Draft Working Paper

PRELIMINARY ASSESSMENT OF AIRSPACE INTERACTIONS

Seattle-Tacoma International Airport
King County International Airport

Port of Seattle
Seattle, Washington

April 1982

Peat, Marwick, Mitchell & Co.

Chapter 5

PRELIMINARY ASSESSMENT OF AIRSPACE INTERACTIONS

Aircraft operations at Seattle-Tacoma International Airport (Sea-Tac) and King County International Airport (Boeing Field) were analyzed to provide preliminary estimates of existing and future levels of airfield capacities and aircraft delays. In addition, a preliminary assessment was made of the effects of airspace interactions in the Seattle area on airfield capacities and aircraft delays at these airports.

This assessment, which was based on the use of analytical techniques appropriate in preliminary analyses using broad-based assumptions, will be used by the Port of Seattle to determine whether the magnitude of the airspace interactions warrants further investigation. If further investigation is warranted, the airspace interactions described herein will be analyzed in detail with more sophisticated techniques in Phase 2 of this study. Also in Phase 2, alternatives and potential actions to mitigate the airspace interactions will be identified, described, and evaluated. These more sophisticated techniques would also be used to assess how changes in ATC procedures and new navigational aids described in the National Airspace System Plan would affect the airspace interactions.

The findings of the preliminary assessment are presented in this chapter.

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AIRFIELD OPERATIONS DATA

The most critical factors affecting airfield capacities and aircraft delays are:

1. Air traffic demand and the types of aircraft used (the aircraft mix)

2. Ceiling and visibility conditions

3. Runway use and air traffic control (ATC) procedures

Air Traffic Demand and Aircraft Mix

Forecasts of aircraft operations for Sea-Tac and Boeing Field are presented in Chapter 3 entitled "Forecast of Aviation Demand" prepared in March 1982 by the Port of Seattle and King County staff. The forecasts of annual and peak hour operations shown in Tables 5-1 and 5-2 were extracted from Chapter 3.

Distributions of air traffic demand were developed from FAA air traffic records and from the air traffic forecasts. The average monthly distribution of aircraft operations is listed in Table 5-3, the daily distribution is listed in Table 5-4, and the hourly distribution is listed in Table 5-5. For this analysis, it is assumed that these distributions will continue in the future.

Table 5-1

AVIATION FORECASTS
Sea-Tac International Airport
1985-2000

	1980 (Actual)	Forecast 1985	Forecast 1990	Forecast 2000
TOTAL AIRCRAFT OPERATIONS				
Air carrier/air taxi	183,698	174,430	186,050	218,870
General aviation-itinerant	27,693	29,300	32,600	40,200
General aviation-local	1,662	1,500	1,400	1,200
Military	551	550	550	550
Total	213,604	205,780	220,600	260,820
PEAK HOUR AIRCRAFT OPERATIONS[a]				
VFR demand				
Air carrier/air taxi	47	47	48	51
General aviation-itinerant	7	7	7	8
General aviation-local	0	0	0	0
Military	0	0	0	0
Total	54	54	55	59
IFR demand				
Air carrier/air taxi	47	47	48	51
General aviation-itinerant	4	4	4	4
General aviation-local	0	0	0	0
Military	0	0	0	0
Total	51	51	52	55

a. Peak hour of average day, peak month.

Source: Port of Seattle.

Table 5-2

AVIATION FORECASTS
King County International Airport
(Boeing Field)
1985-2000

	1980 (Actual)	Forecast 1985	1990	2000
TOTAL AIRCRAFT OPERATIONS				
Air carrier/air taxi	15,999	17,000	20,000	26,000
General aviation-itinerant	247,342	262,500	284,500	329,000
General aviation-local	145,055	142,000	138,000	131,000
Military	2,457	2,500	2,500	2,500
Total	410,853	424,000	445,000	488,500
PEAK HOUR AIRCRAFT OPERATIONS[a]				
VFR demand				
Air carrier/air taxi	2	2	3	6
General aviation-itinerant	105	111	121	136
General aviation-local	90	89	88	84
Military	1	1	1	1
Total	198	203	213	227
IFR demand				
Air carrier/air taxi	2	2	3	6
General aviation-itinerant	26	29	33	38
General aviation-local	0	0	0	0
Military	0	0	0	0
Total	28	31	36	44

a. Peak hour of average day, peak month.

Sources: Port of Seattle, King County.

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Table 5-3

AVERAGE MONTHLY DISTRIBUTION OF AIRCRAFT OPERATIONS

	Percent of annual operations	
	Sea-Tac International Airport	King County International Airport (Boeing Field)
January	7.7%	6.5%
February	7.0	6.7
March	8.1	8.5
April	7.3	8.7
May	7.8	9.5
June	9.1	9.5
July	9.9	10.8
August	9.9	10.2
September	8.7	9.4
October	8.4	8.3
November	7.8	6.3
December	8.3	5.1
Total	100.0%	100.0%

Sources: Peat, Marwick, Mitchell & Co.
Federal Aviation Administration Air Traffic Records.

Table 5-4

AVERAGE DAILY DISTRIBUTION OF AIRCRAFT OPERATIONS

Sea-Tac International Airport

Day type	Number of days in day type	Percent of weekly operations in one day	Percent of weekly operations in day type
Peak	2	15.2%	30.4%
Average	3	14.5	43.5
Low	2	13.1	26.1
Total week	7	14.3% (average)	100.0%

King County International Airport (Boeing Field)

Day type	Number of days in day type	Percent of weekly operations in one day	Percent of weekly operations in day type
Peak	2	15.2%	30.4%
Average	2	14.7	29.4
Low	3	13.4	40.2
Total week	7	14.3% (average)	100.0%

Sources: Peat, Marwick, Mitchell & Co.
Federal Aviation Administration Air Traffic Records.

Table 5-5

HOURLY DISTRIBUTION OF AIRCRAFT OPERATIONS

Hour of day	Sea-Tac International Airport (Percent of daily traffic)	King County International Airport (Boeing Field) (Percent of daily traffic)
0-1	1.3%	0.2%
1-2	0.6	0.2
2-3	0.5	0.2
3-4	0.5	0.2
4-5	0.3	0.2
5-6	1.5	0.2
6-7	2.6	1.2
7-8	5.9	1.7
8-9	5.0	3.2
9-10	5.3	4.4
10-11	5.4	6.1
11-12	6.2	7.1
12-13	7.8	7.9
13-14	6.6	7.7
14-15	5.8	8.2
15-16	4.9	9.1
16-17	5.2	13.6
17-18	6.8	10.0
18-19	6.9	7.8
19-20	6.5	5.0
20-21	5.4	3.0
21-22	4.9	1.7
22-23	2.8	0.7
23-24	1.3	0.4
Total day	100.0%	100.0%

Sources: Peat, Marwick, Mitchell & Co.
Port of Seattle.
King County.

Aircraft mix may be defined in terms of four aircraft classes (A, B, C, and D). The takeoff weights and examples of typical aircraft in each class are as follows:

Aircraft classification	Types of aircraft	Takeoff weight (pounds)
A	Small single-engine aircraft (e.g., Piper PA-23, Cessna C-180, Cessna C-207)	12,500 or less
B	Small twin-engine aircraft (e.g., Piper PA-31, Beech BE-55, Cessna C-310, Learjet LR-25)	12,500 or less and some Learjets
C	Large aircraft (e.g., Convair CV-58, B-707-120, B-727, DC-9, B-737)	More than 12,500 and up to 300,000
D	Heavy aircraft (e.g., B-747, DC-10, L-1011, DC-8-62, B-707-300)	More than 300,000

The aircraft mix for 1980, 1985, 1990, and the year 2000, prepared as part of the aviation demand forecasts, is listed in Table 5-6 for VFR and IFR weather conditions.

Ceiling and Visibility Conditions

Weather has an important effect on airfield operations and runway capacity because spacing between aircraft is often less when there is a high ceiling and good visibility than when conditions are not so favorable. Visual flight rule (VFR) and

Table 5-6

PEAK HOUR AIRCRAFT MIX

Sea-Tac International Airport

Aircraft class	1980 VFR	1980 IFR	1985 VFR	1985 IFR	1990 VFR	1990 IFR	2000 VFR	2000 IFR
A	4%	2%	4%	2%	4%	2%	3%	2%
B	31	29	28	25	29	27	31	31
C	50	53	44	47	40	42	32	35
D	15	16	24	25	27	29	34	36
Total	100%	100%	100%	100%	100%	100%	100%	100%

King County International Airport (Boeing Field)

Aircraft class	1980 VFR	1980 IFR	1985 VFR	1985 IFR	1990 VFR	1990 IFR	2000 VFR	2000 IFR
A	86%	36%	86%	35%	84%	36%	80%	30%
B	10	43	10	45	11	42	14	48
C	4	21	4	20	4	19	5	20
D	0	0	0	0	1	3	1	2
Total	100%	100%	100%	100%	100%	100%	100%	100%

Source: Port of Seattle.

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instrument flight rule (IFR) conditions were used in this analysis, as follows:

VFR	Ceiling at least 1,000 feet, visibility at least three miles
IFR	Ceiling below 1,000 feet and/or visibility below three miles

The average monthly distribution of these weather conditions over the year, based on National Weather Service data for Sea-Tac, is shown in Table 5-7. Weather data on a monthly basis were not available for Boeing Field, although it is generally recognized that the occurrence of IFR conditions is somewhat less frequent at Boeing Field than at Sea-Tac (5.7%* versus 9.4%).

Runway Use and Air Traffic Control Procedures

Runway use involves the number, location, and orientation of active runways as well as the directions, types of operations (e.g., arrivals or departures), and classes of aircraft using each runway. Runway use depends primarily on wind direction and velocity, ATC procedures, air traffic demand, and other local factors. When weather and demand conditions permit, runways are used in accordance with established noise abatement practices.

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*Source: Boeing Field airport layout plan--weather data from U.S. Department of Commerce, 1955-1959.

Table 5-7

PERCENTAGE OCCURRENCE OF MONTHLY VFR AND IFR WEATHER CONDITIONS
Sea-Tac International Airport

Month	Weather conditions[a] VFR	IFR
January	81.9%	18.1%
February	90.2	9.8
March	95.6	4.4
April	95.3	4.7
May	95.5	4.5
June	94.1	5.9
July	93.5	6.5
August	92.9	7.1
September	89.2	10.8
October	86.2	13.8
November	87.4	12.6
December	85.8	14.2
Annual	90.6	9.4

a. VFR - Ceiling at least 1,000 feet, visibility at least three miles. IFR - Ceiling below 1,000 feet and/or visibility below three miles.

Source: Peat, Marwick, Mitchell & Co. analysis of National Weather Service data (1965-1974).

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At Sea-Tac and Boeing Field, there are two basic operating configurations, a north flow configuration and a south flow configuration, as illustrated in Exhibit 5-1. Weather records indicate that the airports can be in the north flow configuration about one-third of the time and in the south flow configuration about two-thirds of the time. These percentages were confirmed in discussions with FAA personnel.

ATC procedures can significantly affect hourly runway capacities, because a decrease in spacing between aircraft will normally increase capacity. To ensure that runway capacities are representative of real-life conditions, the ATC procedures set forth in Chapter 4 and data obtained from field observations at other major airports were used in this analysis.

CAPACITY AND DELAY CALCULATIONS

Hourly and annual airfield capacity and aircraft delays were calculated for Sea-Tac and Boeing Field. The various airspace interactions that occur between Sea-Tac and Boeing Field were reflected in the calculations and the effect of these interactions was quantified in terms of aircraft delay.

Measures of Capacity and Delay

Hourly airfield capacity is defined as the maximum number of aircraft operations that can take place on an airfield in an

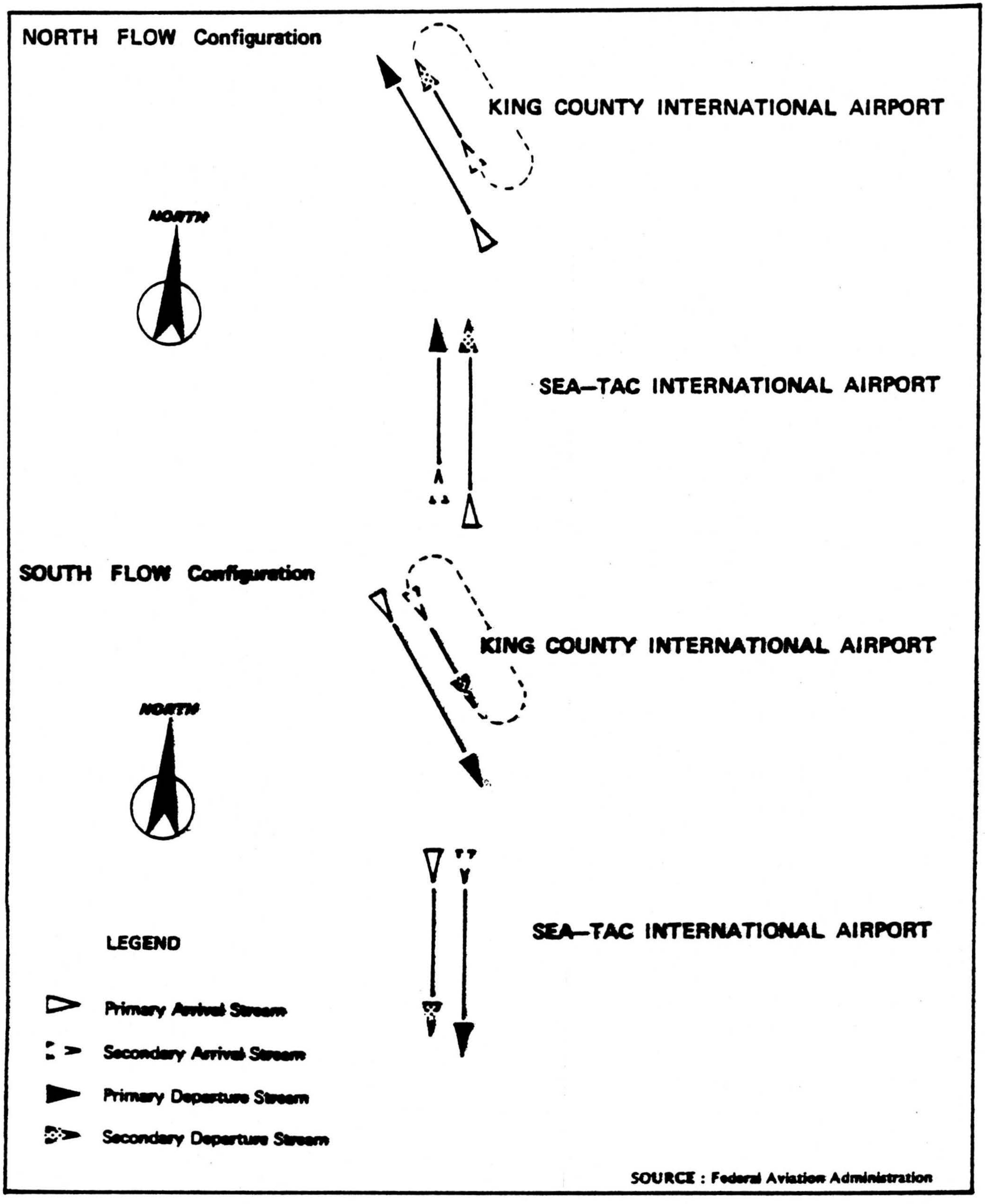

Exhibit 5–1

Airspace Study
Sea-Tac International Airport
King County International Airport
RUNWAY USE

Peat, Marwick, Mitchell & Co. March 1982

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hour under particular runway use and weather conditions. This definition does not depend on assumptions regarding "acceptable" levels of delay to aircraft. Rather, it expresses the maximum physical capability of the airfield to accommodate aircraft operations under a set of specified conditions. Capacity estimates are expressed in aircraft operations per hour.

The delay to an aircraft is defined as the difference between the actual time it takes an aircraft to operate on the airfield and the normal time it would take the aircraft to operate without interference from any other aircraft.* Thus, the delay refers to the time spent waiting to land or to take off. Average annual delay estimates are expressed in minutes per aircraft.

Hourly Runway Capacity

Hourly runway capacities were estimated for the existing runway configurations at Sea-Tac and Boeing Field using computer models developed by PMM&Co. for the FAA.** The capacity values are shown in Table 5-8, together with the peak hour demand for the years 1980, 1985, 1990, and 2000.

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*See Appendix F for a discussion of the relationship between these definitions and definitions that may have been used in runway capacity and delay analyses prior to this study.

**Department of Transportation, "Techniques for Determining Airport Airside Capacity and Delay," FAA-RD-74-124, June 1976.

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Table 5-8

ESTIMATED HOURLY RUNWAY CAPACITIES
AND PEAK HOUR* DEMANDS

	Number of aircraft operations per hour			
	VFR		IFR	
	Capacity	Demand	Capacity	Demand
Sea-Tac International Airport				
1980	77	54	55	51
1985	76	54	55	51
1990	75	55	54	52
2000	72	59	54	55
King County International Airport (Boeing Field)				
1980	210	198	54	28
1985	208	203	56	31
1990	205	213	59	36
2000	199	227	63	44

*Average day, peak month.

Source: Peat, Marwick, Mitchell & Co.

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The hourly capacity of Sea-Tac in VFR conditions is expected to decrease from 77 operations per hour in 1980 to 72 operations per hour by the year 2000. This capacity exceeds the peak hour demand in 1980 and the demand forecast for 1985, 1990, and the year 2000.

In IFR conditions, the hourly capacity of Sea-Tac is expected to remain essentially the same, i.e., 55 operations per hour in 1980--54 operations per hour in the year 2000. Peak hour demand is expected in increase from 51 operations per hour in 1980 to 55 operations per hour by the year 2000, thus exceeding the IFR capacity.

The hourly capacity of Boeing Field in VFR conditions is expected to decrease from 210 operations per hour in 1980 to 199 operations per hour by the year 2000. Peak hour demands in VFR conditions are expected to increase from 198 operations per hour in 1980 to 227 operations per hour by the year 2000. Thus demand at Boeing Field is expected to exceed the capacity in VFR conditions sometime between 1985 and 1990. In IFR conditions, hourly capacity is expected to increase from 54 operations per hour in 1980 to 63 operations per hour by the year 2000. Demand at Boeing Field during IFR conditions is expected to increase from 28 operations per hour to 44 operations per hour during the study period.

Average Annual Aircraft Delays

Table 5-9 presents estimates of average annual aircraft delays obtained using the Annual Delay Aggregation Model developed by PMM&Co. for the FAA. Annual delay values were computed for Sea-Tac and Boeing Field based on the combinations of aircraft mixes, weather conditions, runway configurations, runway use operating strategies, annual demand, and airspace interactions between these two airports. These delays are average values for every aircraft operation that takes place in the year shown.

For the 213,604 total annual operations occurring at Sea-Tac in 1980, the average annual delay to aircraft was estimated to be just over 1/2 minute (0.6 minute). However, by the year 2000, annual delays at Sea-Tac are expected to increase to about 3 minutes per aircraft. For comparison purposes, PMM&Co. estimates of annual delays at other U.S. airports made as part of FAA Improvement Task Force Delay Studies in 1978 are as follows: Atlanta, 4.5 minutes; Denver, 2.9 minutes; John F. Kennedy, 7.6 minutes; LaGuardia, 13.5 minutes; St. Louis, 0.8 minutes; and San Francisco, 2.1 minutes.

At Boeing Field, annual delays are expected to increase from 0.6 minute per aircraft in 1980 to 2.4 minutes per aircraft in the year 2000.

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Table 5-9

AVERAGE ANNUAL AIRCRAFT DELAYS

	Annual demand	Total annual delay (minutes)	Average annual delay (minutes)
Sea-Tac International Airport			
1980	213,604	128,000	0.6
1985	205,780	118,000	0.6
1990	219,760	186,000	0.8
2000	261,830	762,000	2.9
King County International Airport (Boeing Field)			
1980	410,853	245,000	0.6
1985	424,000	311,000	0.7
1990	445,000	492,000	1.1
2000	488,500	1,260,000	2.6

Source: Peat, Marwick, Mitchell & Co.

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Of considerable importance are the aircraft delays that occur during peak hours, particularly during IFR weather conditions, when the effects of the airspace interaction between Sea-Tac and Boeing Field are felt. Table 5-10 presents aircraft delays during the peak hour for the average day of the peak month in VFR conditions, IFR north flow conditions, and IFR south flow conditions.

As shown, average peak hour delays at Sea-Tac in VFR conditions range from 1.9 minutes per aircraft in 1980 to 3.4 minutes per aircraft in the year 2000. However, in IFR conditions, peak hour delays are expected to increase rapidly over the study period. In IFR conditions for a north flow operation, peak hour delays are expected to triple from 4.8 minutes per aircraft in 1980 to 18.7 minutes per aircraft by the year 2000. In IFR conditions for a south flow operation, the situation is even worse: average delays are expected to increase from 11.0 minutes per aircraft in 1980 to more than an hour per aircraft by the year 2000. When delay levels reach such proportions, air carrier service at Sea-Tac will deteriorate as airlines consider diverting or cancelling flights.

At Boeing Field, peak hour delays are typically greatest in VFR conditions because of the higher demand levels relative to capacity. Delays are estimated to increase from about 4 minutes per aircraft in 1980 to over 14 minutes per aircraft by the

Table 5-10

PEAK HOUR AIRCRAFT DELAYS

	Average peak hour delays* (minutes per aircraft)		
	VFR	IFR north flow	IFR south flow
Sea-Tac International Airport			
1980	1.9	4.8	11.0
1985	1.8	3.4	10.7
1990	2.3	8.8	19.4
2000	3.4	18.7	60+
King County International Airport (Boeing Field)			
1980	4.1	0.3	0.3
1985	5.0	0.4	0.3
1990	6.6	0.8	0.4
2000	14.2	1.4	15.5

*Average day, peak month.

Source: Peat, Marwick, Mitchell & Co.

year 2000. Delays in IFR conditions at Boeing Field will be significant late in the forecast period, i.e., more than 15 minutes per aircraft by the year 2000.

EFFECTS OF AIRSPACE INTERACTIONS

As described in Chapter 4, the proximity of Sea-Tac and Boeing Field results in airspace interactions, particularly for a south flow operation when IFR arrival flight paths converge, and for a north flow operation when Sea-Tac IFR departures are held for Boeing Field IFR arrivals. Delay model runs were performed to estimate the effects of these interactions on Sea-Tac and Boeing Field aircraft operations.

Table 5-11 shows the effects of the airspace interactions on total annual aircraft delays at both Sea-Tac and Boeing Field. The predominant effect is on aircraft at Sea-Tac. It is estimated that about 10,000 minutes of delay at Sea-Tac in 1980 were attributable to the airspace interactions. However, by the year 2000, the airspace interactions are expected to result in over 450,000 minutes of delay annually. On the basis of 1981 aircraft operating costs,* aircraft delays translate into a delay cost to the airlines of almost $18.5 million annually by the year 2000. Approximately $11 million of the delay costs is attributable to airspace interactions.

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*Based on 1981 data, the weighted aircraft operating costs (essentially crew and fuel costs) for the Sea-Tac aircraft mix are approximately $24 per minute.

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Table 5-11

EFFECTS OF AIRSPACE INTERACTIONS
ON ANNUAL AIRCRAFT DELAYS

	Annual delay (minutes)		
	With interaction	Assuming no interaction	Difference
Sea-Tac International Airport			
1980	128,000	118,000	10,000
1985	118,000	108,000	10,000
1990	186,000	144,000	42,000
2000	762,000	312,000	450,000
King County International Airport (Boeing Field)			
1980	245,000	245,000	0
1985	311,000	311,000	0
1990	492,000	492,000	0
2000	1,260,000	1,152,000	108,000

Source: Peat, Marwick, Mitchell & Co.

As shown in Table 5-11, the effects of the airspace interactions on Boeing Field operations are negligible until late in the study period (primarily because of the low levels of aircraft operations forecast in IFR conditions). About 108,000 minutes of aircraft delays are expected to be attributable to the interactions by the year 2000.

Table 5-12 shows the effects of the airspace interactions on peak hour delays for the average day, peak month at both Sea-Tac and Boeing Field. Again, the predominant effect is on Sea-Tac aircraft operations, particularly in IFR conditions for a south flow operation: average peak hour delays in 1980 are increased by about 8 minutes per aircraft (from 3.0 minutes per aircraft to 11.0 minutes per aircraft). By the year 2000, it is estimated that the airspace interactions would cause peak hour delays in IFR conditions for a south flow operation to exceed one hour per aircraft (rather than 11.6 minutes per aircraft assuming no interaction).

At Boeing Field, aircraft delays due to the airspace interactions are significant toward the end of the study period: by the year 2000, peak hour delays in IFR conditions for a south flow operation are about 15 minutes per aircraft (rather than 1.3 minutes per aircraft assuming no interaction).

Table 5-12

EFFECTS OF AIRSPACE INTERACTIONS ON
PEAK HOUR AIRCRAFT DELAYS

	Average peak hour delays* (minutes per aircraft)					
	With interaction			Assuming no interaction		
	VFR	IFR North flow	IFR South flow	VFR	IFR North flow	IFR South flow
Sea-Tac International Airport						
1980	1.9	4.8	11.0	1.9	3.0	3.0
1985	1.8	3.4	10.7	1.8	2.9	2.9
1990	2.3	8.8	19.4	2.3	3.4	3.4
2000	3.4	18.7	60+	3.4	11.6	11.6
King County International Airport (Boeing Field)						
1980	4.1	0.3	0.3	4.1	0.3	0.3
1985	5.0	0.4	0.4	5.0	0.4	0.4
1990	6.6	0.8	0.8	6.6	0.8	0.8
2000	14.2	1.4	15.5	14.2	1.3	1.3

*Average day, peak month.

Source: Peat, Marwick, Mitchell & Co.

SENSITIVITY OF DELAY VALUES

Annual service volume is a level of annual aircraft operations that may be used as a reference in preliminary airfield planning. When annual aircraft operations on the airfield are equal to annual service volume, average delay to each aircraft throughout the year is on the order of one to four minutes.

If the number of annual operations exceeds annual service volume, moderate or severe congestion may occur, similar to that experienced at several large air carrier airports such as Chicago O'Hare International Airport, LaGuardia Airport, and William B. Hartsfield Atlanta International Airport.

For analyses of airfield operations, aircraft delays also can be important at levels of annual aircraft operations less than annual service volume. Therefore, delays to aircraft should also be considered in planning and evaluating airfield operations at levels of annual operations less than annual service volume.* In some instances, when annual demand is expected to approach one-half of annual service volume within the planning horizon, nominal construction costs of airfield improvements may be balanced by savings in aircraft delay costs.

*FAA Order 5090-3A recommends the development of additional capacity at an airport for the appropriate time period if the demand is forecast to reach 60% of annual service volume.

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To calculate annual service volume, hourly capacities must be computed for the various operating conditions (runway use, ceiling and visibility, etc.) that occur throughout the year. Information on monthly, daily, and hourly aircraft operations must also be developed. These data were approximated from air traffic activity records and air traffic forecasts.

The estimated annual service volumes for Sea-Tac and Boeing Field, together with projected annual demand levels, are shown below.

	Annual service volume	Annual demand			
		1980	1985	1990	2000
Sea-Tac	260,000	213,604	205,780	219,760	261,830
Boeing Field	485,000	410,853	424,000	445,000	488,500

As shown, annual service volumes will be exceeded by projected annual demands at both airports by the year 2000. As annual aircraft operations approach annual service volume, average delay to each aircraft throughout the year may increase rapidly with relatively small increases in airport operations, thereby causing levels of service on the airfield to deteriorate.

The sensitivity of annual aircraft delays to changes in demand at Sea-Tac and Boeing Field is illustrated in Exhibit 5-2. As annual demand levels at Sea-Tac approach 240,000 operations--which may occur by about 1995--small increases in demand will cause dramatic increases in aircraft delays.

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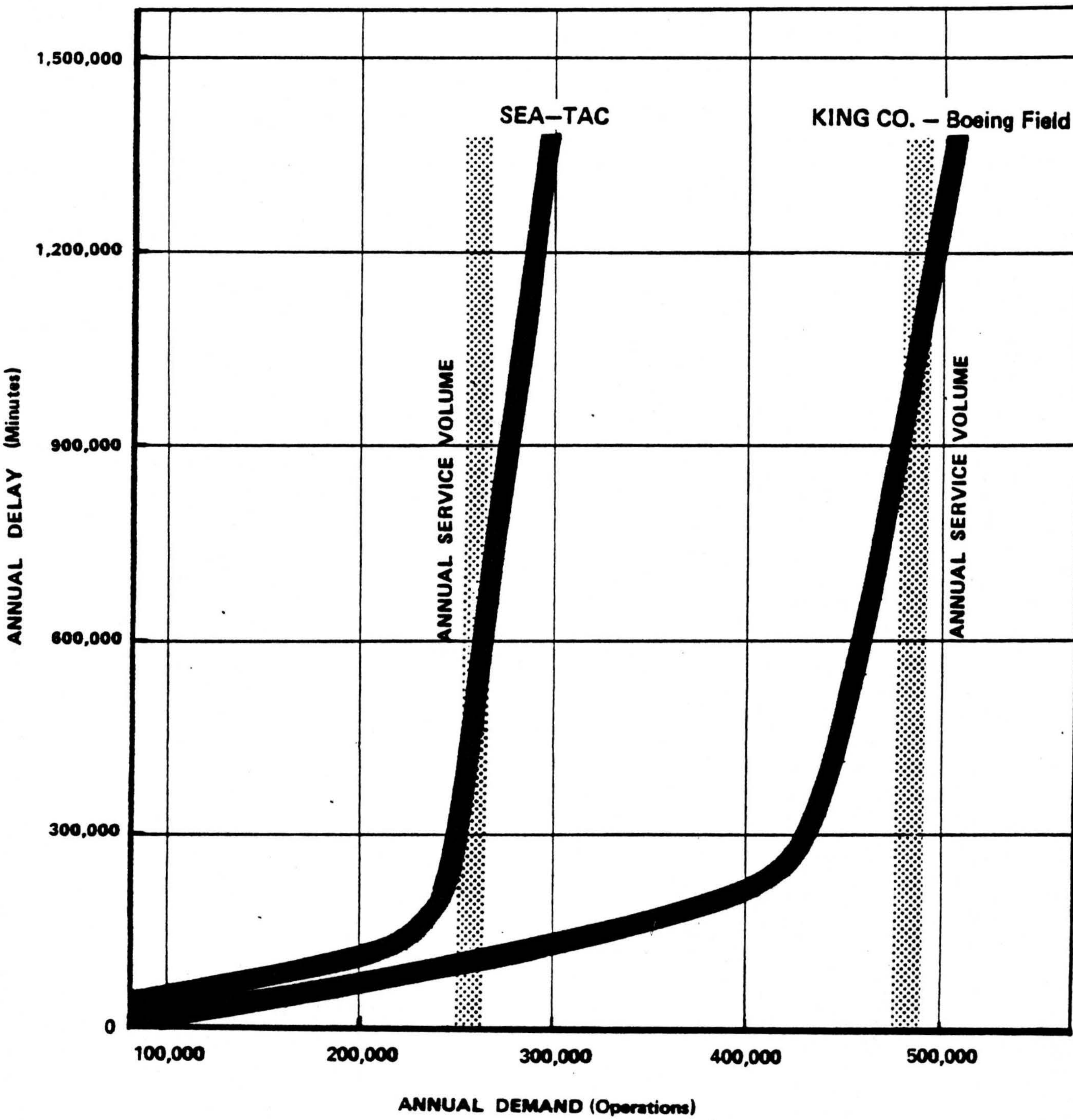

SOURCE : Peat, Marwick, Mitchell & Co.

Exhibit 5–2

Airspace Study
Sea-Tac International Airport
King County International Airport

RELATIONSHIP BETWEEN ANNUAL DELAY AND ANNUAL DEMAND

Peat, Marwick, Mitchell & Co. March 1982

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The situation at Boeing Field is somewhat more critical in the sense that demand levels have almost reached the critical "knee" of the curve--at about 420,000 annual operations--and aircraft delays are estimated to increase quite rapidly with small increases in demand.

As noted earlier, a relatively small change in demand level can result in dramatic increases in aircraft delays. In particular, aircraft delays at Sea-Tac in IFR conditions are very dependent on the arrival demand levels at Boeing Field. The forecasts of air traffic at Sea-Tac and Boeing Field reflect low rates of growth. Consequently, the effects of higher growth rates were examined on a preliminary basis.

To demonstrate the sensitivity of the aircraft delay values at Sea-Tac to Boeing Field arrival demand levels, a run of the annual delay model was made assuming that the demand at Boeing Field exceeded the forecast level in IFR conditions in 1990 by only 4 operations or 10%; i.e., during the peak hour of the average day of the peak month demand was increased from 36 to 40 operations per hour. The results of the model run showed that (a) aircraft delays during the peak hour of the average day, peak month, in IFR conditions and south flow more than tripled, from about 20 minutes per aircraft to more than 60 minutes per aircraft and (b) even though the change in demand was for IFR conditions, the average annual delay

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increased by about 25% from 0.8 minute per aircraft to 1.0 minute per aircraft.

PROPOSED ATC PROCEDURES AND NAVIGATIONAL AIDS

The National Airspace System Plan, prepared by the FAA in December 1981, is a comprehensive plan for modernizing and improving air traffic control and airway facilities services from now to the year 2000. The plan delineates specific improvements to facilities and equipment and supporting research and development associated with the National Airspace System.

Of particular relevance to this study is the part of the Plan that calls for the installation of 1,250 Microwave Landing Systems (MLS) at airports throughout the United States by the year 2000. Sea-Tac is targeted to receive an MLS by 1990. The Plan also points out that a limited amount of additional airspace system capacity will be achieved primarily through a reduction in aircraft separation standards, if a solution to the wake vortex problems can be found. Although solution of the wake vortex problems will reduce delays, it will not eliminate them entirely.

A quantitative assessment of the possible effects of an MLS and changes in aircraft separations on the airspace interactions at Sea-Tac and Boeing Field could not be made with the techniques used in this preliminary analysis. However, as noted earlier, the more sophisticated techniques that would be used in Phase 2 of this study would permit such a quantitative assessment.

CONCLUSIONS

This preliminary assessment of the effects of airspace interactions in the Seattle area on Sea-Tac and Boeing Field aircraft operations has shown that:

1. The airspace interactions occur essentially in IFR conditions, and the most significant effect is during south flow operations--this combination of conditions occurs about 7% of the year. Delays in these conditions are very high, increasing from 11 minutes per aircraft in 1980 to more than 60 minutes per aircraft by the year 2000. The delays during these conditions, which occur only 7% of the year, account for more than 50% of the total annual delay experienced by aircraft at Sea-Tac.

2. The airspace interactions predominantly affect Sea-Tac aircraft operations with aircraft delays being very sensitive to assumed demand levels. Peak hour delays at Sea-Tac in IFR conditions may exceed 60 minutes per aircraft as early as 1990 if growth rates slightly higher than those forecast are realized.

3. Because of the relatively low demand levels forecast for Boeing Field in IFR conditions, congestion will occur later in the forecast period at Boeing Field than at Sea-Tac.

4. At current levels of aircraft delays at Sea-Tac (1980), delay costs are approximately $3 million per year, of which about $250,000 is attributable to the effects of the airspace interactions. However, by the year 2000, these delay costs are expected to increase to about $18.5 million per year, and of this amount, $11 million will be attributable to airspace interactions.

Sea-Tac and Boeing Field have separate and distinct roles in providing aviation facilities and service in the Seattle area. Sea-Tac is the primary air carrier airport and provides facilities for all international and domestic carriers serving the area. Boeing Field serves predominantly general aviation aircraft including a significant volume of the more sophisticated corporate aircraft (because of its location adjacent to Seattle and the aviation facilities and navigational aids available at the airport). Public agencies have made major investments in facilities at both of these airports.

On the basis of this preliminary assessment, it is apparent that the airspace interactions between aircraft operations at Sea-Tac and Boeing Field will result in high delays to aircraft and substantial increases in aircraft operating costs. Aircraft delays may eventually be so high that they could seriously affect airline service at Sea-Tac, and could possibly jeopardize the long-term capability of Boeing Field to serve corporate aircraft.