier via a temporary connection. The construction of the planned new concourse indicated on Plate ANC-2 will provide the satellite with a permanent connection to the central building.

3.1.4.1 Maneuvering and Docking (See Plate ANC-2)

For the Boeing Model 2707, it is anticipated that provisions for single forward-door loading only need initially be installed at Anchorage. The three nose-in positions shown have been based on this premise. The positions shown have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and passenger loading procedures.

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3.1.4.2 Passenger Loading Devices

A single swinging-telescoping loader has been installed on the west face of the new satellite at Anchorage. This loader will mate with the forward door of the 2707 with very little or no modification.

It has been assumed that when loaders are installed at the other two positions shown they will be of a design compatible with the 2707.

3.1.4.3 Fueling System Modifications

On the assumption that all SST gate positions will be at the hexagonal satellite building, only the underground fueling system serving that particular facility was investigated.

The existing system is actually two duplicated systems, one installed by each of two fuel companies. Each system is capable of delivering two different fuel formulations. A considerable flexibility in aircraft parking modes has been provided by locating the hydrants in three clusters of four each at each satellite gate position.

Since it is anticipated that airlines operating the SST's would use only the nose-in parking mode at the satellite, it is judged that two clusters of four hydrants each would be required per SST gate position. Accordingly, the costs per gate position are those estimated for eight new hydrants and the supply laterals required therefor.

3.1.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Costs</u>
Modification of 11 fillets:	
Full-strength pavement @ \$8/s.y.	\$14,000
Shoulder pavement	18,500
Revisions to lights and signs	15,000
Widening of Runway 6 holding apron:	
Full-strength pavement @ \$8/s.y.	15,500
Shoulder pavement	5,000
Revisions to lights	1,000
TOTAL	<u>\$69,000</u>

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Estimated Unit Costs Per Gate Position

Fuel system modifications \$20,000

The average unit cost per gate position of fuel system modifications was obtained by averaging the individual costs for all three of the gate positions determined to be feasible for SST usage.

NOTE: PLATES ANC-1 & 2 are not precisely accurate to the latest planning, since the art work was prepared before the receipt of latest data. The differences, however, do not affect or alter the evaluation, and it was felt that correction of the photo overlays was not warranted.

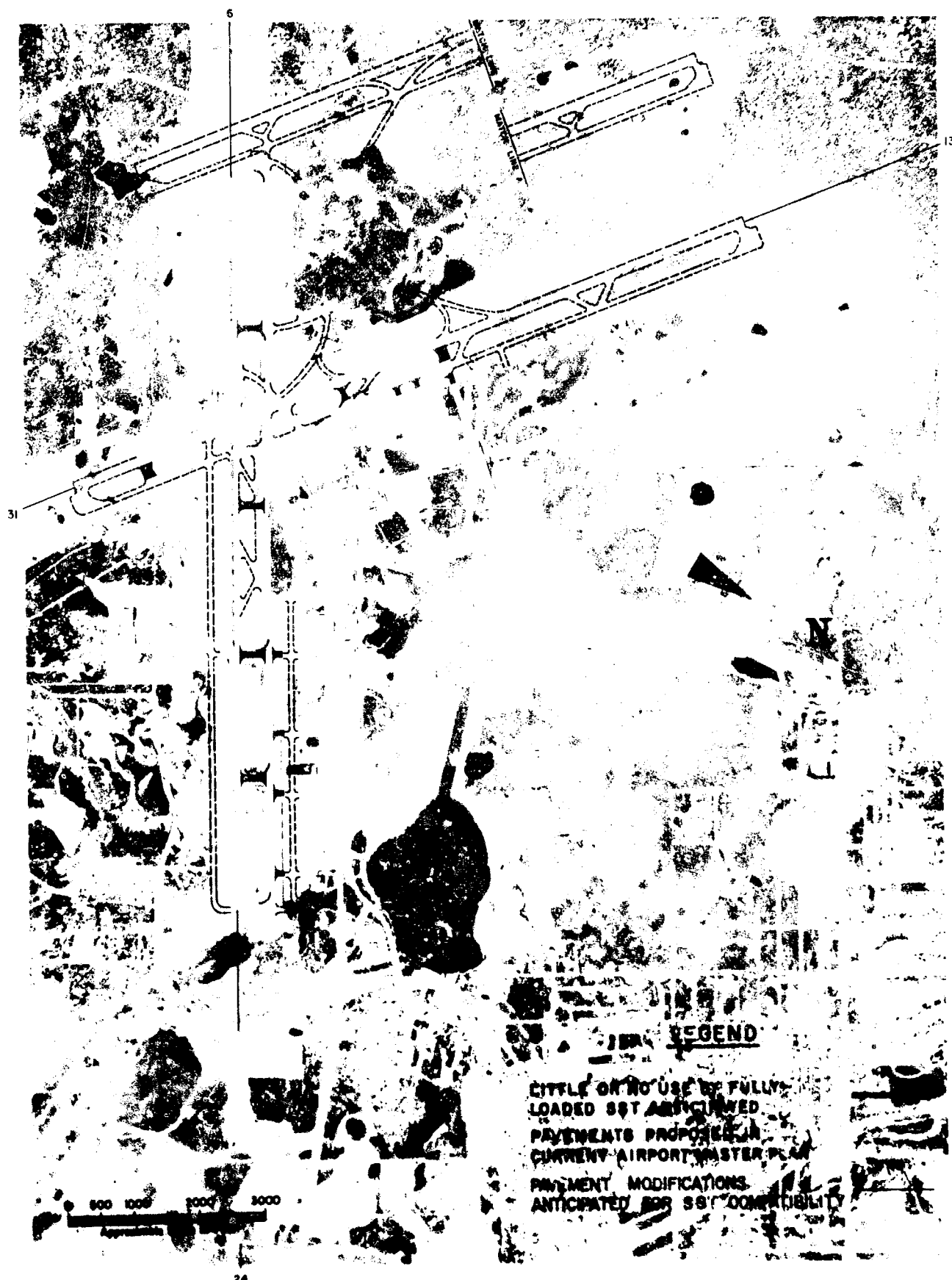
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Anchorage International

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LEGEND

FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN



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Anchorage International

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3.2.1 Evaluation of Pavements

Friendship International Airport was constructed on a tract of low hills, the tops of which were used to fill the valleys. Sands, clays, gravels and mixtures thereof deposited in lens-like layers to depths of 100 feet or more, constitute the old marine deposits underlying the site. During construction, supercompacting equipment located lenses of soft material which were subsequently excavated and replaced with select granular backfill. Modified Proctor densities of about 99 per cent were obtained on the compacted subgrade.

Except for concrete inlays in the terminal-area apron, all of Baltimore's pavements are flexible. Those placed in 1950 during the period of initial construction were composed of a 5-inch granular base disked into the subgrade and compacted to 100 per cent density, 7 inches of bituminous base placed in three lifts, and a surface course 3 inches thick. In 1964-1965, all such pavement was given a leveling course, which varied in thickness from 0 to 4 inches, and a $1\frac{1}{2}$ -inch overlay. Thus, the total thickness of the airport's original pavements varies from $16\frac{1}{2}$ to $20\frac{1}{2}$ inches.

Newer flexible pavements are similar to those constructed in 1950, except that their subbase courses are 10 inches thick and they have not been overlaid. Thus, their total thickness is 20 inches.

For use with the FAA flexible pavement design procedure, an FAA subgrade classification of F1 is recommended by engineers of the Department of Aviation. For use with the Corps of Engineers method, a minimal CBR value of 20 is judged to be reasonably conservative by the Airport's operator and consultants. Using these data, it is found that the following pavement thicknesses, in inches, are required in critical areas:

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	<u>DC-8-55</u>	<u>2707</u>
CBR = 20	18.5	20
F1 (FAA)	15	13.5

For purposes of the study, the Corps of Engineers' pavement design method has been applied. As a result, the 2707 is the critical aircraft.

Since all of the newer pavements are 20 inches thick, they may be presumed adequate for the SST.

As noted above, the older pavements now range in thickness from $16\frac{1}{2}$ inches to $20\frac{1}{2}$ inches, depending on the amount of settlement of the original construction. For the 2707, the $20\frac{1}{2}$ -inch thickness corresponds to the pavement requirements of a subgrade having a CBR value fractionally lower than 20; while the $16\frac{1}{2}$ -inch thickness corresponds to CBR of 26.

It is logical to assume that the recommended minimal CBR value is most apt to reflect the subgrade conditions underlying those areas of older pavement that required 4 inches of leveling courses when the $1\frac{1}{2}$ -inch overlay was placed. Since the pavements in such areas are now $20\frac{1}{2}$ inches thick, the 2707 would impose no additional thickness requirements on the weakest subgrades.

Original pavements that underwent little or no settlement, on the other hand, may be presumed to have stronger subgrades. It is not unreasonable to assume that higher subgrade strengths generally occur in such areas, in which case the $16\frac{1}{2}$ -inch thick pavement would be adequate for the SST.

The range of thicknesses between $16\frac{1}{2}$ and $20\frac{1}{2}$ inches probably reflects the range in values of subgrade strength. Since the SST would appear to be compatible with the thickest and thinnest pavement sections, the conclusion is that all areas of older pavement, as overlaid, are presently adequate.

3.2.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Friendship International Airport were carefully investigated. The geometrics of the

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Fillets were taken from plans made available by the Airport's operator.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at Baltimore are as follows:

- (1) If Runways 15-33 and 10-28 were to remain at their current lengths, several of the exit taxiways nearest to their landing thresholds would receive little or no use by the SST. As plate BAL-1 indicates, however, both runways are to be extended. As a result, the exit taxiways in question will be used routinely by the SST. The assumption has been made that the planned extensions will be completed prior to the introduction of the SST.
- (2) The Airport's operator has from time to time in the past, in conjunction with other work, made improvements to existing intersection fillets. Presumably, others will be improved in the future. However, the present investigation takes into account only those fillet improvements that are firmly planned for 1967.
- (3) As shown on Plate BAL-2, extensive revisions are planned for the terminal apron and its peripheral taxiway. It is assumed that these revisions will have been accomplished prior to the introduction of the SST; hence, certain existing fillets need not be investigated for compatibility with the 2707.

In view of the foregoing, it is believed that the following assessment of required fillet modifications is reasonable and conservative.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	3	5
Rare usage	2	0
Runway-taxiway		
Normal usage	12	0
Rare usage	17	0
Taxiway-terminal apron	See paragraph 3 above.	
At holding apron		
Normal usage	3	0
TOTAL number of fillets investigated	37	5
<u>Curved Taxiways</u>		
Normal usage	3	4

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate BAL-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - At present, there are three major holding aprons at Friendship International Airport. A fourth is being constructed at the runway 33 threshold in conjunction with the extension of that runway. When this construction is completed, there will be holding aprons at each end of runway 10-28 and runway 15-33. Each will require expansion to be adequate for combined SST-747 operations. Cost of this additional paving has been attributed to the SST.

There are small paved areas used for holding near the threshold of runways 4 and 33. Another such area is located adjacent to taxiway "G," near

the end of Runway 10. The Department of Aviation states that these areas will not be used by the supersonic transport, and, therefore, a cost has not been estimated for their enlargement.

Terminal Area Inlays - A number of rigid-pavement inlays have been constructed in the terminal area apron at Friendship, and it is the opinion of the Airport's operator that they would be required at the SST gate positions. Accordingly, a cost per gate position has been estimated and included on the basis given in paragraph 2.2.2.6.

3.2.3 Evaluations of Structures

Bridges and Box Culverts - Two box culverts required investigation. One, a 7'-0" x 5'-0" reinforced-concrete structure, passes beneath runway 10-28, with a depth of cover of about 18 feet, approximately 3,500 feet from the west threshold. The other, a 9'-0" x 6'-6" reinforced-concrete structure, passes beneath taxiway "F" with a depth of cover of about 22 feet.

For both structures, it was found that the critical section was the mid-point of the top slab of the box. The calculated stresses induced in reinforcement and in concrete were found to be below those allowed. Therefore, it is anticipated that no need will arise for strengthening either structure.

There are a number of drainage structures so located in the airfield pavements at Baltimore that they are subjected directly to aircraft gear loads. Each of the different types was investigated to determine its adequacy for supporting the maximum loads of the 2707. The investigations included grates, supporting beams, and footings. All grates and their supporting beams would be under-stressed by the 2707's imposed live load with 30 per cent impact factor. Stresses in footings are within the design limits, as are the soil bearing pressures.

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Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3 and therefore may be considered compatible with the 2707.

3.2.4 Terminal Area (See Plate BAL-2)

The terminal area at Friendship International Airport follows the central-terminal-and-finger-pier concept. Three separate buildings connected by pedestrian concourses compose the center of the terminal area. Two finger piers have been built, but not to their ultimate lengths. Extensions of the two existing piers and the building of a third are in the construction or planning stage. For the purposes of the present study, a "Y" configuration has been assumed for the extension of the North Pier.

3.2.4.1 Maneuvering and Docking

Eight SST positions have been indicated at BAL, two each at Finger Piers "B" and "C" and two at each leg of Finger Pier "A." Internal parking is not feasible owing to restricted maneuvering room and encroachment on the potential parking positions of smaller aircraft. The four positions shown off the end of the piers could possibly be used as taxi-out positions. Clearance has been maintained for forthcoming jumbo jets on all apron taxiways.

3.2.4.2 Passenger Loading Devices

All enplaning and deplaning of passengers at Baltimore is presently by means of mobile ramps. Currently being purchased for installation are ten swinging fixed-length loaders. Since all of the positions shown on Plate BAL-2 are located at terminal facilities yet to be constructed, it has been anticipated that all of the equipment now on order will accommodate the 2707.

3.2.4.3 Fueling System Modifications

Aircraft fueling at Friendship International Airport is now performed

with mobile tenders. The tenders are operationally flexible and can be furnished in quantities sufficient to supply the 2707 needs. Should a hydrant system be installed by the airlines serving Baltimore, it is assumed that the initial installation would be made compatible with the demands of the supersonic transport.

3.2.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Costs</u>
Modification of 5 fillets and 4 curved taxiways:	
Full-strength pavement @ \$7/s.y.	\$11,000
Revisions to lights and signs	7,000
Modification to 4 holding aprons	
Full-strength pavement @ \$7/s.y.	<u>51,000</u>
Total Estimated Costs	\$69,000

Estimated Unit Costs per Gate Position

Terminal apron inlays	\$18,000
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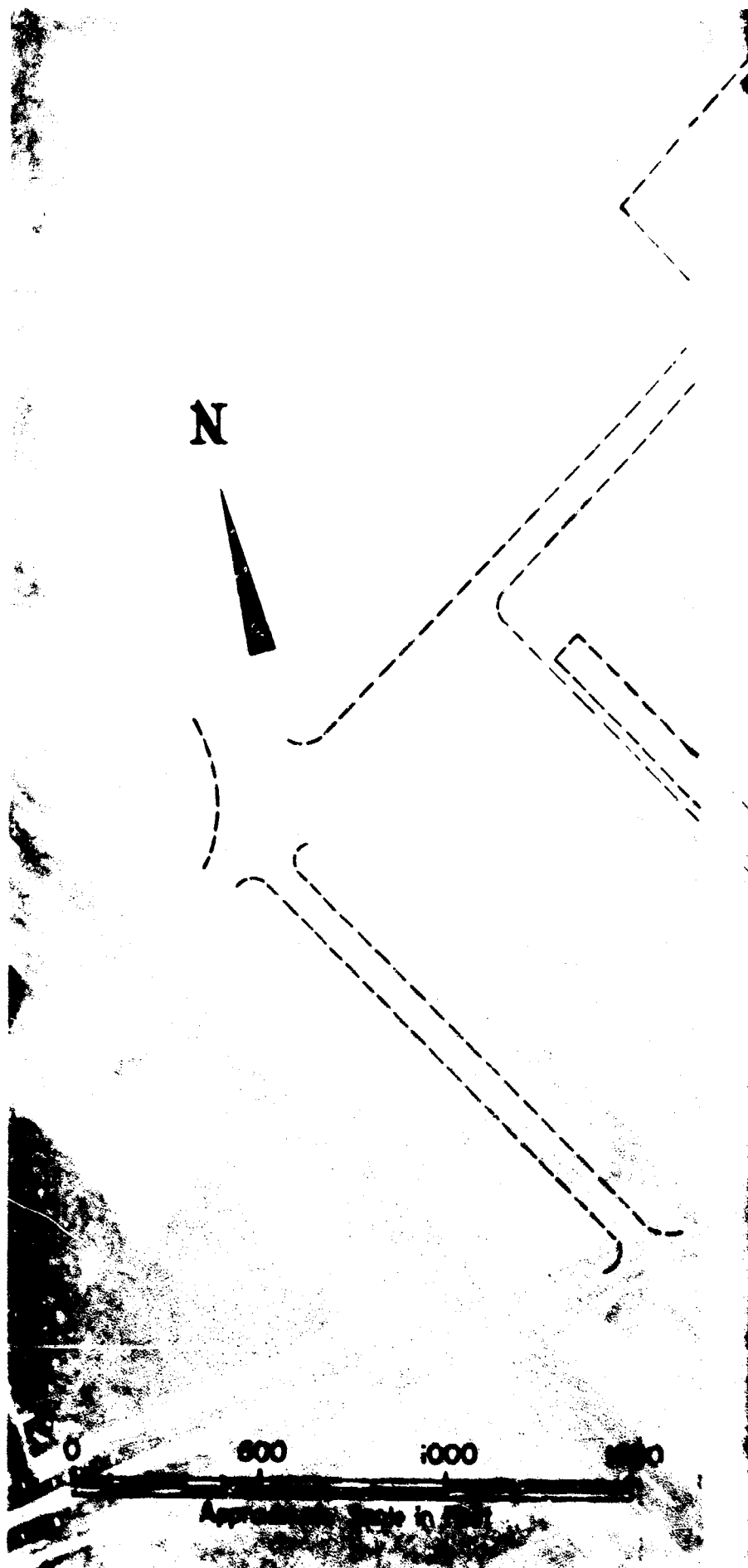


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LEGEND

FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN





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3.3 Airport Evaluation - Logan International Airport - Boston - BOS

3.3.1 Structural Evaluation of Pavements

Logan International Airport is constructed on a hydraulic clay fill having an FAA soil classification of E-7 or E-8. For the prevailing conditions of drainage and frost penetration, the subgrade has been given an F7 classification. No CBR data have been obtained. The hydraulic fill was placed on top of an organic silt layer. The intention was to have the fill displace the silt and come to rest on an underlying layer of firm clay. The organic silt was not fully displaced, however. As a result, there have been settlement problems at the airport.

All existing pavements are flexible. Except in the original terminal area where a 10-foot-thick layer of pit-run gravel was placed prior to paving, the pavements were constructed directly on the clay fill. The typical original pavement section comprised:

- 3-inch surface of asphaltic concrete
- 4-inch penetration macadam base,
- 8-inch waterbound macadam base,
- 24-inch gravel sub-base

for a total thickness of 39 inches.

During the period 1959-1963, certain runway settlements were corrected by leveling courses and an overlay. The program added a minimum of 3 inches to the runways. In the areas of maximum settlement the total thickness of flexible pavement added was as high as 27 inches. Some sections of taxiways that developed settlements have also been corrected. Elsewhere they have received seal coats. The critical pavement areas in the terminal and the pavements at aprons and taxiway intersections have been sealed with a tar-rubber compound to enable them to resist deterioration from fuel spills.

Visual inspection showed all the pavements to be in good condition.

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Some minor longitudinal rutting has appeared over a length of about 100 feet in one of the taxiways, however.

Logan's pavements were designed in accordance with the Equivalent Single Wheel Load method developed by the Civil Aeronautics Administration and retained by the FAA. For the design of critical pavement sections, the use of the method results in a thickness requirement for the DC-8-55 of 39 inches; for the 2707, the requirement is 37 inches. Since all flexible pavements are at least 39 inches thick, the requirements given above for both aircraft are met.

New terminal apron construction in the current expansion program is 15-inch-thick portland cement concrete. In some areas it is being placed directly on old pavements; in others, on 24 inches of gravel sub-base. Aprons so constructed will be compatible with the SST.

3.3.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Logan International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the Airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The one specific assumption adopted for the investigation of the fillets at Logan was that the terminal apron expansion shown on Plates B08-1 and B08-2 will be completed prior to the introduction of SST operations. Accordingly, the adequacy of fillets at the periphery of the existing terminal apron was not investigated.

There are relatively few taxiway-taxiway intersections at Logan, and most of the taxiways are of widths greater than 75 feet. This circumstance

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tends to minimize the need for and costs of fillet modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. A total of 44 fillets and three curved taxiways was studied. It was determined that two fillets would require improvements.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	3	0
Rare usage	1	0
Runway-taxiway		
Normal usage	13	2
Rare usage	20	0
Taxiway-terminal apron	See above discussion	
Normal usage		
At holding aprons		
Normal usage	<u>5</u>	<u>0</u>
TOTAL number of fillets investigated	42	2
Curved taxiways		
Normal usage	1	0
Rare usage (to maintenance area)	2	0

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

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The total costs for the improvements to the pavements tabulated in the right column and shown on Plate BOS-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this Section.

Holding Aprons

Runway 4R - This apron does not meet the criteria of paragraph 2.2.2.4. It is estimated that a widening to the south of approximately 60 feet would be necessary for its use by the SST. Since the south edge of the expanded apron would be immediately adjacent to the existing south bulkhead service road, it is anticipated that the improvement would require the relocation of approximately 800 feet of the service road. An estimated cost for such a relocation (including the placement of fill in the Boston Inner Harbor, riprap slope protection and paving) is included in the summary at the end of this Section, together with the costs estimated for the apron widening.

Runway 15 - The large paved area at the threshold of this runway is more than adequate for a 747 to pass an SST with the wings of the latter fully extended.

Runway 27 - In accord with the criteria established in paragraph 2.2.2.4, apron 27 requires widening. The estimated cost for this has been included in the summary.

Runway 33 - The apron at the runway 33 threshold now consists of a section of pavement placed for planned runway 9R-27L. If this runway (9R-27L) is not constructed prior to the introduction of the SST into service, that section of it which now serves as the runway 33 holding apron will require widening to meet the criteria of paragraph 2.2.2.4. Assuming that runway 9R-27L will not be constructed prior to inauguration of SST service, an appropriate widening has been laid out and estimated for costs.

Runway 22L - The holding apron included in the 1966 Federal-aid airports program would more than adequately meet the maneuvering requirements of the 2707.

3.3.3 Evaluations of Structures

Bridges and Culverts - Two storm-water drainage structures were investigated for 2707 loadings. They are located beneath the taxiways inter-connecting Runway 4L-22R and the east side of the terminal apron.

A double 3-foot x 4-foot reinforced-concrete box culvert supported on piles carries the flexible pavement of one taxiway directly. A check of the pile loads and the stresses in the concrete and reinforcing steel shows that the structure is capable of carrying the 2707. The calculated maximum pile load is about 24 tons, and the steel and concrete stresses are well below their allowable values.

A pile-supported, concrete-bedded, 84-inch diameter concrete pipe culvert carries storm-water runoff beneath the south taxiway. The minimum cover on the section of the pipe subjected to aircraft loadings is about 5.5 feet. Pipe of the lowest strength (Class I) and having a Class A bedding condition was assumed for the investigation. According to the standard design specifications used in the investigation, the pipe itself and its bedding are more than adequate to sustain 2707 live loads, which are at most only 5 per cent in excess of those imposed by the DC-8-55. The adequacy of the piles could be considered questionable for both the DC-8-55 and the 2707.

The culvert and its foundations have performed satisfactorily under traffic that includes heavily-loaded DC-8's. This is an indication that, for the set of conditions unique to this structure, the standard design specifications

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may be unnecessarily conservative. Since anticipated loads only 5 per cent greater than those now being borne without evidence of distress would not warrant the strengthening of existing pile supports, no costs have been attributed to the 2707 for modifications to the 84-inch pipe culvert.

Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3 and therefore may be considered compatible with the 2707.

3.3.4 Terminal Area (See Plate BOS-2)

Logan's current expansion program will substantially increase the number of gate positions. The four new terminal buildings for the expansion and development of second-level passenger-loading facilities on each of the four existing piers will be completed by 2707 operational date. An additional terminal building - the Northwest - will be undertaken about 10 years from now. The ultimate terminal area plan will comprise seven finger piers with end satellites, the four unit terminals, and the two existing curved concourses.

3.3.4.1 Maneuvering and Docking

The four existing piers and their satellites form a "T"-shape. The shapes of the satellites planned for the future finger piers may not necessarily conform to those shown. Aircraft parking positions will be located at finger piers, satellites, and curved concourses.

The following numbers of SST gate positions are feasible as shown on Plate BOS-2.

2 each at Piers "B," "C," and "D"

4 at pier "E"

3 at the future satellite on the southwest terminal pier

3 at the future satellites on the northwest terminal piers

A total of 16 parked SST's has been shown at the outer gate positions of the existing and future piers. The positions shown at the existing "T"-piers

have been investigated on the basis of their anticipated future development. It can be demonstrated that interior positions are also feasible. All passages have allowed clearance for the forthcoming jumbo jets.

3.3.4.2 Passenger Loading Devices

Planning for second-level loading is still in process. If maneuvering clearances and sill-heights of future aircraft are considered in the selection of loading equipment, the 2707 gate positions shown can be readily adapted for simultaneous two-door passenger loading by proper location of telescoping loaders.

No costs are deemed chargeable to the SST for the adaptation of as-yet unselected passenger loading devices.

3.3.4.3 Fuel System Modifications

Aircraft fueling is now performed with mobile tenders. The tenders are operationally flexible and can be furnished in quantities sufficient to supply the 2707. Should a hydrant system be installed by the carriers at Boston, it is assumed that the initial installation would be made compatible with the 2707.

3.3.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Modifications to 4 fillets:	
Full-strength pavement @ \$9/s.y.	4,100
Shoulder pavement	2,700
Revisions to lights and signs	3,000
Widening of Runway 33 holding apron:	
Full-strength pavement @ \$9/s.y.	19,000
Shoulder pavement	5,000
Revisions to lights	2,000
Widening of Runway 4R holding apron:	
Full-strength pavement @ \$9/s.y.	34,000
Shoulder pavement	7,000
Revisions to lights	3,000
Relocate roadway	50,000

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<u>Item</u>	<u>Estimated Cost</u>
Widening of Runway 27 holding apron:	
Full-strength pavement @ \$9/s.y.	6,000
Revisions to lights	<u>1,000</u>
Total Estimated Costs	\$136,800

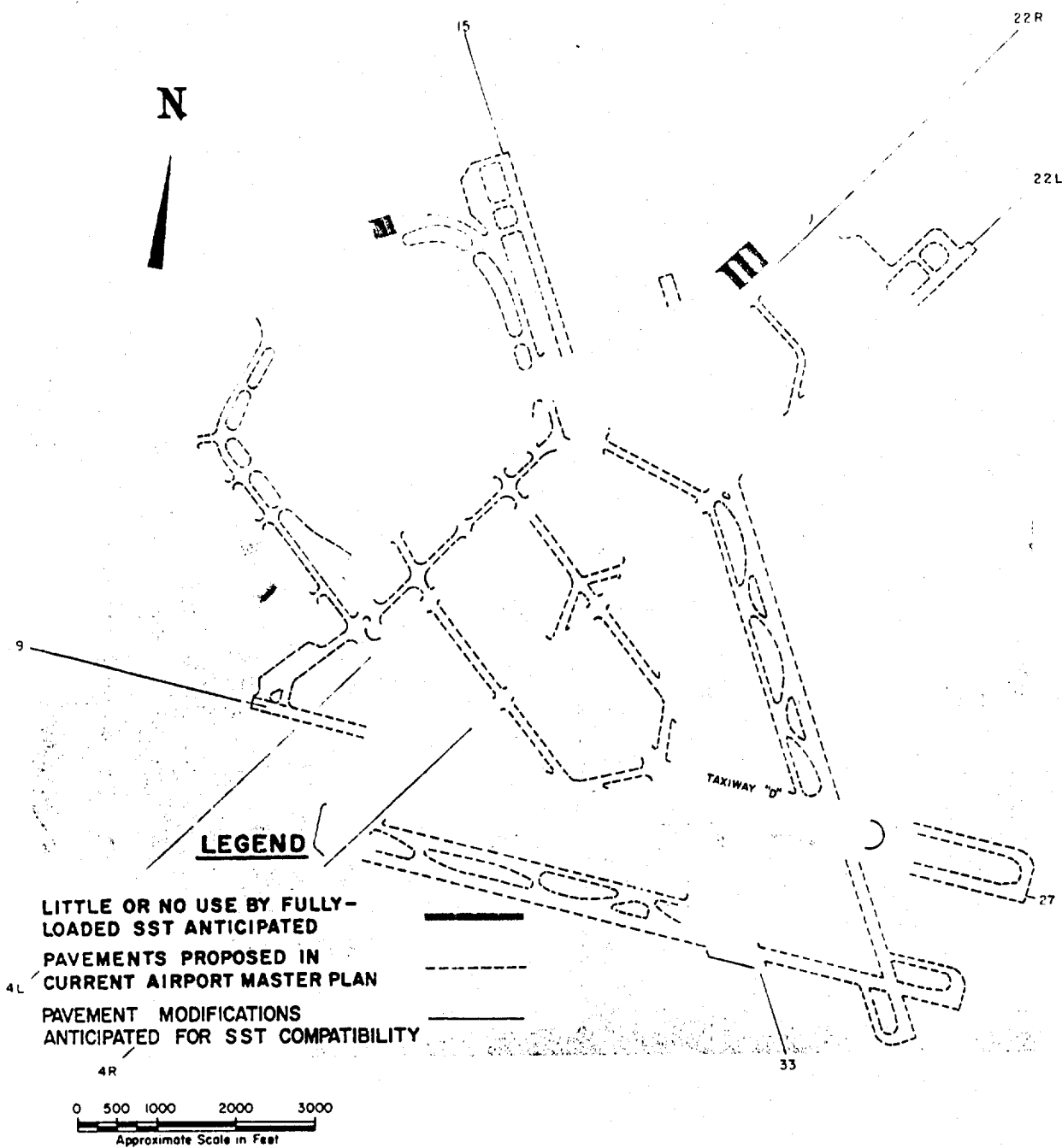
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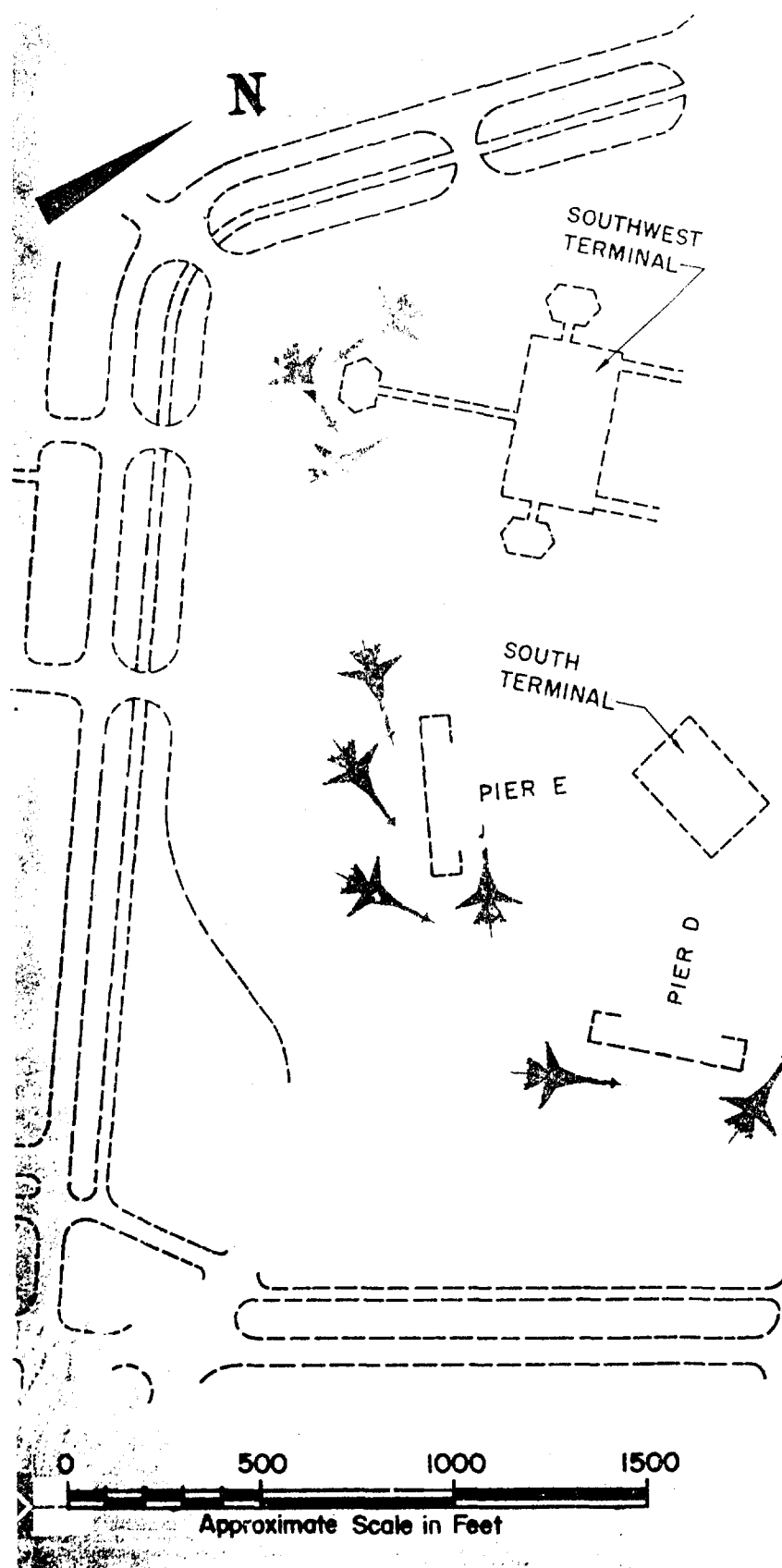
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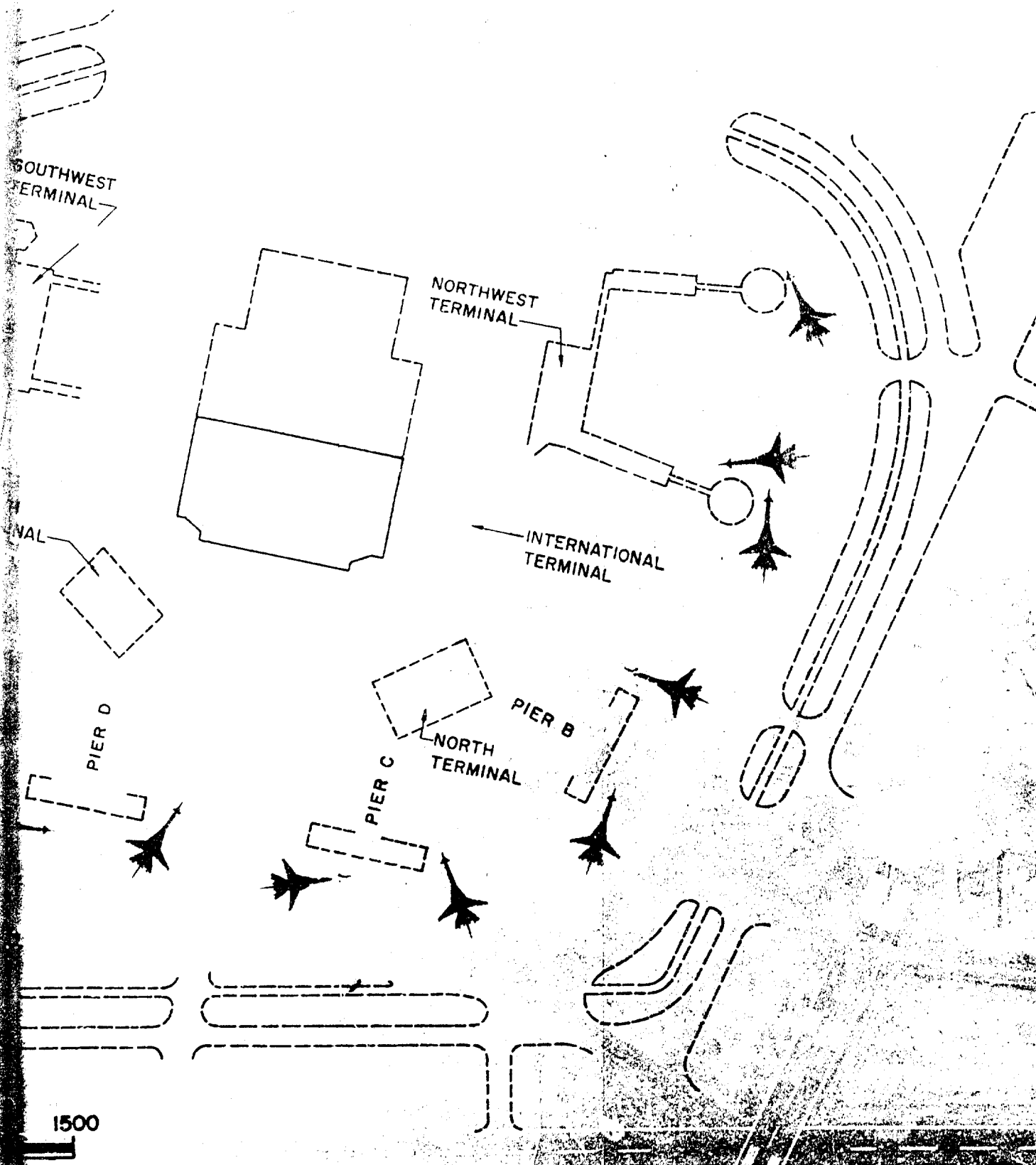


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FEASIBLE SST GATE POSITIONS
 FACILITIES PROPOSED IN CURRENT
 AIRPORT MASTER PLAN
 FACILITIES NOT SHOWN BUT
 EXISTING AS OF SEPTEMBER 1966



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Logan International

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3.4 Airport Evaluation - Washington - Dulles International Airport - DIA

3.4.1 Structural Evaluations of Pavements

All pavements at Dulles International Airport are concrete. Designed for aircraft of 500,000-pound gross weight, they are 15 inches thick on taxiways, aprons, the critical sections of runways, and the central 100 feet of the non-critical sections of runways. The outer 25-foot strips of the noncritical sections of the runways are 12 inches thick.

Engineers of the Bureau of National Capital Airports recommend the use of a modulus of subgrade reaction of $k = 260$ and maximum allowable flexural stresses of 500 pounds per square inch for the 15-inch thick pavements and 680 pounds per square inch for the 12-inch thick pavements. The calculated stresses that would be induced by the 2707 are 61 per cent of the allowable for both the 15-inch and the 12-inch pavements.

From the foregoing, it is easily appreciated that the 2707 would have no problems of compatibility with the Dulles pavements.

3.4.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Dulles International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the Airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at Dulles are as follows:

- (1) Turns of 180° between parallel taxiways are rarely made.

Furthermore, consecutive 90° turns made in opposite directions between two such taxiways are rarely made.

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- (2) Certain cross-taxiways in the vicinity of the terminal apron between the parallel taxiways are intended for future terminal expansion and are rarely turned.
- (3) Under usual operating conditions, takeoffs are from 1L and landings are made on 1R when operations are to the north. When the direction of operations is reversed, takeoffs are from 19L and landings are made on 19R. Nevertheless, we have assumed that arrivals and departures will be made in each direction on both runways. This conservative approach, which preserves flexibility in operations, approximately doubles the cost attributable to the SST for fillet modification.

A total of 134 fillets and 1 curved taxiway was studied. It was determined that 17 fillets would require improvements if the criteria stated in paragraph 2.2.2.3 are to be observed at Dulles. The curved taxiway was found to be adequate.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as New Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	14	14
Rare usage	64	0
Runway-taxiway		
Normal usage	18	0
Rare usage	8	0
Taxiway-terminal apron		
Normal usage	4	3
Rare usage	4	0
At holding aprons		
Normal usage	3	0
Rare usage	<u>2</u>	<u>0</u>
TOTAL number of fillets investigated	117	17
Curved taxiways		
Normal usage	1	0

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate DIA-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this Section.

Holding Aprons - The holding apron serving runways 1L and 30 is adequate by the criteria outlined in paragraph 2.2.2.4 of this report. The 19L apron will require widening. The cost of this widening is attributable to the SST and is included in the cost estimate.

3.4.3 Evaluations of Structures

Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3 and therefore may be considered compatible with the 2707.

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3.4.4 Terminal Area (Service Apron) See PLATE DIA-2

Dulles International is so designed that large airline aircraft are not taxied to the terminal building. All routine ground servicing, as well as the enplaning and deplaning of passengers, is carried out on a long, rectangular aircraft service apron located between the parallel runways at a distance from the terminal building of approximately 2,000 feet. Passengers are carried from the terminal to the apron by mobile lounges. The service apron is divided in half longitudinally by a row of narrow apron operations buildings from which planes are serviced.

3.4.4.1 Maneuvering and Docking

The distance between the apron operations building-line and the edge of apron pavement is 350 feet. A minimum clearance of 25 feet between the parked 2707 and the building-line was maintained in the present study. A 2707 taxiing past a parallel-parked 2707 (both with wings fully extended) can do so while maintaining the same minimum clearance wingtip-to-wingtip.

Four 2707's are shown in typical parallel parking positions.

It should be pointed out that even though the airport will accommodate the 2707 satisfactorily, other considerations are in evidence when the apron is used in conjunction with other large aircraft with greater wing span than the 2707.

If a 2707 passes a parked 747 "jumbo" jet on the apron, approximately 17 feet of additional apron width is needed. If a "jumbo" jet passes a 2707, 7 additional feet of width is needed. (These are assuming a 25-foot wing tip clearance, and a 20-foot wheel strut to pavement edge clearance).

Passing "jumbo" jets are not within the scope of this document, however, consideration should be given to this situation when widening or adding new aprons in the future. (Approximately 32 feet of additional width would be needed.)

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Using the parking positions shown, three advantages are realized:

- (1) The clear areas at those particular positions allow more clearance to taxi in, than those positions in front of another airplane.
- (2) The open areas behind the positions allow more space for the more severe exhaust blast of the SST.
- (3) Passing can be avoided by proper taxi routing in cases where the 747 "jumbo" jets are involved and first in - first out practices cannot be used.

3.4.4.2 Passenger Loading Devices

Dulles International Airport's method of passenger loading, which brings the passengers to the aircraft rather than the aircraft to the terminal, is readily adaptable to the 2707. The only requirement for compatibility is that the mobile lounge be able to mate with the 2707.

Bill heights for the 2707 doors are 15 feet. As presently modified for the DC-8-55, the Dulles mobile lounge will not be able to reach the doors of the 2707 without some manner of adaptation.

There are three reasons for regarding this shortcoming not charged as a cost item at this time:

- (1) As the lounges placed in service in 1962 reach the end of their service life, and as the initial fleet becomes inadequate to cope with traffic volumes, new ones will be ordered. The additional capability required could be built into them at slight cost.
- (2) Simple modifications, such as the addition of a few steps at the end of the walkway, or more basic changes to (or replacement of) the walkway's elevating mechanism, could be made to a

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sufficient number of the lounges now operating to service SST operations.

- (3) The current model of the lounge could be used in conjunction with mobile ramps having the required capability. It is standard practice now with some of the airlines serving Dulles to place a mobile ramp at the aircraft door, and then to dock the mobile lounge at the ramp. When the lounge departs for the terminal building, the ramp remains in place for the use of airline personnel.

For the above reasons, we judge that compatibility of the 2707 and the passenger loading system will be realized and that the cost thereof will be limited.

3.4.4.3 Fueling System Modifications

The aircraft service aprons at Dulles International are served by a hydrant fueling system. In the parking area, fuel is supplied by two 8-inch, two 12-inch, and one 14-inch header mains. Each gate position has two fuels available; consequently, there are four hydrant valves, two per fuel, located in pairs in manholes below the pavement.

The hydrants and lateral fuel pipes may not be of sufficient size to meet the 2707's fueling requirements. Hence, the cost of an assumed modification typical for the Dulles fueling layout is included in the summary of costs at the end of this Section. This cost includes the installation of four hydrants and two lateral lines per 2707 position.

3.4.5 Summary of Estimated Costs

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<u>Item</u>	<u>Estimated Cost</u>
Modifications to 17 fillets:	
Full-strength pavement @ \$15/s.y.	12,000
Shoulder pavement	36,000
Revisions to lights and signs	21,000
Widening of runway 19L holding apron	
Full-strength pavement @ \$15/s.y.	8,500
Revisions to lights	<u>1,000</u>
Total Estimated Cost	\$78,500
Estimated Unit Costs Per Gate Position	
Fuel system modifications	16,000

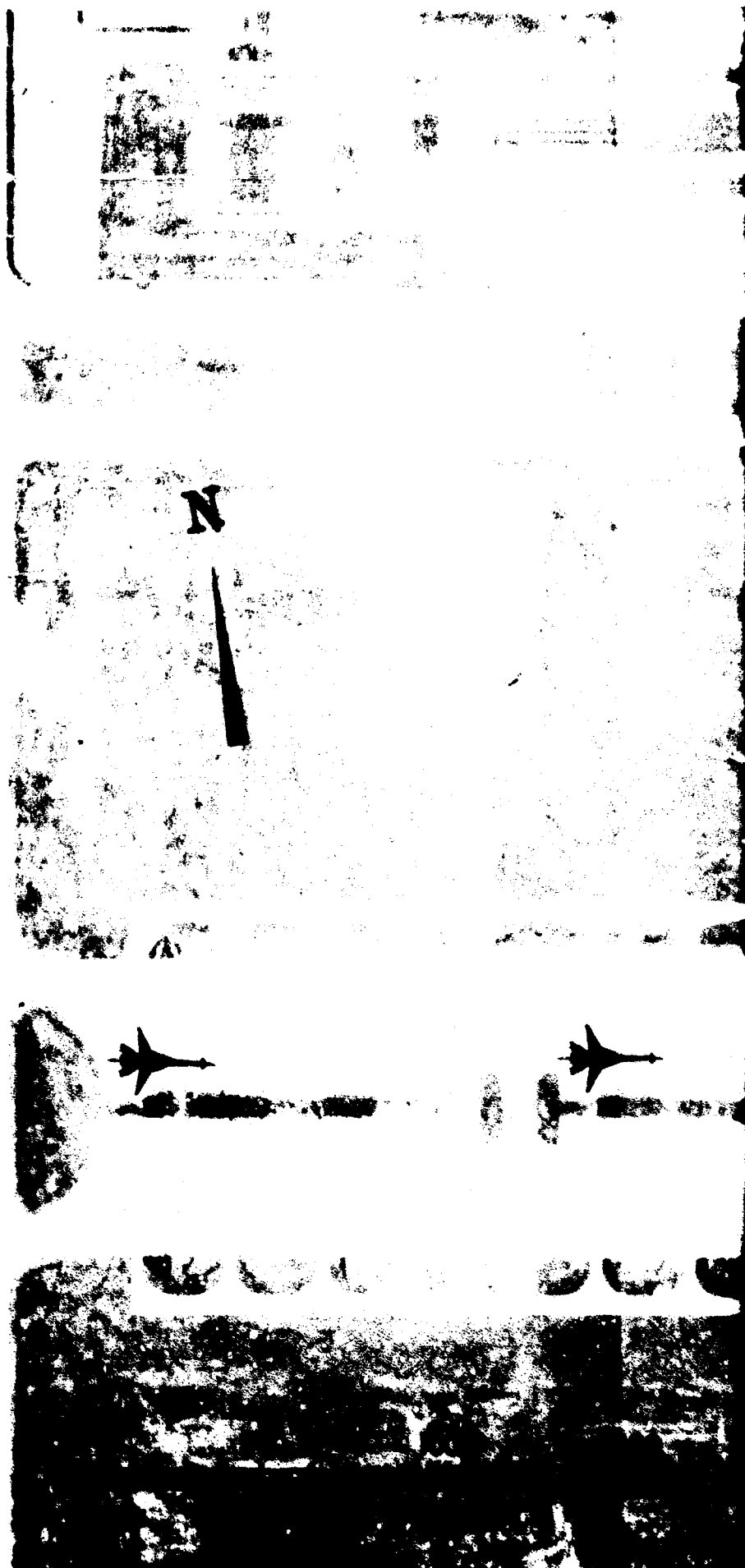
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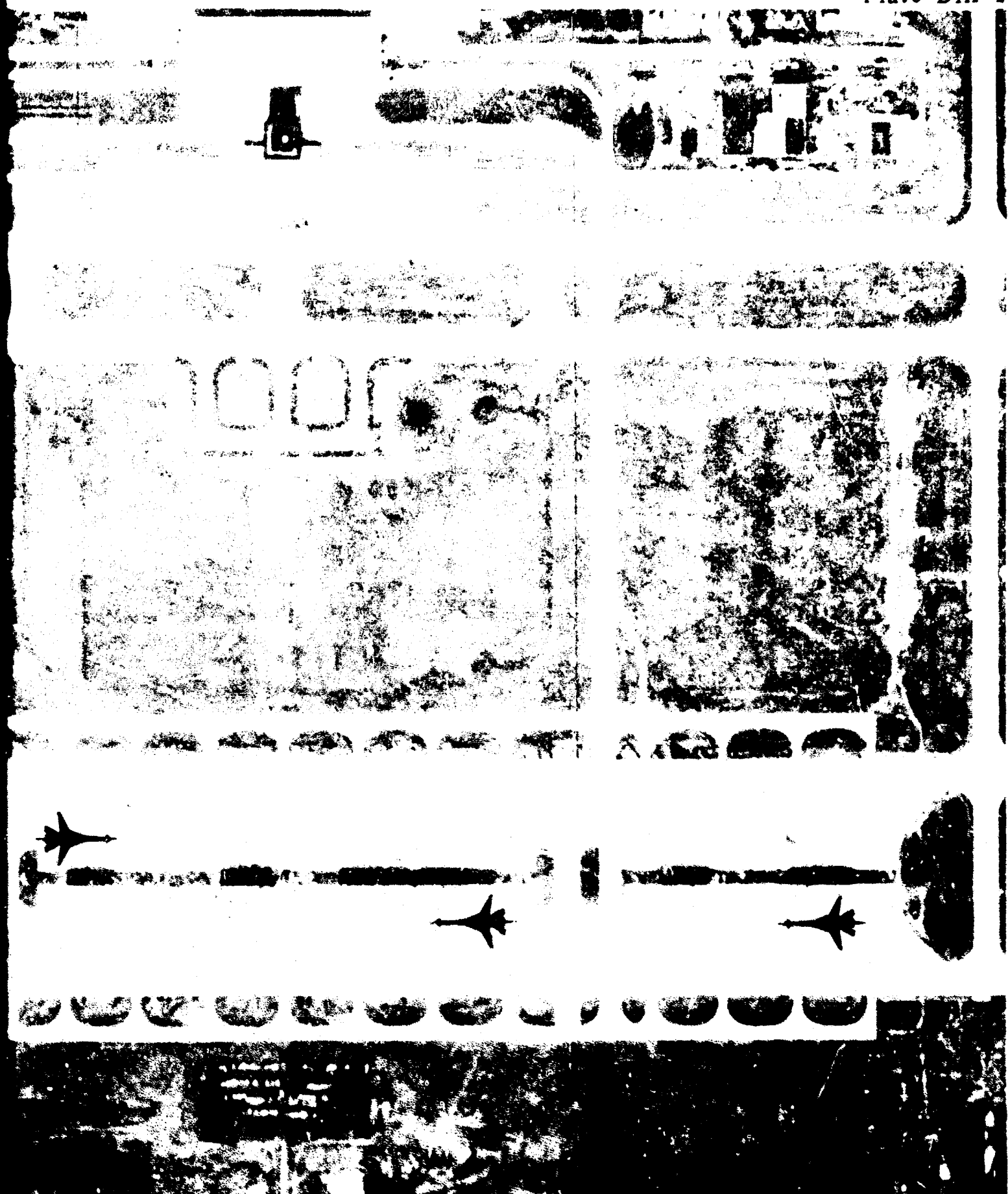


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FEASIBLE SST GATE POSITIONS





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3.5 Airport Evaluation - Detroit Metropolitan Wayne County Airport - DTW

3.5.1 Structural Evaluation of Pavements

All pavements at Detroit are rigid, and in excellent condition. The runways comprise 13-inch-thick slabs at the critical end-of-runway sections and 11-inch-thick slabs in the noncritical interior sections. Taxiways and aprons are 12 inches thick. The subgrade modulus recommended for slab design and analysis is $K = 200$. The maximum allowable concrete flexural stress is 350 pounds per square inch.

When operated on any of these pavements at their maximum weights, both the DC-8-55 and the 2707 induce flexural stresses greater than the allowable. However, the DC-8-55 imposes slightly greater flexural stresses in each case. Therefore, no pavement strengthening costs are attributable to the SST at Detroit.

Since the pavements are apparently unaffected by aircraft operating there today, there is no reason to anticipate that operation of the 2707 at Detroit would adversely affect existing pavements.

3.5.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Detroit Metropolitan Wayne County Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the Airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report.

If runways 3R-21L and 9-27 were to remain at their current lengths, several of the exit taxiways nearest to their landing thresholds would receive little or no use by the SST. As Plate DTW-1 indicates, however, both runways are to be extended. As a result, the exit taxiways in question will be used

routinely by the SST. The assumption has been made that the planned extensions will be completed prior to the introduction of the SST.

At Detroit, all existing runways are 200 feet wide, a circumstance that minimizes the need for and costs of fillet modifications to accommodate the 2707.

A total of 73 fillets and two curved taxiways was studied. Eleven fillets, according to the airport's operator, are scheduled for removal or improvement prior to the anticipated time of initial SST operations.

It was determined that eleven fillets and two curved taxiways would require improvements if the criteria stated in paragraph 2.2.2.3 are to be observed at Detroit. All costs associated with such modifications have been estimated and charged to the use of the airport by the 2707.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	7	10
Rare usage	8	0
Runway-taxiway		
Normal usage	12	1
Rare usage	21	0
Taxiway-terminal apron		
Normal usage	11	0
On maintenance area routes		
Rare usage	<u>3</u>	<u>0</u>
TOTAL number of fillets investigated	62	11
Curved taxiways		
Normal usage	0	2

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to pavements tabulated in the right column above and shown on Plate DTW-2 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - There are holding aprons at each threshold of runway 3L-21R, the instrument runway at Detroit. Each is connected to the runway by a 75-foot-wide curved taxiway. The taxiway curvatures are too severe for the SST. The costs of suitable widenings have been estimated and included in the summary of costs for fillet modifications.

Runway 3L - This apron will require modification to meet the requirements outlined in paragraph 2.2.2.4. A widening will suffice and the cost of such an improvement has been charged against the SST.

Runway 21R - Immediately adjacent to the terminal apron, this holding apron has the same dimensions as apron 3L at the apposite threshold. A widening could interfere with parking at the new United Air Lines satellite as well as at a proposed satellite on finger "G," which is expected to be built in the near future. The exact location and configuration of the finger "G" construction is unknown at this time. It is believed, however, that the terminal apron will be extended into the employees parking lot and will abut the existing holding apron.

Inasmuch as this apron (21R) is adjacent to the terminal apron and widening to meet the requirements of paragraph 2.2.2.4 is not possible without interfering with other functioning pavements, this apron must be considered not suited for SST use and, therefore, no subsequent costs are subscribed to the SST.

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3.5.3 Evaluations of Structures

Bridges - About 2,300 feet from the threshold of runway 3L, there is a simple-span bridge over a storm-water drain. It was designed in accordance with the 1953 Edition of the Standard Specifications for Highway Bridges of the American Association of State Highway Officials. The sections supporting runway 3L-21R and its parallel taxiway were designed for the DC-8 at 300,000 pounds gross weight. These sections are 300 feet wide and 125 feet wide, respectively.

The bridge has a clear opening of 21 feet and a distance center-to-center of bearings of 23 feet. The affected superstructure sections are concrete slabs encasing longitudinal wide-flange steel sections of 10-inch nominal depth weighing 112 pounds per lineal foot (10 WF 112). These stringers which are spaced at 18 inches on centers, have a bottom cover of 3 inches. The crowned slab itself is a minimum of 18 inches thick. In the transverse direction, the slab is lightly reinforced with #4 bars @ 18" o.c.

The superstructure was designed for the DC-8, with a load of 150,000 pounds on the four tires of each truck. Rolling impact was not considered. The four tires in one truck of the 2707 impose a load of 163,700 pounds - 9 per cent greater than that of the DC-8. However, the greater width - 37 inches - of the 2707's truck gives a greater distribution of loads than does the 30-inch wide truck of the DC-8.

The form of construction employed for the bridge is such as to require that a number of unverifiable assumptions be made in any theoretical analysis of its capacity to support heavy concentrated loads. In view of the similarity of the critical loading conditions imposed by the DC-8 and the 2707, however, a precise analysis of the structure is considered unnecessary for the purposes of the present studies. On the basis of the satisfactory

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performance of the structure to date, it is our conclusion that the structure is adequately safe for the DC-8-55. On the basis of the better load-distributing characteristics of the 2707's main-gear trucks, we conclude that it will be equally safe and therefore compatible.

Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3 and therefore may be considered compatible with the 2707.

3.5.4 Terminal Area (See Plate DTW-2)

The layout of Detroit's passenger terminal employs a modification of the unit-terminal concept. When the current expansion is complete, passengers will be processed in two separate terminal buildings located near the ends of a linear building arrangement. The two terminals and the central services building between them will be connected by a passenger concourse from which four of the six loading fingers will extend. (A seventh finger, which is shown on the master plan of the terminal area, would also extend from the linear concourse.)

3.5.4.1 Maneuvering and Docking

Studies of the six existing fingers and of the proposed modifications indicate that the canted and parallel modes of parking would be preferable to the nose-in, where the 2707 is concerned.

The results of the parking studies showed that finger piers "A," "B," "C," "D," and "F" would accommodate the 2707. Finger pier "E," constructed for the local-service airlines, was not studied for use by the 2707. Maneuvering and docking studies for finger pier "G" were not made because of the tentative status of future plans for it.

Eleven SST parking positions have been indicated on Plate DTW-2.

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Two positions may be occupied simultaneously at finger piers "A," "B," "D," and "F," and three at finger pier "C." The particular arrangements selected have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures. Clearances have been maintained for jumbo jets on all apron taxiways where possible.

3.5.4.2 Passenger Loading Devices

A variety of passenger-loading devices are in use, with swinging-telescoping bridges in the majority.

Four swinging-telescoping bridges now installed on the satellite at the end of finger pier "A" could be suitably modified to enable them to serve the two 2707 parking positions indicated at that location on Plate DTW-2.

Finger pier "B" is configured similar to "A," and the same modifications have been assumed for the two 2707 positions shown there.

The two north positions for finger pier "C" would require two new loaders each. For the southerly position shown, one existing loader could be modified vertically, and one new swinging-telescoping loader would be required.

The end position indicated at pier "D" could be served if one existing loader were modified appropriately for second-door loading. For forward-door loading at this position, a short loader now tentatively planned would probably have to be replaced. The remaining position would require one new swinging-telescoping loader for the second door and a vertical adjustment to an existing loader to serve the forward door.

At finger pier "F," four swinging-telescoping loaders would be required to service the two 2707 parking positions shown on Plate DTW-2. The existing nose-loaders will not accommodate the SST and modification does not appear practical. They could possibly be relocated and used elsewhere, however.

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All of the suggested modifications to the presently-planned loading facilities would result in equipment that could be used equally as well with subsonic jet aircraft as with the 2707.

3.5.4.3 Fueling System Modifications

With the exception of United Air Lines, the airlines serving Detroit presently fuel by tenders.

United has an underground fueling system at finger pier "F." The parking arrangement indicated on Plate DTW-2 would require the installation of two new hydrants at each of the two gate positions. The estimated costs of additional hydrants and stubs are attributable to the SST.

3.5.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Modification of 11 fillets and 2 curved taxiways	
Full-strength pavement @ \$12/s.y.	51,000
Shoulder pavement	12,000
Revisions to lights and signs	21,000
Widening of Runway 3L holding apron:	
Full-strength pavement @ \$12/s.y.	46,500
Revisions to lights	<u>2,000</u>
Total Estimated Costs	132,500
Estimated Unit Costs Per Gate Position	
Passenger loading devices	50,000
Fuel system modifications	8,000

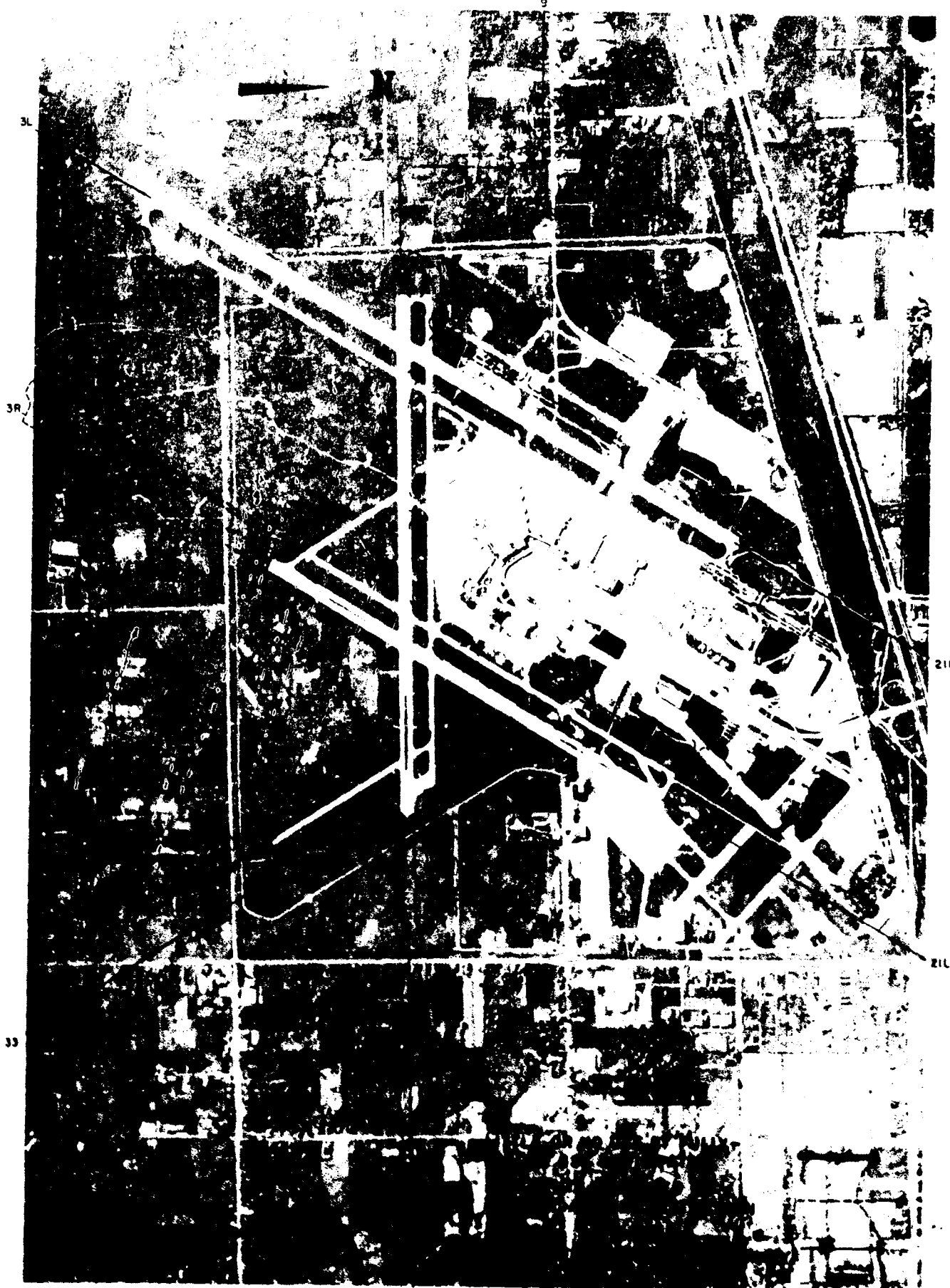
Of the eleven gate positions determined to be feasible for 2707 usage, all were considered in estimating the average unit cost quoted above for passenger-loading devices. The average unit cost per gate position of fuel system modifications was obtained by averaging the individual costs for the two SST parking positions where an underground fueling system now exists.

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FEASIBLE SST GATE POSITIONS



FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN



FACILITIES NOT SHOWN BUT
EXISTING AS OF SEPTEMBER 1966





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3.6 Airport Evaluation - Honolulu International Airport - HNL

3.6.1 Structural Evaluation of Pavements

We have been advised by both the Hawaiian Department of Transportation and the Air Force that, owing to the highly directional prevailing winds at this airport, over ninety-five per cent of all operations are conducted on Runway 8-26. Therefore, the other runways on the airport have been omitted from this SST compatibility study.

Both flexible and rigid pavements are in use at Honolulu. Rigid pavements in the parking areas adjacent to the terminal are 12 inches thick with 6 to 24 inches of compacted coral base. At the Hickam AFB end of the field, the critical pavement portion of runway 8-26 is 15-inch concrete over a 6-inch coral gravel base course. The allowable concrete stress is unknown. Flexible pavements vary in thickness from 24 to 75.5 inches.

All flexible pavements are constructed of a bituminous concrete surface course, a crushed coral base, and where required, a coral sub-base.

The existing soil conditions are rather complex. The terminal area subgrade consists of consolidated alluvium and volcanic tuff over coral rock at shallow to moderate depths. The eastern portion of the airport has a subgrade of interbedded consolidated fine sand and soft, silty clay. The western portion of the airport and the adjacent Hickam Field Air Force Base are in an old swamp area of consolidated soft, silty clay and black mud. The latter two areas were filled with materials of varying characteristics dredged from Pearl Harbor. The dredged material was in turn covered by a pumped coral fill.

As may be inferred from the foregoing, the subgrade conditions are extremely variable, ranging from poor to excellent.

The sub-base rating for the concrete pavement in the terminal area is considered as probably equivalent to at least $k = 400$ based on a subgrade

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rating of $k = 170$ under a 24-inch thick base. The base for the concrete pavement on Runway 8-26 in Hickam Air Force Base is rated by the Corps of Engineers as $k = 300$.

Minimum subgrade CBR values from limited test data range from 3 to 7 in the airfield areas. No data are available for the terminal area.

The entire runway area has been given an FAA Classification of F9 based on an E-12 soil.

Rigid Pavements - In the apron area, the 2707 would induce flexural stresses about 6 per cent greater than the specified allowable 350 pound per square inch. However, the fully-loaded DC-8-55, which induces stresses 13 per cent above the allowable, is the more critical aircraft. Both are judged compatible with the existing pavement.

A maximum allowable stress has not been specified for the pavement at the west end of Runway 8-26. However, it is judged that both the 2707 and the DC-8-55 are compatible with this pavement.

Flexible Pavements - Apron and taxiway flexible pavements constructed in the terminal area are 24 inches thick and are giving good service under DC-8 and other heavy jet traffic. They were designed on the basis of 60,000-pound equivalent single wheel load.

The 24-inch pavement section with the DC-8 loading of 328,000 pounds requires a subgrade CBR of 14.5. In view of the observed performance of such pavements under heavy loads, this value is judged to be representative of the actual minimum subgrade strength. For a CBR of 14.5, the required pavement thickness for the Boeing SST is 26 inches, or 2 inches more than the existing thickness. The apron and taxiways, however, are scheduled for a 3-inch overlay in 1967 - 1968. These pavements, therefore, are considered to be compatible with the 2707.

Taxiway A between Hickam Air Force Base and taxiway D has a minimum pavement thickness of 24 inches. In areas of soft clay or muck, the pavement has been placed on a minimum of 48 inches of compacted select material and 6 inches or more of select backfill. For the DC-8, a 24-inch pavement would require a CBR of 14.5 for the compacted select material. Since this taxiway has performed satisfactorily under DC-8 and other heavy jet traffic, a strength equal to a CBR of at least 14.5 is considered to exist, and on this subgrade the SST would require a flexible pavement thickness of 26 inches. As areas receiving the 3-inch overlay scheduled for 1967 - 1968 include the Honolulu sections of taxiway A and runway 8-26. These pavements are compatible with the 2707.

The section of taxiway A on Hickam Air Force Base is reported to have a minimum thickness of 62 inches. It is now and has for several years been sustaining the loads imposed by the DC-8-55 and other heavy civil aircraft without adverse effects. For this reason, it would appear that the design CBR value of 3 may understate somewhat the true strength of the subgrade. It has been assumed, therefore, that the 62-inch pavement is just adequate for the DC-8-55 at 325,000 pounds, and the corresponding indicated CBR value of 3.8 has been used to determine the thickness required for the 2707.

A value of CBR 3.8 indicates that a 70-inch pavement thickness would be adequate for 2707 operations on the Hickam end of taxiway A. We have been advised that in connection with the anticipated 3-inch overlay by the Department of Transportation, the Air Force may also be expected to carry out an overlay program of not less than 2 inches.

The resulting overlaid pavement will then include a total thickness of 6 inches of asphalt, to half of which a 1.5 base equivalency factor would be applicable, making the equivalent total pavement thickness equal to 65½ inches.

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The $4\frac{1}{2}$ -inch difference between this and the required 70 inches adjusted to $3\frac{1}{2}$ inches by the equivalency factor for bituminous concrete base, becomes attributable to the SST.

Based on limited boring information, the section of the runway east of Hickam Air Force Base is assumed to have a minimum pavement thickness of 66 inches including a 4-inch bituminous surface. The placement in 1967 - 1968 of the planned 3-inch overlay will increase the actual thickness to 69 inches. If allowance is made for the equivalent value as base of the existing 4-inch surface, the effective total pavement thickness at the time the SST enters service will be 71 inches. For noncritical runway areas, the ability of such a pavement to support the 2707 would require a CBR of 3.3.

In view of the improved methods of placing fill and the better quality of materials employed on the Honolulu part of the field as a result of the experience gained over the years by the military forces on the Hickam side, it seems justifiable to assume that the CBR of the Honolulu section of the runway is at least equal to the minimum value of 3.8 posited for taxiway A on the basis of its traffic history. Therefore, the Honolulu segment of Runway 8-26 is compatible with the 2707 requirements.

The 3,350 feet of runway 8-26 immediately west of the Hickam-Honolulu property line, all of which is operationally noncritical, is 74 inches thick. The top $4\frac{1}{2}$ inches is asphaltic concrete surface. The anticipated 2-inch overlay will increase this thickness to 76 inches, of which $3\frac{1}{2}$ inches may be considered as high-quality base. Effectively, then, the runway in the Hickam area may be considered as being 77 and $\frac{3}{4}$ inches thick. As a design thickness for noncritical pavement supporting the SST, this depth of pavement corresponds to a CBR requirement of about 2.9.

Therefore, the 2707 will be compatible with the overlaid Hickam section of Runway 8-26.

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Thus, the only costs of pavement compatibility attributable to the SST are those for a 3 $\frac{1}{2}$ -inch overlay of the Hickam AFB section of taxiway A.

3.6.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections at Honolulu International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report.

Ninety per cent or more of the landings and takeoffs at Honolulu are made in the easterly direction. Nevertheless, it was deemed advisable to treat those taxiway turns that are routine when operations are reversed in the same manner as the more commonly negotiated turns associated with prevailing wind operations. One modifying assumption made for the east-to-west investigation was that taxiway A will be extended to the threshold of runway 26 by the time the SST is in service. Should such an extension prove unwarranted, it is logical to presume that reduced criteria for taxiing turns would be acceptable during periods of east-to-west operations.

Runway 8-26 is 200 feet wide for its full length, and a few of the connecting taxiways are more than 75 feet wide. This circumstance tends to minimize the need for and cost of fillet modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. A total of 31 intersection fillets and three curved taxiways were studied. It was determined that two fillets would require improvements if

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the criteria stated in paragraph 2.2.2.3 are to be observed at Honolulu. The curved taxiways were found to be adequate.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the number of fillets requiring improvements, by type of intersection and class of usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	6	1
Rare usage	8	0
Runway-taxiway		
Normal usage	4	1
Rare usage	6	0
Taxiway-terminal apron	See subsequent discussion of terminal apron	
On maintenance area routes		
Rare usage	<u>5</u>	<u>0</u>
TOTAL number of fillets investigated	29	2
Curved taxiways		
Normal usage	3	0

*For definition of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate HNL-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - The operation of this airport is such that an aircraft receives a "No-Delay" clearance at the gate and proceeds down the taxiway for an immediate takeoff. Should there then arise a reason for not

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taking off, the aircraft returns to the terminal by means of the runway. Holding aprons have not been constructed at either end of the field, and there are no plans at present for any such construction.

Peripheral Taxiways - Terminal Area - At the periphery of the existing terminal area aircraft parking apron, which is of portland cement concrete, there is a peripheral taxiway system of flexible pavement. Typically 300 feet in width, it is marked for the most part for two-way taxiing. (See Plate HNL-2.) If the airport's current standards for clearances between moving aircraft are to be maintained, and if the same operational flexibility characterizing present-day operations is to be available to the SST, these peripheral pavements would require a widening.

A 25-foot width of rigid pavement at the periphery of the aircraft parking apron is reserved for the movements of apron vehicles. For most, but not all, of the feasible SST parking positions, the desirable 13 feet of vertical clearance to the underside of any part of the parked 2707 overhanging this vehicular way would be available. However, it has been assumed that prudence would dictate the relocation of the vehicular way to the adjacent flexible pavement, a measure that would in turn require a further respacing of the peripheral taxiways.

Revisions to the terminal area, including the possible elimination of the two-way taxiing system, will be considered in a master-planning study that is soon to be undertaken. Nevertheless, in the absence of detailed planning, the costs that would be incurred by an adequate widening of the terminal area taxiway system and a relocation of the vehicular way have been estimated and attributed to the achievement of compatibility with the 2707.

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3.6.3 Evaluations of Structures

Culverts - Runway 8-26 and its two parallel taxiways cross Manuwai Canal, which is on the property line of Hickam Field. The investigation was concerned with the runway crossing and the north taxiway crossing.

The canal is carried in a six-cell, reinforced-concrete box culvert beneath the north taxiway (taxiway A). The cells of the box are 10 feet wide by 9 feet deep inside, and the interior walls are structurally hinged top and bottom. It is possible, therefore, to analyze the top and bottom slabs of the culvert independently, since structural continuity is provided only by the end sidewalls.

The top slab is of ample strength, and on the basis that wall loads are carried by narrow strips of the bottom slab, the bottom slab is also adequate for the 2707.

The canal is carried beneath Runway 8-26 in part by three-box and two-box reinforced-concrete culverts, and in part of 6-foot-diameter reinforced-concrete pipe culverts. About fifteen years ago, the box and pipe culverts were strengthened. The pipes were lined with 3 inches of reinforced concrete, and 10 inches of double-reinforced concrete were added to the tops of the box culverts.

The strengthened 6-foot pipes, which now have 10-inch wall thicknesses, were checked for the loads imposed by the 2707 and found to be adequate.

Other Pipes and Conduits - From the available data it is judged that all other pipes and all conduits beneath the airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered compatible with the 2707.

3.6.4 Terminal Area (See Plate HNL-2)

The terminal area at Honolulu consists of a central terminal building

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and elevated concourses. The concourses form a "Y," with the central terminal at the top.

To the west of the main building and paralleling the east-west runway is a series of buildings that accommodates international arrivals. From the center of the terminal area to the east, another series of buildings curve gradually to the north.

Perimeter gate positions are located on the airfield side of these buildings. They are not assigned to specific carriers, but are assigned by the tower on arrival.

3.6.4.1 Maneuvering and Docking

All 19 gate positions are virtually identical in plan layout, fuel hydrant positioning, and guidance striping. When the 2707 enters service at Honolulu, it is probable that only one method of parking will be used.

Nose-in parking would result in the longest passenger walking distances and would greatly increase the requirements, discussed above, of relocations of the terminal area peripheral taxiway system. That mode of parking, therefore, was given no further consideration for this terminal.

Both parallel and canted parking would be feasible (See Plate HNL-2), and it appears that no particular advantage would be gained by standardizing on one mode to the exclusion of the other except blast considerations. Parked either way the 2707 would generally occupy two existing gate positions. Nine feasible positions are shown.

Those positions ultimately selected for 2707 parking will remain compatible with current subsonic aircraft. The low blast fences installed on the terminal apron for the powered maneuvering of such aircraft need not be disturbed for the maneuvering of the SST, which will require tugs for outgoing aircraft. If a slight upward articulation of the lowered nose of the 2707 should be required to clear the fences, it is anticipated that such a

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maneuver would be acceptable.

The terminal apron must be widened to permit apron movements to clear parked aircraft. The cost of this modification is included in the estimate.

3.6.4.2 Passenger Loading Devices

Honolulu International Airport presently uses mobile ramps. The Department of Transportation does not contemplate the installation of second-level loading devices in the foreseeable future.

3.6.4.3 Fueling System Modifications

Each of the 19 existing gate positions at Honolulu is fueled by an underground system, including a pair of hydrant pits along a line perpendicular to the terminal face spaced at 80 feet distance. Some of these pits have additional fuel lines carrying a duty-free fuel used in certain overseas operations.

It has been assumed for purposes of the present study that a flexibility of choice of supply equal to that offered by the existing system would be required by the airlines operating SST's. Therefore, the estimated costs per gate position for modifications to the fuel system include those incurred at each SST position shown for providing three new hydrant pits, together with the same number of hydrants and laterals presently installed. A further assumption has been that all three of the servicing oil companies would make use of the same lateral trench at each 2707 gate position.

3.6.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Taxiway "A" overlay @ \$2.50/s.y.	\$104,000
Modify one fillet on Hickam A.F.B.	
Full-strength pavement @ \$16/s.y.	10,000
Shoulder pavement	3,000
Revisions to lights and signs	1,000

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Summary of Estimated Costs (Continued)

<u>Item</u>	<u>Estimated Cost</u>
Modify one fillet on H.I.A.	
Full-strength pavement @ \$7/s.y.	\$ 6,000
Revisions to lights and signs	1,000
Expand terminal apron	
Full-strength pavement @ \$7/s.y.	150,000
Shoulder pavement	19,000
Revisions to lights and signs	<u>10,000</u>
Total Estimated Costs	\$304,000
Estimated Unit Costs Per Gate Position	
Fuel system modifications	\$ 16,000

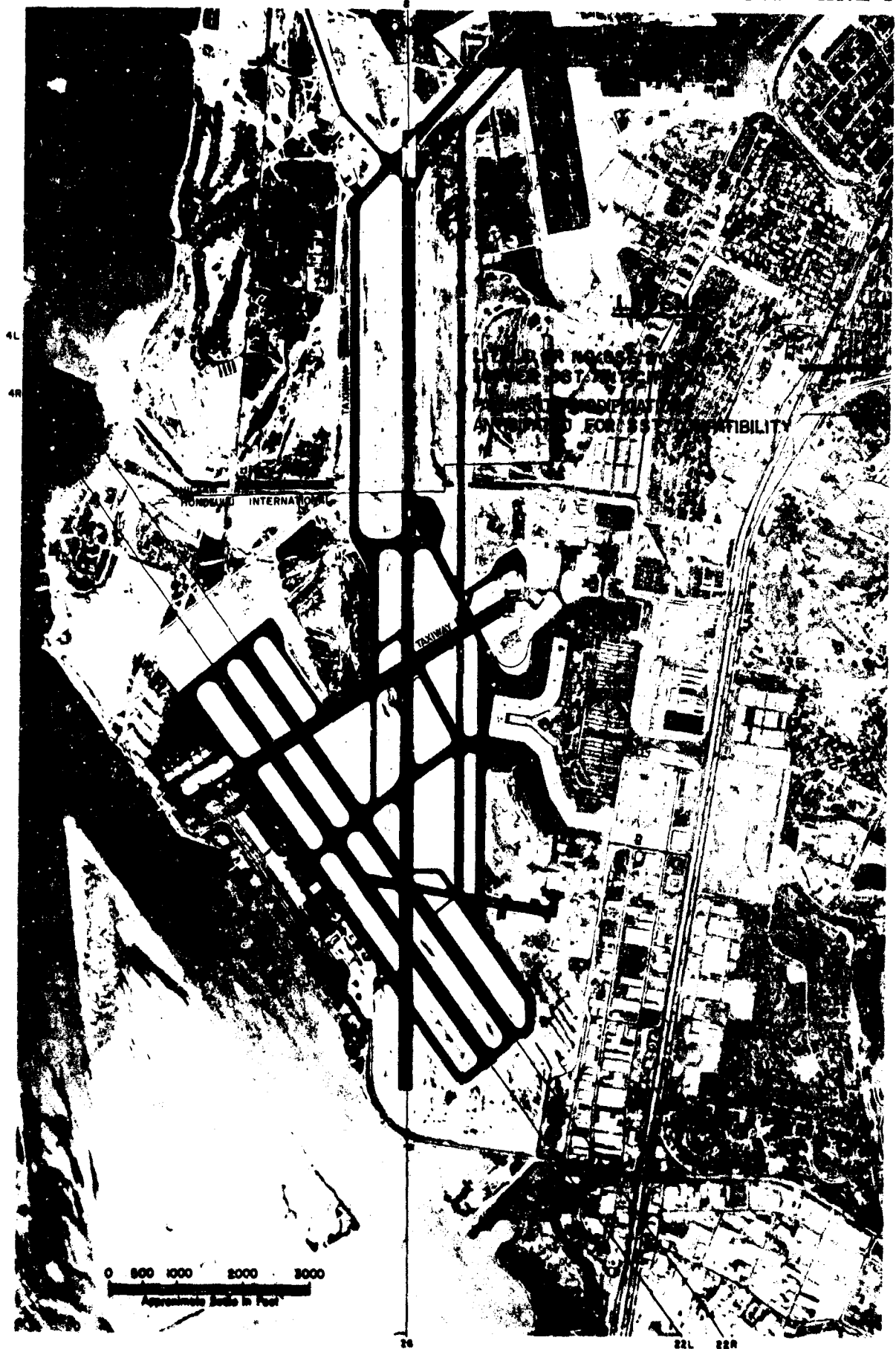
All of the nine gate positions found to be feasible were included in the estimation of the average cost for fuel system modifications quoted above.

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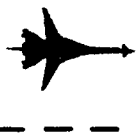
Honolulu International

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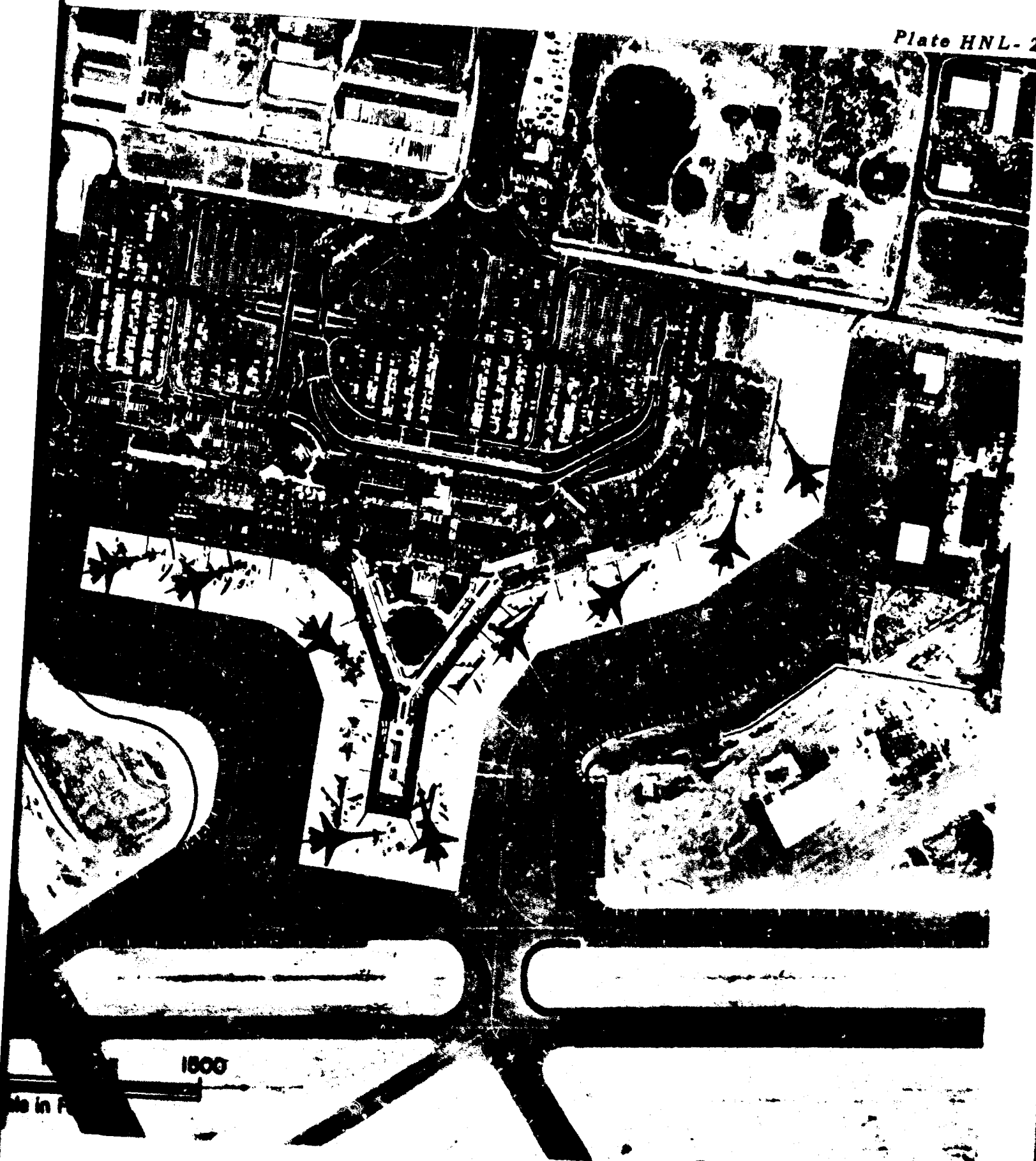
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LEGEND

FEASIBLE SST GATE POSITIONS
TERMINAL APRON EXPANSION
ASSUMED FOR SST USAGE



Approximate Scale in Feet



1800

do in P

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Honolulu International

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3.7 Airport Evaluation - Houston Intercontinental Airport - HOU

Now under construction on a 7200-acre site north of Houston is the first major airport in the United States planned for a previously undeveloped tract since Dulles International Airport was constructed in the late 1950's. The planners and designers of Houston Intercontinental began their work at a time when the general compatibility requirements of the supersonic transport were beginning to become apparent. As a result, the specific compatibility requirements of the 2707 would make necessary only minor modifications at this new airport.

3.7.1 Evaluations of Pavements

"The sandy loam topsoil varies in thickness from 1 foot to 3 feet and in its present condition is fairly loose. It is underlain by sandy clay, clay loam, and clay subsoils, and, in its present state, it has low stability and poor drainage. A relatively high-strength subsoil can be produced, however, by removing the sandy topsoil, compacting the subsoil and shaping it to drain, and replacing the sandy topsoil at a high density." (Houston's Jetero Airport: Location and Configuration, Frank H. Newman, Jr., Journal of the Aero-Space Space Transport Division, Vol. 89, No. AT1, April, 1963, Proceedings of the American Society of Civil Engineers.)

Base courses, 9 to 12 inches thick, of high stability soil cement were placed upon the compacted subgrade prepared as described above. The combined modulus of subgrade reaction achieved by these means varies from $k = 265$ to $k = 450$.

These preparations were made for rigid pavements, the only kind placed here. The airport's designers selected slab thicknesses of 11, 12, and 14 inches to accommodate the various conditions of support and eventual use.

A tabulation of data pertinent to the present investigation is given:

t	k	f_c	Per Cent of f_c	
			DC-8-55	Boeing 2707
14	365	375	88	87
14	265	425	84	83
12	400	415	93	92
12	355	500	81	79
11	450	500	83	83

where t = thickness of concrete slab (inches)

k = modulus of subgrade reaction (pound/inches³) and

f_c = recommended maximum allowable flexural stress in slab (psi)

From the above results it can easily be appreciated that Houston's pavements will be compatible with the 2707.

3.7.2 Requirements for New Pavements

Fillets - The fillets proposed at pavement intersections on Houston Intercontinental Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the Airport's operator and verified, as constructed, from an aerial photograph.

If Runway 8-26 and 14-32 were to remain at their present lengths, several of the exit taxiways nearest to their landing thresholds would receive little or no use by the SST. As Plate HOU-1 indicates, however, both runways are to be extended. As a result, the exit taxiways in question will be used routinely by the supersonic transport. The assumption has been made that the planned extensions will be completed prior to the introduction of the SST.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report.

A total of 91 fillets were individually reviewed. It was determined that 16 of these fillets would require improvements.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	18	16
Rare usage	28	0
Runway-taxiway		
Normal usage	6	0
Rare usage	8	0
Taxiway-terminal apron		
Normal usage	5	0
Rare usage	0	0
At holding aprons		
Normal usage	9	0
Rare usage	<u>1</u>	<u>0</u>
TOTAL number of fillets investigated	75	16

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate HOU-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - The 325-foot wide holding aprons that will serve the thresholds on Runway 8-26, the ILS runway, are more than ample for holding and passing the 2707. By the criteria stated in paragraph 2.2.2.4, the 250-foot wide aprons of Runway 14-32 are inadequate. The costs of an adequate widening have been estimated and allocated to the Boeing 2707. Plate HOU-1 shows the widening assumed.

3.7.3 Evaluations of Structures

Bridges - Six aircraft overpass structures will be required in the terminal area when the third runway is constructed. They will be designed for

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the heaviest aircraft that can be reasonably anticipated at the time, and for that reason would be adequate for the 2707.

Culverts - A system of culverts will serve to drain the taxiway infield areas. Having been designed for 100,000-pound equivalent single wheel loads, these structures have the strength required to resist live loads imposed by the 2707.

Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath the airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered compatible with the 2707.

3.7.4 Terminal Area

The terminal at Houston Intercontinental Airport is based on the concept of unit terminals for passenger processing and multiple satellites for boarding and deplaning. (See Plate HOU-2, an aerial photograph of the airport site showing the construction as of mid-July 1966, with the Master Plan superimposed.)

Two unit terminals are scheduled for construction during the first phase of development. Each terminal will ultimately be served by four satellite stations each designed to provide gate positions for five subsonic jet aircraft. The unit terminals are square in plan, and the concourses connecting them to the satellite flight stations are extensions of their diagonals. Thus, separate aprons are provided on two opposing sides of the unit terminals.

These aprons are 750 feet wide and they permit two-way taxiing operations with all gate positions occupied by current jet aircraft. The gate positions for each aircraft are designed for nose-in parking; however, each airline may, at its own option, make the rearrangements necessary to permit canted or parallel parking.

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3.7.4.1 Maneuvering and Docking

Plate HOU-2 shows two possible positions for docking the 2707 at each of the eight satellites. Position "A" appears to be the optimum position to satisfy the criteria of availability of adjacent gate arrangements and of minimal expenditures for passenger loading bridges.

For simultaneous occupancy of a single satellite by two SST's, a combination of Positions "A" and "B" appears most feasible. It should be noted, however, that the 2707 in Position "B" would intrude upon the inner taxiing lane of the apron.

3.7.4.2 Passenger Loading Devices

The need for modifications to passenger loading devices will depend upon the equipment selected by the individual airlines. It is assumed that the selection of any passenger-loading equipment will be made so that it will be compatible with 2707.

3.7.4.3 Fueling System Modifications

An underground hydrant fueling system has been designed for Houston Intercontinental. It will consist of one 12-inch and four 16-inch supply mains feeding two 10-inch lines looping around each of the satellites. The system will be pressure-controlled from the tank farm and will be capable of supplying 20,000 gallons per minute at 100 pounds per square inch. Hydrant locations at leased gate positions have been determined by each airline on the basis of its current aircraft equipment and intended mode of parking.

It has been assumed that those positions to be used for 2707 docking will require new hydrants and lateral connections. The costs thereof have been estimated as attributed to the requirements of the 2707.

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3.7.5 Summary of Estimated Costs

Modifications to 16 fillets	
Full-strength pavement @ \$15/s.y.	\$ 41,600
Revisions to lights and signs	22,400
Widening of 2 holding aprons	
Full-strength pavement @ \$15/s.y.	98,000
Revisions to lights	<u>2,000</u>
Total Estimated Costs	\$164,000
Estimated Unit Costs Per Gate Position	
Fuel system modifications	\$ 7,000

The average cost per gate position quoted above for fuel system modifications is the average of the costs incurred by providing for one SST Position "A" and one SST Position "B" at any satellite.

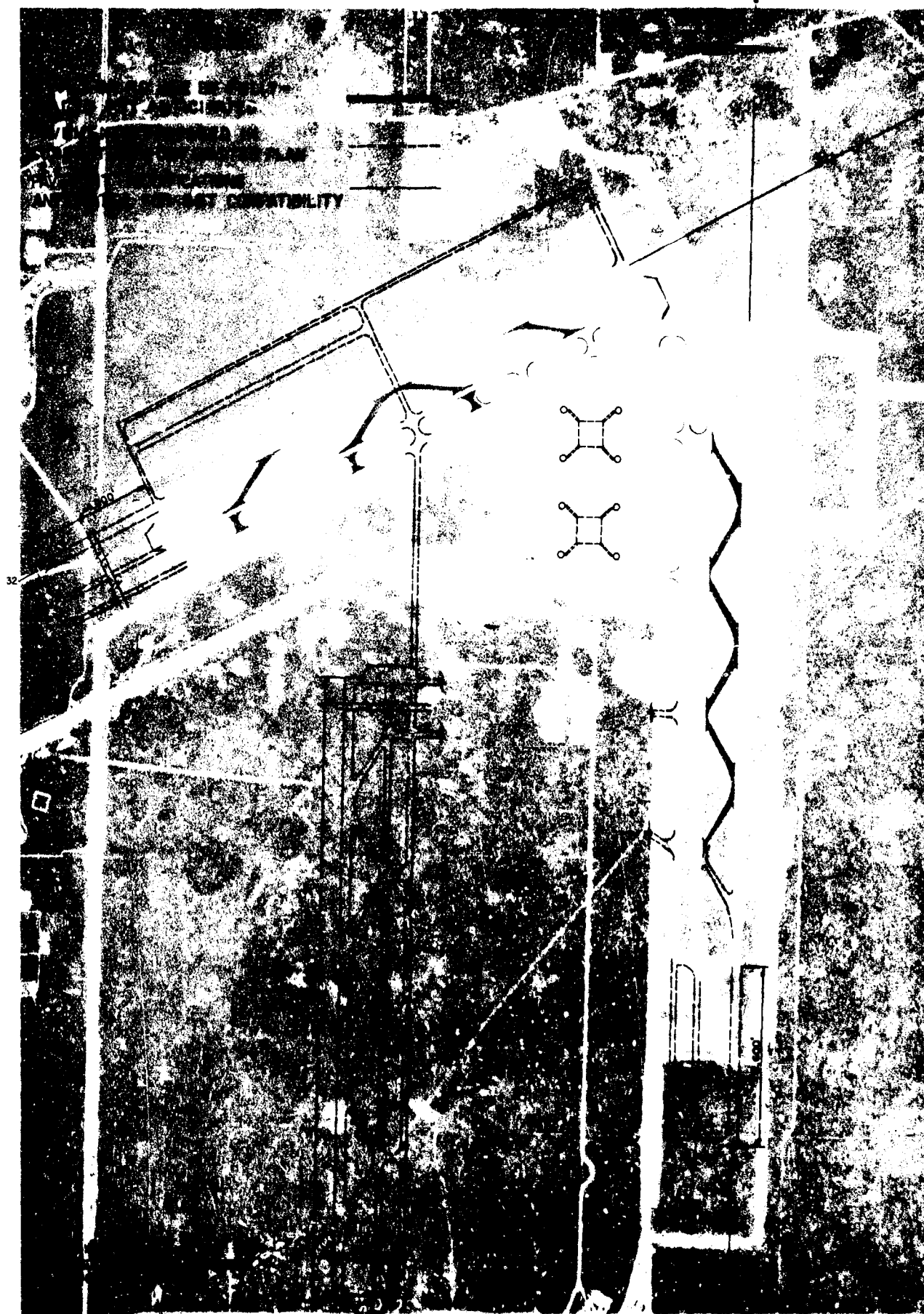
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Houston Intercontinental

LEGEND

FEASIBLE SST GATE POSITIONS

FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN



Houston-Partial Terminal Area



Houston Intercontinental

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3.8 Airport Evaluation - John F. Kennedy International Airport - New York - JFK

3.8.1 Structural Evaluation of Pavements

Both rigid and flexible pavements have been constructed at John F. Kennedy International Airport. In some places, the rigid pavements have received bituminous leveling courses.

The pavements are founded for the most part on dredged sand. Engineers of the Port of New York Authority recommend the use of a California Bearing Ratio (CBR) of 15 for analyses of flexible pavements and a modulus of subgrade reaction (k) of 300 for analyses of rigid pavements.

Rigid Pavements - All runways, some taxiways and sections of taxiways, and by far the greater area of apron pavements are of portland cement concrete. The runway pavements, which have been designed for a maximum allowable flexural stress of 430 pounds per square inch are 12 inches thick. All other rigid pavements are 13 inches thick. Their maximum allowable flexural stress is 365 pounds per square inch.

On both the 12 inch and 13 inch thick pavements, the DC-8-55 at 328,000 pounds induces higher stresses than does the 2707 at 675,000 pounds. At 98 and 95 per cent, respectively, of the maximum allowable stress, neither vehicle overstresses the 12 inch pavements. However, on the 13 inch pavements, which have the lower maximum allowable stress, the DC-8 induces a slight overstress (4 per cent), while the 2707 induces a stress approximately equal to the allowable.

On the basis of these findings, it is concluded that the rigid pavements at Kennedy are adequate for both vehicles.

Flexible Pavements - Most taxiway pavements at Kennedy are of flexible construction. According to the Port Authority's engineers and planners, all

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such pavements either are 22 inches thick now or will be overlaid to that thickness prior to the inauguration of SST services. The typical section comprises a 4 inch surface course, a 12 in base (consisting of 8 inches of asphaltic concrete and 4 inches of crushed stone), and a 6 inch sub-base.

The use of the Corps of Engineers' design method with the recommended CBR value of 15 results in the following pavement thickness requirements:

for the DC-8-55	23.5 inches
for the 2707	25 inches

Under most circumstances, each inch of asphaltic concrete base may be considered the equivalent of $1\frac{1}{2}$ inch of a base of lesser quality. In the judgment of the New York Port Authority's engineers, however, an equivalency factor should not be applied to Kennedy's flexible taxiway sections. Therefore, the thickness deficiency of pavements subjected to 2707 loadings is 3 inches.

Since the deficiency for DC-8 loadings is only $1\frac{1}{2}$ inch, it may be assumed that no overlay would be considered in the absence of SST operations. For this reason, the full amount of the costs estimated for a 3 inch thick asphaltic concrete overlay have been allocated to operations by the 2707.

Estimation of the areas to be overlaid was based mainly on the judgment of the Port Authority's engineers with some additional interpolation. Plate JFK-1 shows the areas eliminated from consideration because of probable infrequent use by fully-loaded SST's.

There are sections of 18 inch thick flexible pavement on the aprons serving the International Arrivals Building and the unit terminal building occupied by Northeast Airlines, Northwest Airlines, and Braniff International. They comprise a 4 inch surface, an 8 inch base, and a 6 inch sub-base. In theory, they are deficient by $5\frac{1}{2}$ inches (23.5 per cent) for the DC-8 and by 7 inches (28 per cent) for the 2707.

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Since most of the flexible sections are surrounded by concrete pavements, their improvement would not be a simple matter. (See Plates JFK-2 and JFK-7.) Overlays of adequate thickness would create serious drainage problems. If a remedial program were to become necessary, it would likely be one of removing the flexible surface and base and placing in their stead a 13-inch-thick concrete pavement. As has been noted in the discussion of rigid pavements, this thickness would be required for either of the aircraft being compared.

However, the existing pavements are said by the Port Authority's engineers to be in good condition after years of frequently repeated, highly channelized heavy loadings. The Port Authority's engineers have stated further that they do not foresee the need for strengthening overlays prior to the introduction of the SST.

From a comparison of the theoretical thickness deficiencies expressed as percentages, we judge that the two terminal apron pavements in question would probably be compatible with the 2707. Therefore, no costs for their strengthening are attributed to SST compatibility in the "best" estimate given at the end of this Section.

In the unlikely event that pavement distress traceable to SST operations occurs, it would be reasonable to attribute to such operations the full cost of a pavement improvement. Anticipating that such an improvement would be made by inlaying concrete, we have reported as a "high" estimate the full estimated costs of removing existing flexible pavements and replacing them with a 13-inch rigid slab.

3.8.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on John F. Kennedy International Airport were carefully investigated. The geometrics of

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the fillets were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at Kennedy are as follows:

- (1) If runway 4L-22R were to remain at its present length, several of the exit taxiways nearest to the landing threshold would receive little or no use by the SST. As Plate JFK-1 indicates, however, this runway is planned to be extended. As a result, the exit taxiways in question would be used routinely by the supersonic transport. The assumption has been made that the planned extensions will be completed prior to the introduction of the SST.
- (2) Runway 7-25 is presently decommissioned. It is uncertain whether it will be reactivated in the future. For this report, we have assumed that it would not be used as a runway by the supersonic transport.
- (3) Turns of 180° between the terminal peripheral taxiways are rarely made. Furthermore, consecutive 90° turns made in opposite directions between these two taxiways are rarely made.
- (4) The Port Authority has in the past modified fillets in conjunction with other major projects. It may be expected that additional improvements will be made from time to time. Nevertheless, the cost estimates given in this report have been based upon the conservative assumption

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that existing fillets of inadequate radii would be improved solely because of the higher maneuvering requirement of the 2707.

Runways 13L-31R and 7-25 have been built to a width of 200 feet and some of the taxiways at JFK are wider than the normal 75 feet. This circumstance tends to reduce the need for and costs of fillet modifications to accommodate the 2707. However, by current FAA recommendations, many existing intersections have fillets of inadequate radii.

Each fillet that would be traversed by the SST was investigated individually. A total of 223 fillets was studied. It was determined that 97 of them would require improvements if the criteria stated in paragraph 2.2.2.3 are to be observed at Kennedy.

A dual peripheral taxiway system curves around the entire terminal area. It is at intersections in this system that the great preponderance of pavement improvements would be required. There are four additional curved taxiways, at locations away from the terminals. All curved taxiways were found to be of adequate radii.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	24	59
Rare usage	5	7
Runway-taxiway		
Normal usage	30	1
Rare usage	24	0
Taxiway-terminal apron		
Normal usage	10	26
Rare usage	5	0
At holding aprons		
Normal usage	7	4
Rare usage	3	0
On maintenance area routes		
Rare usage	<u>18</u>	<u>0</u>
TOTAL number of fillets investigated	126	97

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate JFK-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - According to the Port of New York Authority's engineers, the following are the minimum desired SST-holding capabilities of the runway threshold aprons:

- (1) Hold two SST's at runways 31L, 22R, and 13R.
- (2) Hold one SST at runways 4L, 31R and 13L.
- (3) Ignore SST-holding requirements at runway 4R.

An additional requirement of the Port Authority is that the total

number of SST's and subsonic jets that can be held at once on the apron should be equal to the total number of subsonic jets that it was designed to hold.

Runway 31L - The holding apron for runway 31L is a trapezoidal-shaped pavement located at the end of a decommissioned runway which is now designated taxiway Z. Its width is adequate for holding the 2707 and it is backed by a 10 foot high blast fence. It has sufficient area to hold three large subsonic jets.

To enable this apron to hold two 2707's and one large subsonic jet, it would be necessary to lengthen the pavement. All costs for such improvements would be attributable to the SST.

Runway 22R - The apron here is presently adequate for the current subsonic jets. It is adequate in width for holding SST's and is backed by a blast fence erected to protect a taxiway. The expansion required to accommodate two 2707's and one current large jet aircraft is delineated on Plate JFK-1.

Runway 13R - There is an "L"-shaped holding apron adjacent to the takeoff threshold of runway 13R. The long leg of the apron is parallel and close to a taxiway serving airline maintenance facilities, and a blast fence now separates the two. The entire apron will presently accommodate five large subsonic aircraft. If this apron were widened toward the runway to the maximum extent allowable within the FAA recommendations, (namely 400 feet), it would accommodate two SST's and three present-day subsonic jets. Because of the restricted distance between taxiway "Q" and runway "13R," widening of this apron is limited to 300 feet, about 10 feet short of the criteria required by paragraph 2.2.2.4. (See Plate JFK-1)

Port Authority engineers have questioned the effects that the efflux from a holding SST might have on the high tail surfaces of aircraft on the adjacent taxiway. Studies indicate that, as the 2707 swings from the apron toward the hold bar, the distance from its exhaust nozzles

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to the adjacent taxiway centerline is about 300 feet. The effect of this could be felt on taxiway "Q," but should not be regarded as severe.

The costs of an expansion toward runway 13R have been estimated and attributed in full to the SST.

Runway 4L - The holding apron here can presently accommodate three subsonic jets. It must be widened to be adequate for the 2707 by the criteria stated. Additionally, it would be necessary to lengthen the apron to hold one SST and two current large jets. The costs of such a lengthening, including that for placing fill in Jamaica Bay, have been estimated and are included in the summary contained at the end of this section.

Runway 31R - The apron recently constructed at the threshold of the extended runway 31R has been designed to hold three large subsonic jets. If the criteria described in paragraph 2.2.2.4 are adopted at JFK, a 60-foot widening of this apron would be required. The widened apron could accommodate one 2707 and two present-day jets without lengthening.

Runway 13L - The threshold apron recently completed during the extension of runway 13L is not wide enough for an existing subsonic jet to pass a 2707 that is holding. There appears to be no practical solution to the problem involved in expanding the apron's depth. The rear edge of the apron is separated from 150th Street by a 14 foot high steel blast fence; consequently, the apron cannot be widened toward 150th Street. Relocating the street itself to the southwest would not be warranted.

Additionally, the apron that originally served 13L is inadequate for the same reason cited for the inadequacy of the recently completed apron and for the same reason as the latter, it could not be widened practically. The assumption therefore is that SST's required to hold will do so in the large area

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formed by the intersection of taxiways "A" and "X".

For the foregoing reasons, no charges have been allocated to the 7.7 for apron expansion at the Runway 13L threshold.

3.8.3 Evaluations of Structures

Bridges - There are four taxiway bridges on the airport. The older pair, designed in 1946, carry the dual circumferential taxiways over Van Wyck Expressway, the primary access road. The second pair, designed in 1962, carry the same taxiways over the 150th Street entrance roadway.

Plans of the new pair of bridges have been reviewed, and it has been determined that they are fully capable of supporting the 2707 at maximum gross ramp weight.

The Van Wyck Expressway bridges are two-span continuous structures with center-to-center-of-bearing distances of about 65 feet in each span. The load-carrying superstructure members are 36-inch-deep, wide-flange steel beams weighing 280 pounds per lineal foot (36 WF 280), spaced at slightly less than 6 feet on center. The beams are spliced at the center support of each bridge. In addition to their own weight, they carry the dead load of a 6-inch-thick concrete wearing course and a 1-foot-thick reinforced concrete slab, which is haunched down to the top of the lower flange of the beams. Composite action between steel and concrete was not assumed in the design.

The 300,000-pound live load was assumed to act through two sets of dual wheels spaced 40 feet apart, with a dual-wheel spacing of 5 feet.

The superstructure of each bridge is supported by 3-foot-thick deep abutments and a solid-wall center pier. These are in turn founded on a 4-foot-thick concrete slab extending from abutment to abutment. The slab also carries the expressway's pavements.

The governing design specifications were the applicable requirements

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of the 1944 "Standard Specifications for Highway Bridges" of the American Association of State Highway Officials.

Assuming the amount of distribution of the wheel loads warranted by the properties of the existing slab, it is found that both the 2707 and the DC-8-55 produce serious overstresses in the steel beams. The calculated stresses resulting from 2707 loads would be only 7.8 per cent greater than those resulting from the DC-8-55. Improvements of the bridges should already have been made. For this reason, it is deemed inappropriate to assess any costs of structural modifications of the Van Wyck Expressway Bridges to the 2707.

Box Culverts - Seven large, reinforced-concrete box culverts were investigated, as listed below:

<u>Size</u>	<u>Type</u>	<u>Approximate Depth of Cover (Ft)</u>
13'-6" x 6'-6"	Single box	5
13'-6" x 6'-6"	Double box	6
9'-6" x 7'-6"	Double box	4½
9'-6" x 7'-6"	Double box	3½
13'-0" x 6'-6"	Single box	4
10'-6" x 6'-6"	Single box	4½
13'-0" x 7'-0"	Triple box	5½

Using conservative analytical assumptions, it was found that the 2707 would impose varying degrees of stress above the design values. In none of the structures were the overstresses found to exceed 25 per cent.

To reconstruct or strengthen any of these culverts would temporarily entail severe airport operational penalties. For this reason, and because the overstresses caused by the 2707 are within acceptably safe working limits for the reinforcing steel, it is anticipated that no modifications would be made solely on account of 2707 traffic.

Pipes and Conduits - From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered

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compatible with the 2707.

3.8.4 Terminal Area (See Plates JFK-2 through -8)

The terminal area at Kennedy now comprises an International Arrivals Building and six domestic unit terminals. Two other unit terminals, one for a non U. S. A. airline, are presently projected for completion within a few years.

The seven existing terminals fall into three basic classifications:

- (1) The central building with two or more concourses extending outward into the aircraft apron (Eastern, United-Delta, American, and the International Arrivals Building);
- (2) The self-contained terminal at which the aircraft dock by nosing in (PAA and Braniff-Northeast-Northwest);
- (3) The central terminal with concourses and satellite buildings (TWA).

3.8.4.1 Maneuvering and Docking

Studies were made of all terminals, and it was determined that the 2707 could be accommodated at each. Plates JFK2-8 show symbols at gate positions representative of those where it is believed feasible for the 2707 to be maneuvered and docked by conventional techniques. The positions shown are also those studied for costs of additional hydrants and modifications of passenger loading devices.

3.8.4.2 Passenger Loading Devices

A total of 20 loading positions are shown. Five at the IAB (International Arrivals Building), three at TWA, three at American, two at United Delta, two at Eastern, two at Braniff-NW, and two at Pan American.

The following listing gives loading methods with estimated modifications and additions required at the different terminals.

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3.8.4.2.1 International Arrivals Building - IAB (See Plate JFK-2)

Only BOAC, which will probably be accommodating arrivals as well as departures in its new terminal building before the operational date of the 2707 has installed passenger loading bridges at the IAB. This gate position serviced by these loaders is not a recommended 2707 position. Since none of the gates recommended now has loading devices, none is considered chargeable to the 2707.

3.8.4.2.2 Trans World Airlines Terminal (See Plate JFK-3)

Currently, passenger-loading is accomplished via swinging-telescoping loaders of a length adequate to serve the 2707. Adjustments to the vertical articulation of the loaders would be required to accommodate the sill heights of the 2707, and the costs thereof are attributable to the achievement of compatibility.

3.8.4.2.3 American Airlines Terminal (See Plate JFK-4)

The East Concourse could be equipped to serve the 2707 with two telescoping loaders. The end position of the West Concourse presently has one bi-rail nose loader which could be vertically adjusted to mate with the second door of the 2707. Either another bi-rail loader or a swinging-telescoping loader attached to an extended holdroom would be required for the forward door. For the canted position at the West Concourse, it has been estimated that a new swinging-telescoping loader would be provided for the second door and a swinging, fixed-length loader for the forward door.

3.8.4.2.4 United-Delta Air Lines Terminal (See Plate JFK-5)

The South Concourse could accommodate two 2707's. The westerly position could be served by two existing swinging-telescoping loaders, which would require vertical adjustment to the sill heights of the 2707. The second position at the South Concourse would require two new loaders, but are not charged to 2707 because none now exist.

The North Concourse does not at present have loading devices. Therefore, the modification or replacement costs of any future loaders are not considered chargeable to the 2707. Two telescoping loaders appear to be the optimum solution.

3.8.4.2.5 Eastern Air Lines Terminal (See Plate JFK-6)

This terminal does not at present have any second-level passenger-loading devices. Possible future loading devices for 2707 operations would require second-story additions to the existing single-level North and South Concourses. This is not planned so the costs of passenger-loading devices have not been considered chargeable to the 2707.

3.8.4.2.6 Braniff-Northwest Terminal (See Plate JFK-7)

At the terminal's southwest corner, a position is available with two existing loaders suitable for 2707 use. One fixed-length, swinging loader with a fixed cab would require a rotating cab or replacement with more appropriate equipment. The second loader, a swinging-telescoping bridge, would require vertical adjustment to the elevation of the 2707 door sill. The east side of this terminal does not presently have loading devices. Two new loaders are suggested for the 2707 position shown there.

3.8.4.2.7 Pan American World Airways Terminal (See Plate JFK-8)

The existing loaders are a swinging type having an open platform with handrails. They reach only to the forward doors of current jet aircraft. The platforms would have to be extended and heightened to reach the 2707 forward door and clear the canard. The 2707 rear door does not fall under the canopy, therefore, in order to protect passengers from inclement weather, an enclosed, swinging-telescoping loader would be required at each 2707 gate position to serve the rear door.

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Fueling System Modifications

Underground fueling systems are presently installed at the International Arrivals Building and at the permanent terminals of the various airlines. Fueling at temporary terminals is still carried on by fuel tenders. At the International Arrivals Building, the airlines can choose among the fuels of four different suppliers, and there are eight hydrants for each aircraft gate position.

The installation of new hydrants and laterals connecting them to the existing mains would be required at each 2707 gate position to achieve compatibility with existing underground fueling systems. The average cost of fueling system modifications reported in the summary was obtained for the total of individual estimates made for each position shown. The individual estimates were based on new installations capable of providing the same flexibility of supply now provided at the subsonic jet gate positions.

3.8.5 Blast Fences

The Port of New York Authority has erected blast fences at eight locations at Kennedy where aircraft either holding or taking off direct their engine blasts at other facilities.

Fences at Runway 13L Threshold - There are three fences in the vicinity of the runway 13L threshold. One is at the edge of the original holding apron, which cannot accommodate a 2707 for holding.

The second is a 14-foot-high fence between the new holding apron and 150th Street. As previously pointed out, this apron cannot be widened to hold a 2707. Neither fence, therefore, will be required to protect adjacent facilities from the blast plumes of the holding 2707.

The third fence, which is 8 feet high, is on the extended runway centerline and about 250 feet from the takeoff threshold. This fence also

protects vehicles on 150th Street. The evaluation of the blast components as they pass over 150th Street would make it unnecessary to build this fence, which offers adequate protection from thrust components of jet velocities.

Fences at Runway 13R Threshold - As has been pointed out, 2707's swinging from this apron toward the hold bar are not expected to direct severe blast at aircraft on the taxiway leading to the maintenance facilities. Therefore, no consideration was given to modifying the existing blast fence at this threshold.

Fence at Runway 22R Threshold - The holding apron serving runway 22R, which we have assumed will be expanded, is separated from an adjacent taxiway by a metal blast fence 10 feet high. If it is assumed that runways 22R and 22L are used during peak hours for takeoffs, aircraft taxiing behind the apron of runway 22R would cross the axis of the 2707's engine efflux. At the distance intervening between the taxiway and the 2707's exhaust nozzles, however, the velocity of the efflux at breakaway power and at the elevations involved is unobjectionable. (See paragraph 2.2.5 and Plate JFK-1.)

The fence should be extended as required by the apron expansion needed for holding the SST to offer the same blast protection as now exists. The cost of lengthening the fence has been estimated and attributed to the 2707.

Fences at Runway 31L - There are two fences associated with the runway 31L threshold. One is adjacent to the holding apron on the decommissioned north-south runway now known as taxiway Z. To match required apron widening and extension, the existing fence will have to be removed, replaced and extended. This fence will retain its present height of 10 feet. It is required only to furnish the same protection for runway 4R as now exists. The 2707 will be so aligned with 4R when holding on this apron that its engine efflux will be parallel to the runway.

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The other, directly to the rear of the runway threshold, must remain at its present height of 10 feet. To raise it to a greater height will create an unacceptable hazard in this location.

3.8.6 Summary of Estimated Costs

At Kennedy, as at one other of the 15 airports, a "best" estimate and a "high" estimate are being submitted for various reasons. The "best" estimate reflects our considered judgment as to what costs are most properly attributable to the 2707. The high estimate represents what we consider to be the maximum potential cost that might be incurred by the SST.

<u>Item</u>	<u>Estimated Cost</u>
Taxiway overlays @ \$2.20/s.y.	\$ 990,000
Modifications to 97 fillets	
Full-strength pavement @ \$15/s.y.	423,000
Shoulder pavement	185,000
Revisions to lights and signs	146,000
Expansion of 4L holding apron	
Full-strength pavement @ \$15/s.y.	85,000
Shoulder pavement	13,000
Revisions to lights	2,000
Embankment	152,000
Expansion of 13R holding apron	
Full-strength pavement @ \$15/s.y.	115,000
Shoulder pavement	9,000
Revisions to lights	2,000
Expansion of 22R holding apron	
Full-strength pavement @ \$15/s.y.	232,000
Shoulder pavement	6,000
Revisions to lights	5,000
Blast fence	42,000
Expansion of 31R holding apron	
Full-strength pavement @ \$15/s.y.	80,000
Shoulder pavement	10,000
Revisions to lights	2,000

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<u>Item</u>	<u>Estimated Cost</u>	
Expansion of 3LL holding apron		
Full-strength pavement @ \$15/s.y.		142,000
Shoulder pavement		12,000
Revisions to lights		3,000
Blast fence		<u>75,000</u>
Subtotal		\$2,731,000
	Best Estimate	High Estimate
Terminal apron inlays @ \$17/s.y.	<u>0</u>	<u>1,700,000</u>
Total Estimated Costs	\$2,731,000	\$4,431,000
Estimated Unit Costs Per Gate Position		
Passenger loading devices		\$67,000
Fuel system modifications		\$20,000

Of the gate positions determined to be feasible for SST usage, 9 were considered in the estimation of the average unit cost of passenger loading devices quoted above. The average unit cost per gate position of fuel system modifications was obtained by averaging the individual gate costs for all SST gates.

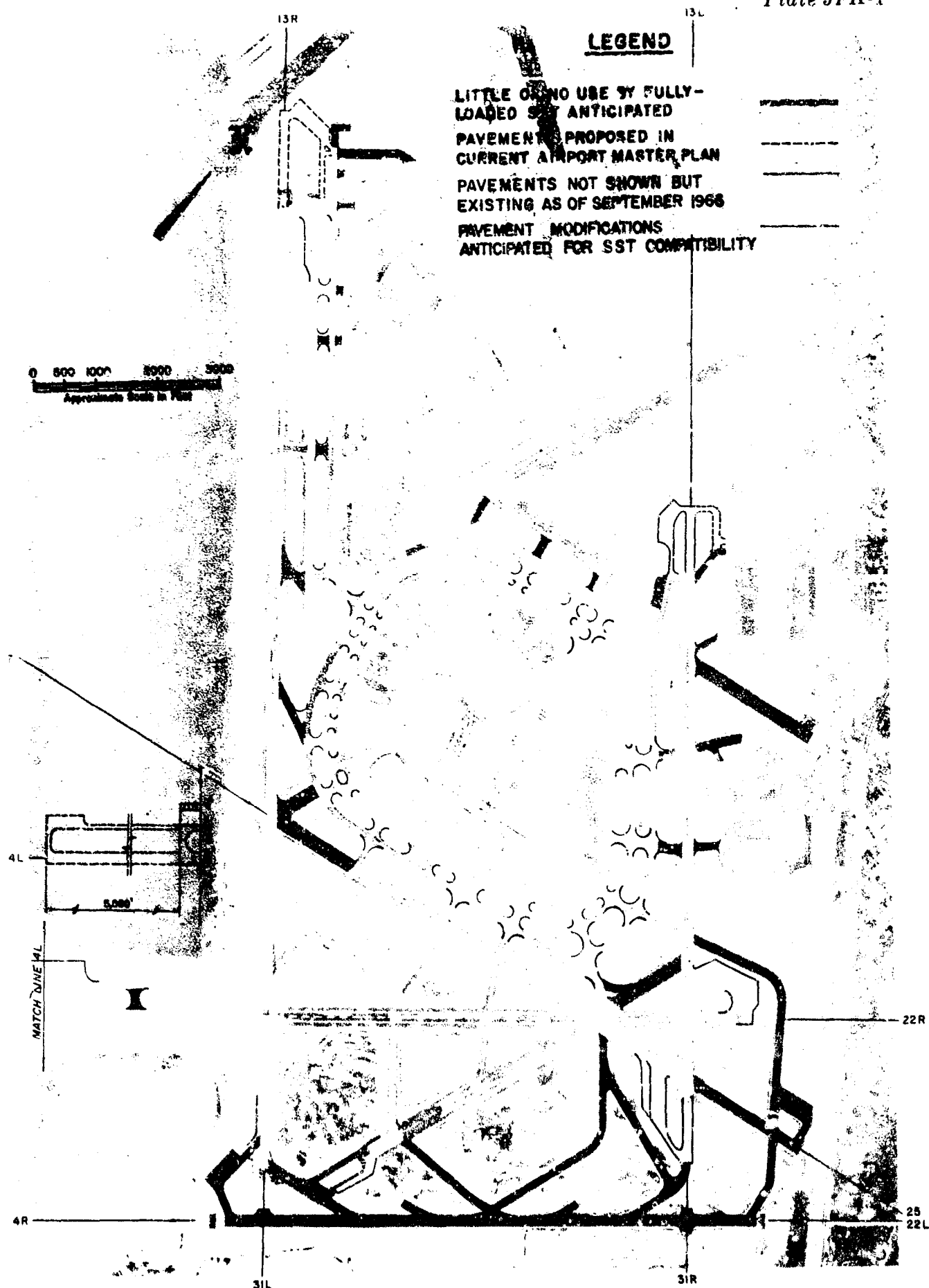
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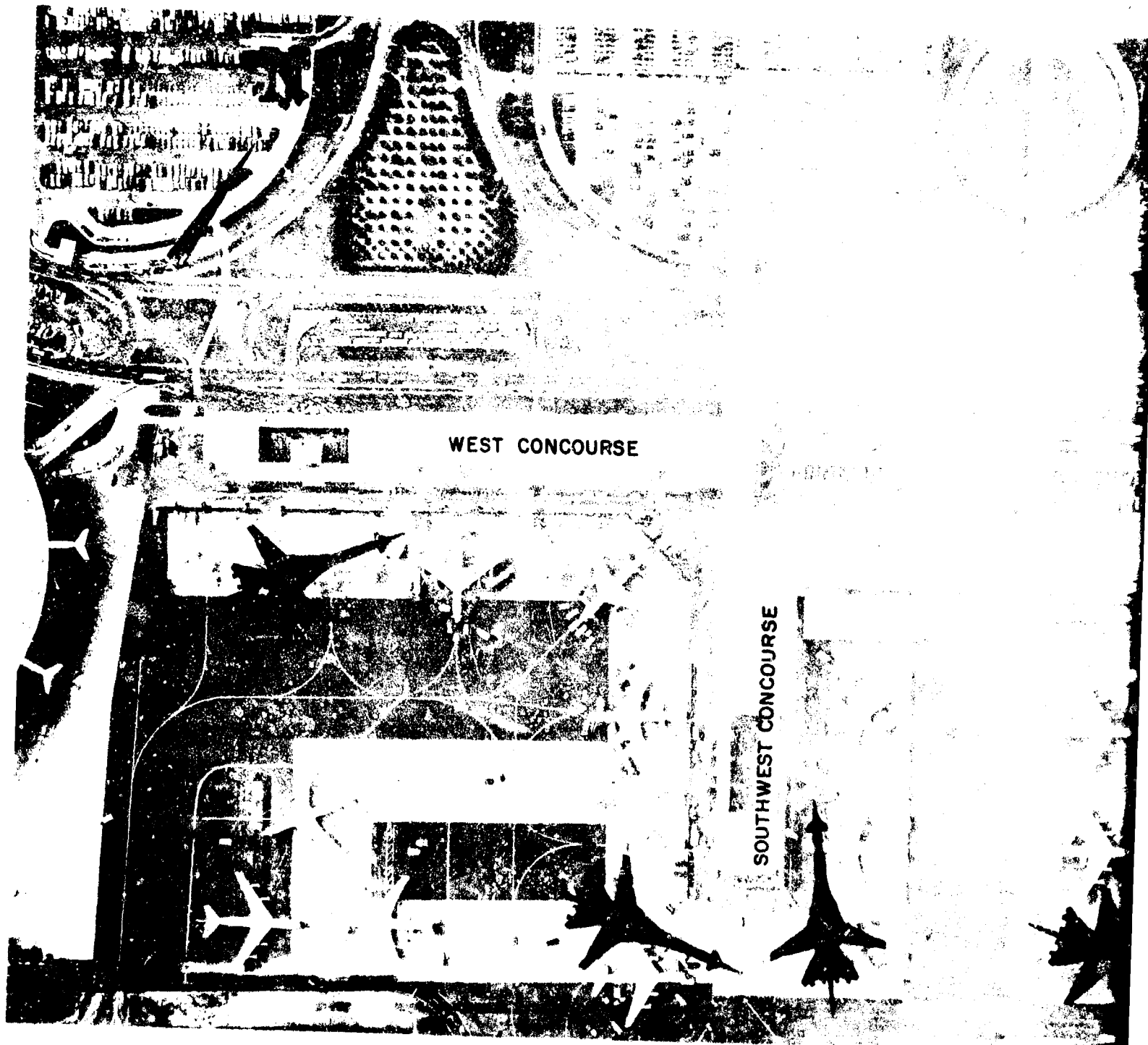
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John F. Kennedy International

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LEGEND

FEASIBLE SST GATE POSITIONS

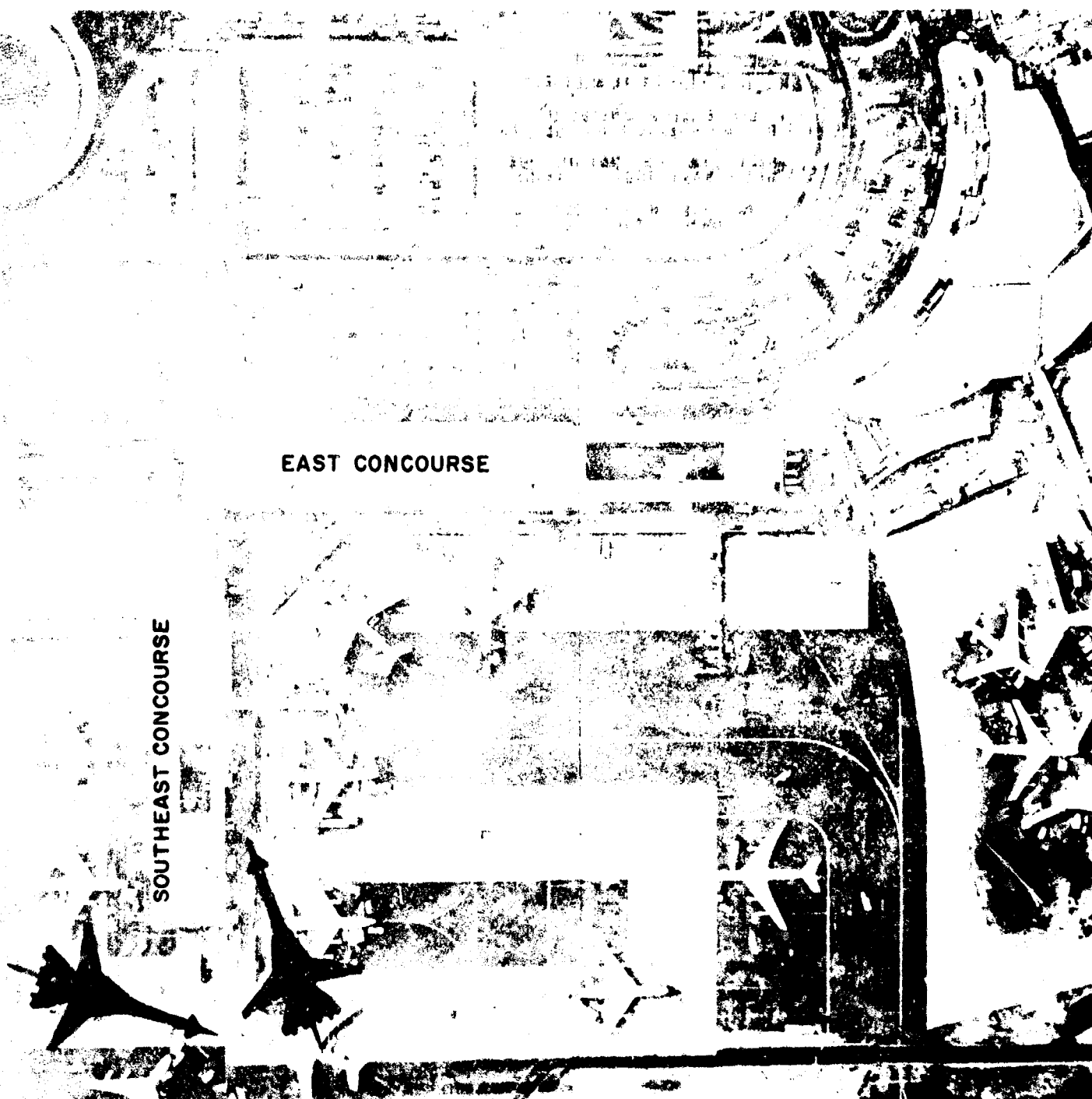


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Approximate Scale in Feet

International Arrivals Building



2
John F. Kennedy International

125
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LEGEND

FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN



TWA Terminal



2

John F. Kennedy International

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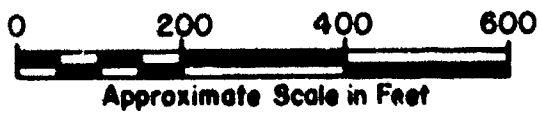
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LEGEND

FEASIBLE SST GATE POSITIONS



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American Airlines Terminal



2

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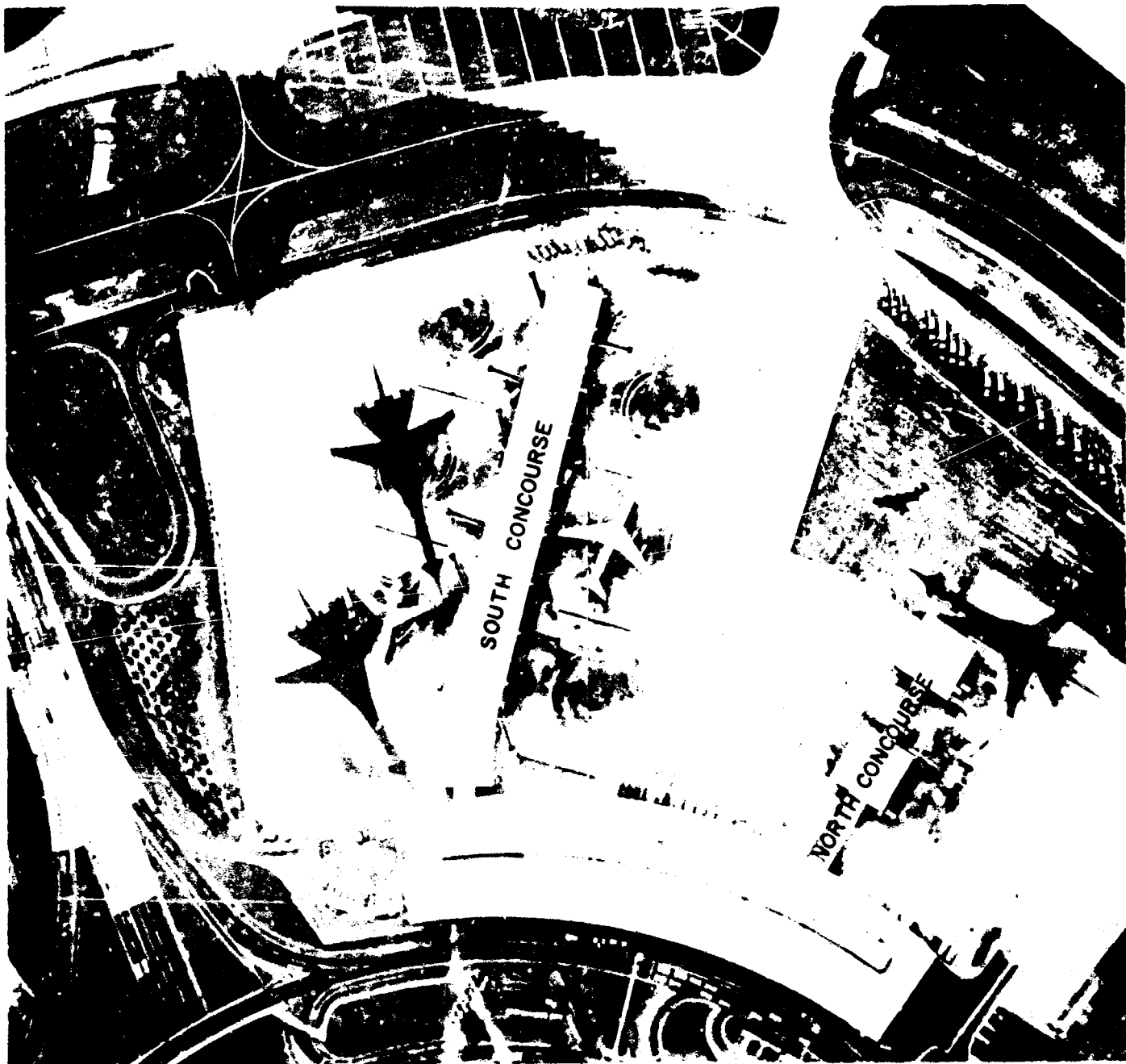
FEASIBLE SST GATE POSITIONS



1

Jo

United-Delta Air Lines Terminal



2

John F. Kennedy International

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NOF

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FEASIBLE SST GATE POSITIONS



SOU

1

Jol

Eastern Air Lines Terminal



2
John F. Kennedy International

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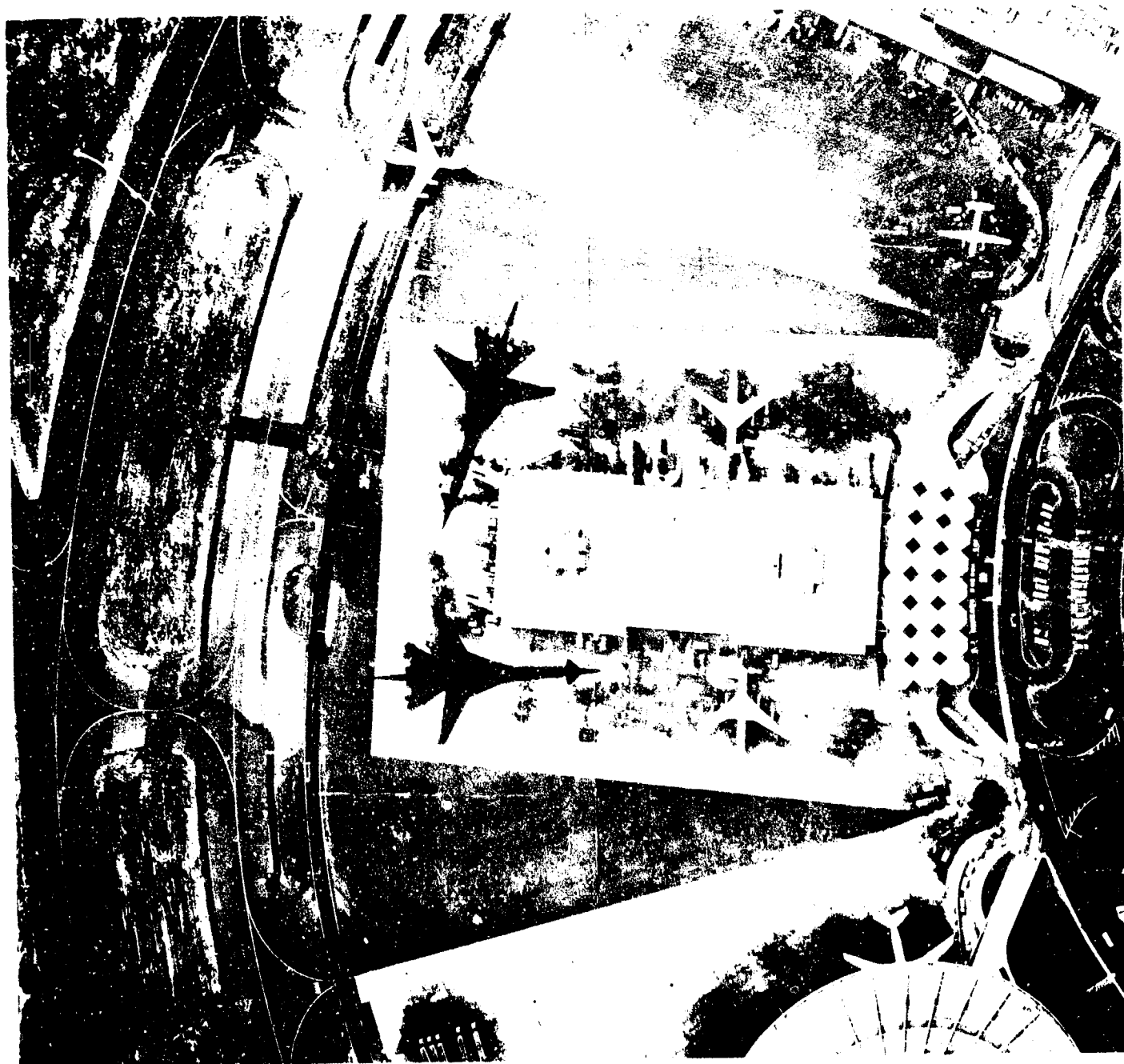
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FEASIBLE SST GATE POSITIONS



Joh

Braniff - Northeast - Northwest Airlines Terminal



2

John F. Kennedy International

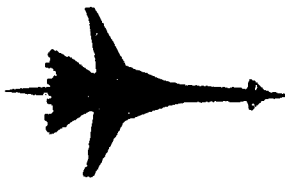
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LEGEND

FEASIBLE SST GATE POSITIONS



Joh

PAA Terminal



2

John F. Kennedy International

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3.9 Airport Evaluation - Los Angeles International Airport - LAX

3.9.1 Structural Evaluation of Pavements

Both rigid and flexible pavements have been constructed at Los Angeles International Airport. A considerable body of data on existing pavement sections and subgrade conditions has been furnished by the Airport's operator.

In the area of the airport west of Sepulveda Boulevard (See Plate LAX-1), the natural subgrade soil is a loose sand. When excavated and recompact in layers, it provides a good subgrade for runway and taxiway construction. For rigid pavement design, the recommended modulus of subgrade reaction is generally $k = 300$ at the top of the base course. On one 2,300-foot section of Runway 7L-25R, a value of $k = 250$ is applicable. For the design of flexible pavements, the FAA subgrade group is Fa and the California Bearing Ratio (CBR) is 10.

East of Sepulveda Boulevard the subgrade is a clay soil. The recommended modulus of reaction (k) is 300, the FAA subgrade group is F5, and the CBR is 5.

Rigid Pavements - Portland cement concrete pavements in thicknesses of 9, 10, 12, and 15 inches are presently in use. Tabulated below are data pertinent to the study:

t	k	f_c	Per cent of f_c	
			DC-8-55	2707
9	300	400	135	146
10	250	400	125	135
12	300	400	105	102
15	300	400	78	75

where t = thickness of concrete slab (inches);

k = recommended modulus of reaction on base (pound/inch³);

f_c = recommended maximum allowable flexural stress in slab
(pound/inch²).

On the basis of the foregoing it is concluded that 12- and 15-inch concrete pavements are compatible with the SST. If the 10-inch runway 7L-25R pavement performs satisfactorily under current jet traffic, it may also be considered compatible with the SST, notwithstanding its indicated overstress, which is 10 per cent more than that imposed by the fully-loaded DC-8-55. The 9-inch pavement occurs only at the Runway 25L holding apron, scheduled soon to be abandoned.

Flexible Pavements - Pavement thickness requirements in inches are as follows:

	<u>West of Sepulveda Blvd.</u>		<u>East of Sepulveda Blvd.</u>	
	<u>DC-8-55</u>	<u>2707</u>	<u>DC-8-55</u>	<u>2707</u>
Critical Areas				
Corps of Engineers	32	34	52	58
FAA Method	11.5	11	30	27.5
Noncritical Areas				
Corps of Engineers	29	31	47	52
FAA Method	9.5	9.5	24	22

A number of flexible taxiway and runway pavements west of Sepulveda Boulevard are 19 inches thick. These have been a source of trouble. On the basis of its experience with them, the Department of Airports has concluded that the CBR method of pavement design is the method more applicable at Los Angeles. In general, the 19-inch flexible pavements are scheduled to be replaced with 15-inch concrete pavements (which are compatible with the 2707 requirements) in the near future. Such pavements include portions of runways 7R-25L, 7L-25R, and taxiways J-38 and H-36.

All of the terminal apron taxiways are 37 inches thick, and are considered compatible with the 2707.

Runway 6-24 and sections of runway 7R-25L - all west of Sepulveda Boulevard - are flexible pavement 22 to 25 inches thick. Since the 2707 requires a flexible pavement thickness in critical and noncritical areas 2 inches greater than does the DC-8, the proportional cost of that thickness of a strengthening overlay has been charged to the SST as a compatibility expense.

East of Sepulveda Boulevard, taxiway 2-J, which has a theoretical thickness deficiency of 15 inches, has been holding up very well under frequent heavy loadings. This is attributed to its adobe subgrade. It is not anticipated that taxiway 2-J would require any improvements to support 2707 loadings.

3.9.2 Requirements For New Pavements

Fillets - The fillets at existing pavement intersections on Los Angeles International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at Los Angeles are as follows:

- (1) Runway 16-34, which is very seldom used, will either be relocated or abandoned.
- (2) Taxiway "K" between the threshold of runway 7L and taxiway 53-J will be widened from its present 60-foot width to 75 feet.
- (3) Taxiway "K" between a point opposite Satellite 5 and the United Air Lines maintenance apron at the eastern end of the airport is used only rarely; i.e., when taxiway J is closed.
- (4) Taxiway "F" is used only by the military and by the nonscheduled supplemental carriers.

Most operations at Los Angeles are to the west. However, there may be five to ten days a year when the direction and velocity of the wind dictates that landings and takeoffs be made to the east. Because of the density of traffic at the airport, it is essential that ground traffic not be unnecessarily delayed at any time. Hence, we have investigated the geometry of taxiing turns that are made only when operations are to the east as well as of those that are made when operations are to the west.

Most landings to the west turn off the 7-25 runways prior to their intersection with existing runway 16-34. Nevertheless, and for the same reason, the geometry of all turnoffs west of the intersection have been considered as though they received normal usage.

The taxiway fillets at the edge of the terminal area apron, on the other hand, have not been investigated. Since operations with the 2707 would require expansions on all three of the accessible sides of the apron, the existing fillets would be eliminated.

Runway 7R-25L is 200 feet wide, a circumstance that minimizes the need for and costs of fillet modifications to accommodate the 2707. Many of the taxiways are more than 75 feet wide, with the same result.

Each fillet that would be traversed by the SST was investigated individually. A total of 163 fillets and two curved taxiways was studied. The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers and types of fillets requiring improvements.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	20	14
Rare usage	43	0
Runway-taxiway		
Normal usage	11	1
Rare usage	50	0
Taxiway-terminal apron	15	0
At holding aprons		
Normal usage	6	0
Rare usage	1	0
On maintenance area routes		
Rare usage	<u>2</u>	<u>0</u>
TOTAL number of fillets investigated	148	15
Curved taxiways		
Normal usage	1	1

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate LAX-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - Holding aprons have been constructed at the threshold of existing runway 24 (future runway 24L) and between the thresholds of runways 25L and 25R. Both would require improvement if they are to meet the criteria stated in paragraph 2.2.2.4 for the holding and bypass maneuvering of the 2707.

It has been determined that a 60-foot widening would be appropriate for the full length of the apron serving the runway 25 threshold. A 50-foot

widening and a variable lengthening would provide SST compatibility for the runway 24 apron.

The latter improvement would require the relocation of a blast fence and an extension of approximately 100 feet of a 58-inch by 36-inch corrugated metal pipe arch. Both improvements, of course, would require new shoulders and the resetting of existing edge lights. The apron at the runway 24 threshold would, in addition, require the installation of several new edge lights.

These improvements allow holding one SST at a time on either apron. The aprons could be expanded to accommodate two SST's simultaneously, however, the airplanes would then be too close to runway thresholds for safety.

The costs of such improvements have been estimated and allocated in full to the use of the airport by the 2707.

Terminal Aprons - In order to maintain the terminal-area maneuvering standards adopted in paragraph 2.2 for the 2707, a major modification of the existing taxiway and apron system would be required.

An apron improvement appropriate to the requirements of the SST has been laid out and estimated. (See Plates LAX-1 and LAX-2.) The cost reported at the end of this section for full-strength pavement includes the individual costs for grading, reinforced-concrete pavement, marking, lighting, signing, and the resetting of numerous drainage and utility appurtenances.

3.9.3 Evaluations of Structures

The Los Angeles Airport has a substantial array of substructures, some over which the 2707 will pass and some not. Each of the major structures have been handled as a separate item.

3.9.3.1 Subway

Los Angeles International Airport is transected by Sepulveda Boulevard, which runs in an approximately north-south direction just east of the terminal

area complex. The relationship of highway and airport facilities is such that the parallel east-west runways and taxiways south of the terminal area must be carried over the highway. The vehicular subway constructed for this purpose is a two-span, reinforced-concrete rigid frame. About 1,900 feet in length, it was originally constructed to carry the two 7-25 runways, sections of two high-speed turnoffs, and taxiway K, which is now used only for towing. There were extensive sections designed not for live loads, but for the dead loads of shallow infield fills. Subsequent to the original construction, taxiway J was constructed between the north runway of the 7-25 pair and taxiway K. This required a strengthening of a length of the "light" subway construction. A 384,000-pound vehicle with 30 per cent rolling impact was used as the design live loading.

Investigation included analyses of the effects of the 2707 on the original "heavy" sections and on the strengthened "light" sections.

In the "light" sections, the reinforcement at the bottom of the slab and at the top of the abutment walls is highly stressed. The more severe overstress is found in the latter part of the frame.

The strengthening of the "light" section that was performed when taxiway J was constructed resulted in a much-increased capacity of the reinforced slab over the center bent and between the bent and the abutments. However, it did little to improve the properties of the frame at the top of the abutments, where the maximum stresses caused by the 2707 occur. A modification designed to improve the frame's structural properties in this area would be highly expensive and would entail severe airport operational penalties during construction.

Since the conservatively calculated overstresses are less than a third of the design value allowed for the reinforcement, it is judged that

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the "light" sections of the Sepulveda Boulevard tunnel would not be modified for 2707 loadings. Hence, no costs for modifications to the "light" sections of the tunnel have been charged.

The "heavy" sections carrying the runways and taxiway K were originally designed for a 300,000-pound vehicle with an increase for rolling impact of 33 1/3 per cent. The rigid frames were constructed in 60-foot-long sections. They have clear spans of 36 feet 9 inches and a height from top of footing to underside of deck that varies between 20 feet 6 inches and 22 feet 6 inches.

As in the "light" section, the 2707 would create over-stresses in the slab of the "heavy" section. However, the reinforcement in these sections would be stressed only about 15 per cent above the allowable -- under the circumstances, a level below that warranting strengthening construction.

The center bent of the frame, which separates the southbound and northbound traffic, is composed of an upper girder section, a lower crash-wall section, and heavy columns spaced at 15 feet center-to-center. This results in a wall with opening 10 feet wide and about 10 feet high, separated by 5-foot-wide column sections.

A critical condition created both by the trucks of the DC-8 and the 2707 is shear in the girder members of the center bent. Because of the closer tire-spacing of its main gear trucks, the DC-8 creates a greater shear stress in the concrete of the center bent girders than would the 2707.

In view of the foregoing, it appears that the tunnel must be strengthened to accommodate the forthcoming large aircraft. However, since other aircraft will be in service before the 2707 is operational, the cost of this work is not attributable to the 2707.

3.9.3.2 Box Culvert

The perimeter drain at Los Angeles is an 8-foot 6-inch by 10-foot

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30-inch reinforced-concrete box culvert that passes in various places below aprons, taxiways, and runways. This structure was checked for the live load condition imposed by the 2707. The calculated maximum stresses in the concrete and reinforcing steel at critical sections were found to be within their respective allowable values.

3.9.3.3 Passenger and Baggage Channels

The ticketing buildings on the perimeter of the circulation roadway are connected to their respective satellites by passenger and baggage channels running beneath the aircraft parking apron. Certain of the satellites are similarly interconnected with one another by passenger channels.

As pointed out in a subsequent part of this section, it would be most unlikely that the 2707 would ever be maneuvered between the ticketing buildings and satellites, or onto the aprons between satellites. For that reason, no investigation was made of the adequacy of the existing channel construction with the 2707.

3.9.3.4 Pipes and Conduits

From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered compatible with the 2707.

3.9.4 Terminal Area (See Plate LAX-2)

The Los Angeles International Airport terminal area employs the unit terminal-and-satellite concept. Ticketing buildings arranged along opposite sides of the parking and central services areas are connected each to its own satellite by channels beneath the apron. The entire perimeter of a satellite is thus available for positioning aircraft.

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3.9.4.1 Maneuvering and Docking

Due to the proximity of the satellites to each other and to their respective ticketing buildings, parking of the 2707 is not recommended at interior gate positions. The ten exterior positions indicated on the photo would require improvements to the existing taxiway and apron system. The terminal area occupancy that could be attained without major modifications to the buildings is indicated on Plate LAX-2. One position is available at Satellites 5, 6, and 7, two at Satellites 2 and 4, and three at Satellite 3.

Parking positions are all canted with the exception of Satellite No. 4. The particular arrangements selected have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures. With some restriping, the positions will allow passage of existing subsonic jets, but space is not adequate for passage of forthcoming jumbo jets to the inner apron areas.

3.9.4.2 Passenger Loading System Modifications

The airlines at Los Angeles employ both second-level loading devices and mobile ramps. The second-level devices include fixed and swinging nose-loaders and swing-telescoping bridges.

At Satellite No. 2, since no loaders now exist in the vicinity of the SST parking positions; the new equipment that would be required to serve the 2707 is not considered chargeable.

For both northerly parking position shown at Satellite No. 3, two existing swinging-telescoping loaders could be modified to meet the forward and second doors of the 2707. For the southerly position shown, two existing loaders could also be modified to serve the two doors. The cost of modifications which would be needed is reflected in the estimate at the end of this section.

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New swinging-telescoping loaders would be required at Satellite No. 4 to serve the positions indicated. It is not considered feasible to modify the existing equipment, which has been designed primarily to accommodate nose-in loading of subsonic aircraft. Existing equipment could remain for nose-in loading of subsonic aircraft.

Loaders currently exist at Satellite No. 5. The new devices that would be required have been considered chargeable to the 2707.

The existing swinging-telescoping loader at Satellite No. 6 could be modified to serve the forward door. A new loader of a similar design would be needed to serve the second door.

New loaders would be required at Satellite No. 7 to serve the canted parking position indicated. Since loaders exist in all other positions, the new ones required have been charged to the 2707.

3.9.4.3 Fueling System Modifications

All of the satellite terminals are served by underground fueling systems. The number of oil companies with installations capable of supplying jet fuel to each is one at Satellite No.'s 3, 4, 5, and 7 and four at Satellite No.'s 2 and 6. There are approximately 600 electrically-activated hydrants on the aprons.

The installations at each satellite were examined to determine compatibility with the fueling requirements of the 2707.

At Satellite No.'s 2 and 6, the loops of each supplier are adequate to accommodate the SST positions indicated at each. The costs estimated for modifications to the systems are those for improvements that would provide the same choices to the tenant airlines as are open to them now.

The existing fueling system at Satellite No. 3 appears to have the least capacity of any of those on the airport. If the loop system were to be

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increased, it would be primarily to increase supply to all positions, and any capacity added solely for the SST would be proportionally minor. The costs of two new hydrants at each SST aircraft position, and those of new lateral connections to the loop, are the only expenses considered attributable to the SST.

The loop systems serving Satellite No.'s 4, 5, and 7 appear adequate for the SST positions feasible at each. The typical improvement of two new hydrants and a new lateral would be required at each of the positions.

3.9.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>	
Overlay pavement @ \$1.20/s.y.	\$ 260,000	
Modifications to 15 fillets and 1 curved taxiway		
Full-strength pavement @ \$15/s.y.	54,000	
Shoulder pavement	18,000	
Revisions to lights and signs	15,000	
Widening of runway 24L holding apron		
Full-strength pavement @ \$15/s.y.	32,000	
Shoulder pavement	6,000	
Revisions to lights	3,000	
Relocated blast fence and obstruction lights	3,000	
Extension of 58 inches by 36 inches CMP arch	4,000	
Widening of runway 25L-25R holding apron		
Full-strength pavement @ \$15/s.y.	41,000	
Shoulder pavement	5,000	
Revisions to lights	1,000	
Widening of terminal aprons		
Full-strength pavement @ \$15/s.y.	693,000	
Shoulder pavement	84,000	
Revisions to lights and signs	<u>36,000</u>	
Subtotal	\$1,255,000	
	Best Estimate	High Estimate
Fire and Rescue Equipment (As requested by airport operator)	<u>0</u>	<u>150,000</u>
Total Estimated Costs	\$1,255,000	\$1,405,000

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Estimated Unit Costs Per Gate Position

Passenger loading devices

\$80,000

Fuel system modifications

20,000

Eight of the gate positions determined to be feasible for SST usage were considered in the estimation of the average unit cost of passenger loading devices quoted above. The average unit cost per gate position of fuel system modifications was obtained by averaging the individual gate costs for all SST gates.

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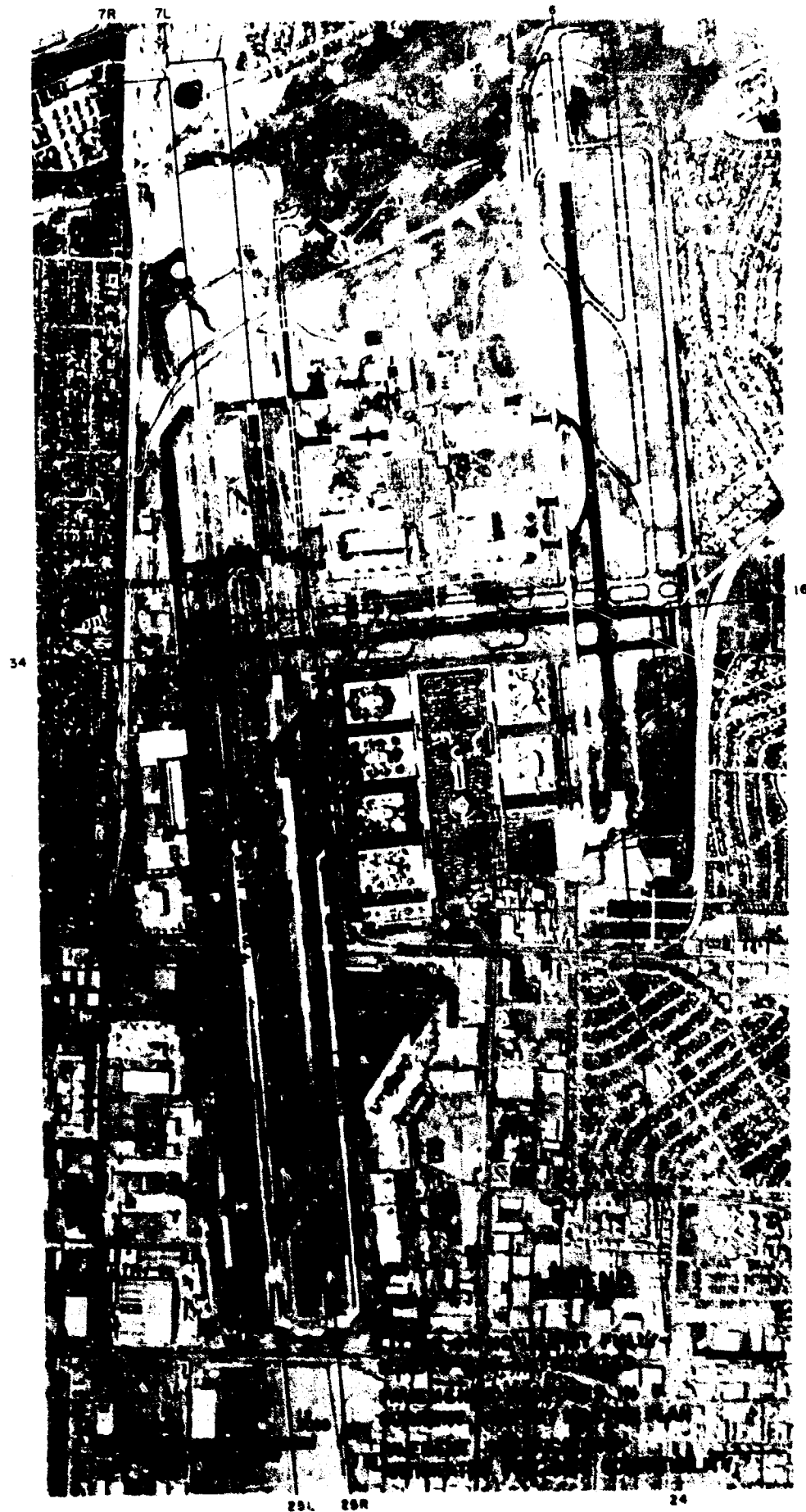
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Los Angeles International

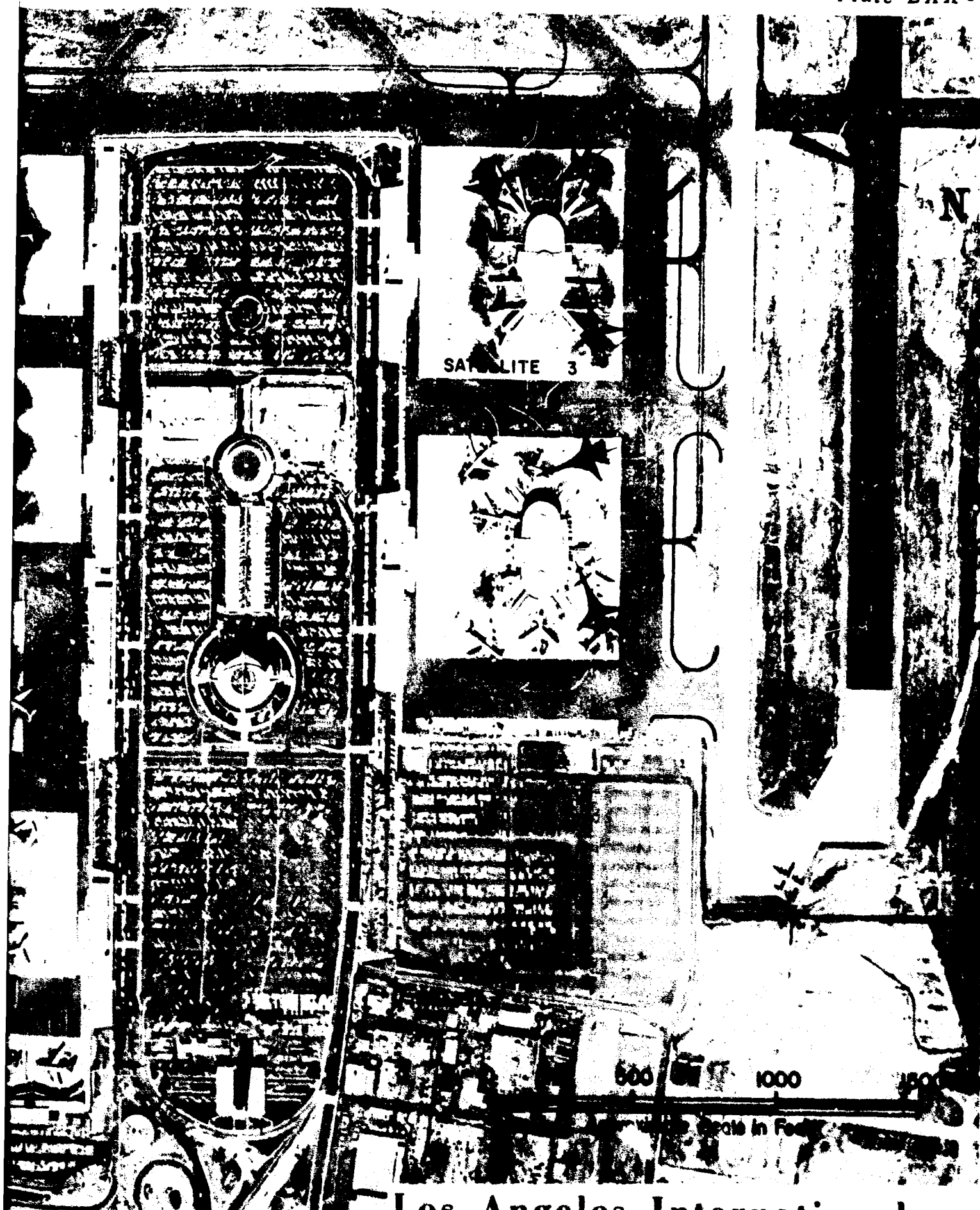
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LEGEND

FEASIBLE SST GATE POSITIONS
TERMINAL APRON EXPANSION
ASSUMED FOR SST USAGE





Los Angeles International

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3.10 Airport Evaluation - Miami International Airport - MIA

3.10.1 Structural Evaluation of Pavements

Both rigid and flexible pavements have been constructed at Miami International Airport. In some areas, rigid pavements have received bituminous overlays.

Rigid Pavements - The largest areas of rigid pavement at Miami are the aircraft parking areas adjacent to the piers extending from the terminal building. All of them are 10-inch slabs placed on a 12-inch compacted base of blended sand and rock with a measured minimum CBR of 60.

Almost all of the remaining concrete pavement in the terminal area is 8 inches thick. The stabilized sand base varies in thickness from 0 to 8 inches. Almost all of this pavement has been overlaid with 3 inches of asphaltic concrete, and the remaining section is scheduled for a 3 3/4-inch overlay. Short sections of runways 9R-27L and 12-30 are also paved with 8-inch concrete supported by stabilized sand bases of various depths up to 8 inches. They have not been overlaid.

There are several small areas paved with 6-inch concrete on stabilized sand bases.

All rigid pavements that might be subjected to heavy SST loadings have been inspected. The majority of the 10-inch thick terminal apron slabs are presently in good condition. The overlaid 8-inch slabs are uniformly in good condition. All 6- and 8-inch slabs not as yet overlaid are judged to be in need of improvement. The overlay scheduled for the 8-inch terminal area concrete will correct the largest single area of distressed concrete, and it may be assumed that the remaining areas of distress will be improved prior to the introduction of the SST.

The data pertinent to rigid pavement design and the calculated stresses induced on slabs without overlays by the DC-8-55 and the 2707 are tabulated:

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t	k	f_c	Per cent of f_c	
			DC-8-55	Model 2707
6	320	407	204	228
8	400	400	145	155
10	600	350	123	124

where t = thickness of concrete slab (inches)

k = recommended modulus of reaction on sand base (pound/inch³)

f_c = recommended maximum allowable flexural stress in slab
(pound/inch²)

Many of the thinner pavements without overlays are obviously seriously overstressed by the fully-loaded DC-8-55, and would be subjected to ever higher stresses by the SST at maximum gross weight. Nevertheless, should it become necessary to overlay any pavements not presently programmed for improvement, the thickness requirements of nonrigid overlays adequate for DC-8-55 loadings would exceed those of the 2707 by fractions of an inch. Therefore, although the 2707 would create the greater stress on existing rigid pavements, the costs of strengthening overlays would be attributable entirely to the DC-8-55.

Flexible Pavements - Miami's airport has been under development since the mid-1920's, and a wide variety of flexible pavement sections may be found there today. Some of the older and lighter pavements have been reconstructed; others of marginal strength have received asphaltic concrete overlays. As a result, all of Miami's flexible pavements are now 12 or more inches thick. It is expected that the Dade County Port Authority's program of annual inspection and correction will continue, and that its pavements will always be adequate for the loads they are required to carry.

The authority's current standards for flexible pavement include 8 to 12 inches of stabilized subbase, 10 to 12 inches of Miami Oolitic limerock, and

2 inches of asphaltic concrete surface course.

The FAA method of flexible pavement design has been used in the present investigation to determine the pavement thicknesses required for the DC-8-55 and the Model 2707. For the recommended subgrade classification of Fa, the DC-8 requires $11\frac{1}{2}$ inches of pavement in critical pavement areas and the 2707, 11 inches.

It is concluded, therefore, that all of Miami's flexible pavements are compatible with the 2707.

3.10.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Miami International Airport were carefully investigated, using both plans and aerial photographs.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at Miami are as follows:

- (1) If runway 12-30 were to remain at its current length, several of the exit taxiways nearest to the runway 12 landing threshold would receive little or no use by the SST. As Plate MIA-1 indicates, however, the runway is to be extended. As a result, the exit taxiways in question will be used routinely by the SST. The assumption has been made that the planned extension will be completed prior to the introduction of the SST.
- (2) Runway 17-35 will have been decommissioned prior to the advent of the SST.

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- (3) The Dade County Port Authority has a continuing program of fillet improvement, and it is possible that some fillets will be improved prior to the introduction of the SST. However, the present investigation takes into account only those fillet improvements that are firmly planned for 1967.
- (4) The continuing growth of air traffic at Miami has already led the Port Authority to investigate the necessity for expansion of the terminal area. It is now anticipated that an expansion of the apron to the west will have been accomplished before the initiation of SST service. For this reason, the fillets on the terminal area's peripheral taxiways were excluded from the investigation of pavement geometry.

Runway 9L-27R, one of the two runways receiving primary use at Miami International, is 200 feet wide. This circumstance tends to minimize the need for and costs of fillet modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. A total of 147 fillets was studied. It was determined that 15 fillets would require improvements if the criteria stated in paragraph 2.2.2.3 were to be observed at Miami.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the number of fillets requiring improvements, by type of intersection and class of usage.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	10	8
Rare usage	29	1
Runway-taxiway		
Normal usage	14	5
Rare usage	38	1
Taxiway-terminal apron		
Normal usage	7	0
Rare usage	3	0
At holding aprons		
Normal usage	13	0
Rare usage	11	0
On maintenance area routes		
Rare usage	<u>7</u>	<u>0</u>
TOTAL number of fillets investigated	132	15

*For definitions of "normal" and "rare" usage and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

Holding Aprons - There are holding aprons at each end of each of the four runways at Miami. All but two of the eight aprons meet the criteria stated in paragraph 2.2.2.4. The two inadequate aprons are located at the ends of runway 17-35. In conjunction with the anticipated terminal apron expansion previously mentioned, this runway (which is used only rarely by the airlines) will be either abandoned or relocated farther to the west.

In addition to the holding aprons at the runway thresholds, there are supplementary aprons located approximately 1,300 feet from the thresholds of runways 9R and 9L. It is considered extremely unlikely that such aprons would ever be utilized by SST aircraft, and no improvements to them have been anticipated.

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3.10.3 Evaluations of Structures

Box Culverts - Aircraft loadings are carried directly by box culverts installed in places to carry the flows of shallow drainage canals. One such structure loops around the west side of the terminal area at distances ranging from 100 to 400 feet from the face of the terminal building. Since it is anticipated that gate positions for the SST would be at least 450 feet farther out, this drainage structure was not investigated.

Another box culvert has been installed at the taxiway entrance to the National Airlines maintenance area. It was not investigated for two reasons: first, the existing maintenance area is not likely to be used for maintenance on 2707; second, should the aircraft enter the area, there is little if any likelihood that they would have heavy passenger or fuel loads on board either when entering or leaving.

Pipes and Conduits - Owing to the high level of ground water at Miami, pipe and conduit have been installed with shallow cover under both rigid and flexible pavements. In recognition of the effects on such installations of live loads transmitted through shallow cover, great precaution has been taken in their selection and installation. From the available data it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore are considered compatible with the 2707.

3.10.4 Terminal Area (See Plate MIA-2)

The terminal area at Miami comprises a long, central terminal and services building, the several segments of which form a "U," from which six concourses, or passenger loading piers, extend at diverging angles of 30°. Concourse 4, the International Building, is in the form of a "T"; the others are linear, some with and some without angular turns. The resulting apron

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areas lend themselves conveniently to the arrangement of aircraft of various space requirements, with the smaller aircraft assuming positions near the base of the pier and the larger aircraft occupying the gates farther out.

3.10.4.1 Maneuvering and Docking

Seventeen SST parking positions have been indicated (see Plate MIA-2) at the six Miami finger piers: two each at Concourses 1, 2, and 6; three at Concourses 5 and 3; and five at Concourse 4. To maintain the maximum degree of flexibility for maneuvering the 2707, as well as smaller aircraft, various combinations of the three basic parking modes - nose-in, parallel, and canted - can be used, as required by the geometry of the concourses, the aprons, and the peripheral apron taxiway, and by the systems of passenger loading known to be preferred by the airlines serving Miami. The particular arrangements selected have been checked for convenience of maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures.

Because there are no firm plans for the terminal-area expansion previously discussed in this section, no investigation of its compatibility with the 2707 could be made. It is possible that new facilities that cannot be foreseen at this time will be provided for the maneuvering and docking of aircraft larger than those now in use.

3.10.4.2 Passenger Loading Devices

At five of the six terminal building concourses, some use is made of second-level passenger loading devices. Only those installed at the outermost gate positions are of concern to the present investigation. A summary of these is given below:

Concourse 1	bi-rail-mounted nose-loaders
Concourse 2	none; mobile ramps used

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Concourse 3 bi-rail nose-loaders

Concourse 4 both bi-rail nose-loaders and mobile ramps

Concourse 5 swinging-telescoping bridges for forward-door loading,
and mobile ramps for second-door loading

The scheduled modifications to Concourse 6 include the installation of bridges similar to those on Concourse 5; however, their locations have not been fixed as of this writing.

At the SST gate positions shown for Concourses 1, 3, and 4 the length of the nose of the 2707 would require either new swinging-telescopic loaders or swing-loaders in conjunction with short fixed bridges. An alternative consideration by the airport operator consists of simple building extensions on which the rail mounted loaders could be rehung. This solution may be preferable to the operators, since the loaders would be retained and additional badly-needed hold-room space would be provided.

At the three gate positions shown for Concourse 5, the 2707 can be parked close enough to the face of the terminal to be reached by the existing swinging-telescoping bridges. Some modification to the bridges would be needed to enable them to be raised to the level of the sill of the doors of the 2707.

For the purpose of this report, new extendable loaders and swinging-telescoping loaders have been estimated, where needed. The estimates for the extendable loaders include the costs of the requisite hold-room expansions, which would replace the more costly telescoping bridges that would otherwise be required. Loaders for the positions indicated at Concourses 2 and 6 are not considered chargeable to the SST, since none now exist in these areas. All positions at other concourses will require new or relocated loaders.

With the exception of the loaders used for the SST's forward door, all of the suggested modifications to or relocations of existing loading

devices would result in equipment that could be used equally as well with the large subsonic jets as well as the SST.

The estimated cost of modifications to existing loading devices is an average based upon the individual estimates made for the gate positions shown on Concourses 1, 3, 4, and 5.

3.10.4.3 Fueling System

Underground hydrant fueling facilities have been installed at Concourses 3, 4, 5, and 6. The system at Concourse 4 is electrically operated; those at the other concourses are actuated by pressure-sensing devices. An under-apron transfer system has been installed but never placed in service at Concourse 1. It is designed to delivery fuel received from tenders at the outer edge of the parking apron to hydrants located under the aircraft fueling receptables.

The costs of the future underground systems that will probably be installed eventually at Concourses 1 and 2, are not considered chargeable to the 2707.

The existing 12-inch and 14-inch loops serving the remaining concourses are sufficient to meet the requirements of the SST. A system of new laterals and two new hydrants at each position would be required for the 2707 and is reflected in the cost estimate.

3.10.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Improvements to 15 fillets	
Full-strength pavement @ \$6/s.y.	\$ 47,000
Shoulder pavement	12,000
Revisions to lights and signs	<u>12,000</u>
Total Estimated Costs	\$ 71,000
Estimated Unit Costs Per Gate Position	
Passenger loading devices	\$110,000
Fuel system modifications	7,000

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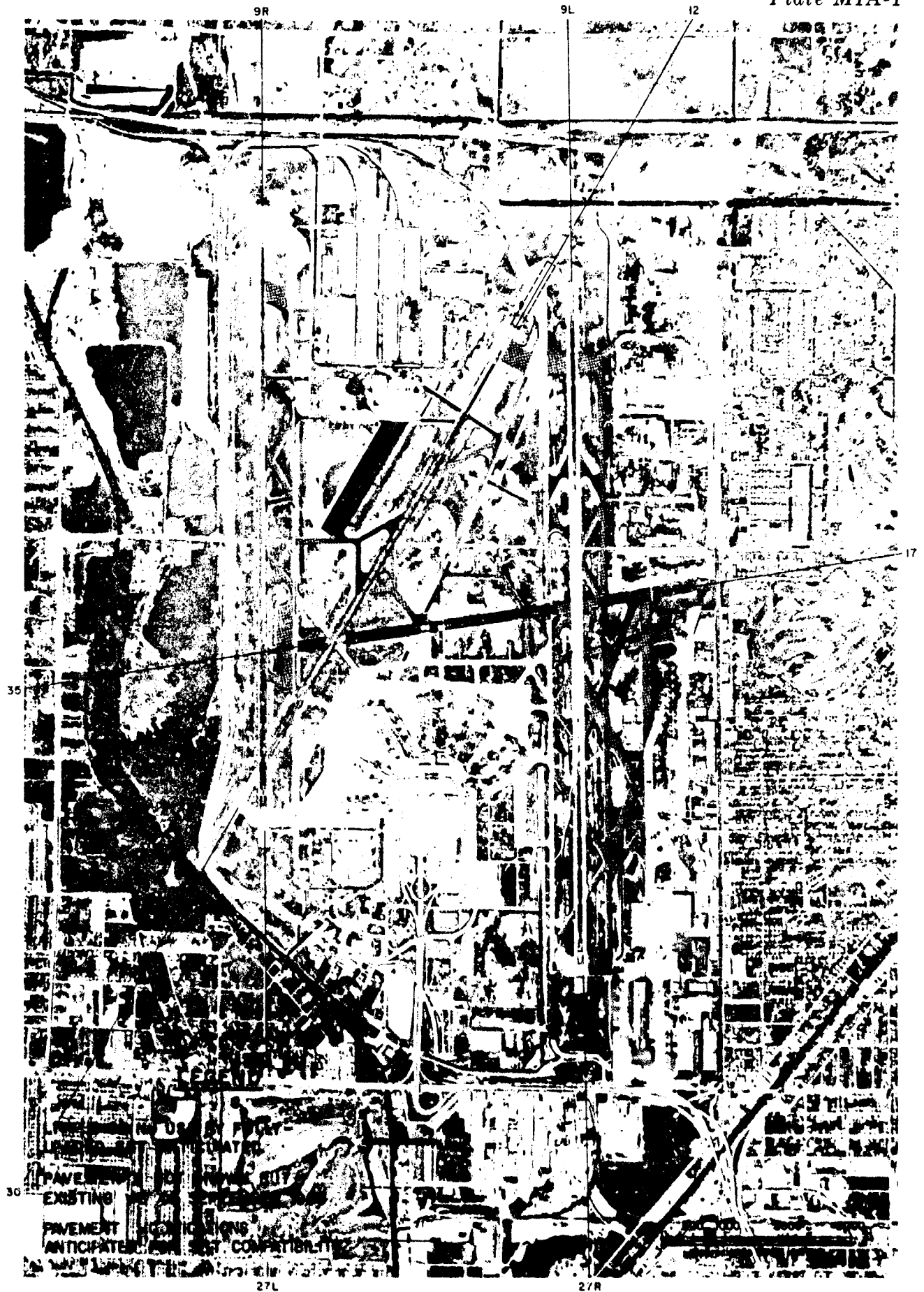
Of the 17 gate positions determined to be feasible for SST usage, 13 were considered in the estimation of the average unit cost of passenger loading devices, quoted above. The average unit cost per gate position of fuel system modifications was obtained by averaging the individual gate costs for the 13 SST gates where an underground fueling system exists or will be installed in the future.

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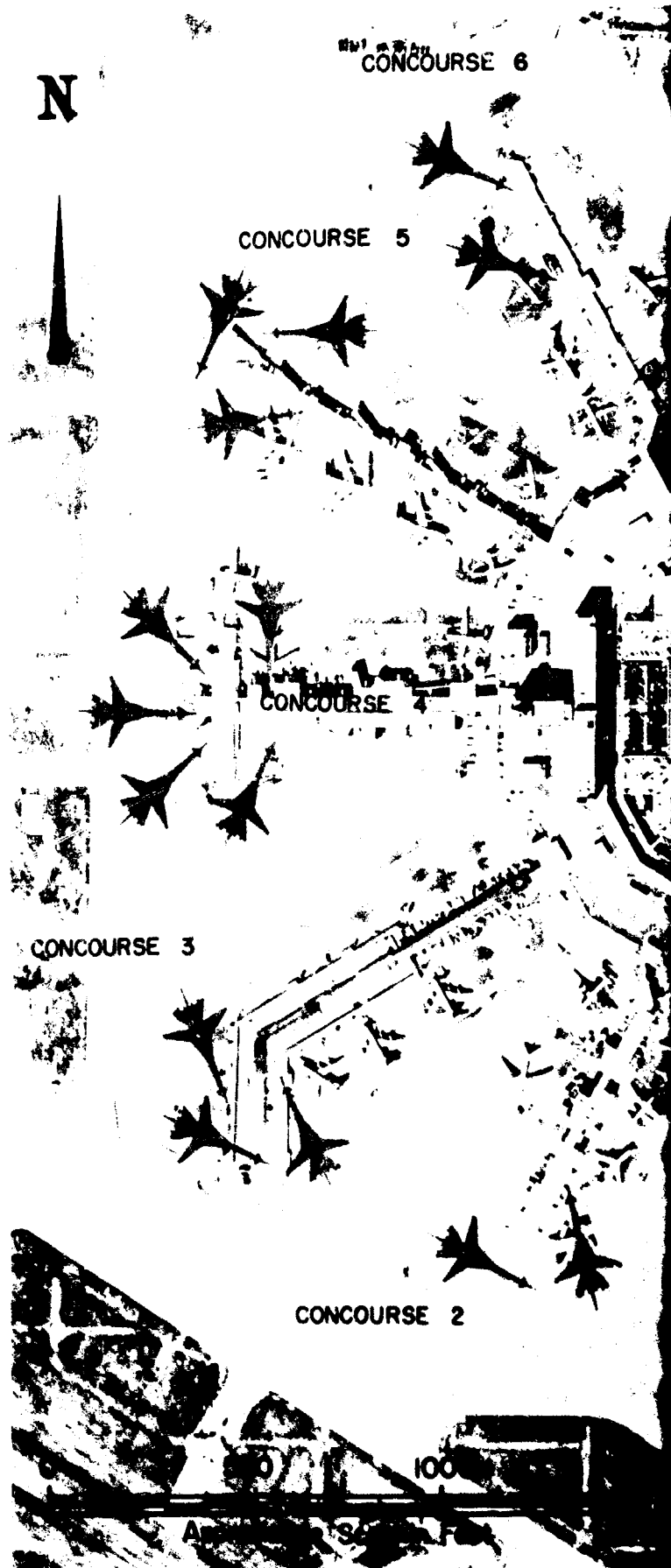


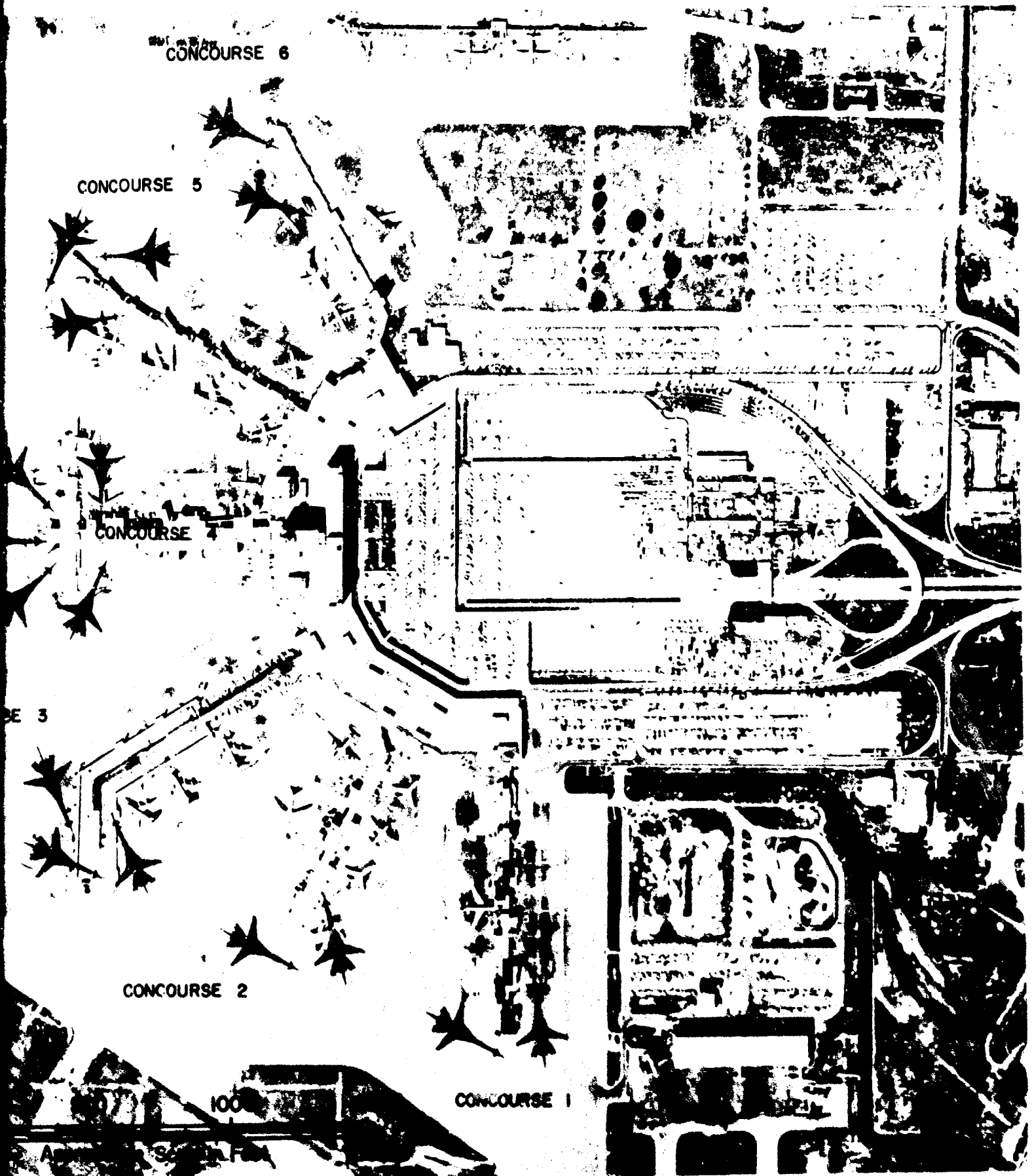
Miami International 157

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LEGEND

FEASIBLE SST GATE POSITIONS





2 Miami International

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3.11 Airport Evaluation - O'Hare International Airport - Chicago - ORD

3.11.1 Structural Evaluation of Pavements

Both rigid and flexible pavements have been constructed at O'Hare International Airport. In some places, the rigid pavements have received bituminous overlays. Engineers of the Chicago Department of Aviation recommend the use of a subgrade modulus of reaction of $k = 100$ for the design of rigid pavements and an FAA soil strength classification of F4.

Rigid Pavements - The critical areas at the ends of runway 14R-32L, four of its exit taxiways, sections of the taxiway parallel to it and the terminal area apron consist of 15-inch-thick concrete pavement over 12-inch of crushed-stone base. The modulus of reaction recommended for use on top of the stone base is $k = 190$.

For such conditions, it is calculated that both the SST and the DC-8-55 induce flexural stresses about 6 per cent higher than the recommended maximum allowable, which is 330 pounds per square inch.

The noncritical length of runway 14R-32L is an 11-inch-thick concrete pavement supported by a 16-inch-thick base. The recommended modulus of reaction at the top of the base is $k = 220$, and the maximum flexural stress allowed in the concrete is 330 pounds per square inch.

The calculated stresses induced by the DC-8-55 and the 2707 in this pavement are approximately 51 per cent higher than the allowable recommended.

Some overlays have been placed in the past, which is an indication that calculated overstresses of this magnitude are unacceptable. Since the stresses induced by some of today's vehicles are no less than those that the fully-loaded 2707 would induce, none of the costs of such pavement improvements as may be required for the noncritical area of runway 14R-32L should be attributable to the SST.

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Runway 14L-32R and taxiways serving it are 12-inch-thick concrete pavements. Asphaltic concrete overlays ranging in thickness from two to four inches have been placed over much of the original construction. The flexural stresses induced in all of these pavements are somewhat higher for DC-8-55 loadings than for 2707 loadings. The costs of any future pavement improvements, therefore, would not be attributable to the SST.

Flexible Pavements - The FAA method was used to design O'Hare's flexible pavements, which are 27 and 29 inches thick. The Boeing Company's analyses of the pavement thickness needed for operations by the DC-8-55 and the 2707 result in a 25.5-inch requirement for the former and a 23.5-inch requirement for the latter. Since such thicknesses are equalled or exceeded by all existing flexible sections, it is anticipated that the SST will be compatible with them.

3.11.2 Requirements for New Pavements

Filletts - The fillets at existing pavement intersections on O'Hare International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at O'Hare are as follows:

- (1) Existing runways 9-27 and 4-22 will almost certainly be decommissioned prior to the introduction of SST operations.
- (2) Turns of 180° between the inner and outer circular apron taxiways are rarely made. Furthermore, consecutive 90° turns made in opposite directions between these two taxiways are rarely made.

Many of the taxiways at O'Hare have been built to a width of 100 feet, and runway 14R-32L is 200 feet wide. This circumstance tends to minimize the need for and costs of fillet modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. A total of 101 fillets and five curved taxiways was studied. It was determined that 9 fillets would require improvements if the criteria stated in paragraph 2.2.2.3 are to be observed at O'Hare. The curved taxiways were found to be adequate.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	8	1
Rare usage	7	0
Runway-taxiway		
Normal usage	14	3
Rare usage	8	0
Inner and outer circular taxiways		
Normal usage	23	5
At holding aprons		
Normal usage	5	0
On maintenance area routes		
Rare usage	<u>27</u>	<u>0</u>
TOTAL number of fillets investigated	92	9
Curves taxiways		
Normal usage	5	0

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

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The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate ORD-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - The holding aprons at the thresholds of runway 14R-32L are not adequate for the 2707 by the criteria stated in paragraph 2.2.2.4. Each will require a widening of approximately 40 feet. Costs for this additional paving have been assessed against the SST and are included in the cost summary at the end of this section.

The three other aprons that presently exist are inadequate. However, one of them will cease to be useful for holding at the threshold when the planned extension to the northwest of runway 14L-32R is accomplished. Another is on existing runway 9-27, which will be decommissioned, as previously noted. The third, which is not located at a threshold, is used to hold inbound aircraft when the terminal area aprons cannot accept them immediately after landing. It is not foreseen that this apron would be used for holding SST's.

As a result of the above findings, no costs have been estimated for the expansion of these latter holding aprons.

3.11.3 Evaluations of Structures

Bridges and Culverts - A circumferential taxiway bridge is being completed over the airport access highway. It has been designed for a hypothetical aircraft of 600,000-pound maximum gross weight. Although the 2707 is 75,000 pounds heavier, the configuration of its main landing gear (see

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paragraph 2.1), in comparison with the bridge design criteria, is such that the loads are more advantageously distributed.

Investigation of stresses and foundation bearing pressures indicates that the structure will be compatible with the 2707.

Pipes and Conduits - From the available data, it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered compatible with the 2707.

3.11.4 Terminal Area (See Plate ORD-2)

The terminal area at O'Hare International Airport is basically patterned on the central-terminal-and-finger-pier concept. The central domestic terminal is actually two buildings branching from a circular central services core. The international terminal is located away from the domestic terminal, but connected to it by concourses.

Five finger concourses extend into the apron area from this terminal complex. The pattern is one of alternating "Y"-shaped and linear buildings so arranged that the two linear buildings are parallel to and about 700 feet clear of branches of the "Y"-shaped buildings that flank them on both sides. The branches of the two "Y"-shaped domestic concourses have an interior angle of about 70° . At the "Y" serving the international arrivals terminal, the interior angle is about 60° . The master plan for the terminal area shows that two additional linear fingers are planned, one at each end of the existing pattern.

3.11.4.1 Maneuvering and Docking

Maneuverability studies of existing facilities indicate that there are at least 19 parking positions where the 2707 could be readily accommodated. As may be seen on Plate ORD-2, the finger pier configuration readily lends itself to canted parking at interior positions and to parallel parking at end

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positions. Both modes of parking, when used in such circumstances, have the inherent advantage of minimizing both the need for and extent of modifications to existing passenger loading devices and the required lengths of new loaders.

No parking studies were made of the two linear concourses proposed in the master plan of the terminal area because of the status of planning. The parking arrangements shown allow taxiway clearances for forthcoming jumbo jets, however, some restriping may be required, and single lane traffic must be utilized on the inner aprons where two-way traffic is now the practice.

3.11.4.2 Passenger Loading Devices

An inventory was made of the passenger loading devices presently in use at O'Hare. Four models have been installed:

- (1) swinging-telescoping bridges with a maximum extension of 107 feet;
- (2) rail-mounted nose-loaders having about 6 feet of horizontal travel;
- (3) swinging nose-loader (one installed);
- (4) swinging, extensible nose-loader (one installed).

With the typical canted parking position shown it is possible to utilize the swinging-telescoping bridges existing at some locations. These bridges would have to be modified vertically in order to reach the door-sills of the 2707.

At Pier D, four existing swinging-telescoping loaders could be modified and utilized for two of the three parking positions shown. Two new loaders would be required to serve the SST parked at the end position.

The end position at Concourse "E" would require replacement of nose-loaders with new loaders. The center position could be served by one existing

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loader, after the necessary modifications, and by one new loader at a new location. The interior position could be served by modifying the two existing loaders.

At Concourse "F," the end positions would require new equipment. Both interior positions shown could be served with the existing swinging-telescoping loaders, appropriately modified.

Each of the two parking positions shown at Concourse "G" could be serviced by modification of existing equipment.

The remaining positions at Concourses "B," "C," "H," and "K" would require new loaders. Since there is no existing second-story loading equipment at Concourses "B" and "C," none of the costs of such equipment have been attributed to the 2707. At Concourses "H" and "K," however, there are existing bi-rail loaders; hence, the costs of new equipment have been judged attributable to the SST.

3.11.4.3 Fueling System Modifications

Except at the International Arrivals Building, where the existing system has been abandoned, all concourses are served by loop fuel systems having a combined capacity of 46,300 g.p.m. At present, the typical jet gate position is served by two sets of underwing hydrants, each of which is connected to a different supply loop.

At each of the SST positions shown on Plate ORD-2, two new fueling hydrants are considered to be necessary to permit the 2707 to be refueled at its maximum rate. To serve these new hydrants, new laterals have been provided for in the cost estimates.

The average cost of additional hydrants reported in the summary at the end of this section was obtained from the total of the individual estimates for each position shown, with the exception of those positions at the

International Arrivals Building (Concourse BC).

3.11.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Modification of 9 fillets	
Full-strength pavement @ \$10/s.y.	\$ 24,000
Shoulder pavement	20,000
Revisions to lights and signs	12,000
Widening of 2 holding aprons	
Full-strength pavement @ \$10/s.y.	44,000
Shoulder pavement	14,000
Revisions to lights	<u>3,000</u>
Total Estimated Costs	\$117,000
Estimated Unit Costs Per Gate Position	
Passenger loading devices	50,000
Fuel system modifications	12,000

Of the 19 gate positions determined to be feasible for SST usage, 15 were considered in the estimation of the average unit cost of passenger loading devices and fuel system modifications quoted above.

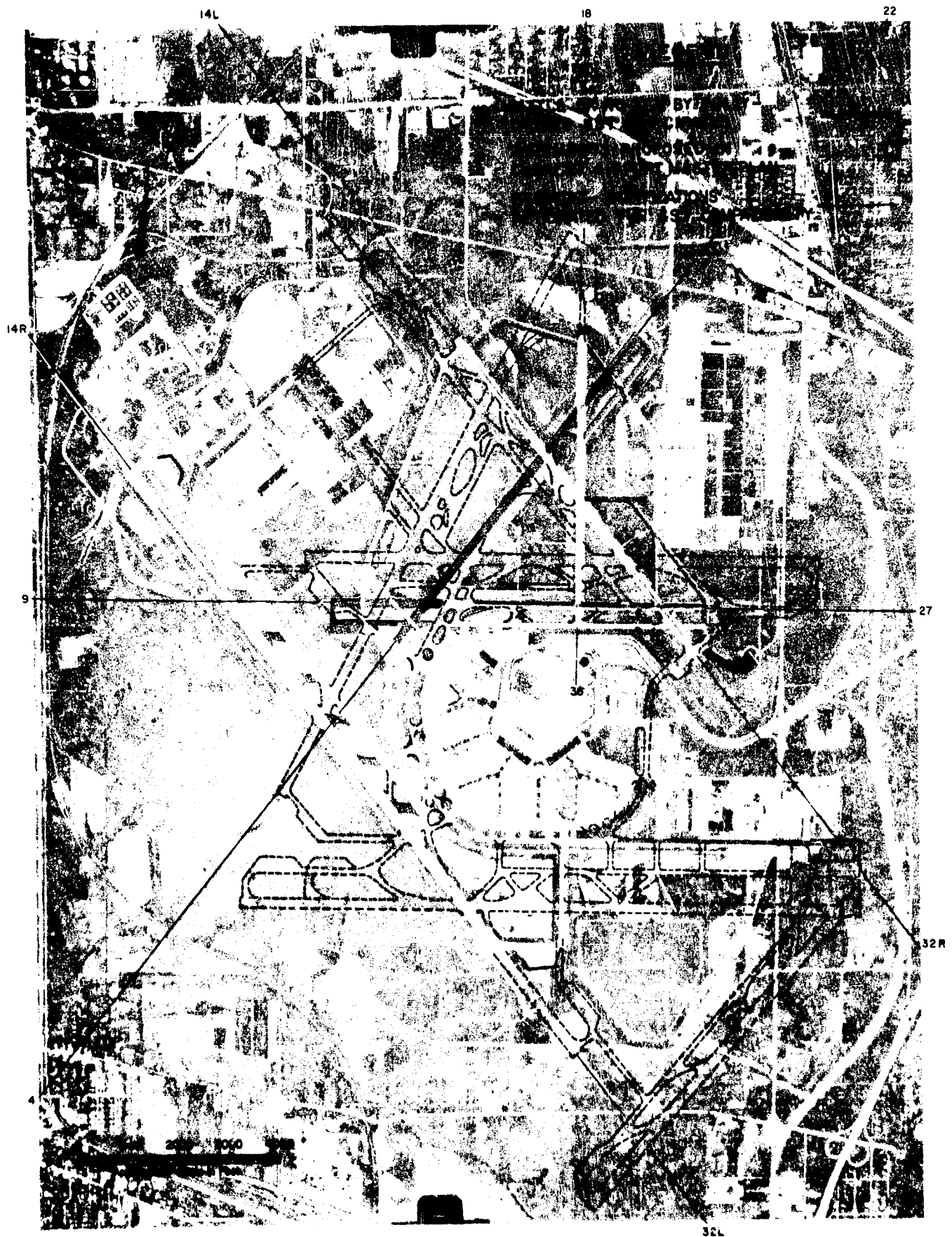
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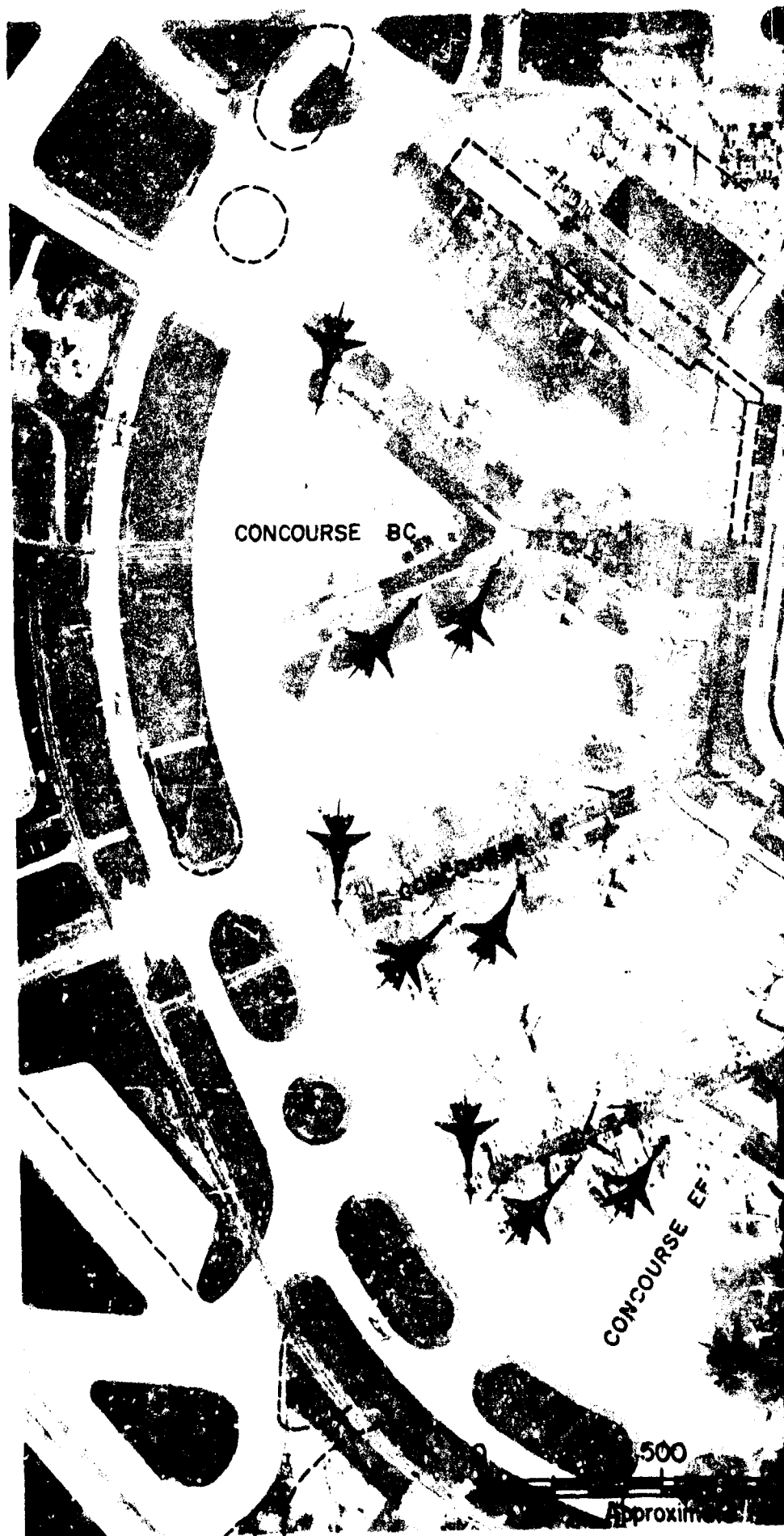


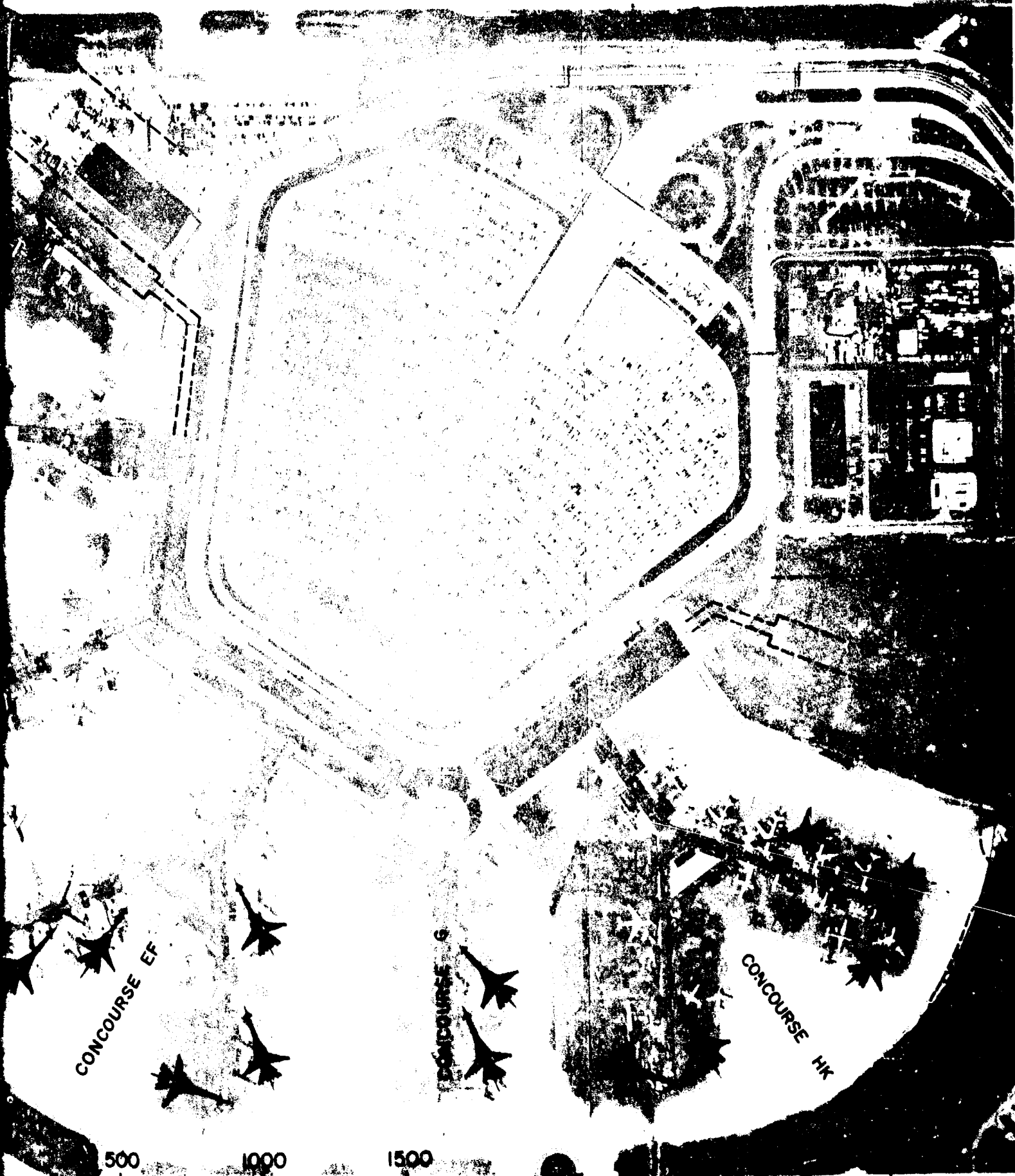
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LEGEND

FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN





500 1000 1500

Approximate Scale in Feet

O'Hare International

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3.12 Airport Evaluation - Portland International Airport - PDX

3.12.1 Structural Evaluation of Pavements

All pavements at Portland International Airport are flexible. They have been constructed partly on a dredged sand of variable thickness, but principally on existing flood plain deposits, which are clay and silt soils.

The following subgrade ratings have been recommended by the Port of Portland Aviation Department:

Area 1) Runway 10L-28R, adjacent taxiways, and terminal apron:

CBR = 10.6

Area 2) Runway 10R-28L and adjacent taxiways: CBR = 15

The pavements in Area 1 are 37 inches thick. In Area 2, a recent 2-inch-thick bituminous overlay placed on the original bituminous surfaces has brought the critical-area pavements up to a total thickness of 26 inches and the noncritical pavements to 23 inches.

The comparison of pavement thickness requirements, in inches, as determined by the Corps of Engineers' method is as follows:

	<u>Critical</u>		<u>Noncritical</u>	
	<u>DC-8-55</u>	<u>2707</u>	<u>DC-8-55</u>	<u>2707</u>
Area 1 (CBR = 10.6)	31	33	28	30
Area 2 (CBR = 15)	23	25	21	22.5

Since the required thicknesses are exceeded everywhere by the actual thicknesses, it is concluded that the existing pavements are adequate to sustain the maximum gross weight of the 2707. Supporting this conclusion is the belief that the SST will be operated infrequently at maximum gross weight at Portland International Airport.

3.12.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Portland International Airport were carefully investigated. The geometrics of the fillets

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were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The one specific assumption made for the investigation of the fillets at Portland was that the few fillets that are presently substandard in terms of the FAA's recommendations will have been brought up to those recommendations before the SST enters service. This assumption is based on information received from the airport's operator.

Runway 10R-28L has been built to a width of 200 feet. This circumstance tends to minimize the need for and costs of fillet modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. From the layout of the parallel runways and their connecting taxiways, it appears that, when operations are into the west, takeoffs are from 28L and landings are made on 28R. When the direction of operation is reversed, takeoffs are from 10L and landings are made on 10R. Nevertheless, it has been assumed that arrivals and departures will be made in each direction on both runways.

A total of 42 fillets and three curved taxiways was studied. It was determined that one fillet should be improved if the criteria stated in paragraph 2.2.2.3 1 to be observed at Portland. The curved taxiways were found to be adequate.

The following tabulation shows the numbers of fillets studied and those requiring improvements, by type of intersection and class of usage.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	8	1
Rare usage	8	0
Runway-taxiway		
Normal usage	8	0
Rare usage	8	0
Taxiway-terminal apron		
Normal usage	7	0
Rare usage	1	0
At holding aprons		
Normal usage	<u>1</u>	<u>0</u>
TOTAL number of fillets investigated	41	1
Curved taxiways		
Normal usage	3	0

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate PIX-1 have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - The holding aprons located near the thresholds of runways 10L and 28L are both inadequate by the criteria outlined in paragraph 2.2.2.4. The cost of enlarging these aprons is attributable to the SST and has been included in the cost summary of this report.

3.12.3 Evaluation of Structures

Pipes and Conduits - From the available data, it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore are considered

compatible with the 2707.

3.12.4 Terminal Area (See Plate PDX-2)

The terminal area at Portland International Airport is patterned on the concept of the central terminal with finger piers. Two piers, providing a total of 24 gate positions, extend divergently from Portland's central terminal building. The clear distance between them at their ends is approximately 800 feet, which provides ample maneuvering space. The angle of convergence of the piers is such that the 2707 could maneuver well into the apron area. However, neither of the two interior gate positions adjacent to the terminal building are recommended for use by the 2707 because of blast considerations.

An extension of the north pier has been proposed, but construction has not yet started.

3.12.4.1 Maneuvering and Docking

The Portland airport management has indicated that two SST gate positions will probably be adequate initially. To attain the maximum degree of flexibility in maneuvering, one gate each at the two existing piers could be utilized. As shown on Plate PDX-2 adequate space is available to accommodate additional positions if and when they are needed.

The two parking positions shown have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to the existing gate arrangements and passenger loading procedures. Clearance for forthcoming jumbo jets has been maintained on the apron taxiways.

3.12.4.2 Passenger Loading Devices

Nine gate positions, located near the base of the piers, currently have passenger-loading bridges. The remaining 15 gates utilize mobile ramps to load and unload passengers. The loading devices are of three different kinds.

- (1) Six rail-mounted nose-loaders having about six feet of horizontal travel;

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- (2) Two swinging-nontelelescoping nose-loaders;
- (3) One swinging-nontelelescoping loader with rotating cab.

Where rail-mounted nose-loaders are now installed on the outer perimeter, it would be necessary to provide a new loader of the necessary length to clear the canard of the 2707 and meet the door height. Initially, only forward door-loading will be required at Portland International, so one new loader will be required at each 2707 position.

The Port of Portland is presently planning a thorough study of terminal area requirements for the coming generations of airline aircraft, and it may well be that improvements made for new, large subsonic jets will result in facilities that are compatible with the 2707. Nevertheless, the costs estimated for new passenger-loading devices are attributed in full in the summary of costs.

3.12.4.3 Fuel System Modifications

Aircraft fueling is now performed with mobile tenders which are operationally flexible and can be furnished in quantities sufficient to supply the needs of the 2707. Although fueling by tenders may require slightly more time than fueling by underground systems, the total annual gallonage pumped at Portland is not anticipated by the airport's authorities to warrant the installation of an underground system. However, should such a system be installed, it is assumed that the initial installation would be made compatible with the demands of the supersonic transport.

3.12.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Modification of one fillet	
Full-strength pavement @ \$8/s.y.	\$10,000
Revisions to lights and signs	1,500

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<u>Item</u>	<u>Estimated Cost</u>
Widening of holding aprons	
Apron 28L	
Full-strength pavement @ \$8/s.y.	\$17,800
Revision to lights	500
Apron 10L	
Full-strength pavement @ \$8/s.y.	14,200
Revision to lights	<u>500</u>
Total Estimated Costs	\$44,500
Estimated Unit Costs Per Gate Position	
Passenger loading devices	40,000

Both of the two gate positions determined to be feasible for SST usage were considered in estimating the average unit cost quoted above.

NOTE: Plates PDX-1 and PDX-2 do not reflect the latest Master Planning information. This information was received too late to be incorporated into the airport and terminal layouts. The differences are minor, however, and do not affect the study results; and since the planning is not yet final, it was felt that updating the layouts was not warranted.

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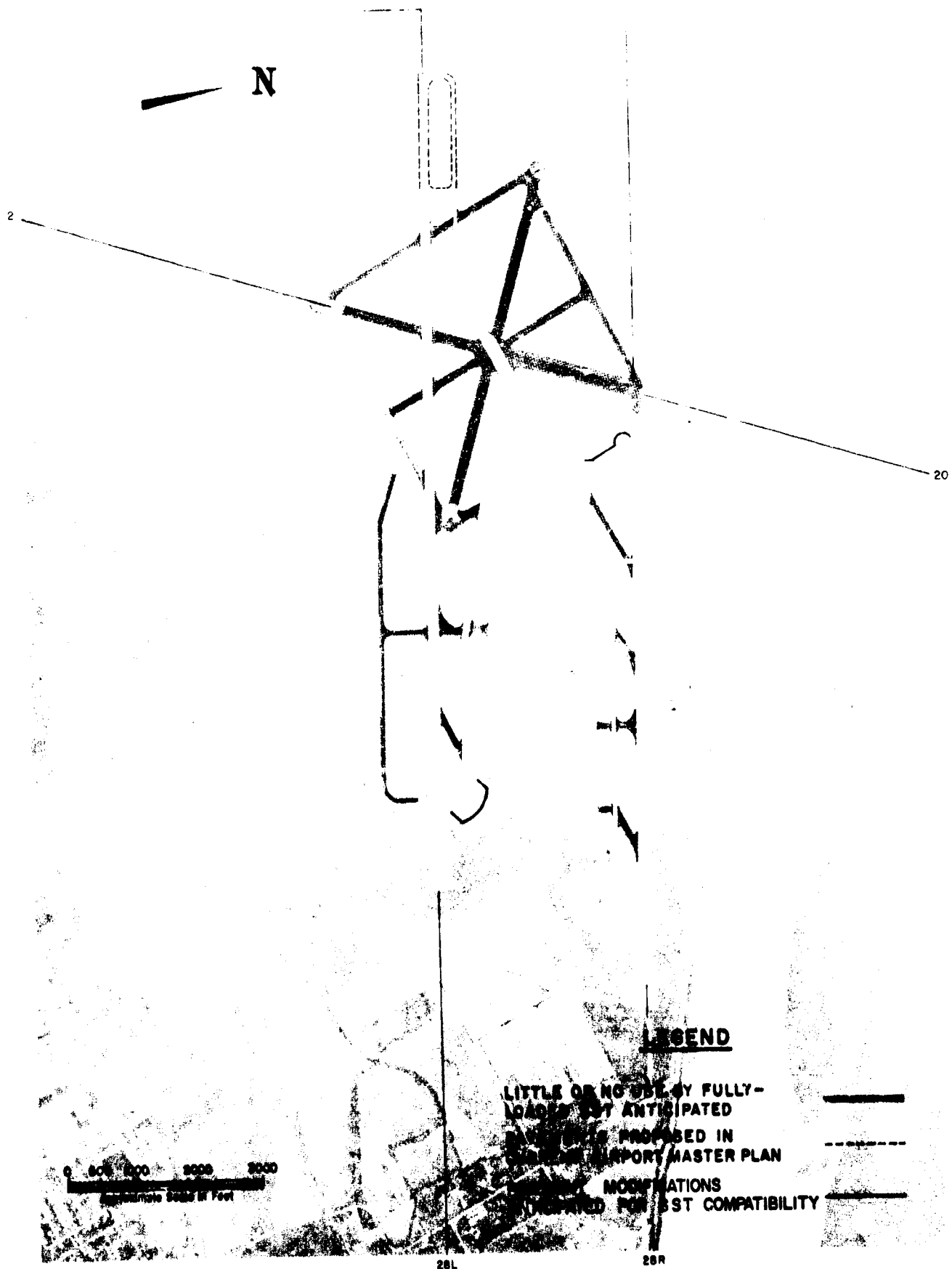
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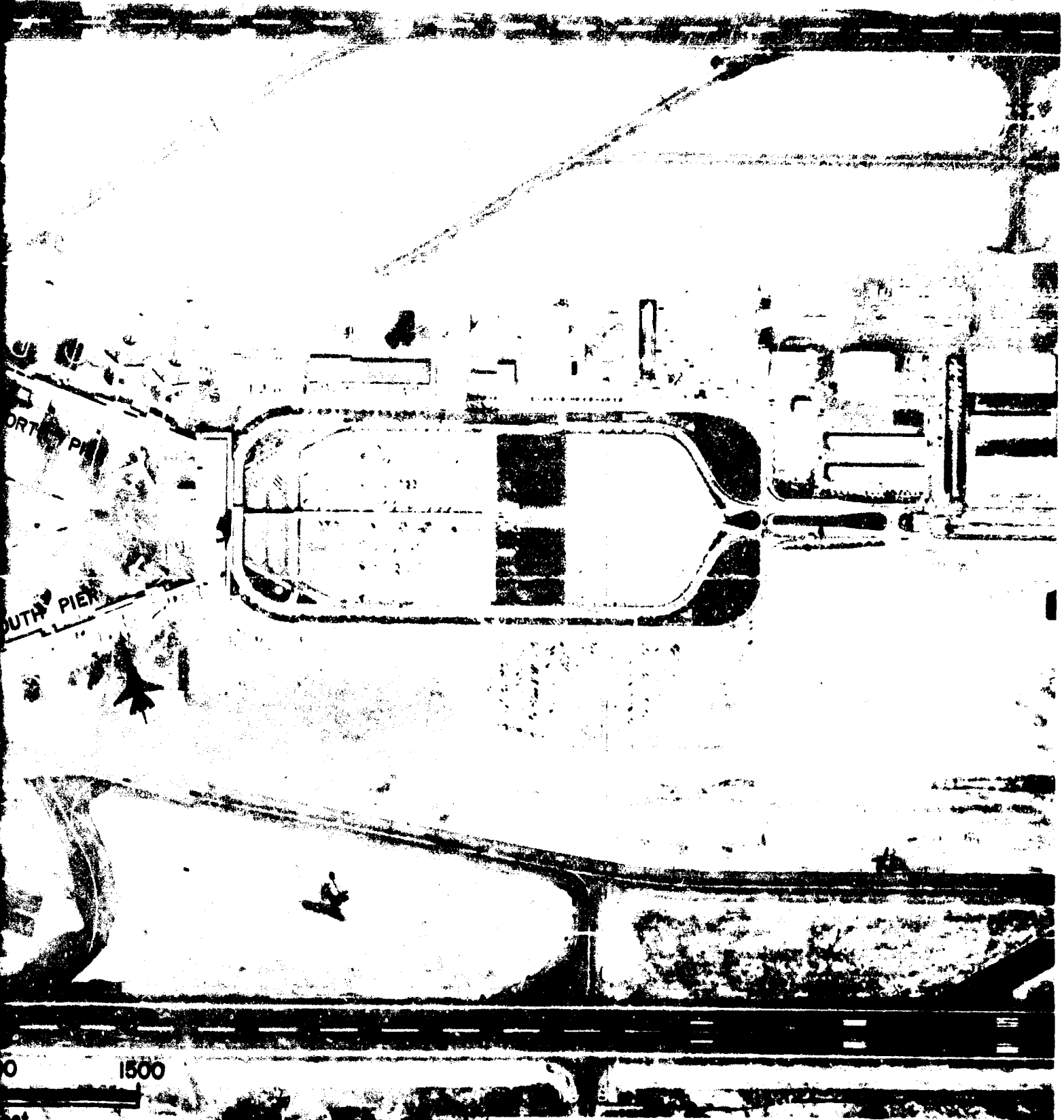
FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN

NORTH PIER

SOUTH PIER

0 500 1000 1500

Approximate Scale in Feet



Portland International

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3.13 Airport Evaluation - Philadelphia International Airport - PHL

3.13.1 Structural Evaluation of Pavements

Both rigid and flexible pavements have been constructed at Philadelphia International Airport. Some sections of rigid pavement have received bituminous overlays.

Most of the airport pavements have been or are being constructed on sand fills that have been placed hydraulically and allowed to settle over a tidal marsh.

Rigid Pavements

The terminal apron and certain of the existing taxiways are 12-inch-thick portland cement concrete. Engineers of the Division of Aviation recommend a value for the modulus of reaction of the subgrade of $k = 250$. They also recommend the use of a maximum allowable flexural stress in the slabs of 295 pounds per square inch. The choice of the latter value is based upon their observations of the performance of the rigid pavements that have required overlays.

The Boeing Company's analyses of the stresses that would be induced by the DC-8-55 and the 2707 on Philadelphia's rigid pavements show that each would cause serious stress conditions:

DC-8-55 @ 328,000 pounds	149 per cent of allowable
2707 @ 675,000 pounds	144 per cent of allowable

Since the SST would create the lesser overstress, no costs have been allocated to it for the improvements of rigid pavements.

Flexible Pavements

Little is known with certainty of the thickness or composition of the airport's original pavements. However, data are readily available for improvements made during the last fifteen years.

In 1951, the existing east-west runway was extended approximately 2,300 feet westward on a subgrade composed of 6 feet of selected backfill classified as E-2 soil. The new pavement was composed of an 11-inch-thick, drybound macadam base and a 3-inch-thick bituminous surface.

In 1959, a further extension of about 2,200 feet was added. A thick layer of selected backfill was also placed for this extension. The upper 4 feet of the material was classified as an E-2 soil with good drainage characteristics; and a subgrade classification of Fa was used in the design. The 14½-inch-thick pavement structure was made up of 11 inches of waterbound macadam base and 3½ inches of bituminous surface. At the same time, a minimum of 1½ inch of bituminous overlay was added to the previous construction of runway 9-27.

The most recent design for a flexible pavement at Philadelphia is that for the taxiway parallel to runway 17-35. For an F2 subgrade classification, the pavement section specified is 5 inches of subbase, 10 inches of penetrated macadam, and 3 inches of bituminous surface.

Since the Engineers judge that the old construction of unknown thickness is performing as well as the newer construction, they have recommended that the present investigation of Philadelphia's flexible pavements be based on the known FAA subgrade classification of F2 and a California Bearing Ratio of 20.

Use of the methods employed by the FAA and the Corps of Engineers for the design of flexible pavements in critical areas yields the following required total thicknesses:

	<u>FAA Method</u>	<u>C. of E. Method</u>
DC-8-55	18 inches	18.5 inches
2707	16.5 inches	20 inches

By the Corps of Engineers' method, the 1959 extension of runway 9-27 would be deficient by 5½ inches. However, the results of standard tests

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performed on the selected backfill placed there, as well as the requirements of the specifications under which it was placed, indicate that at least this much of the backfill may be considered as subbase.

It is concluded, therefore, that the existing flexible pavements at Philadelphia will be compatible with the 2707 and that planned future pavements will be at least equal to those now in use.

3.13.2 Requirements for New Pavements

The requirements for new pavements have been reviewed upon the assumption that all of the proposed work shown on the Airport Plan, Plate PHL-1, will be constructed by the time the SST is operating. It should be noted that the complete implementation of the facilities proposed in the current Master Plan will revise and eliminate significant sections of the current pavements, particularly the terminal area periphery taxiway, and will convert runway 4-22 into a taxiway. Runway 9R-27L, its parallel taxiway, and a by-pass taxiway system are currently under construction, and contract drawings for the work have been reviewed.

Filletts - A careful investigation was made both of filletts at existing intersections that are to remain after implementation of the Master Plan and of filletts that are to be constructed at new pavement intersections. The geometrics of existing filletts were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph. The geometrics of filletts currently in the construction stage conform to the FAA's recommendations.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report.

Each fillet that would be traversed by the SST was investigated individually. A total of 68 intersection filletts and two curved taxiways was studied.

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It was determined that the two curved taxiways, and 12 of the fillets, would require improvements if the criteria stated in paragraph 2.2.2.3 are to be observed at Philadelphia.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the number of fillets requiring improvements, by type of intersection and class of usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	9	10
Rare usage	18	0
Runway-taxiway		
Normal usage	9	1
Rare usage	13	0
Taxiway-terminal apron	See above discussion	
Normal usage	4	0
At holding aprons		
Normal usage	<u>3</u>	<u>1</u>
TOTAL number of fillets investigated	56	12
Curved taxiways		
Normal usage	0	2

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate PHL-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - If the airport is developed in accordance with the

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current Airport Master Plan, there will be a total of six holding aprons serving the six runway thresholds. Those at Runway ends 9L, 9R, 27L, and 35 are either existing or under construction. Among them, all but the apron at Runways 35 and 9R thresholds are of dimensions adequate for the requirement that a Boeing 747 jet be able to by-pass a 2707 holding with wings in the full open position. Suitable widening for these thresholds has been laid out, and the subsequent cost estimate is included in the summary at the end of this report.

The other two remaining aprons, which will serve runway ends are not yet constructed. It is anticipated that their final designs will be such as to accommodate the SST in the manner deemed appropriate by the airport's operator.

3.13.3 Evaluations of Structures

Grates and Drains - There are a number of drainage structures so located in the airfield pavements that they are subjected directly to aircraft gear loads. Each of the different types was investigated to determine its adequacy for supporting the maximum loads imposed by the 2707. The investigations included grates, frames, supporting beams, and footings.

The grates are understressed by the most severe loads that can be transmitted by the gear of the 2707. Cast iron grate frames could be moderately overstressed, but not seriously enough to warrant their replacement. The interior beams supporting multiple grate arrangements would be slightly overstressed if considered as acting by themselves, but adequate if considered as acting compositely with their concrete encasements. Maximum base pressures are considered unobjectionable. Small overstresses have been calculated for the hooked bars in the toes of footings, but again, as with the grating frames, we do not consider that such overstresses would warrant the replacement of an existing structure.

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Pipes and Conduits - From the available data, it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore are considered compatible with the 2707.

3.13.4 Terminal Area (See Plate PHL-2)

The existing terminal area at Philadelphia International employs the central terminal-and-finger pier concept. The central terminal building is a long, rectangular structure from which three concourses extend to the south at slightly divergent angles.

At the present time, a major redevelopment of the terminal complex is anticipated. The current terminal area concept envisions two unit terminals with six satellite clusters providing 66 gate positions. This scheme is superimposed upon an aerial photograph of the existing terminal area.

3.13.4.1 Maneuvering and Docking

Studies were based on the future terminal concept. Twelve gate positions would be readily available to the 2707 at the satellites. Others could be available if more become necessary. The positions shown allow use of conventional type loaders. All apron passage points allow for jumbo jet clearance. The west position at each satellite has taxi-out capability. The easternmost satellite could be more readily utilized if the edge of the planned apron were moved further east, however, this was not considered necessary for general airport compatibility.

Some restriping will be necessary but it is assumed that this would be handled in the future planned expansion.

3.13.4.2 Passenger Loading Devices

Mobile ramps are presently used for the enplaning and deplaning of passengers at Philadelphia. Second-level loading will be employed when the

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terminal complex is improved. It was assumed that the loading devices eventually selected will be compatible with the 2707 at those gate positions where it will dock. No charges have been allocated to the 2707 for modifications, relocations, or replacements of passenger-loading devices.

3.13.4.3 Fueling System Modifications

Aircraft fueling at Philadelphia is accomplished by mobile tenders. The tenders are operationally flexible and can be used to supply the 2707. Should a hydrant system be installed, it is assumed that the initial installation would be made compatible with the requirements of the SST.

3.13.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Widening 12 fillets and 2 curved taxiways	
Full-strength pavement @ \$15/s.y.	\$ 55,000
Revisions to lights and signs	19,000
Widening 2 holding aprons	
Full-strength pavement @ \$15/s.y.	128,000
Shoulder pavement @ \$4/s.y.	9,000
Revisions to lights	<u>1,500</u>
Total Estimated Costs	\$212,500

NOTE: Plate PHL-1 and PHL-2 are not precisely accurate to the latest planning, since the art work was prepared before the receipt of latest data. The differences are minor, however, and do not affect the study results; and since the planning is not final as yet, it was felt that updating the photos was not warranted.

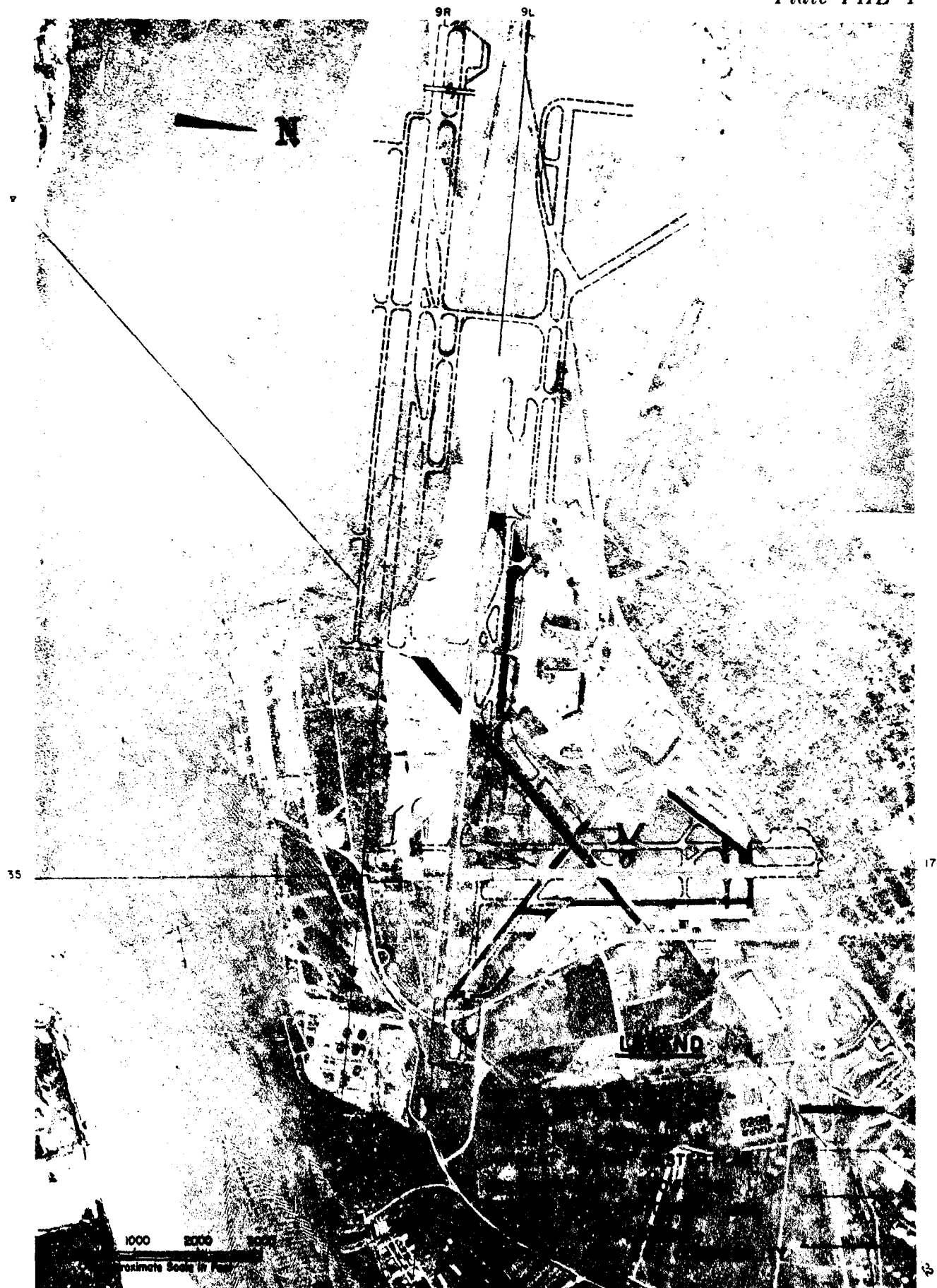
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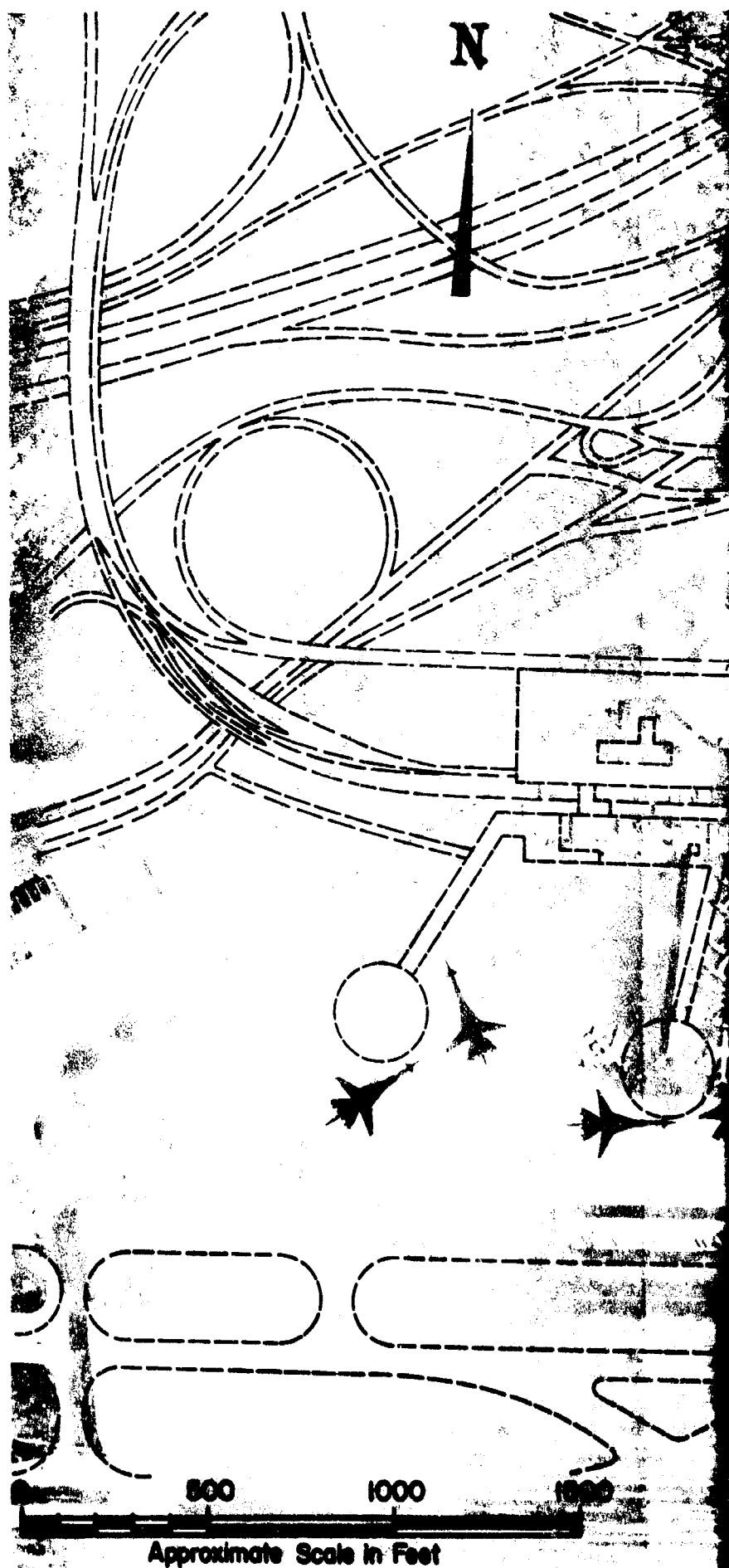


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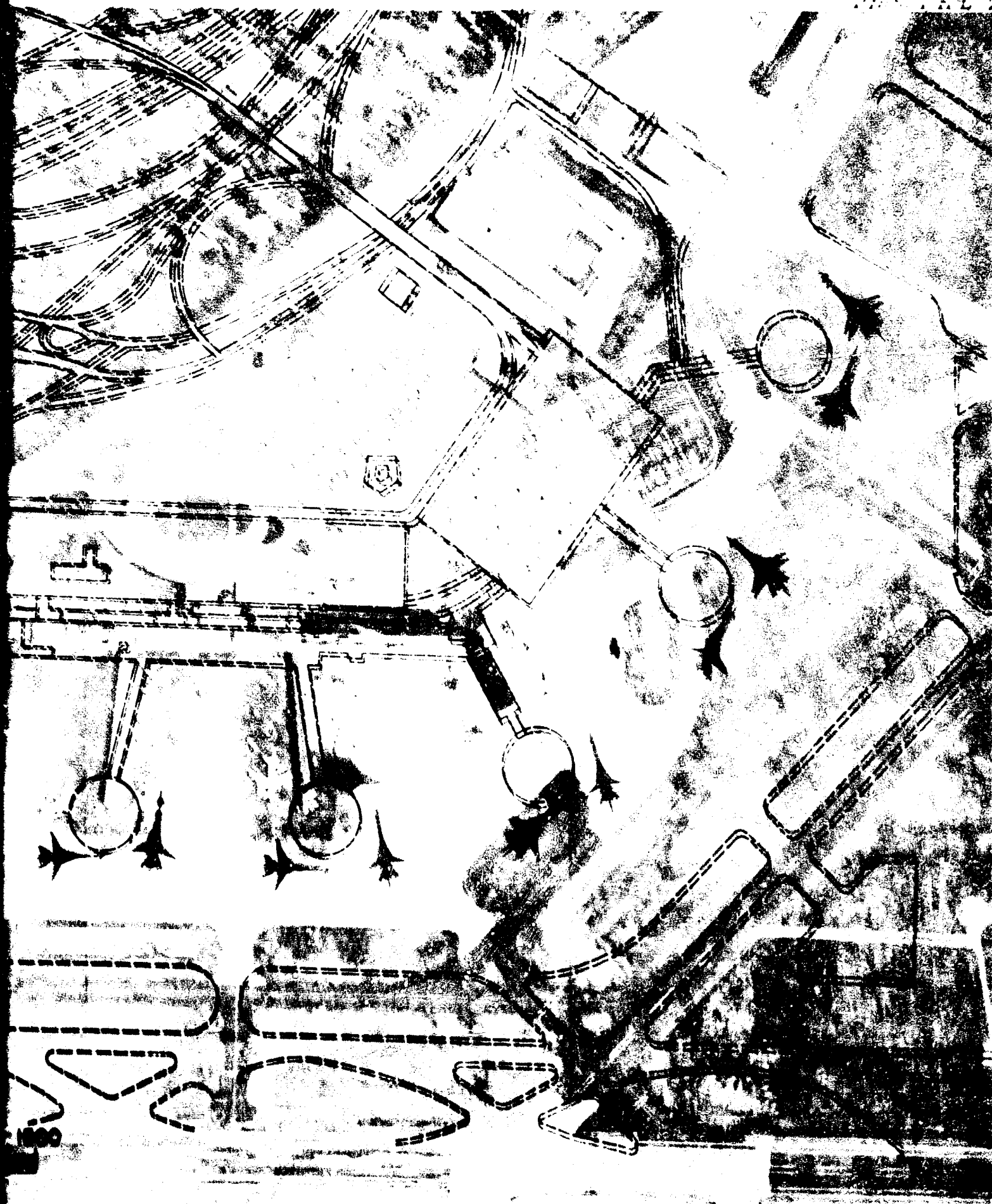
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LEGEND

FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
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Philadelphia International

3.14 Airport Evaluation - Seattle-Tacoma International Airport - SEA

3.14.1 Structural Evaluation of Pavements

Excluding those pavements deemed to receive little or no usage by the supersonic transport at maximum ramp weight, all pavements at Seattle-Tacoma International Airport are rigid or rigid with bituminous overlays.

The locations of the different pavement sections are tabulated below:

12-inch rigid pavement	2,500-foot length at each end of existing Runway 16-34 and the three holding aprons; 10,000-foot length of Taxiway 1; and the south-east terminal apron.
10-inch rigid pavement	Majority of the terminal area; Taxiway 3; and 1,900-foot length of Taxiway 1 between Taxiway 3 and Taxiway 6.
8-inch rigid pavement with 5-inch bituminous overlay	1,250-foot length of portion of Runway 16-34.
6-inch rigid pavement with 8-inch bituminous overlay	Remaining interior portion of Runway 16-34.
6-inch rigid pavement with 6-inch crushed-stone base and 4-inch bituminous overlay	Runway 2-20.

The flexural stresses induced by the DC-8-55 are everywhere higher than those that would be induced by the 2707. Therefore, the costs of any pavement improvements that might become necessary would not be attributable to the SST.

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3.14.2 Requirements for New Pavements

Fillets - The fillets at existing pavement intersections on Seattle-Tacoma International Airport were carefully investigated. The geometrics of the fillets were taken from detailed site plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The specific assumptions made for the investigation of the fillets at Seattle are as follows:

- (1) Existing runway 2-20 will almost certainly be decommissioned prior to the introduction of SST operations.
- (2) The terminal apron depth is such that relatively wide sweeping turns may be made from the entering taxiways without interfering with parked aircraft.

Several of the old runways at Seattle may be used as taxiways. This circumstance tends to minimize the need for and costs of fillet modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. A total of 52 fillets was studied. It was determined that one fillet would require improvement if the criteria stated in paragraph 2.2.2.3 are to be observed at Seattle.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets requiring improvements, by type of intersection and class of usage.

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PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	6	0
Rare usage	8	0
Runway-taxiway		
Normal usage	4	0
Rare usage	9	0
Taxiway-terminal apron		
Normal usage	8	1
Rare usage	2	0
At holding aprons		
Normal usage	6	0
Rare usage	2	0
On maintenance area routes		
Rare usage	<u>6</u>	<u>0</u>
TOTAL number of fillets investigated	51	1

*For definition of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate SEA-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - The supplementary holding apron located approximately 1,700 feet from the threshold of Runway 34 is adequate by the criteria outlined in paragraph 2.2.2.4.

If those criteria were to be observed at Seattle, both the runway 34 and the runway 16 holding aprons would have to be widened. The cost of widening these aprons in the manner shown on Plate SEA-1 have been estimated and allocated to the 2707. It is assumed that the apron 34 would be enlarged by replacing

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25 feet of the existing 50-foot-wide shoulder with full-strength pavement, and with the remainder of the widening on the inside. The provision of a 50-foot shoulder at the edge of the widened pavement would require a fill approximately 40 feet high. The cost of such a fill would be excessive; therefore, the cost allocated for the widening is based upon the economical solution described above.

To avoid the expense of removing and replacing the blast fence, apron 16 is also widened to the inside. The runway 16 displaced threshold makes this especially feasible.

3.14.3 Evaluations of Structures

Subway - The southward extension of runway 16-34 required the construction of a subway to carry South 188th Street beneath the runway and its parallel taxiway. The subway is a reinforced-concrete, two-span rigid frame with clear interior spans of 33 feet 6 inches. Reinforced concrete struts spaced at 10 feet on centers in the subgrade brace the footings of the exterior legs of the frame against the forces of lateral earth pressure. The minimum depth of cover above the top of the subway at the runway and taxiway crossings is about eight feet.

The structure was designed for an aircraft-imposed live loading of 600,000 pounds. An analysis was made of stresses in the frame and its footings and of pressures on the soil under its footings resulting from the passage of the 2707 on the pavement above. All conditions were found to be satisfactory.

Pipes and Conduits - From the available data, it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered compatible with the 2707.

3.14.4 Terminal Area (See Plate SEA-2)

The terminal area at Seattle-Tacoma International is based upon the central terminal-and-finger pier concept. Present planning for the terminal

calls for four concourses diverging at 90° from each other off the north and south ends of the main building.

Concourse "B," after extending from the central terminal for some distance, bears 45° so that its outer face parallels the north-south runway. Concourse "C," when completed, will be a mirror image of Concourse "B" if the existing master plan remains unchanged.

3.14.4.1 Maneuvering and Docking

Studies were made of the four existing concourses and it was determined that the 2707 could be readily accommodated at each. Gate positions representative of those which appear feasible for the airplane to be docked and maneuvered by conventional techniques are shown on Plate SEA-2. These positions include those studied for costs of additional fuel hydrants and modifications of passenger loading devices.

Seven SST's have been positioned at Seattle-Tacoma. Owing to the unusually large apron space available in the terminal area, it is feasible to park nose-in at most positions. The use of this parking mode minimizes the 2707's encroachment on adjacent parking positions, which can be occupied by subsonic or piston-engine aircraft. The outer SST parking position shown at Concourse "B" has been canted slightly from a perpendicular to the concourse face in order to facilitate maneuvering on departure.

One parallel position has been shown at the existing extremity of Concourse "C." Power-out departures could be made from this position, under certain circumstances, providing engine blast effects on swinging away were not objectionable.

All parking positions shown on Plate SEA-2 have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading

procedures. Clearance has been maintained for taxiing of the forthcoming jumbo jets.

3.14.4.2 Passenger Loading Devices

The airlines at Seattle-Tacoma employ both second-level loading devices and mobile ramps. The second-level devices include:

- (1) fixed-length swinging nose-loaders;
- (2) fixed-bridge nose-loaders; and
- (3) swinging-telescoping bridges.

Owing to the configuration of the SST, none of the loading devices now on the market could be used for nose-in parking, and the availability of an appropriate new device would be a prerequisite to the use of this mode of parking by the 2707.

The costs of providing a new type of nose-loading device capable of two-door loading have been estimated. The costs of the two new loaders of conventional design required for the parallel parking-position shown at Concourse "C" have not been considered, since it is assumed that future passenger-loading installations at this concourse, when made, will be compatible with the SST.

The costs of the new two-door loaders are attributable to the 2707. They are reported in the summary at the end of this section.

3.14.4.3 Fueling System Modifications

Both mobile fuel tenders and underground fueling systems are in use at Seattle-Tacoma.

The mobile tenders are operationally flexible and can be furnished in quantities sufficient to supply the SST's total need. Should hydrant systems be installed in places now served by tenders, it is assumed that the initial installation would be made compatible with the requirements of the SST.

Underground hydrant fueling facilities have been installed at Concourses

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"C" and "D" and at the interior positions on the west side of Concourse "B."

For per-gate-position estimating purposes, the costs of two new hydrants and of a new lateral connecting them to the supply lines has been assumed attributable to the 2707 only at those positions that could be served by the supply lines as they exist today.

3.14.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>
Modifications to i fillet	
Full-strength pavement @ \$11/s.y.	\$ 2,000
Shoulder pavement	1,000
Revisions to lights and signs	1,000
Widening of Runway 34 holding apron	
Full-strength pavement @ \$11/s.y.	44,000
Revisions to lights and restripping taxiways	<u>6,000</u>
Total Estimated Costs	\$54,000
Estimated Unit Costs Per Gate Position	
Passenger loading devices	\$150,000
Fuel system modifications	11,000

Of the seven gate positions determined to be feasible for SST usage, five were considered in the estimation of the average unit cost of passenger loading devices quoted above. The average unit cost per gate position of fuel system modifications was obtained by averaging the individual gate costs for the four SST gates where an underground fueling system exists.

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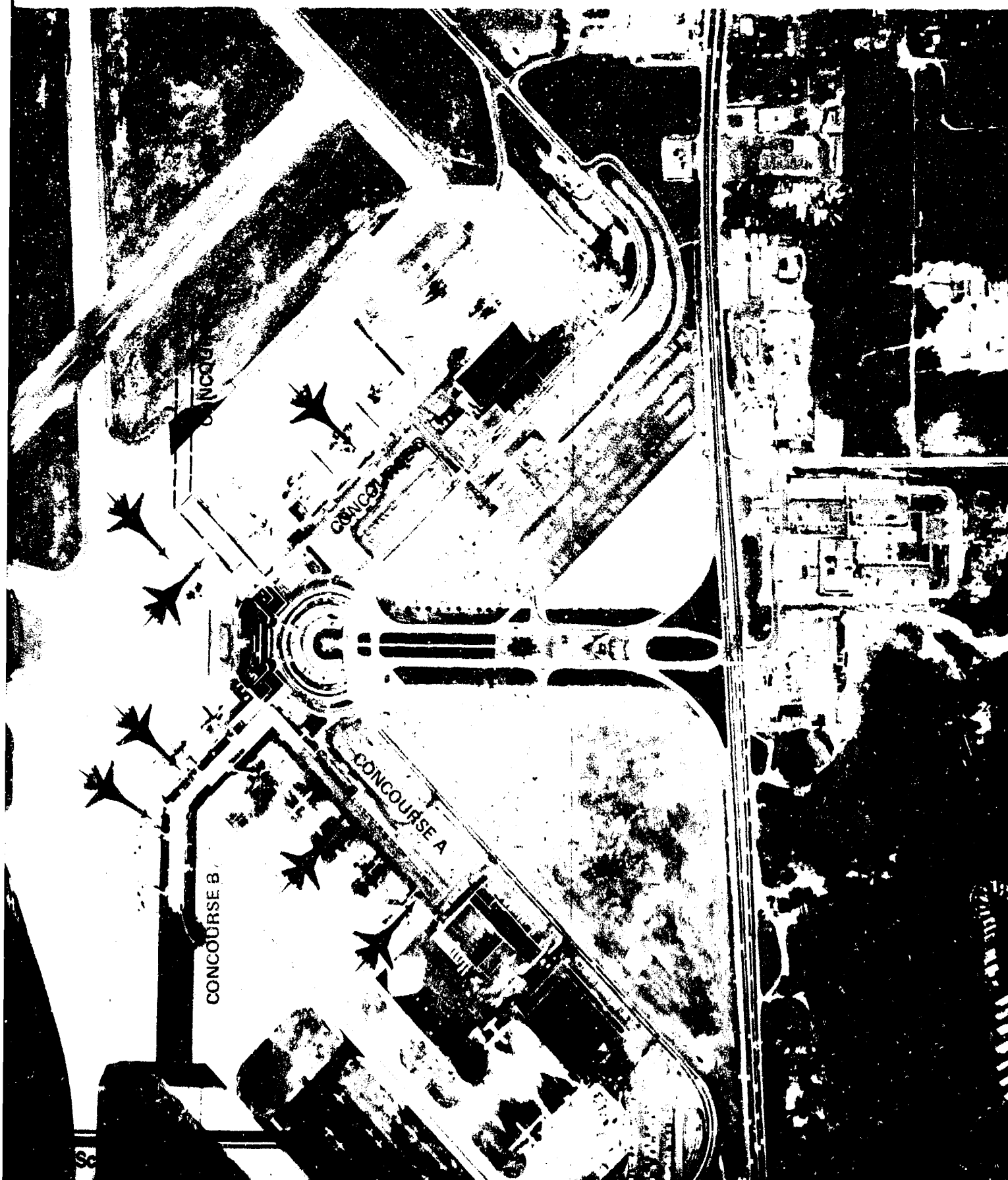
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3.15 Airport Evaluation - San Francisco International Airport - SFO

3.15.1 Structural Evaluation of Pavements

At San Francisco International, concrete pavement is generally used for the critical end-sections of runways, for holding aprons, for certain taxiways, and for hardstands on certain terminal aprons. All other pavement, including noncritical sections of runways and the greater proportion of terminal aprons, is flexible. In areas of flexible pavement distress, it is now the practice to make improvements with concrete inlays. On runways, the central 60 feet is inlaid; on taxiways, the central 45 feet. Elsewhere, flexible pavements that are considered substandard are being resurfaced.

The airport has been constructed largely on a reclaimed portion of San Francisco Bay by dry-fill placement of sandy soil from a nearby borrow area. Because the Bay here was once a tidal marsh on organic silt of a depth as great as 60 feet, both differential and overall settlements of the airport have occurred in the past and are expected to continue.

The Public Utilities Commission, which operates the airport, has advised that the airport soil classification is F2 and that a subgrade CBR value of 15 is appropriate for the SST compatibility evaluation. (The Corps of Engineers' method of flexible pavement design is preferred by the Commission.) It has also given a k value of 400 for the top of the cement-treated base used extensively for both rigid and flexible pavements. For the rigid pavement, all of which is 13 inches thick, 325 pounds per square inch is the allowable flexural working stress.

Rigid Pavements - The DC-8-55 induces a flexural stress of 356 pounds per square inch in the concrete pavements; the 2707, a stress of 345 pounds per square inch. In the unlikely event that overstresses as minor as these should require improvements to rigid pavements, these costs would be properly attributable to heavily-loaded subsonic jet aircraft, rather than to the 2707.

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Sections of rigid pavement have been constructed in the terminal apron area. At Concourses "G," "F," and "FF" there are wide strips of concrete at the aircraft parking positions. At Concourses "C" and "E" small concrete pads have been inlaid.

Flexible Pavements - All flexible pavements that will be used by the SST are 18 inches thick except for the new aprons at Concourses "G," "F," and "FF," which are 20 inches thick. The cement-treated base is considered to be a high quality base (compressive strength = 750 psi). Its thickness is 10 inches in the 18-inch pavements and 12 inches in the 20-inch pavements. Each section comprises, in addition, 4 inches of untreated base and 4 inches of asphaltic-concrete surfacing.

Equivalency factors for the cement-treated bases and for one inch of the 4-inch-thick surface are based on the judgment of the consultant to the Public Utilities Commission and the findings of a recent government research report.¹ For the approximately 70,000-pound equivalent single-wheel load of both the 2707 and the DC-8-55, an equivalency factor of 1.34 has been used for the cement-treated base. For both aircraft, the factor of 1.4 recommended by the Commission's consultant for the lowest inch of asphaltic concrete surface has been used. The equivalent total pavement thicknesses so derived are as follows:

<u>Actual Thickness</u>	<u>Equivalent Thickness</u>
18-inch pavements	21.8 inches
20-inch pavements	24.5 inches

1 Thickness Design Procedure for Airfields Containing Stabilized Pavement Components. Final Report, Contract No. ARDS-286, Prepared for Federal Aviation Agency by Soil Testing Services, Inc., September, 1964.

Engineers of the Public Utilities Commission advise that values ranging from CBR 15 to CBR 80 have been obtained from field measurements of subgrade strengths. In discussions with these engineers, the conclusion was reached that a CBR value of 20 might be more representative of the minimum prevailing subgrade strength than the lowest recorded value of 15. In at least one instance, the Commission, in an application for Federal aid, has indicated a subgrade strength of not less than CBR 20 for a particular area of the airport.

The Commission has expressed the thought that CBR 15, rather than CBR 20, should be adopted to provide a factor of safety for anticipated growth versions of the SST. While this position is understandable, it is not in accordance with the guidelines given by the FAA for the compatibility study, and its adoption for the investigation of one airport would represent a departure from the procedure used for all others in the study.

Nevertheless, for illustrative purposes, the thickness requirements obtained by the use of both values in the CBR equation are shown in the following tabulation:

	<u>Critical</u>		<u>Noncritical</u>	
	<u>DC-8-55</u>	<u>2707</u>	<u>DC-8-55</u>	<u>2707</u>
CBR = 15	23.5	25	21	22.5
CBR = 20	18.5	20	16.5	18

From this it is judged that the 2707 would be fully compatible with the noncritical sections of 18-inch pavement and with the 20-inch apron pavements. The use of CBR 20 for the subgrade indicates an ample reserve of pavement thickness, while the use of the conservative CBR 15 indicates negligible deficiencies in thickness -- 0.7 and 0.5 inches, respectively.

The critical sections of the 18-inch pavements are more than adequate if CBR 20 is accepted. For CBR 15, on the other hand, there would be deficiencies of 3 1/4 inches for the 2707 and 1 3/4 inches for the DC-8. (The equivalent

thickness of the pavement, 21.8 inches, actually corresponds for the SST to a CBR value of 18.).

For the 2707 at 675,000 pounds, therefore, the best estimate is that no costs would be incurred for the strengthening of pavements. (Concrete inlays in terminal aprons are treated in a subsequent part of this section of the report.)

In recognition that some pavement areas may experience little or no settlement and resulting corrective overlay, that the cement-treated stone base of the flexible pavement may perform less well under the SST than it has under present aircraft, and that at least in some areas a CBR of 15 may be more nearly correct than one of CBR 20, certain pavement overlay costs could be estimated as a potential expense which is not definitely anticipated.

Our "high" estimate, therefore, provides for an overlay to an average thickness of $2\frac{1}{2}$ inches over the areas of critical 18-inch flexible apron and taxiway pavements.

3.15.2 Requirements for New Pavements

Fillets - The fillets of existing pavement intersections at San Francisco International Airport were carefully investigated. The geometrics of the fillets were taken from plans made available by the airport's operator and verified, as constructed, from an aerial photograph.

The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in paragraph 2.2.2.3 of this report. The airport's operator is planning and making improvements to cope with the increased sizes of aircraft under development; and it may be expected that fillet improvements will be made in the future. Nevertheless, the cost estimates given in this report have been based upon the conservative assumption that existing fillets of inadequate radii will be improved solely because of the higher maneuvering requirements of the SST.

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All of the runways at San Francisco have been built to a width of 200 feet. This circumstance tends to minimize the need for and costs of modifications to accommodate the 2707.

Each fillet that would be traversed by the SST was investigated individually. A total of 138 fillets and ten curved taxiways was investigated. It was determined that 12 fillets and two curved taxiways would require improvements if the criteria stated in paragraph 2.2.2.3 are to be observed at San Francisco.

The following tabulation presents our assessment, which is believed to be reasonable and conservative, of the numbers of fillets and curved taxiways requiring improvements, by type and usage.

PAVEMENT FUNCTION AND USAGE*

<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Taxiway-taxiway		
Normal usage	20	6
Rare usage	8	1
Runway-taxiway		
Normal usage	25	0
Rare usage	30	0
Taxiway-terminal apron		
Normal usage	12	2
At holding aprons		
Normal usage	13	3
Rare usage	8	0
On maintenance area routes		
Rare usage	<u>10</u>	<u>0</u>
TOTAL number of fillets investigated	126	12

*For definitions of "normal" and "rare" usage, and for the operational criteria associated therewith, see paragraph 2.2.2.3 of this report.

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<u>Fillets; by Type of Intersection</u>	<u>No. of Pavements Adequate as Now Constructed</u>	<u>No. of Pavements To be Improved</u>
Curved Taxiways		
Normal usage	6	2
Rare usage (to maintenance area)	<u>2</u>	<u>0</u>
TOTAL number of curved taxiways investigated	8	2

The total costs for the improvements to the pavements tabulated in the right column above and shown on Plate SFO-1 are attributable to the 2707. They have been estimated using current construction costs, and the results are summarized at the end of this section.

Holding Aprons - The holding aprons at the thresholds of runways 28L and 28R, the primary takeoff thresholds, both require minor enlargement for the SST by the criteria stated in paragraph 2.2.2.4. Costs attributable to the SST for these modifications are included in the cost summary at the end of this section.

Supplementary aprons are located west of the 28L and 28R thresholds. It is doubtful that they would be used by supersonic transports.

The 1L holding apron is less than adequate by the criteria but inasmuch as it is adjacent to the terminal apron, there seems to be no justification for enlarging it.

The holding apron at runway 10L is also inadequate but enlargement is infeasible. Widening toward taxiway B would violate the FMA separation recommendation (and the separation established by paragraph 2.2.2.4).

The holding apron at the threshold of runway 1R is too shallow for holding the SST. The possibilities for expansion are severely limited by two major drainage canals and by the Bayshore Freeway. Since there appears to be no practical solution for expansion, and since this is a secondary takeoff threshold, no enlargement of these aprons has been postulated.

Similarly, the apron at the end of runway 19R presents an area too shallow for holding the SST and impractical to improve. Its expansion would require an expensive filling operation in San Francisco Bay. Since future plans for takeoff to the south from extended runways do not include holding aprons, we have concluded that the apron does not require modification.

Terminal Area Inlays - A considerable amount of rigid-pavement inlays has been placed in the terminal-area pavements at aircraft gate positions. It is assumed that such pavement would be required at gate positions used by the SST. The pads for the SST would coincide with an appreciable proportion of the inlay area now in place. It is assumed, however, that at least as much additional pavement would be placed to fair the required new inlay areas into those now in place. Accordingly, we have reported a cost per gate position estimated on the basis given in paragraph 2.2.2.6.

3.15.3 Evaluations of Structures

Pipes and Conduits - From the available data, it is judged that all pipes and conduits beneath airfield pavements, including the battery of culverts carrying the South Airport Canal under the threshold of runway 1R, are within the range of acceptable conditions as defined in paragraph 2.2.3, and therefore may be considered compatible with the 2707.

3.15.4 Terminal Area (see Plate SFO-2)

The San Francisco terminal area comprises two concourse-connected central terminal buildings. Three passenger-loading piers extend from each of the central terminal buildings onto the aircraft parking apron. There are satellite buildings at the outer ends of three of the piers (piers "B," "G," and "F"); pier "D" is T-shaped; and Piers "E" and "G" are linear. Pier "F" has a Y-shape, with satellites at both extremities of the arms of the Y. The older of these is designated pier "F"; the satellite just constructed is

designated pier "FF."

The master plan for the terminal area includes a third central terminal building from the center of which will extend a Y-shaped pier (pier "A") having satellites at its extremities. When completed, the arc enclosed by the interconnected terminals will be 270°.

3.15.4.1 Maneuvering and Docking

The 2707 can be readily accommodated at a minimum of 13 apron parking positions. (See Plate SFO-2.) The most convenient parking modes appear to be the parallel and the canted. Three positions would be simultaneously available at pier "G," which handles international flights; one each at piers "B" and "E"; and two each at the remaining piers. The particular arrangements selected have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures.

3.15.4.2 Passenger Loading Devices

Both second-level loading bridges and mobile ramps are employed by the airlines at San Francisco. The second-level devices include fixed-length nose-loaders and swinging-telescoping bridges.

At pier "B," two of the existing swinging-telescoping bridges could be modified to serve both the forward and second doors of the 2707.

At both positions indicated at pier "C," the SST could be served by existing bridges, which would require modifications enabling them to reach the forward and second door-sill heights of the 2707.

For the two positions indicated at pier "D," four new loaders would be required. It is feasible that two of them could be of nonpivoting, the other of the swinging-telescoping type.

One position is indicated at pier "E." The existing fixed-length

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nose-loader serving the position would have to be replaced. Two new swinging telescoping loaders would be required. It will be necessary to revise the taxiway stripping approximately 50 feet northeast to accommodate the position.

The two positions at pier "F" can be accommodated by modifying four of the existing swinging-telescoping loaders to be adaptable to the sill heights of the SST. Some minor restripping is required.

Two positions are indicated at pier "FF." The fixed-length nose-loaders planned for these positions would have to be replaced by four swinging-telescoping loaders, which could accommodate both the 2707 and subsonic aircraft.

At pier "G," three SST positions are shown. Four existing short nose-loaders would need to be replaced by swinging-telescoping loaders. Two new swinging-telescoping loaders would be required at new locations. Some stripping changes would be necessary for subsonic jet access, especially the forthcoming jumbo jets, as space for passage of these aircraft have been maintained where possible.

3.15.4.3 Fueling System Modifications

Hydrant fueling systems have been installed at all piers except pier "E." The system at "D" is no longer in use owing to a rearrangement of parking. For the purposes of this study, the systems at piers "B," "C," "F," and "G" have been considered. Three oil companies have installations at pier "G"; two at pier "F"; and one company serves piers "B" and "C."

For per-gate-position estimating purposes, the costs of new hydrants and of new laterals connecting them to the loops have been considered attributable to the 2707. At each pier, a flexibility of choice among fuels equal to that provided by the existing systems has been presumed necessary.

Depending upon the SST parking positions ultimately selected by the airlines, it might be possible to connect a few of the required new hydrants to

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existing laterals, a circumstance that might result in a relatively large saving for a particular gate position. However, in the interest of obtaining a conservative estimate of costs for achieving compatibility between the 2707 and existing fueling systems, it has been assumed that new laterals would be required for all gate positions now served by such systems.

Mobile tenders are used for fueling at piers "D" and "E." They are operationally flexible and can be furnished in numbers adequate to serve the fueling demands of the 2707. Should underground fueling systems be installed at these piers prior to the introduction of the SST, it is assumed that their designers would take its fueling requirements into account.

3.15.5 Summary of Estimated Costs

<u>Item</u>	<u>Estimated Cost</u>	
Modifications to 12 fillets and 2 curved taxiways		
Full-strength pavement @ \$12/s.y.		\$ 32,000
Shoulder pavement		22,000
Revisions to lights and signs		16,000
Modification to 2 holding aprons		
Full-strength pavement @ \$12/s.y.		38,000
Shoulder pavement		11,000
Revisions to lights		<u>4,000</u>
Subtotal		\$123,000
	Best Estimate	High Estimate
Taxiway overlays @ \$1.20/s.y.	<u>0</u>	<u>540,000</u>
Total Estimated Costs	\$123,000	\$663,000
Estimated Unit Costs Per Gate Position		
Passenger loading devices		\$ 68,000
Fuel system modifications		22,000
Terminal apron inlays		18,000

Of the thirteen gate positions determined to be feasible for SST usage, all were considered in estimating the average unit cost of passenger-loading devices quoted above. The average unit cost per gate position of fuel system modifications was obtained by averaging the individual gate costs for the nine

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SST gates where an underground fueling system is, or will in the near future become, operational. Full rigid-pavement inlays were estimated for each position.

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RECORD

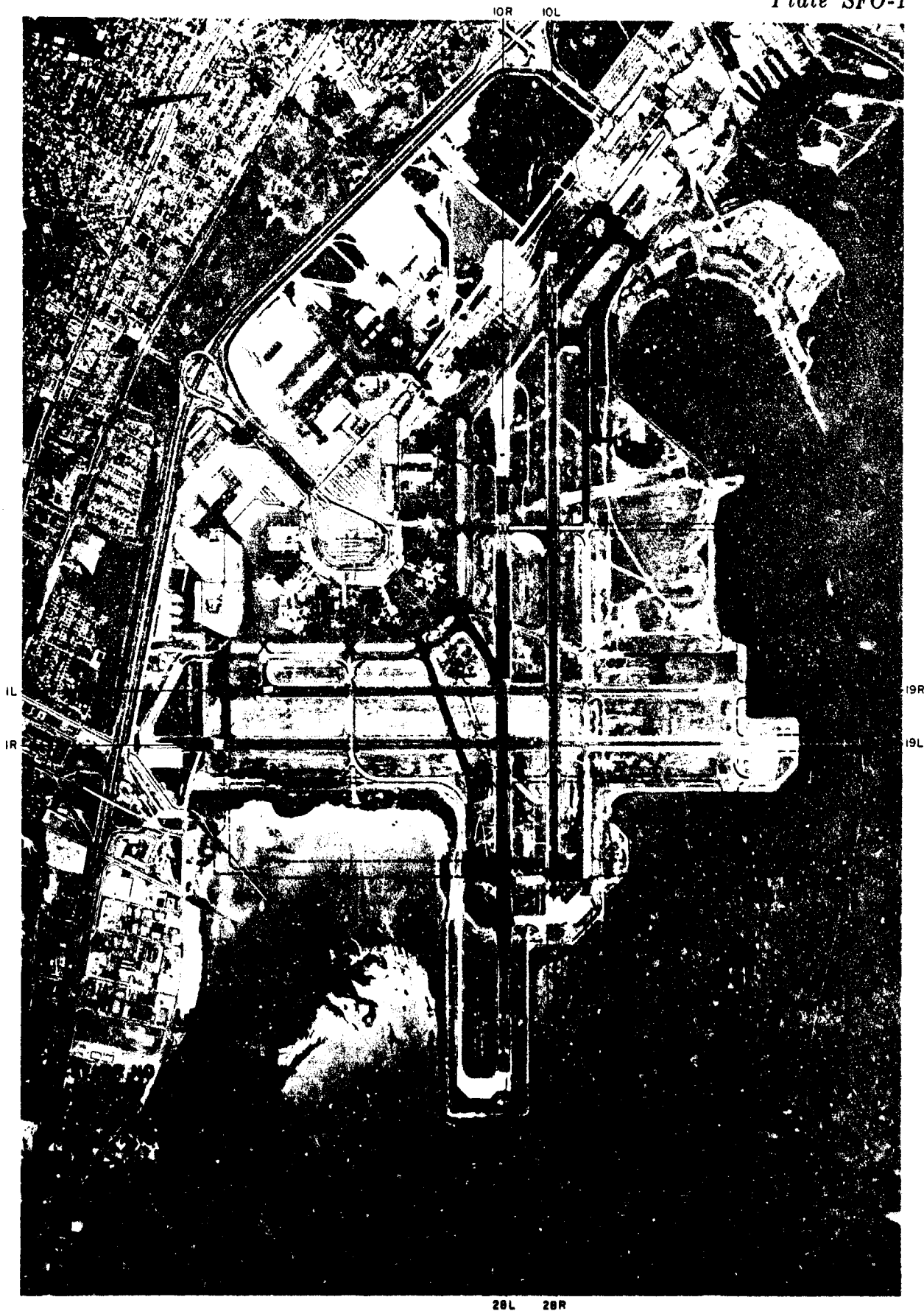
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San Francisco International 206

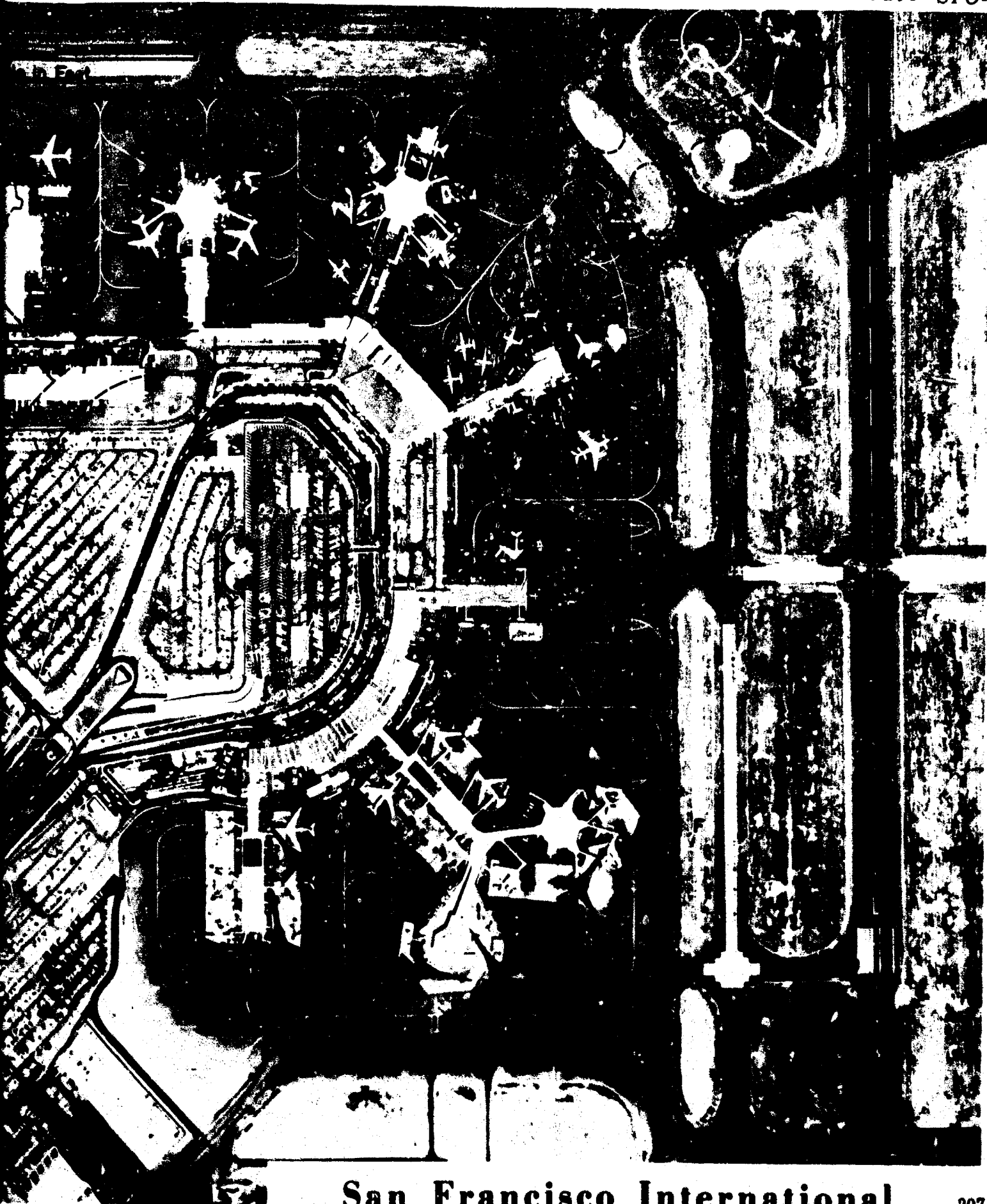
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LEGEND

FEASIBLE SST GATE POSITIONS
FACILITIES PROPOSED IN CURRENT
AIRPORT MASTER PLAN



Approximate Scale in Feet



San Francisco International

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4.0 SUMMARY AND CONCLUSIONS

Results exhibited in this report are primarily the effects of updating previous reports in accordance with the latest configuration of the 2707.

Since there has been no change in the 675,000 pounds gross weight of the airplane, pavement thickness requirements remain about the same.

Aircraft taxiing characteristics have been somewhat eased by the reduction in the wheel base dimension. Runway intersections and runway-taxiway intersections should be adequate as existing. The 2707 will be able to maneuver smoothly around these turns without exceeding the desired turning angle. On the taxiway to taxiway (including curved taxiways) turns, many fillets will still need some modifications. Of the 1416 checked, 226 require enlargement for normal maneuvering. These findings were based on a practical clearance between the centerline of the outside truck and the pavement edge, while rolling the nose gear in a direct, smooth path from pavement centerline, across and back to pavement centerline of the connecting taxiway.

Holding aprons have also been reviewed even though their use by the SST will probably be only occasional. The latest landing gear spacing permits easier maneuvering into the aprons, however, 29 of those reviewed will require some modifications if used by the 2707.

The overall length of the 2707 including the added length of the current prototype configuration and the addition of the canard surfaces produce rearrangement in docking at some of the more compactly planned airports. Aprons at three airports remain in need of enlargement. Maneuvering and docking can be accomplished without great difficulty at most of the airports reviewed, however. Minor rearrangement of parking and striping is advisable at some airports, however, the SST will still occupy not more than two subsonic parking positions in all but a few cases.

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At every airport investigated, some type of pipe, culvert, or conduit was subjected to SST loading. The worst case appeared to impose stresses no greater than 8 per cent above presently operating subsonic transports. Since the structures show no evidence of distress from these loads, removal or replacement of undamaged structures for an anticipated 8 per cent increase in loading would seem unnecessary. As a result, the 2707 is considered compatible with no recommended changes.

At five of the fifteen airports, there are or will be vehicle subways subject to airplane loads. Substantial overstressing would occur if the 2707 were operated over some of those existing. Equal overstressing, however, would occur if the structures in question were subjected to loads of the forthcoming large subsonic jets. It is anticipated that these structures will be improved before the 2707 is in operation. For this reason, it can be reasonably presumed that at the time it is placed into service the 2707 and the airports will be compatible.

One principal impact the 2707 will have on the airport is its effect on passenger loading devices. The greater door heights will require modifications to the heights of the existing second story passenger loaders. The study shows that a minimum of 163 loading positions will accommodate the 2707 at the 14 airports using terminal loading devices.

At those airports where underground fuel distribution systems are not installed or planned, refueling of the 2707 can be accomplished by the use of trucks. Most of the existing underground systems have combined fueling rate capacities at the recommended gate positions in excess of the 2707 requirements. In most cases, however, new laterals and hydrants should be installed to locate them for SST convenience of accessibility.

Engine exhaust characteristics will be more severe from the SST than present jets. However, due to the greater mounting heights and upward thrust

angle, the airports should accommodate the 2707 with negligible airport modifications. The above assumes a power-in and tow-out concept. Exhaust plumes for breakaway power was considered when selecting the parking positions shown herein and some previously selected gates were eliminated for this reason. A few airports have some positions which have power-out capability.

Runway lengths of all airports investigated were adequate for the 2707. Due to high thrust and variable-sweep wing, the SST can both land and takeoff satisfactorily on existing runways as indicated by the unshaded runways on the plate 1 photographs.

Special fire and rescue equipment beyond that in service when the 2707 becomes operational is not anticipated.

At the airports studied, the total cost of modification was estimated to be \$5,676,300. This figure does not include costs of improvements and airport expansion which will be necessary to handle the large subsonic jets that will be in service before the SST. Where applicable, both the best and also a high estimate have been included. It was not possible to include the fueling and passenger loader costs in the total estimate, since it was not determined how many gates would be required. Average costs were given per gate positions. A cost summary for the 15 studied airports follows:

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Airport	Average Cost Per Gate Position			Cost of Other Modifications	
	Apron Inlay	Fuel System Modifications	Passenger Loaders	Best Estimate	High Estimate
1. ANC		20,000		69,000	69,000
2. BAL	18,000			69,000	69,000
3. BOS				136,800	136,800
4. DIA		16,000		173,000	173,000
5. DTW		8,000	50,000	132,500	132,500
6. HNL		16,000		324,000	324,000
7. HOU		7,000		164,000	164,000
8. JFK		20,000	67,000	2,731,000	4,431,000
9. LOS		20,000	80,000	1,255,000	1,405,000
10. MIA		7,000	110,000	71,000	71,000
11. ORD		12,000	50,000	117,000	117,000
12. PDX			40,000	44,500	44,500
13. PHL				212,500	212,500
14. SEA		11,000	150,000	54,000	54,000
15. SFO	18,000	22,000	68,000	<u>123,000</u>	<u>663,000</u>
TOTAL				5,676,300	8,066,300

The present configuration of the 2707 remains essentially compatible with all airports covered in this study. None of the airports will require extensive investments for improvements needed to accommodate the SST. Some of the airports are marginal where space is concerned, however, all can accept the 2707 with the modifications and conditions shown. Airport passenger and aircraft volumes are, of course, not within the scope of this study, and many of the airports may have to expand more rapidly than now planned if traffic volumes increase to the point of experts' predictions. These expansions may very well negate some

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of the estimated modification costs shown above, as planning and designs would readily accommodate all forthcoming aircraft including the SST.

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