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1991-92 Aviation System Capacity Plan

U.S. Department
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Administration

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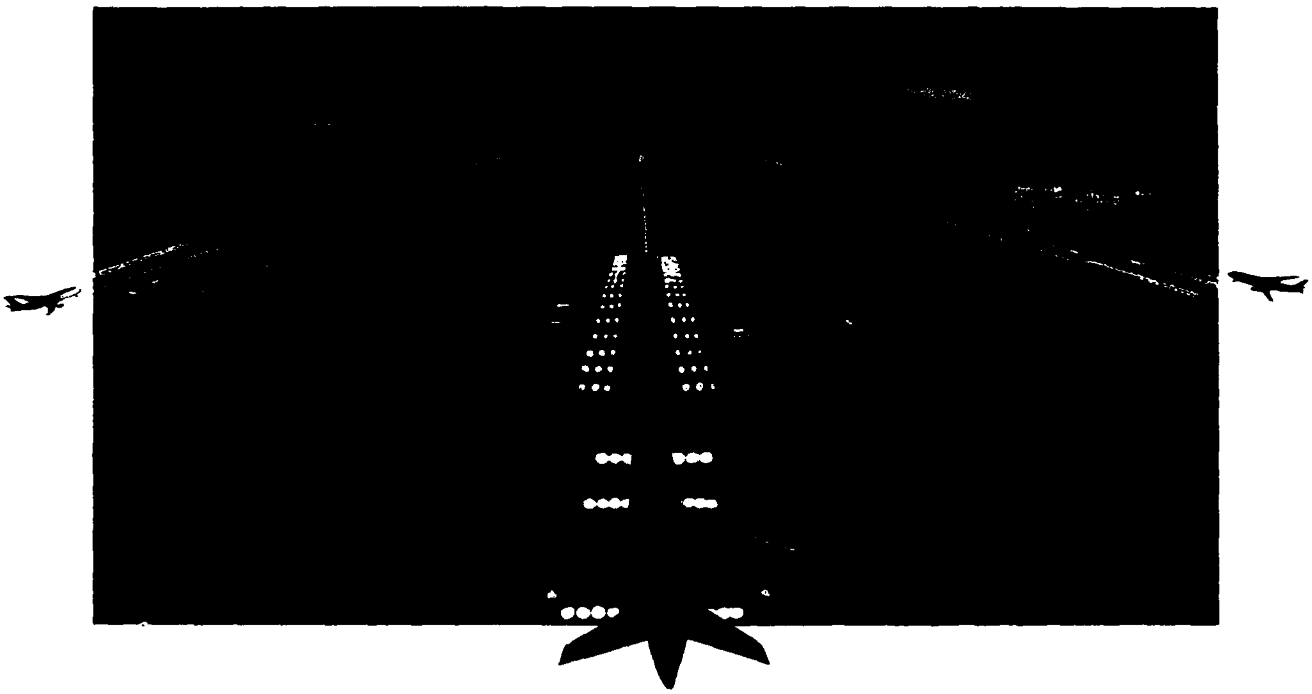

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16. Abstract

This is a comprehensive review of the Federal Aviation Administration's program to improve the capacity of the National Air Transportation System. The plan identifies the causes and extent of capacity and delay problems currently associated with air travel in the U.S., and outlines various planned and ongoing FAA projects that will reduce the severity of the problems in the future. The major areas of discussion are:

1) Airport Development,
2) Airport and Airspace Capacity,
3) Technology for Capacity Improvement, and
4) Marketplace Solutions.

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Chapter 1

Introduction

1.1 The Need for Aviation System Capacity Improvement

In 1990, 23 airports each exceeded 20,000 hours of airline flight delays.[1] By 2000, the number of airports which could exceed 20,000 hours of annual aircraft delay is projected to grow from 23 to 40, unless capacity improvements are made. The purpose of this plan is to identify and facilitate actions that can be taken by both the public and private sectors to prevent the projected growth in delays. These actions include:

In 1990, 23 airports each exceeded 20,000 hours of airline flight delays. By 2000, the number of airports which could exceed 20,000 hours of annual aircraft delay is projected to grow from 23 to 40.

- Airport Development,
- Airspace Development and New Airspace Procedures,
- New Technology, and
- Marketplace Solutions.

While current forecasts project serious delays in the absence of capacity improvements, the message shown in the following pages is positive. For example, much is currently being done to improve the situation through new construction and Air Traffic Control (ATC) procedural enhancements. In addition, there are many emerging technologies in the surveillance, communications, and navigation areas that will further improve the efficiency of existing and new runways.

1. With an average airline operating cost of about $1,600 per hour of delay, this means that each of these 23 airports incurred a minimum of $32 million dollars of delay in 1990.

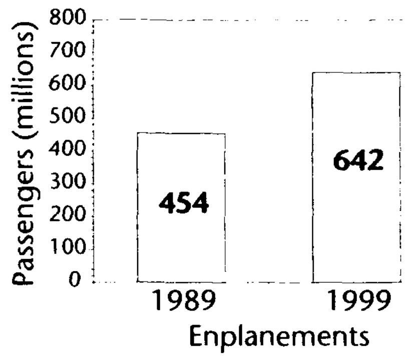
2 Level of Aviation Activity

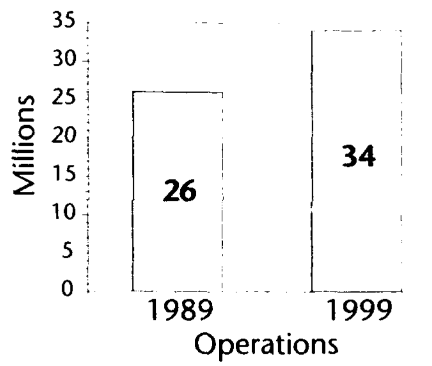
This plan concentrates on the top 100 airports in the U.S. as asured by 1989 enplanements, shown in Figure 1-1. The top) airports[2] account for 90% of the 454 million airline passengers .o enplaned nationally in 1989.

In 1999, 642 million passengers are forecast to enplane at these ports.[3] This represents a projected owth in enplanements of % over the next 10 years.

In 1989, approximately 26 million aircraft operations occurred these top 100 airports. By 1999, operations are forecast to grow 34 million at the same 100 airports; a projected growth in erations of 31%.[4]

The top 100 airports account for 90% of 454 million airline passen s who enplaned nationa.ly in 1989.





1.2.1 Activity Statistics at Top 100 Airports

Of the top 100 airports, enplanements increased at 54 airports ›m Calendar Year (CY)88 to CY89, and decreased at 46.[5] Aircraft ›erations increased from Fiscal Year (FY)89 to FY90 at 77 air- ›rts.[6]

Aircraft operations increased from Fiscal Year 89 to FY90 at 77 airports.

2. The top 100 airports were chosen based on CY89 passenger enplanement data as listed in *Airport Activity Statistics of Certificated Route Air Carriers*, 1989 enplanement data. A national map of the 100 airports is pictured in Figure 1-1, and recent operations and enplanement data are provided in Table A-1 of Appendix A.

3. Based on FAA's *Terminal Area Forecast*. Current enplanement data, a ten year forecast, and percentage growth that the forecast represents are shown in Table A-2 (Appendix A).

4. Table A-3 (Appendix A) shows 1989 aircraft operations, 1999 forecasts, and percent change by airport.

5. See Table A-4 (Appendix A) for a ranking by percentage growth in enplanements at the top 100 airports.

6. See Table A-5 (Appendix A) for a ranking by percentage growth in operations at the top 100 airports. Operations data were unavailable for Agana Field (NGM) in Guam.

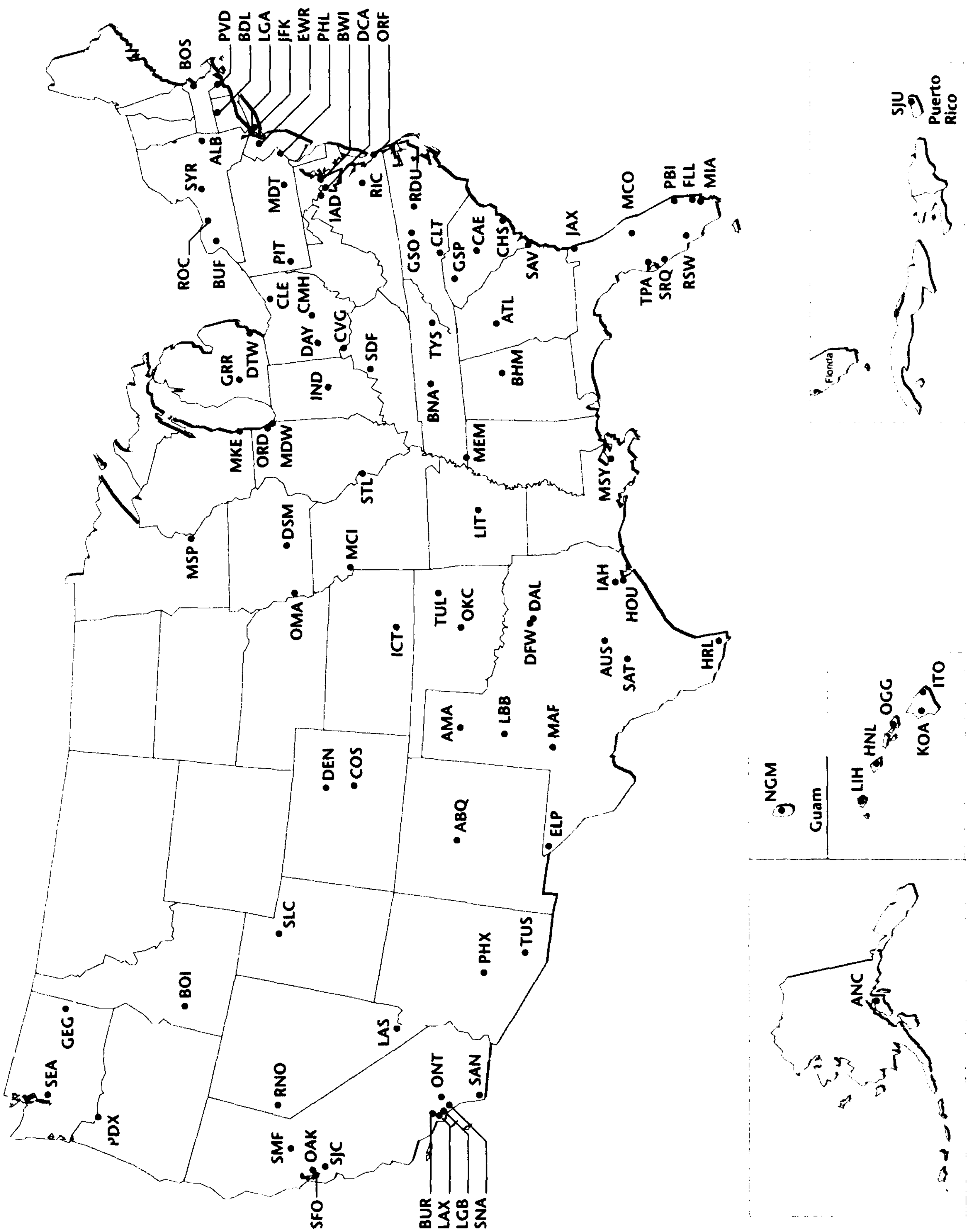


Figure 1-1. The Top 100 Airports by 1989 Enplanements.
Source: Airport Activity Statistics of Certificated Route Air Carriers, 1989

1.2.2 Traffic Volumes in the 20 Air Route Traffic Control Centers (ARTCCs)

ARTCC volume statistics for 1990 showed that Instrument ight Rules (IFR) operations increased at 15 of the 20 Continental iited States (CONUS) ARTCCs over 1989.[7]

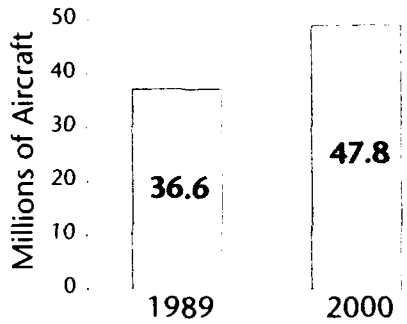
In 1989, the number of aircraft flying under instrument rules ndled by ARTCCs increased by 0.5% over 1988 to 36.6 million erations. Commercial aircraft handled at the centers decreased by 3%, compared with a decline of 5.9% in noncommercial aircraft ndled. The number of commuter aircraft handled increased by 4%; the number of air carrier aircraft handled increased by 3.9%; e number of general aviation aircraft handled declined by 1.2%; id the number of military aircraft handled declined by 13.2%.

Aircraft operations at the centers are expected to grow by an erage of 2.3% a year between 1990 and 2000. In absolute num-rs, center operations are forecast to increase from 36.6 million rcraft handled in 1989 to 47.8 million in 2000. In 1989, 47.9% of ie traffic handled at centers were air carrier flights. This propor-on is expected to increase only slightly to about 49.8% in 2000. In 989, only 14.2% of the traffic handled were commuter operations. y the year 2002, approximately 20.0% of the centers' workload is pected to be generated by commuters. The projected annual owth rates by user groups over the forecast period are: air carrier, 4%; commuter/air taxi, 3.0%; and general aviation, 2.3%.

Instrument Flight Rules (IFR) operations increased at 15 of the 20 Continental United States (CONUS) ARTCCs over 1989.

In 1989, the number of aircraft flying under instrument rules handled by ARTCCs increased by 0.5% over 1988 to 36.6 million operations.

ARTCC operations are forecast *to increase from 36.6 million* aircraft handled in 1989 to 47.8 million in 2000.



ARTCC Operations

7. Figure 1-2 provides a map of the 20 CONUS ARTCCs. Figure 1-3 provides a comparison of the number of operations during FY89 versus the number of operations in FY90 at each of the 20 ARTCCs in CONUS. Figure 1-4 shows FY90 operations and a 10-year forecast.

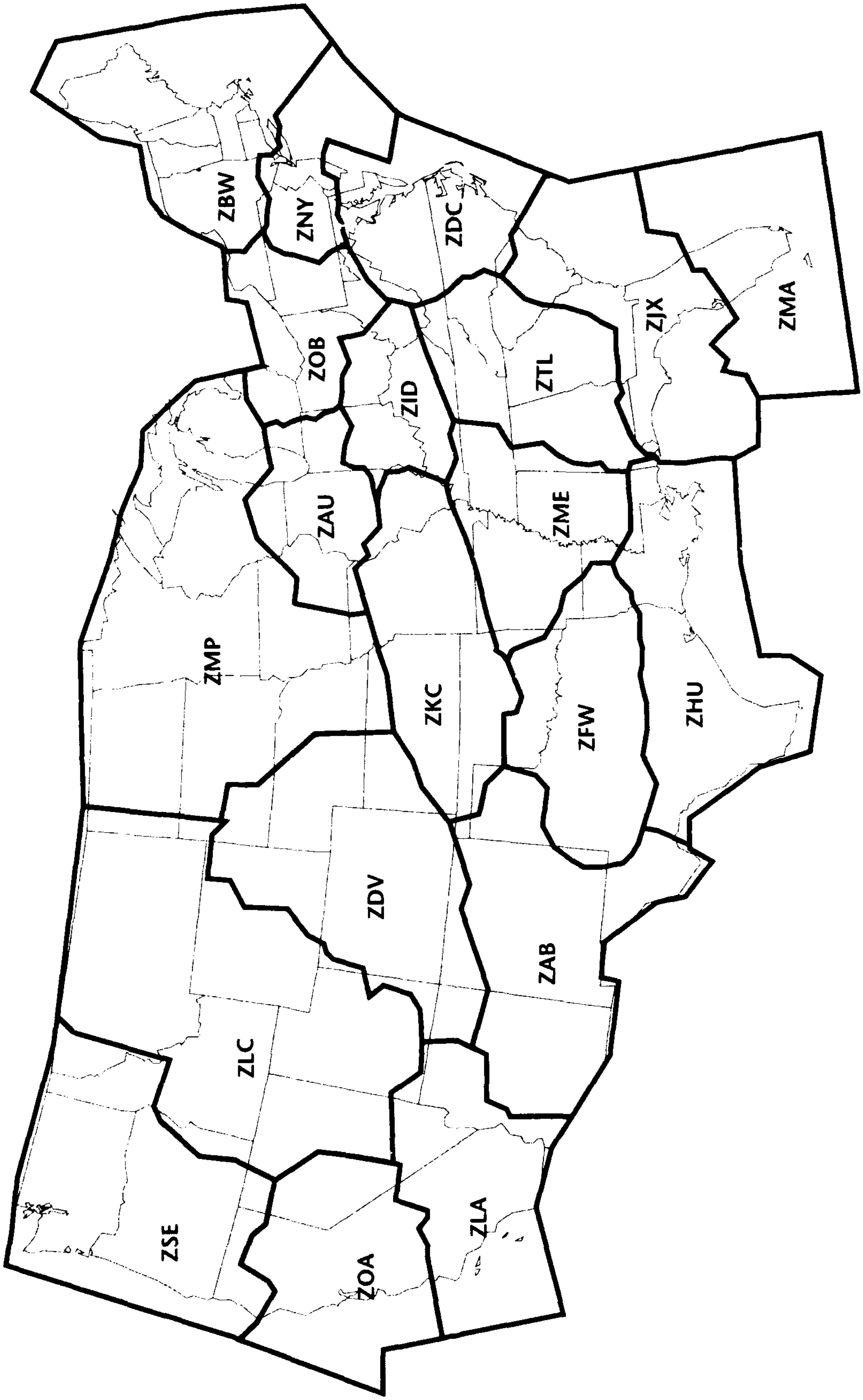


Figure 1-2. The 20 Continental U.S. Air Route Traffic Control Centers

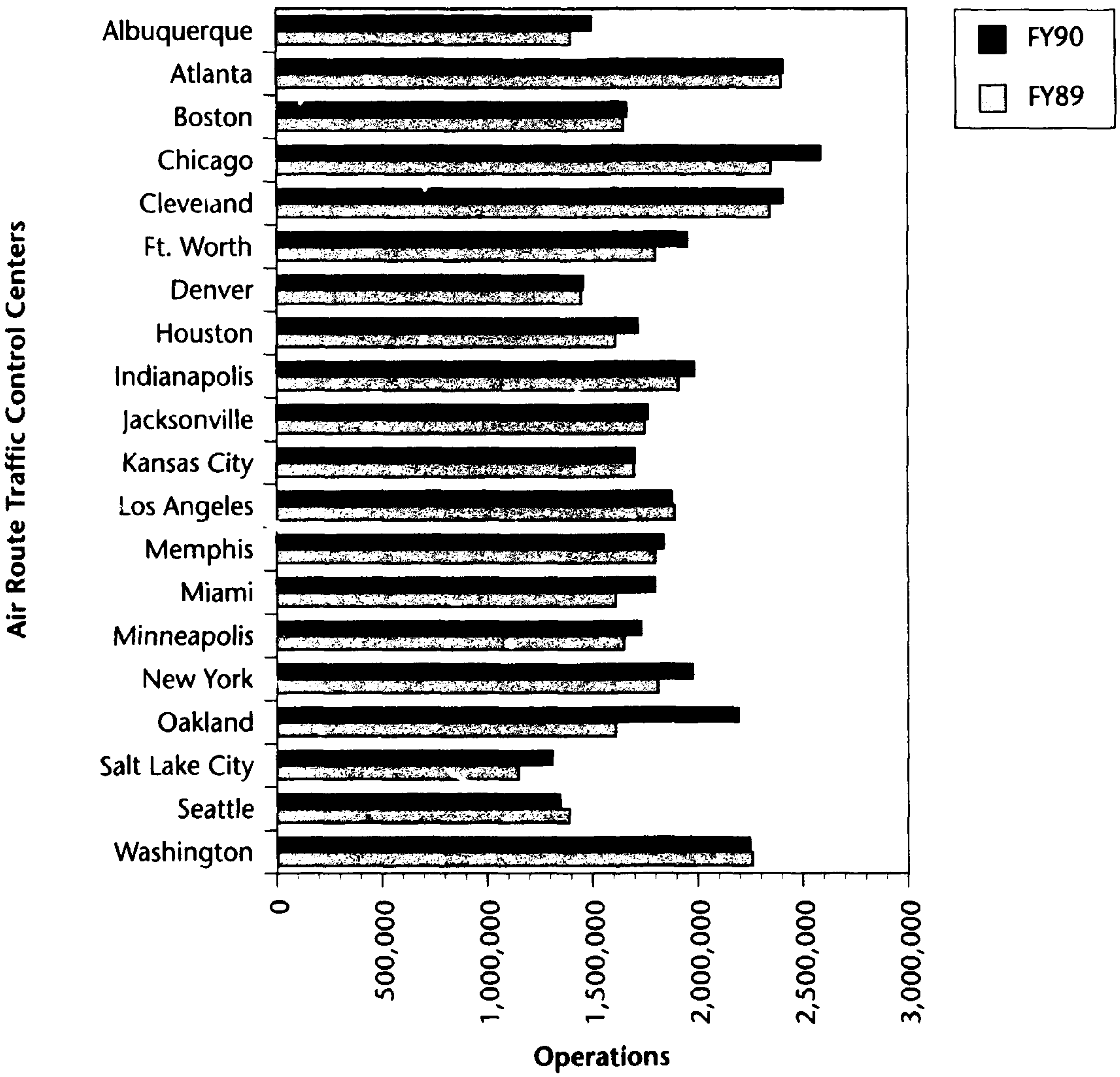


Figure 1-3. Operations at Air Route Traffic Control Centers
(Source: ATO-130 Air Traffic Activity and Delays Report, Sept. 1990)

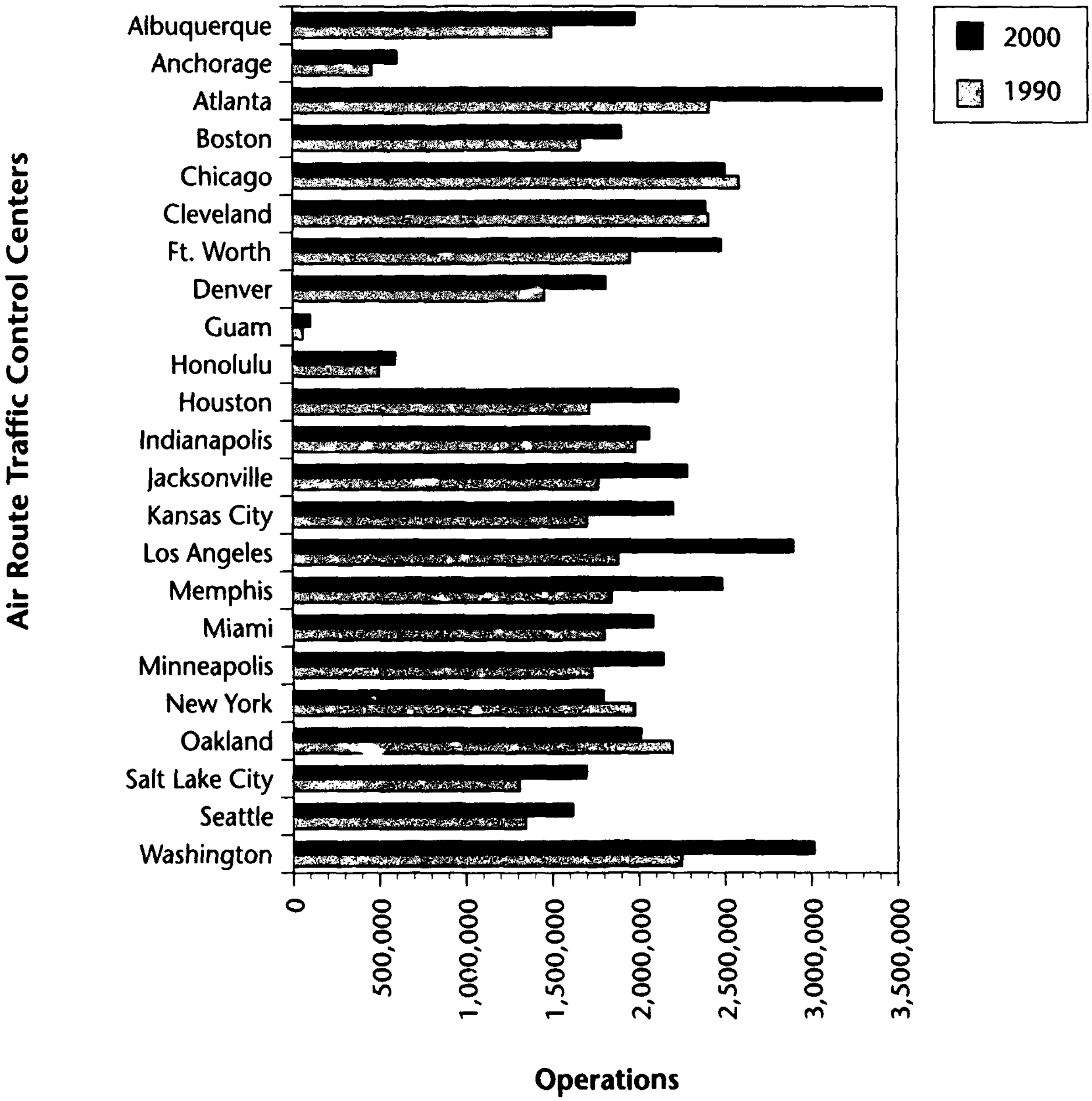


Figure 1-4. Air Route Traffic Control Center Forecasts
(Source: APO ARTCC Forecasts Fiscal Years 1990-2000, April 1991.)

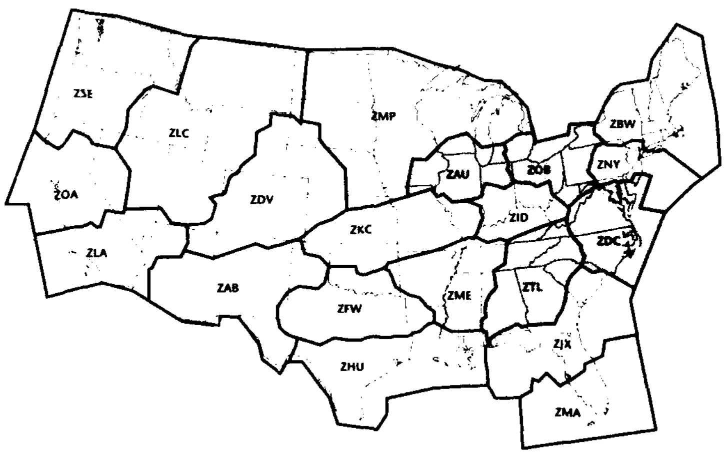
The busiest Federal Aviation Administration (FAA) ARTCCs in 1989 were: Chicago, Cleveland, Atlanta, and Washington. Forecasts for 2000 indicate a change in ranking of the busiest ARTCCs to: Atlanta, Washington, Los Angeles, and Chicago.

Chicago Center, the busiest FAA ARTCC in 1989, handling 2.6 million aircraft, is projected to handle 3.4 million aircraft by the year 2000. Oakland Center is forecast to experience the largest absolute growth, from 1.7 million aircraft operations in 1989 to 2.5 million in the year 2000. This is attributable to the expected increase in airport hubbing activity in the western United States. The projected annual average growth rate of the Los Angeles Center over the period from 1989 to 2000 is significantly higher (3.4%) than the projected national rate of 2.3%. These growth rates reflect the increasing importance of the Pacific markets.

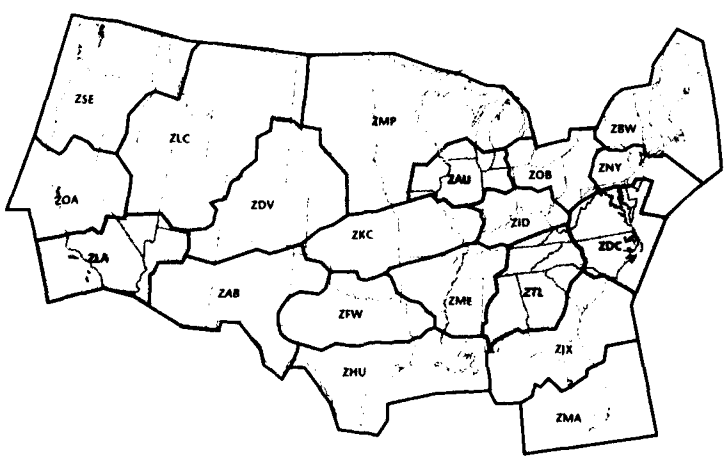
The busiest FAA ARTCCs in 1989 were: Chicago, Cleveland, Atlanta, and Washington.

Forecasts for 2000 indicate a change in ranking of the busiest ARTCCs to: Atlanta, Washington, Los Angeles, and Chicago.

Busiest ARTCCs in 1989



Forecast Top ARTCCs in 1999



1.3 Delay[8]

1.3.1 Delay by Cause

Weather was attributed as the primary cause of 53% of operations delayed by 15 minutes or more in 1990, down from 57% in 1989.[9] Terminal air traffic volume accounted for a record 36% of delays greater than 15 minutes, (up from 29% in 1989), while air traffic center volume accounted for 2% of delays. Runway construction was the cause of 4% of delay in FY90, National Airspace System (NAS) equipment interruptions for 2%, and 3% was attributed to other causes.

Although flight delays exceeding 15 minutes were experienced on 404,367 flights in 1990, an increase of 3.3% over 1989, the total remains below the 1986 level of 418,000. In FY90, weather and terminal volume increased from 86% to 89% of total delays. Terminal volume was the primary cause of delay greater than 15 minutes 36% of the time in FY90, up from 29% the year before. With the exception of the split between terminal and center volume delays, the basic distribution of delay by cause has remained fairly consistent over the past six years.[10]

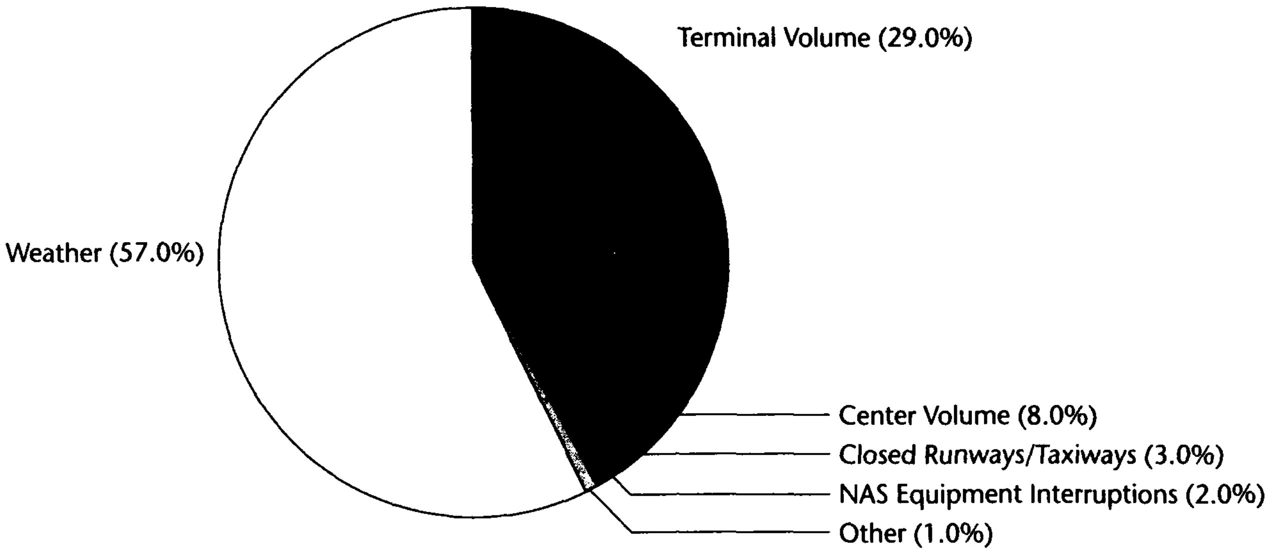
Weather was attributed as the primary cause of 53% of operations delayed by 15 minutes or more in 1990, down from 57% in 1989.

Terminal air traffic volume accounted for a record 36% of delays greater than 15 minutes, (up from 29% in 1989), while air traffic center volume accounted for 2% of delays.

Although flight delays exceeding 15 minutes were experienced on 404,367 flights in 1990, an increase of 3.3% over 1989, the total remains below the 1986 level of 418,000.

8. Operations and enplanement data from the top 100 airports and the 20 CONUS ARTCCs presented in Section 1.1 are measures of airport and system activity. Delay can be thought of as another system performance parameter; as an indicator that capacity is perhaps being reached and even exceeded. Although no existing delay reporting system is fully comprehensive, this Plan aims to identify problem areas through available data, such as the following delay information and the previously mentioned aviation activity statistics.
9. See Figure 1-5 for the breakdown of FY89 and FY90 primary causes of delay.
10. See Table 1-1 for the 5-year history of this breakdown of delay by primary cause.

FY 1989



FY 1990

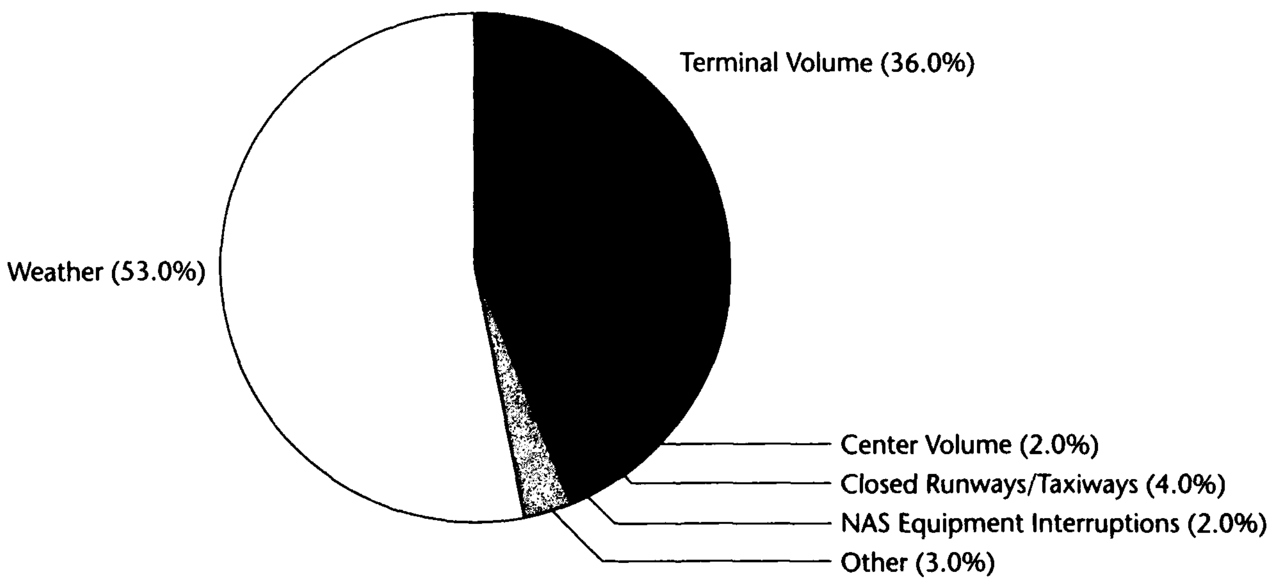


Figure 1-5. Primary Cause of Delay of 15 Minutes or More in FY89 and FY90

Source: Air Traffic Operations Management System (ATOMS) Data

Table 1-1. Distribution of Delay Greater Than 15 Minutes by Cause, 1984-1990

Distribution of Delay Greater than 15 Minutes by Cause						
Cause	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
Weather	68%	67%	67%	70%	57%	53%
Terminal Volume	12%	16%	11%	9%	29%	36%
Center Volume	11%	10%	13%	12%	8%	2%
Closed Runways/Taxiways	6%	3%	4%	5%	3%	4%
NAS Equipment	2%	3%	4%	3%	2%	2%
Other	1%	1%	1%	1%	1%	3%
Total Operations Delayed (000s)	**334**	**418**	**325**	**322**	**392**	**404**
Percent Change from Previous Year	-17%	+25%	-22%	-1%	+21%	+3%

1.3.2 Delay by Phase of Flight [11]

Nearly 80% of all flights are delayed 1-14 minutes in taxi-in or taxi-out phases of flight. Only 5% of flights have any gate-hold delay. More delays occur during the taxi-out phase than any other phase.[12] However, since taxi-in delays have remained relatively constant at 2.1 to 2.3 minutes, it appears that the real bottleneck continues to be runway access for take-off.

Nearly 80% of all flights are delayed 1-14 minutes in taxi-in or taxi-out phases of flight.

Taxi-in and taxi-out delay increased slightly from 1989 to 1990, while airborne delay remained about the same during the period.

11. The Airline Service Quality Performance (ASQP) data is collected, in general, from airlines with one-percent or more of the total domestic scheduled service passenger revenue. Airlines reporting as of July 1, 1991 include: Air West, Alaska, American, Continental, Delta, Midway, Northwest, Pan American, Southwest, TWA, United, and USAir. Actual departure time, flight duration, and arrival times are reported along with the differences between these and the equivalent data published in the *Official Airline Guide* (OAG) and entered in the Computer Reservation System (CRS).

    Taxi-in Delay: The difference between touchdown time and gate arrival time, minus a standard taxi-in time for a particular type of aircraft and airline at a specific airport.

    Taxi-out Delay: The difference between the time of lift-off and the time that the aircraft departed the gate, minus a standard taxi-out time established for a particular type of aircraft and airline at a specific airport.

    Airborne Delay: The difference between the time of lift-off from the origin airport and touchdown, minus the computer-generated optimum profile flight time for a particular flight, based on atmospheric conditions, aircraft loading, etc.

    Gate-hold Delay: The difference between the time that departure of an aircraft is authorized by ATC and the time that the aircraft would have left the gate area in the absence of an ATC gatehold.

    Mins./op: Average delay per operation.

12. Table 1-2 presents the percentage of operations delayed by 15 minutes or more.

To put this in perspective, there were 26 million operations in 1989. With an average airborne delay of 4.3 minutes per aircraft, this means that there was a total of over 1.8 million hours of delay, which, at an estimated $1,600 per hour, cost the airlines $2.9 billion.

Table 1-2. Percent of Operations Delayed

Percent of Operations Delayed 15 Minutes or More (Total ASQP System)[13]				
Year	1987	1988	1989	1990
Percent Delayed	8.0	8.6	9.7	10.3

Note: All delay measurements were obtained based on a 5th percentile for actual elapsed times for each city pair and air carrier.

Table 1-3. Average Delay by Phase of Flight

Average Delay by Phase of Flight (mins. per flight — total ASQP system)[13]				
Phase	**1987**	**1988**	**1989**	**1990**
Gate-hold	1.0	1.0	1.0	1.0
Taxi-out	6.6	6.8	7.0	7.2
Airborne	3.9	4.0	4.3	4.3
Taxi-in	2.1	2.1	2.2	2.3
Total	13.7	14.0	14.6	14.9
Mins./Op.	6.8	7.0	7.3	7.5

13. The Airline Service Quality Performance (ASQP) data is explained in footnote 11 on the previous page.

1.3.3 Identification of Forecast Delay-Problem Airports

In FY1990, the number of airline flight delays in excess of 15 minutes increased compared to 1989 at 14 of 22 major airports.[14] The percentage of flights delayed at these airports ranged from 0.1% of flights at Las Vegas to 9.7% at New York–La Guardia. The three top airports in delays exceeding 15 minutes were in the New York area.

In FY1990, the number of airline flight delays in excess of 15 minutes increased compared to 1989 at 14 of 22 major airports. The percentage of flights delayed at these airports ranged from 0.1% of flights at Las Vegas to 9.7% at New York–La Guardia.

Forecasts suggest that, in the absence of capacity improvements, delay in the system will continue to grow.[15] In 1990, 23 airports each exceeded 20,000 hours of airline flight delays. Assuming no improvements in airport capacity are made, 40 airports are forecast to each exceed 20,000 hours of airline flight delays by the year 2000. Figure 1-6 shows delays per 1,000 operations. Figure 1-7 shows the airports exceeding 20,000 hours of annual aircraft delay in 1990, while Figure 1-8 shows the airports exceeding 20,000 hours of annual aircraft delay in 2000, assuming there are no capacity improvements.

14. Figure 1-6. Delays Per 1,000 Operations.
15. Table 1-5. 1990 Actual and 2000 Forecast Air Carrier Delay Hours.

Table 1-4. Percentage of Operations Delayed 15 Minutes or More.

Airports	Percentage of Operations Delayed 15 Minutes or More				
	1986	1987	1988	1989	1990
New York La Guardia	8.9	6.5	5.2	9.6	9.7
Newark Intl.	13.8	6.5	6.7	10.6	8.8
New York Kennedy	7.0	6.5	5.3	6.1	7.7
Chicago O'Hare Intl.	5.6	4.6	5.5	10.3	6.9
San Francisco Intl.	5.3	6.2	6.3	7.1	5.7
Atlanta Hartsfield Intl.	6.5	6.2	3.5	2.5	3.9
Philadelphia Intl.	2.0	3.7	2.6	2.2	3.6
Boston Logan Intl.	7.3	4.8	3.7	2.9	3.3
Minneapolis Intl.	3.9	0.7	1.4	0.8	3.2
St. Louis-Lambert Intl.	4.4	1.6	2.7	2.9	2.8
Denver Stapleton Intl.	3.2	3.7	3.7	2.7	2.7
Dallas-Ft. Worth Intl.	2.6	2.0	1.4	2.4	2.7
Detroit Metropolitan	1.3	1.5	1.5	1.6	1.9
Houston Intl.	0.2	0.5	0.7	0.6	1.3
Washington National	3.2	2.3	1.5	1.0	1.2
Pittsburgh Intl.	0.6	0.7	0.7	0.8	0.9
Los Angeles Intl.	1.1	3.3	1.7	1.1	0.8
Miami Intl.	0.7	0.4	0.3	0.2	0.7
Cleveland Hopkins Intl.	0.3	0.1	0.5	0.3	0.5
Kansas City Intl.	1.0	0.5	0.2	0.3	0.3
Ft. Lauderdale Intl.	0.3	0.2	0.2	0.3	0.3
Las Vegas McCarran Intl.	0.0	0.1	0.1	0.2	0.1

Table 1-5. 1990 Actual and 2000 Forecast Air Carrier Delay Hours.

Annual Aircraft Delay in Excess of 20,000 Hours					
1990		2000			
Chicago O'Hare	ORD	Chicago O'Hare	ORD	Washington National	DCA
Atlanta Hartsfield	ATL	Dallas-Ft. Worth	DFW	Kansas City	MCI
Dallas-Ft. Worth	DFW	Atlanta Hartsfield	ATL	Cleveland	CLE
Los Angeles	LAX	San Francisco	SFO	Charlotte-Douglas	CLT
Newark	EWR	Washington Dulles	IAD	Cincinnati	CVG
San Francisco	SFO	Newark	EWR	Honolulu	HNL
Boston	BOS	St. Louis	STL	Houston	IAH
New York John F. Kennedy	JFK	Los Angeles	LAX	Las Vegas	LAS
St. Louis	STL	Phoenix	PHX	Windsor Locks	BDL
Phoenix	PHX	New York John F. Kennedy	JFK	Chicago Midway	MDW
Miami	MIA	Miami	MIA	Memphis	MEM
Philadelphia	PHL	Philadelphia	PHL	Baltimore Washington	BWI
Washington National	DCA	Boston	BOS	Ontario	ONT
Pittsburgh	PIT	Detroit	DTW	Ft. Lauderdale	FLL
Detroit	DTW	Pittsburgh	PIT	Raleigh-Durham	RDU
Orlando	MCO	New York La Guardia	LGA	San Jose	SJC
Minneapolis	MSP	Orlando	MCO	Seattle-Tacoma	SEA
Charlotte	CLT	Minneapolis	MSP	Dayton	DAY
Denver Stapleton	DEN	Salt Lake City	SLC	San Diego	SAN
Honolulu	HNL	Nashville	BNA	Tampa	TPA
Houston	IAH				
Seattle-Tacoma	SEA				
New York La Guardia	LGA				

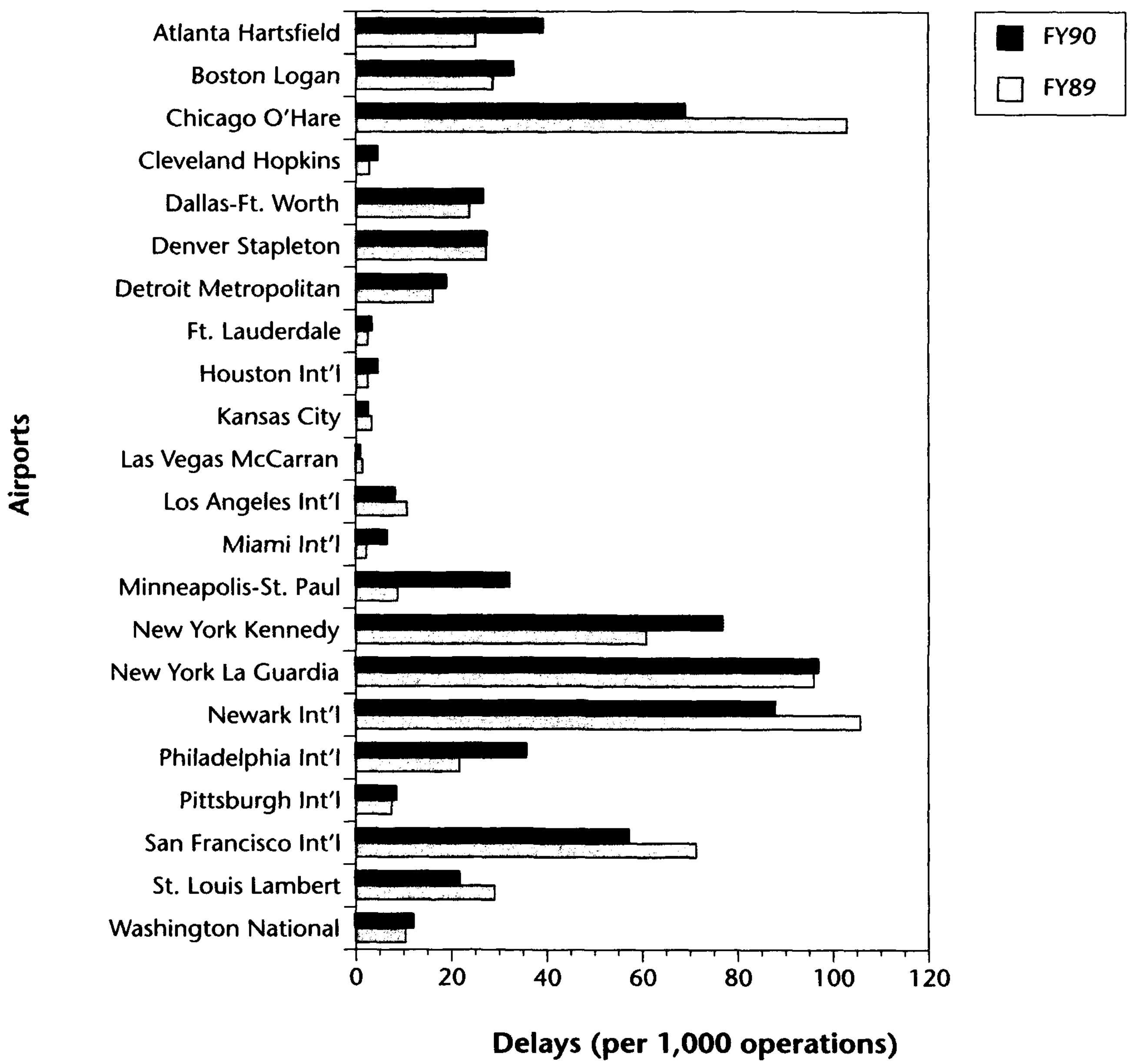


Figure 1-6. Delays Per 1,000 Operations
(Source: ATOMS Data)

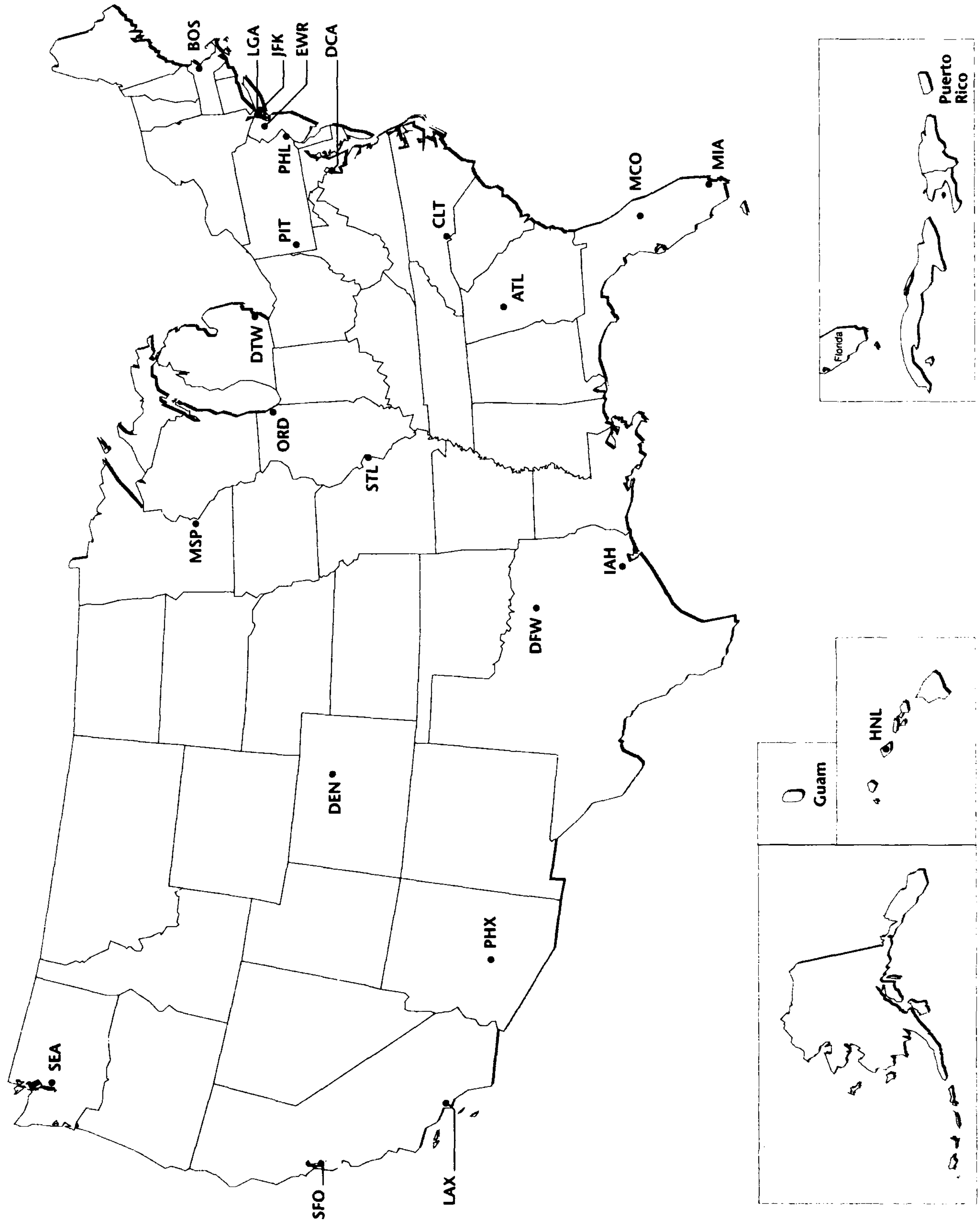


Figure 1-7. Airports Exceeding 20,000 Hours of Annual Aircraft Delay in 1990

Source: FAA Office of Policy and Plans

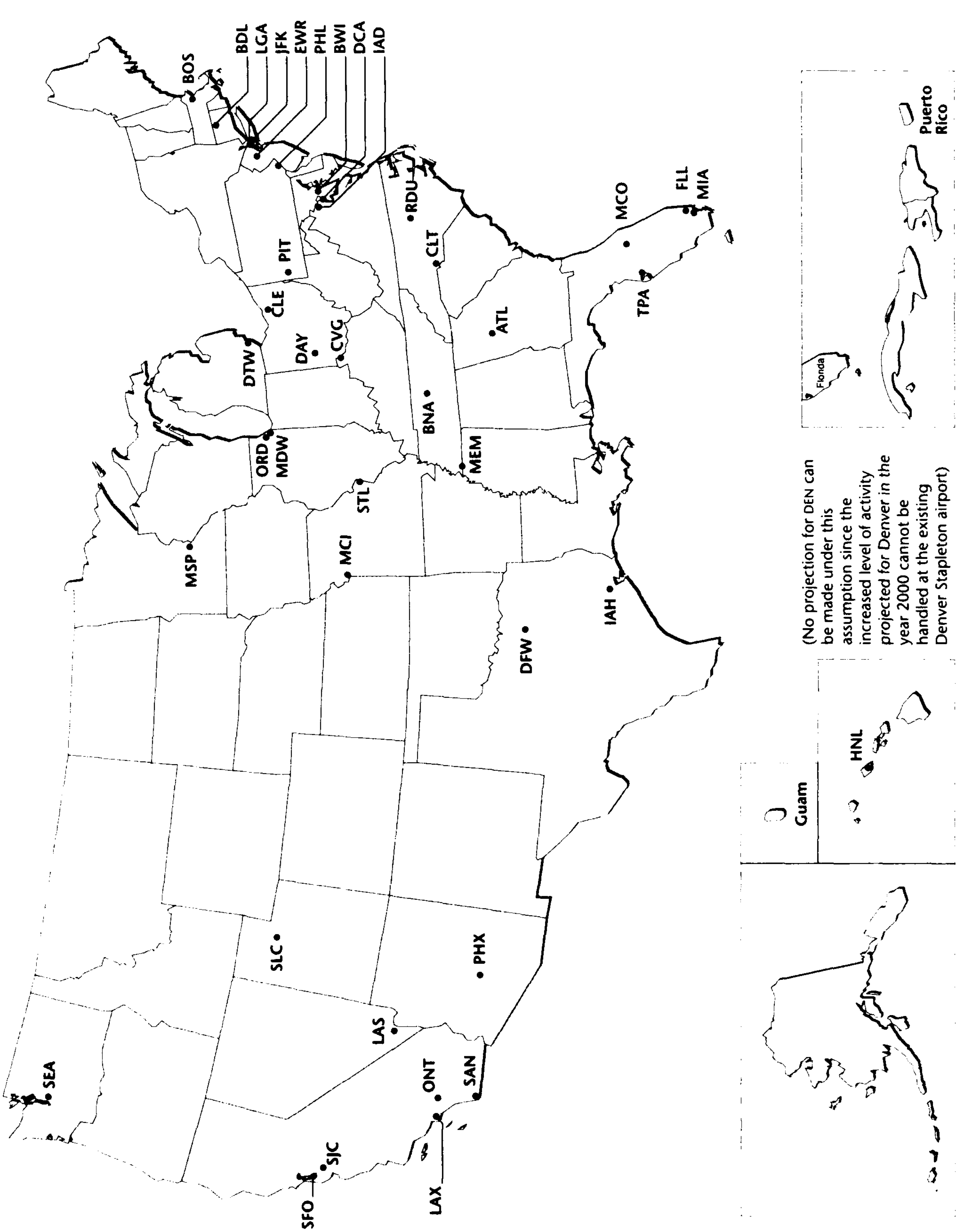


Figure 1-8. Airports Exceeding 20,000 Hours of Annual Aircraft Delay in 2000, Assuming No Capacity Improvements

Source: FAA Office of Policy and Plans

Chapter 2

Airport Development

2.1 Airport Capacity Design Teams

The data in the previous chapter indicate that delay increased slightly in 1990 over the previous year. Forecasts indicate that, absent of any capacity improvements, delay will increase substantially over the next decade.

Delay increased slightly between 1989 and 1990 and will increase substantially over the next decade without capacity improvements.

These delays are generally attributable to one or more of several conditions which include weather, traffic volume, restricted runway capability, and NAS equipment limitations. Each of these factors can affect individual airports to varying degrees, but much delay could be eliminated if the specific delay causes were identified and resources applied to reduce the delay impact deficiency.

Since 1985, the FAA has co-sponsored airport capacity design teams at delay-impacted airports across the country. Airport operators, airlines, and other aviation industry representatives work together with FAA representatives to analyze the capacity problems at each individual airport and recommend improvements that have the potential for reducing or eliminating the delay problem.

2.1.1 Airport Capacity Design Teams — Potential Savings from Improvements

The Airport Capacity Design Teams identify and assess various corrective actions which, if implemented, will increase the capacity, improve operational efficiency and reduce delay at the airports under study. These changes may include improvements to the airfield (runways, taxiways, etc.), facilities and equipment (navigation and guidance aids), and operational procedures. The capacity teams' examination of each alternative is intended to determine its *technical merits.* Environmental, socioeconomic, and political issues are not evaluated here but in the master planning process. Alternatives are examined with the assistance of computer simulation provided by the FAA Technical Center at Atlantic City, New Jersey. In their final report, the capacity team recommends certain projects for implementation. As can be seen from the summary of recommendations in Appendix B, the typical design team will make 20 to 30 recommendations to reduce delay at each airport. Consequently, it is virtually impossible to summarize the expected benefits of each of these recommendations in a single table. However, in many cases, the recommended improvements to the airfield represent the biggest capacity gains, particularly since they frequently incorporate the benefits of improved procedures and upgraded navigational equipment. The following table summarizes the delay savings benefits drawn from the final reports of various design teams and some current studies in progress. Delay savings are stated in millions of dollars and thousands of hours of delay saved at the highest future demand level considered by the design team. A breakdown of the summarized material and additional information is contained in Appendix E of this report.

Table 2-1 shows potential savings from airfield improvements recommended by Airport Capacity Design Teams. Figure 2-1 shows the location of Airport Capacity Design Teams in the U.S. Figure 2-2 is a three-year plan for Airport Capacity Design Teams. Table 2-2 is the status of Airport Capacity Design Teams.

Airport Capacity Design Teams have developed more than 800 projects to increase airport capacity.

The Airport Capacity Design Teams have developed more than 800 projects to increase airport capacity. New runways are being considered at more than 20 major airports as a direct result of Design Team efforts.

The status of these projects is given in Appendix B.

Table 2-1. Potential Savings from Airfield Improvements Recommended by Airport Capacity Design Teams. [1]

Airport Design Team	Major Recommended Improvements	Demand		Savings	
		Baseline	Highest	Hours (000)	Dollars ($M)
Atlanta	Fifth concourse, commuter/GA terminal and runway complex	750,000	796,500	147.0	$220.5
Charlotte	Third and fourth parallel runways	430,000	600,000	92.6	$129.7
Detroit	Two new runways	409,000	600,000	227.4	$412.9
Kansas City	Four new runways, high speed runway exits	212,000	450,000	185.8	$192.0
Memphis	New runway, taxiway extension, angled runway exit	382,000	510,000	51.5	$85.5
Miami	New taxiways, taxiway extension, improved runway exits, new holding areas	326,825	532,700	—	$41.0
Orlando	Fourth runway, new taxiways, staging areas	294,000	600,000	—	$59.6
Phoenix	New runway, new taxiways, holding area, angled exits, widened fillets	465,000	650,000	944.7	$1,020.3
St. Louis	Two new runways, taxiway extensions, angled runway exits	530,000	740,000	2,227.0	$3,294.0
Salt Lake City	New runway, revised taxiway exits	269,600	418,000	65.8	$71.7
Seattle-Tacoma	New runway, new taxiways, high speed exits	320,000	425,000	436.4	$628.4
Washington Dulles	Two new runways	320,000	450,000	14.6	$19.9

1. The potential annual delay savings in hours and dollars shown in the table represent the sum of the estimated savings benefits of the major recommended improvements for each airport. However, the savings benefits of these individual alternatives are *not necessarily additive*. They have been totaled here only to give an approximation on a single page of the impact these improvements could have in reducing delay at these airports.

It should also be noted that the particular combination of computer models and analytic methods used to calculate the annual delay costs and benefits is unique to each airport. Therefore, it is difficult, if not impossible, to compare one airport to another.

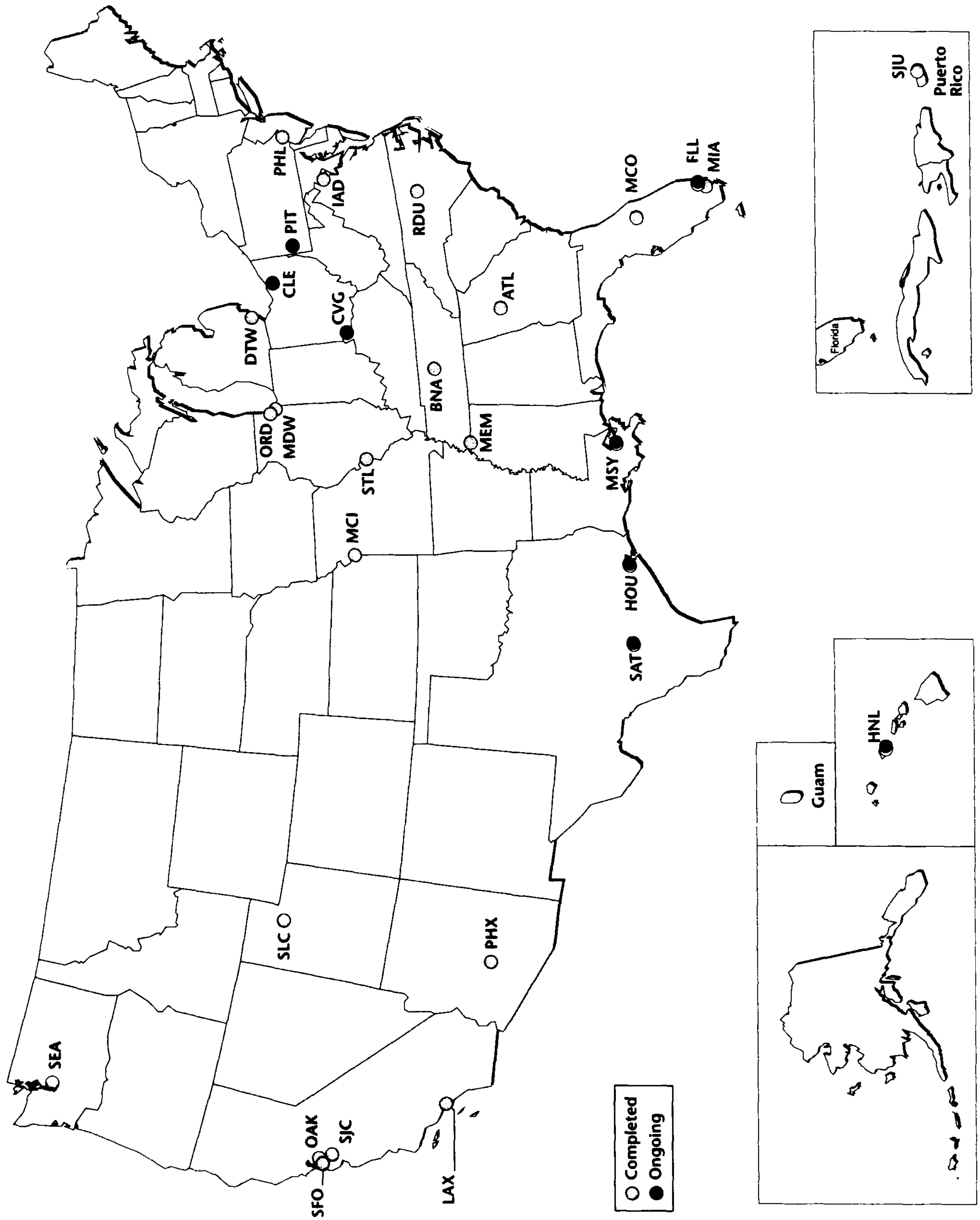


Figure 2-1. Location of Airport Capacity Design Teams in the U.S.

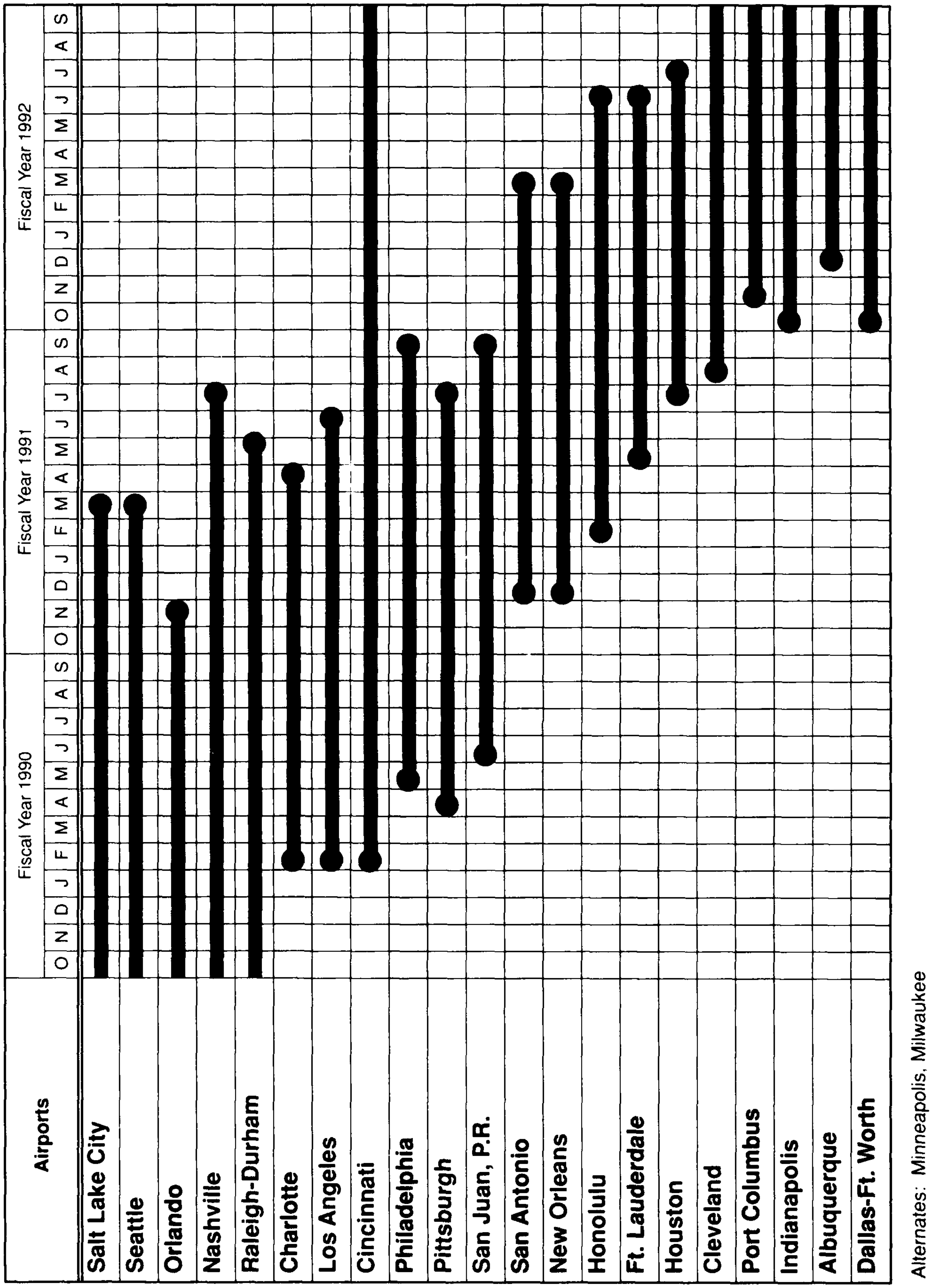


Figure 2-2. Three Year Plan for Airport Capacity Design Teams.

Table 2-2. Status of Airport Capacity Design Teams.[2]

Airport Capacity Design Team Status		
Completed		**Ongoing**
Atlanta	Philadelphia	Cincinnati
Charlotte	Phoenix	Cleveland*
Chicago	Raleigh-Durham	Fort Lauderdale*
Detroit	Salt Lake City	Honolulu*
Kansas City	San Francisco	Houston*
Los Angeles	San Juan, P.R.	New Orleans*
Memphis	San Jose	Pittsburgh
Miami	Seattle	San Antonio*
Nashville	St. Louis	
Oakland	Washington-Dulles	
Orlando		

* Projects recently initiated

2. Airport Capacity Design Status as of 10-31-91.

2.2 New Construction — New Airports and New and Extended Runways

The construction of new airports, as well as new runways and extensions of existing runways, are the most direct and significant actions that can be taken to improve airport capacity. Large capacity increases, both under Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) conditions, come from the addition of new runways that are properly placed to allow additional independent arrival and/or departure streams. The resulting increase in capacity is from 33% to 100% (depending on whether the baseline is a single, dual, or triple runway configuration.)

Sixty-two of the top 100 airports have proposed new runways or runway extensions to increase airport capacity.[3]

Eighteen of the 23 airports exceeding 20,000 hours of air carrier flight delay in 1990[4] are in the process of constructing or planning the construction of new runways or extensions of existing runways.

Of the 40 airports that are forecast to exceed 20,000 hours of annual air carrier delay in 2000, if no further improvements are made, 29 propose to build new runways or runway extensions.[5]

The total anticipated cost of completing these new runways and runway extensions exceeds $6.5 billion. The proposed projects are in various stages of development. Of the 109 known projects, 77 are shown on an approved airport layout plan (ALP), 26 are known to have completed an environmental impact statement (EIS), 15 are known to have completed an application for an Airport Improvement Program (AIP) grant, and 14 have already begun construction.[6]

New parallel runways were put into service at Cincinnati, Indianapolis, Las Vegas, and Little Rock in 1990 and early 1991. All runway extensions at Baltimore-Washington also became operational in 1990, and a runway at Cleveland was reconstructed. Figure 2-3 shows which of the top 100 airports are planning new runways. Figure 2-4 shows which of the airports forecasted to exceed 20,000 hours of annual delay in 2000 are planning new runways. Table 2-3 shows new and extended runways that are planned or proposed.

The construction of new airports, as well as new runways and extensions of existing runways, are the most direct and significant actions that can be taken to improve airport capacity.

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Eighteen of the 23 airports exceeding 20,000 hours of air carrier flight delay in 1990 are in the process of constructing or planning the construction of new runways or extensions of existing runways.

3. The airports having runway projects are pictured in Figure 2-3 and summarized in Table 2-3, on page 2-10, with the projected IFR capacity benefit, the estimated project cost (to the nearest million), and an estimated operational date. Although the single figure of IFR capacity benefit does not reflect all the many significant capacity benefits resulting from this new construction, it is provided as a common benchmark.
4. 20,000 hours of flight delay translates into over $32 million per year at the cost of $1600 per hour of airport delay.
5. As reflected in Figure 2-4, on page 2-9.
6. As reflected in Appendix C.

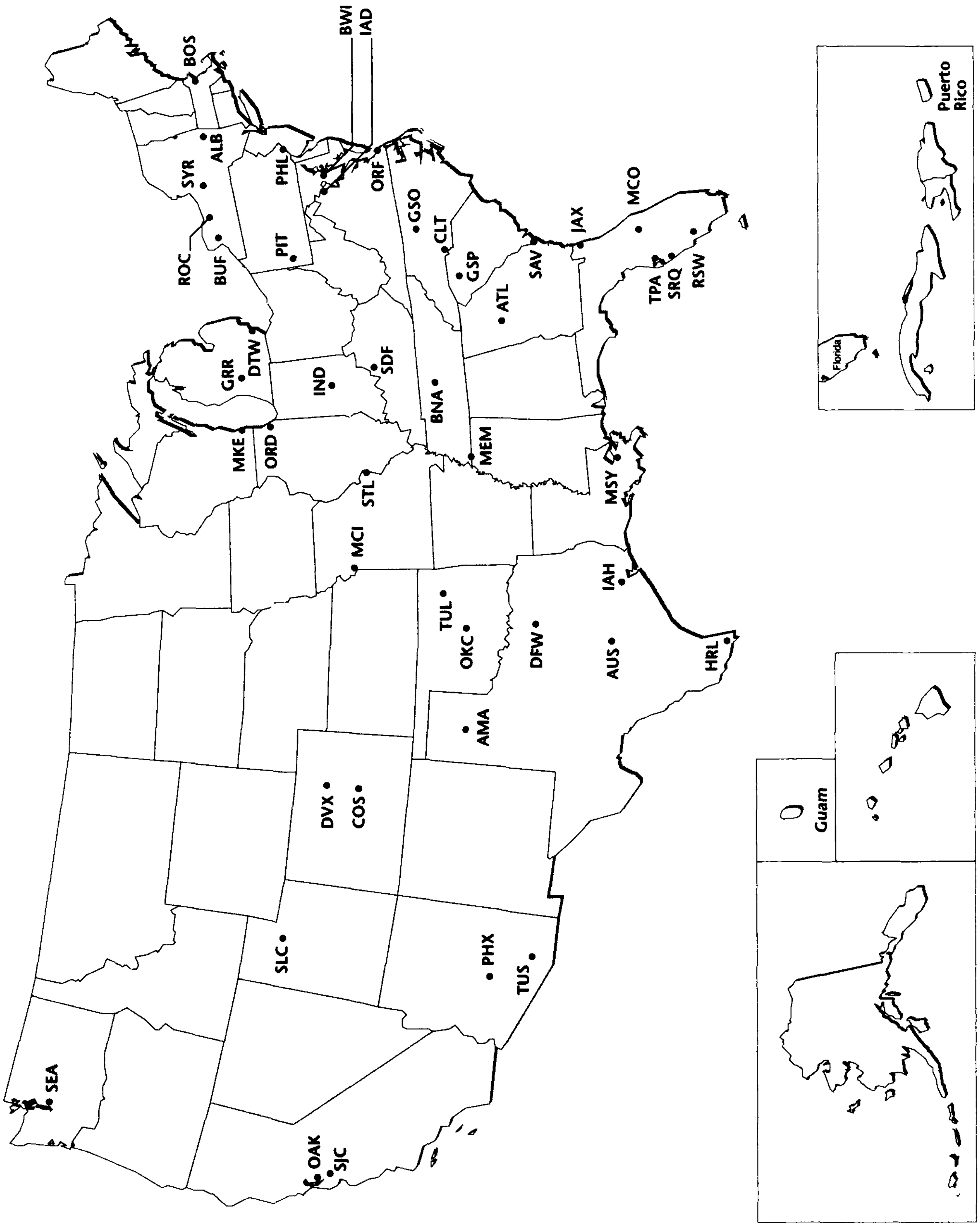


Figure 2-3. New Runways Planned or Proposed Among the Top 100 Airports.

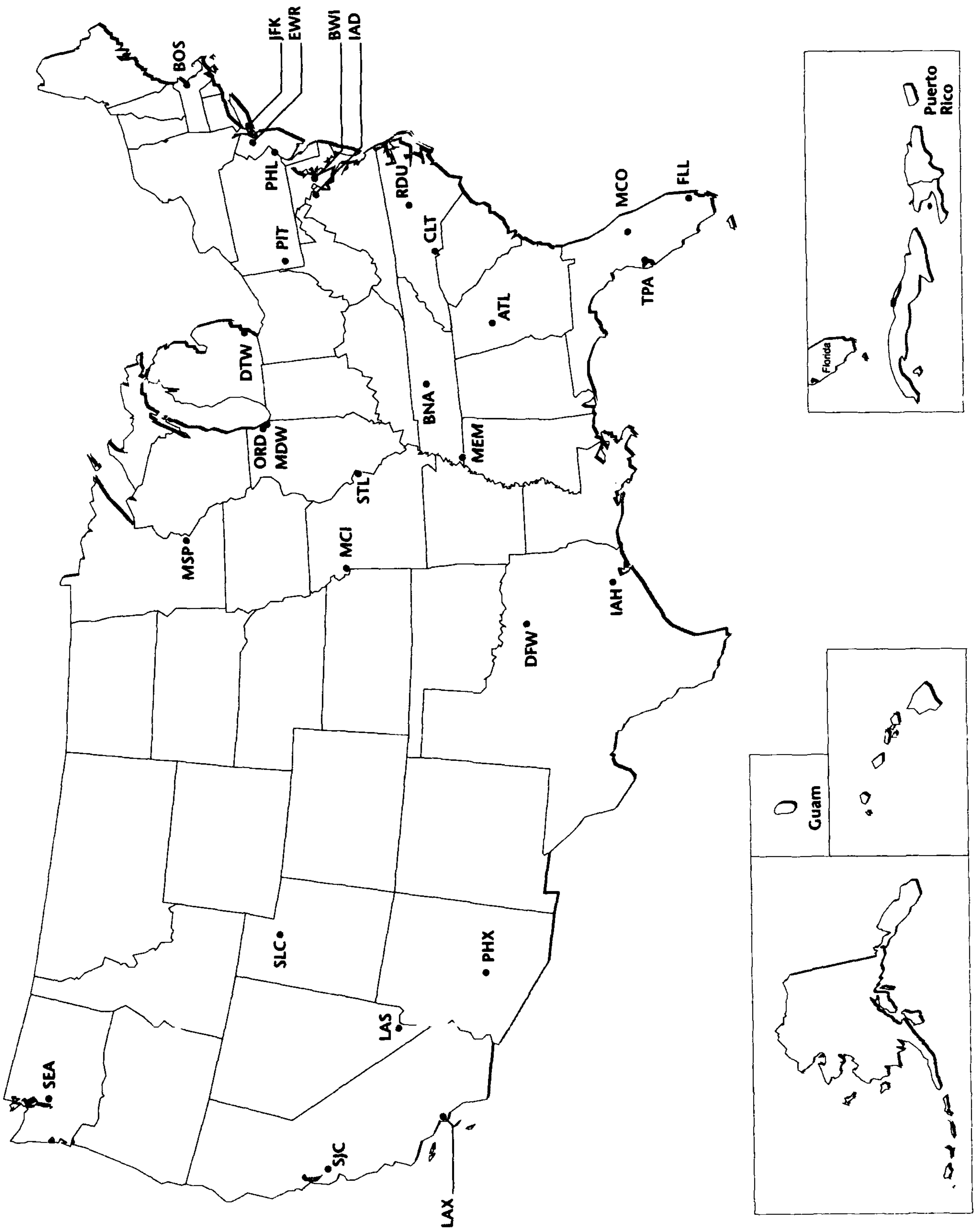


Figure 2-4. New Runways or Extensions Planned/Proposed Among Airports Forecasted to Exceed 20,000 Hours of Annual Aircraft Delay in 2000

Table 2-3. New and Extended Runways Planned or Proposed+

		IFR Capacity (ARR/HR)†		Est.	Est.
Airport	Runway	New Config.	Current Best	Cost ($M)	Date Oper.
Albuquerque (ABQ)	3/21 extension	26[2]	26[2]	$11	1991
Albany (ALB)	10/28 extension	26[2]	26[2]	$2	1997
	1R/19L parallel	++	26[2]	$15	1999
Amarillo (AMA)	13/31 extension	++			1997
Atlanta (ATL)	E/W parallel	63[6]	52[1]	$130	1995
Austin New Airport (AUS)[12]	Parallels — 17/35	52[1]	26[2]	$550*	1997
Baltimore (BWI)	10R/28L	52[11]	26[2]	$38	1996
Birmingham (BHM)	18/36 extension	26[2]	26[2]	$43	1996
Boston (BOS)	14/32	36[4]	26[2]		
	15L extension	26[2]	26[2]		
Buffalo (BUF)	5L/23R	26[2,8]	26[2,8]		1999
	14/32 extension	26[2,8]	26[2,8]	$4	1993
Charlotte (CLT)	18L/36R extension	52[7,8]	52[1,2]	$7	1993
	18/36 parallel	78[3,10]	52[1,8]	$17	1996
Chicago Midway (MDW)	22L extension	26[2]	26[2]	$8	1991
Chicago O'Hare (ORD)	9/27	78[3]	52[1]		
	14/32	78[3]	52[1]		
Colorado Springs (COS)	17L/35R	52[1]	26[2]	$38	1992
Columbus (CMH)	10L extension	52[7]	36[4]	$8	1995
	28R extension	52[7]	36[4]	$3	1994
Dallas-Fort Worth (DFW)	17R/35L extension	52[1]	52[1]	$24	1991
	18L/36R extension	52[1]	52[1]	$24	1993
Dallas-Fort Worth (DFW)	16L/34R	78[3]	52[1]	$100	1993
	16R/34L	78[3,10]	52[1]	$95	1997
Denver New (DVX)[12]	New Airport	78[3,10]	52[1]	$2,500**	1993
Detroit (DTW)	9R/27L	52[1]	52[1]	$69	1992
	4/22 parallel	63[6]	52[1]	$58	1995
Fort Lauderdale (FLL)	9R/27L extension	52[1]	26[2]	$26	1995
Fort Myers (RSW)	6/24 extension	26[2]	26[2]	$10	1992
	6R/24L parallel	52[1]	26[2]	$120	1999

+ See endnotes 1-11, on page 2-13, which describe the IFR arrival capacity of the current and potential new configurations.

* Cost for New Airport (Phase I) land, terminal, runways, etc.

** Cost for New Airport Phase I.

Table 2-3. New and Extended Runways Planned or Proposed (continued)+

Airport	Runway	IFR Capacity (ARR/HR)† New Config.	IFR Capacity (ARR/HR)† Current Best	Est. Cost ($M)	Est. Date Oper.
Grand Rapids (GRR)	8L/26R parallel	52[1]	26[2]	$25	1994
	8L/26R extension	26[2]	26[2]	$30	1995
Greensboro (GSO)	5/23 parallel	52[1]	26[2]	$20	2010
	14/32 extension	26[2]	26[2]	$14	1998
Greer (GSP)	3/21 parallel	52[1]	26[2]	$25	1995
Harlingen (HRL)	13L/31R	52[7]	26[2]	$5	1995
	13/31 extension	26[2]	26[2]	$7	1995
Houston (IAH)	8L/26R	78[3]	52[1]	$44	1999
	9R/27L	52[1]	52[1]	$44	2002
	14R/32L extension	52[1]	52[1]	$8	1997
Indianapolis (IND)	5L/23R replacement	36[4]	36[4]	$42	1996
Islip (ISP)	8/24 extension	26[2]	26[2]		
Jacksonville (JAX)	7R/25L parallel	52[1]	26[2]	$37	
Kansas City (MCI)	1R/19L	52[1]	26[2]	$46	1992
	9R/27L	26[2]	26[2]	$60	1999
	18L/36R	52[1]	26[2]	$65	1999
	18R/36L	78[3]	26[2]	$90	1999
Knoxville (TYS)	5R/23L extension	36[4]	26[2]	$17	1992
Las Vegas (LAS)	1L/19R extension	26[2]	26[2]		1997
	7R/25L	++	26[2]	$42	1991
Little Rock (LIT)	4R/22L	52[1]	26[2]	$80	1991
Los Angeles (LAX)	6L/24R extension	52[1]	52[1]	$4	1995
Louisville (SDF)	East parallel	52[1]	26[2]	$175	1995
	West parallel	52[1]	26[2]	$175	1997
Lubbock (LBB)	8/26 extension	26[2]	26[2]	$6	1995
Memphis (MEM)	18L/36R parallel	52[7]	36[4]	$105	1994
Midland (MAF)	10/28 extension	52[7]	26[2]	$6	1992
Milwaukee (MKE)	7L/25R	52[7]	26[2]	$150	2003
	1L/19R extension	26[2]	26[2]	$13	1993
Minneapolis (MSP)	4/22 extension	52[1]	36[4]	$11	1992
Nashville (BNA)	2C/20C extension	52[1]	52[1]	$34	1995
	2E/20E extension	++	52[1]		

+ See endnotes 1-11, on page 2-13, which describe the IFR arrival capacity of the current and potential new configurations.

Table 2-3. New and Extended Runways Planned or Proposed (continued)[+]

Airport	Runway	IFR Capacity (ARR/HR)[†] New Config.	IFR Capacity (ARR/HR)[†] Current Best	Est. Cost ($M)	Est. Date Oper.
New Orleans (MSY)	1/19 parallel	52[1]	26[2]	$180	2000
	10/28 parallel	52[1]	26[2]	$40	1995
	10/28 extension	26[2]	26[2]	$10	1991
New York Kennedy (JFK)	4L/22R extension	52[7]	36[4]		
Newark (EWR)	11/29 extension	52[7]	26[2]		
Norfolk (ORF)	5R/23L	26[2]	26[2]	$13	1994
	14/32 extension	26[2]	26[2]	$2	1996
Oakland (OAK)	11R/29L	++	26[2]	$143	
Oklahoma City (OKC)	17L/35R extension	52[1]	52[1]	$24	2001
	17R/35L extension	52[1]	52[1]	$20	2001
	17/35 parallel	52[1]	52[1]	$55	2001
Orlando (MCO)	17L/35R 4th parallel	78[3]	52[1]	$80	1993
Philadelphia (PHL)	8/26 parallel-commuter	52[1]	52[7]	$169	
	17/35 extension				
	relocate 9L/27R	52[1]	52[7]	$55	1997
Phoenix (PHX)	8S/26S 3rd parallel	52[1]	26[2]	$88	1994
Pittsburgh (PIT)	10C/28C extension	52[1]	52[1]	$10	1995
	4th parallel 10/28	78[3]	52[1]	$100	1995
	14R/32L		52[1]	$100	1995
Raleigh-Durham (RDU)	relocate 5R/23L	63[6]	36[4]	$45	1996
Rochester (ROC)	4R/22L parallel	++	26[2]	$5	2000
	4/22 extension	52[7]	26[2]	$1	1996
	10/28 extension	52[7]	26[2]	$2	1994
Salt Lake City (SLC)	16/34 west parallel	63[6]	36[4]	$95	1994
San Jose (SJC)	30R/12L extension	26[2]	26[2]	$10	
Sarasota-Bradenton (SRQ)	14L/32R parallel	26[2]	26[2]		
Savannah (SAV)	9L/27R parallel	52[1]	26[2]	$20	2010
	18/36 extension	26[2]	26[2]	$4	1995
Seattle-Tacoma (SEA)	16/34 west parallel	36[4]	26[2]		
Spokane (GEG)	3L/21R	52[1]	26[2]	$11	1996
St. Louis (STL)	13/31	52[7]	26[2]	$1	

+ See endnotes 1-11, on page 2-13, which describe the IFR arrival capacity of the current and potential new configurations.

Table 2-3. New and Extended Runways Planned or Proposed (concluded)+

Airport	Runway	IFR Capacity (ARR/HR)† New Config.	Current Best	Est. Cost ($M)	Est. Date Oper.
Syracuse (SYR)	10L/28R	52[1]	26[2]	$5	1997
Tampa (TPA)	18R/36L 3rd parallel	52[1]	52[1]	$53	1997
Tucson (TUS)	11R/29L parallel	26[2]	26[2]	$143	1995
Tulsa (TUL)	17/35 parallel	78[3]	52[1]	$100	1998
Washington (IAD)	1W/19W parallel	78[3]	52[1]	$60	2000
	12/30 parallel	52[1]	52[1]		
	12/30 extension	52[1]	52[1]	$7	1992
West Palm Beach (PBI)	9L/27R extension	26[2]	26[2]	$4	1994

Total Available Estimated Costs of Construction: $6.4 Billion*

\+ See endnotes 1-11, below, which describe the IFR arrival capacity of the current and potential new configurations.

++ Information on runway location is unavailable or too tentative to determine IFR multiple approach benefit of this new construction project.

* Includes the total costs of the New Austin airport and the New Denver airport, $550 million and $2,500 million, respectively. *Does not include the cost of projects completed in 1989.*

† Estimates of generalized hourly IFR arrival capacity increases are included in Table 2-3. Based on a 1987 report, the IFR arrival capacity of any single runway that can be operated independently is 26 arrivals/hour; a dependent parallel pair, 36 arrivals/hour; and independent parallels, 52 (2 x a single runway) arrivals/hour. Other configurations are multiples of the above. These values are provided to illustrate the approximate magnitude of the capacity increase provided. They should not be taken as the exact capacity of a particular airport since site-specific conditions (e.g., varying fleet mixes) can result in differences from these estimates.

Endnotes

1. Independent parallel approaches [52 IFR arrivals per hour].
2. Single runway approaches [26 IFR arrivals per hour].
3. Triple approaches (currently not authorized) [78 IFR arrivals per hour].
4. Dependent parallel approaches [36 IFR arrivals per hour].
5. Triple approaches with parallel and converging pairs may permit more than 52 IFR arrivals if procedures are developed.
6. Triple parallel approaches with dependent and independent pairs (currently not authorized) [63 IFR arrivals per hour].
7. Converging IFR approaches to minima higher than category (CAT) I ILS [52 IFR arrivals per hour].
8. Added capacity during noise abatement operations.
9. Independent parallel approaches with one short runway.
10. If independent quadruple approaches are approved [104 IFR arrivals per hour].
11. Independent parallel approaches (3,400 to 4,300 ft.) [52 IFR arrivals per hour].

2.3 Civilian Use of Military Airfield Capacity

As indicated in Table 2-3, new airports or new runways or runway extensions at existing airports, offer the greatest potential for increasing airport capacity. One element in providing such capacity is the possible redistribution of some commercial and general aviation traffic to new or enhanced reliever or satellite airports.

The ability to develop new airports has become increasingly difficult in recent years. A combination of community opposition, competing residential and commercial interests, environmental concerns, and cost factors have significantly constrained development of new airports and, in some cases, expansion of existing facilities.

As part of its overall strategy for capacity enhancement, the FAA is pursuing an initiative for the implementation of joint-use of existing military airfields and/or adaptation of former military facilities to civilian use. This initiative, the Military Airport Program (MAP), provides for the designation of current or former military airfields by the Secretary of Transportation for participation in MAP. Parties wishing to participate apply to the FAA for designation of the particular facility. In determining whether or not to designate a facility, the FAA may consider (1) proximity to major metropolitan air carrier airports with current or projected high levels of air carrier delay; (2) capacity of existing airspace and traffic flow patterns in the metropolitan area; (3) the availability of local sponsors for civil development; (4) existing levels of operation; and (5) existing facilities as well as any other appropriate factors.

The current 20 joint-use facilities have had a modest impact on system capacity. Examples of such facilities are Dillingham Army Airfield, Hawaii, and Rickenbacker Air National Guard Base, Columbus, Ohio. These facilities provide congestion relief to the airports at Honolulu and Port Columbus respectively, both projected to exceed 20,000 hours of air carrier delay before the end of the decade without further improvements.

Currently two former military airports have been designated by the Secretary for participation in MAP. These are the former Stewart Air Force Base near Newburgh, NY, and the former Ellington Air Force Base at Houston, TX.

A recent General Accounting Office (GAO) report on MAP observed that for a joint-use facility to have major impact it must be located in a major metropolitan area and near enough to a congested airport so as to be a reasonable alternative. The airfield should be in demand by either commercial or general aviation which are not adequately served by an uncongested airport in the area and the military host should not limit civilian demand. The use of existing and former joint-use airfields is not a panacea for aviation system capacity problems but is an integral component in the FAA's strategy to maximize the safe utilization of the nation's air capacity system.

The ability to develop new airports has become increasingly difficult in recent years. As part of its overall strategy for capacity enhancement, the FAA is pursuing an initiative (the Military Airport Program (MAP)) for the implementation of joint-use of existing military airfields and/or adaptation of former military facilities to civilian use.

Chapter 3

Airport and Airspace Capacity

The most direct way to bring about an increase in capacity is to improve the number of hourly operations at airports. Two initiatives that are directly aimed at that end are discussed in this section. One is to develop and implement capacity-enhancing approach procedures. The other is to sponsor airspace planning projects that make use of national and local expertise to improve the operations of specific airports and the surrounding airspace with an emphasis on making use of tools and techniques that are available in the near term.

3.1 Instrument Approach Procedures

In FY90, more than half of all delays were attributed to adverse weather conditions. These delays are in part the result of instrument approach procedures that are much more restrictive than the visual procedures in effect during better weather conditions. Much of the delay could be eliminated if the approach procedures used during IFR operations were closer to those observed during VFR operations.

During the past few years the FAA has developed new, capacity-enhancing approach procedures. In most cases, these are multiple approach procedures aimed at increasing the number of airports and runway combinations that can be used simultaneously, either independently or dependently, in less than visual approach conditions.[1] Some of these procedures require new technology or favorable research results in order to be implemented.

In FY90, more than half of all delays were attributed to *adverse weather conditions.*

Much of the delay could be eliminated if the approach procedures used during IFR operations were closer to those observed during VFR operations.

During the past few years the FAA has developed new, capacity-enhancing approach procedures.

1. In general, depending on the airport aircraft mix, single-runway IFR approach procedures allow about 26 arrivals per hour. Hence, two simultaneous approach streams, when operating independently of each other, double arrival capacity to 52 per hour. Three streams would allow 78 hourly arrivals, and so on. Such procedures are called "independent," because the aircraft in one stream do not interfere with arrivals in the other. Conversely, "dependent" procedures place restrictions between the aircraft streams, and, as a result, hourly capacity for dual dependent approaches is somewhere between 26 and 52 arrivals. In the case of dependent triple streams, the arrival capacity is somewhere between 52 and 78, depending on airport runway configurations.

The following sections present a brief description of the most promising approach concepts being developed, their estimated benefits, supporting technology, and candidate sites that might benefit from the new procedures. The busiest 100 airports are listed in Table 3-3 (described in Section 3.1.7), together with the new procedures that each can potentially use. Site specific analysis is needed to determine which procedures are most beneficial to each airport.

3.1.1 Wake Vortex Restrictions

Wake vortex hazards limit aircraft spacing and, hence, the arrival and departure capacities of airports. Better understanding of the properties of wake vortices and of aircraft response to them will result in reduced separation standards based on measured data. They will also allow the development of a wake vortex alerting system based on meteorological data. These developments would make possible reduced in-trail and departure separation and could possibly reduce the minimum spacing required between parallel runways for dependent parallel operations to as low as 1,000 feet.

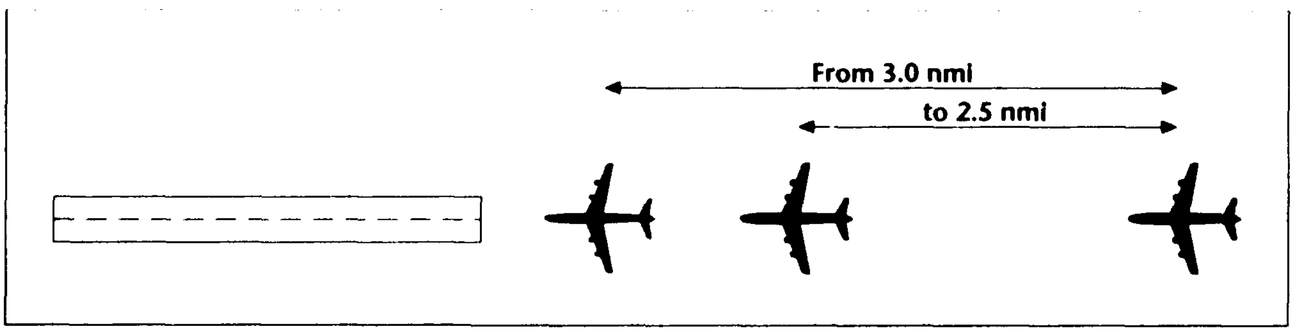
Recent efforts have helped improve the understanding of wake vortices by obtaining the wake vortex signatures of B-757 and B-767 aircraft and by measuring the characteristics of wake vortices under varying meteorological conditions. However, much more research is required before wake vortex associated spacing criteria can be revised.

Research is underway to better understand the properties of wake vorticies and how aircraft respond to them. This could possibly reduce the minimum separation required between parallel runways for dependent parallel operations to as low as 1,000 feet.

An improvement in the separation standard from 3.0 to 2.5 nmi on wet runways between certain classes of aircraft is currently undergoing demonstration. This may permit an increase of 3 to 5 additional arrivals per hour.

3.1.2 Improved Longitudinal Separation on Wet Runways

Air traffic control procedures include minimum longitudinal separation standards for aircraft in approach streams inside the final approach fix. The separation distances vary from 2.5 to 6 nmi, depending on the relative sizes of the leading and trailing aircraft. The minimum separations are intended to protect the trailing



Improved Longitudinal Spacing on Wet Runways

aircraft from the leading aircraft wake vortices. The minimum separation is also set to avoid situations in which the trailing aircraft lands before the leading aircraft has exited the runway. An improvement in the separation standard from 3.0 to 2.5 nmi on wet runways between certain classes of aircraft is currently undergoing demonstration at several airports. This improvement can potentially provide capacity gains of three to five arrivals per runway per hour. Most airports can benefit from the reduced separation standards.

3.1.3 Parallel Instrument Approaches

Currently, the separation between parallel runways must be at least 4,300 feet for simultaneous independent operations, and at least 2,500 feet for dependent parallel operations. The FAA is actively pursuing ways to reduce the runway spacing required for independent operations to as low as 2,500 feet and to increase the capacity of dependent runway configurations by reducing the required diagonal separation between aircraft on adjacent runways and the minimum separation distance between runways.

3.1.3.1 Independent Parallel Instrument Approaches Using a Precision Runway Monitor

The flexibility inherent in having two independent arrival streams provides a significant advantage relative to the dependent arrival case in which diagonal separations must be maintained. It can increase the number of operations per hour from about 26 to 52. These reductions are based on the use of the Precision Runway Monitor (PRM) (described in Section 4.1.3) in place of the existing terminal radar and displays.

During 1990, demonstrations conducted at Memphis (MEM) and Raleigh-Durham (RDU) showed that independent parallel approaches to runways 3,400 feet apart are possible using this new radar display technology. As a result, procedures to allow independent approaches to parallel runways 3,400 feet apart using the PRM will be published in 1991. The PRM will be developed into a production system to support these approaches. The first system will be commissioned at Raleigh-Durham in 1993, with four additional airports being added over the next two years.

During 1991, the FAA is conducting simulations at its Technical Center of independent approaches down to 3,000 feet of runway spacing using the new technology. These simulations will

The FAA is actively pursuing ways to reduce the required spacing between parallel runways for conducting simultaneous independent instrument approaches from 4,300 feet to as low as 2,500 feet.

Demonstrations at MEM and RDU have shown that independent parallel approaches to runways 3,400 feet apart are possible using the Precision Runway Monitor (PRM).

help demonstrate the feasibility of conducting simultaneous parallel approaches to runways with centerlines as close as 3,000 feet.

Airports that might benefit from PRM implementation are listed in Table 3-1, segregated by runway separation. Included are the airports selected to receive the first five systems. The other airports are preliminary candidates only. Some of the candidate airports are currently able to operate independent parallel approaches. Therefore, PRM use would apply only if these airports stopped operating their largest-spaced runways (4,300 feet or more) and instead activated parallel runways that are closer to each other.

Twenty-one of the top 100 airports are preliminary candidates for the PRM.

Table 3-1. Candidate Airports for Independent Parallel Approaches Using the Precision Runway Monitor (PRM)

Runway Separation 3,400 to 4,299 feet[2]		Runway Separation 3,000 to 3,399 feet[2]	
Atlanta (ATL)[3]	Selected Site	Denver (DVX)[3]	
Baltimore (BWI)[3]	Selected Site	Harlingen (HRL)	
Detroit (DTW)		Long Beach (LGB)	
Fort Lauderdale (FLL)		Minneapolis-St. Paul (MSP)	Selected Site[5]
Memphis (MEM)	Selected Site	New York (JFK)	
Milwaukee (MKE)		Philadelphia (PHL)[3]	
Phoenix (PHX)		Portland (PDX)	
Pittsburgh (PIT)[4]			
Raleigh-Durham (RDU)	Selected Site	**Runway Separation 2,500 to 2,999 feet[2]**	
Salt Lake City (SLC)		Columbus (CMH)	
Tampa (TPA)		Dallas-Love Field (DAL)	
		Indianapolis (IND)	

2. Some of the airports in each spacing category may also have parallel runways with a different spacing category. However, airports are listed only one time under the spacing category most likely to be used, that is, runways with the largest spacing category.
3. Applicable upon construction of new runway(s).
4. Runways are 5,540 feet apart; a new runway is planned that will create a parallel set separated by 3,100 feet or 4,300 feet.
5. Runways at MSP are 3,380 feet apart; waiver is required for PRM.

3.1.3.2 Dependent Parallel Instrument Approaches

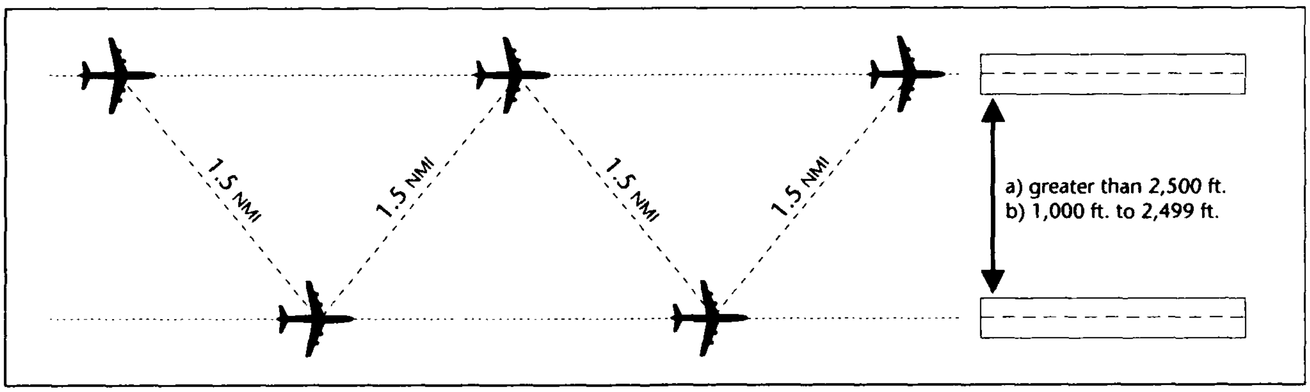
Existing rules for dependent IFR operations require that the spacing between parallel runways be at least 2,500 feet and the diagonal separation between aircraft on adjacent approaches be at least 2.0 nmi. The diagonal separation requirement places speed and in-trail restrictions on aircraft which reduce the arrival rate and operational flexibility of dependent parallel approaches, limiting the capacity increase associated with using two arrival streams.

Demonstration programs carried out in 1990 have shown that this diagonal separation can be safely changed to 1.5 nmi for runways at least 2,500 feet apart. This spacing would permit approximately four additional arrivals per hour compared to 2.0 nmi spacing. Procedure changes that will permit a 1.5 nmi diagonal separation for these runways will be issued in 1992.

A preliminary analysis has been made of the capacity gains that might be achieved by dependent operations on parallel runways 1,000 to 2,499 feet apart. The analysis has shown that arrival capacity increases of 46 to 65 percent are possible relative to single runway operations for diagonal separations between aircraft of 1.5 and 2.0 nmi respectively. Work is underway to validate these results and to determine whether such operations are feasible.

Demonstrations have shown that a reduction in diagonal separation from 2.0 to 1.5 nmi for runways at least 2,500 feet apart would permit approximately 4 additional arrivals per hour.

A preliminary analysis has shown that arrival capacity gains of 46% to 65% are possible relative to single runway operations for dependent operations on parallel runways 1,000 to 2,499 feet apart.

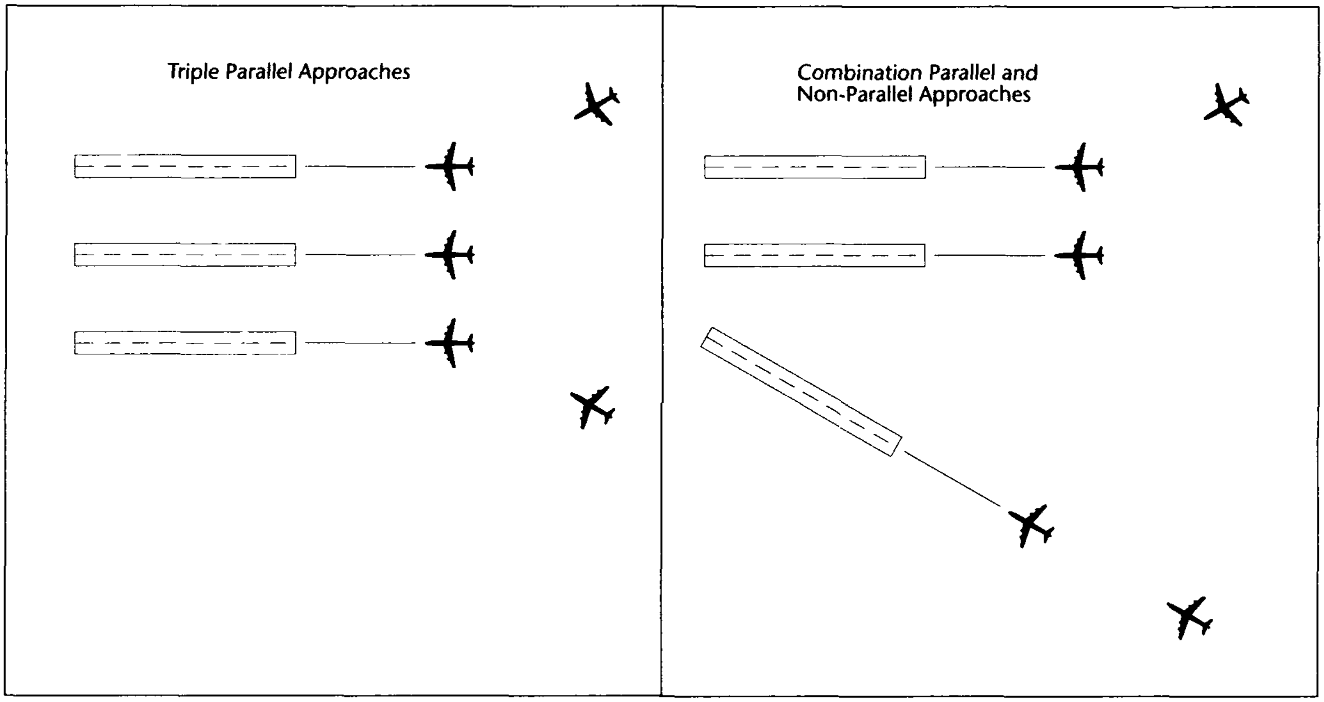


Dependent Parallel Instrument Approaches

3.1.4 Triple and Quadruple Instrument Approaches

At some airports, combinations of independent parallel and converging instrument approaches could be used to implement triple or quadruple arrival streams with multiple departure streams. The primary applications of this concept involve airports that have independent arrival streams to parallel runways. For such airports, a favorably located additional parallel runway or a converging runway may be used for an additional arrival stream. The use of triple parallel approaches would result in a 50 percent increase in arrival capacity, whereas quadruple approaches would provide a 100 percent increase in IFR conditions compared to dual independent approaches.

The use of triple parallel approaches would result in a 50% increase in arrival capacity; quadruple approaches would provide a 100% increase in IFR conditions compared to dual independent approaches.



Triple Instrument Approaches

Several airports, such as Atlanta, Dallas-Fort Worth, and Pittsburgh are planning on building parallel runways that will give them the capability of conducting triple and quadruple simultaneous parallel approaches. Dallas-Fort Worth has an existing configuration for triple approaches, as does Chicago O'Hare. Triple approaches using two parallel runways and one converging runway were approved at Dallas-Fort Worth in 1989. Preliminary analysis indicates that, of the top 100 airports, 15 are possible candidates for these type approaches.

Fifteen of the top 100 airports are possible candidates for triple or quadruple parallel approaches.

Work is currently underway to develop procedures and provide new technology that will optimize the use of these new runways. Simulations at the FAA Technical Center in 1988 and 1989 have resulted in the approval of triple and quadruple simultaneous parallel approaches at Dallas-Fort Worth. This approval is contingent upon construction of Runway 16L 5,000 feet from, and parallel to, Runway 17L, and Runway 16R 5,800 feet from, and parallel to, Runway 18R.

Simulations at the FAA Technical Center have resulted in the approval of triple and quadruple simultaneous parallel approaches at DFW.

The success of the 1988 and 1989 simulations has led to further simulations to develop generic procedures. This development process involves the use of the latest technology equipment such as Precision Runway Monitors and high resolution color displays for controllers. The goal is to develop generic procedures at the closest runway spacings while maintaining an equivalent or increased level of safety compared to today's operations.

3.1.5 Converging Approaches

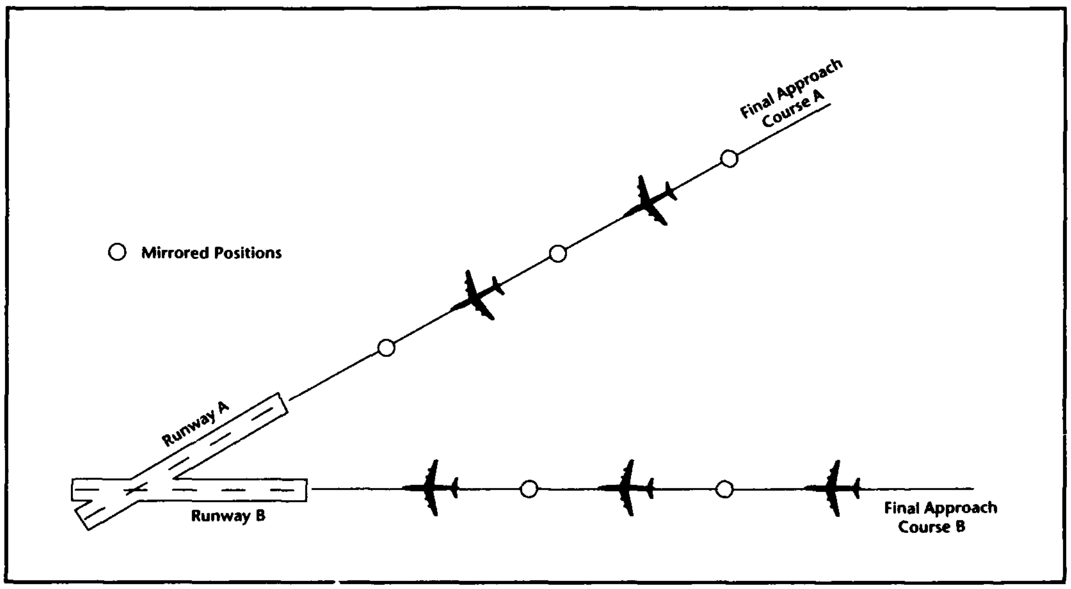
Converging runway approach improvements must take account of the wide variety of converging runway configurations that are in use. Numerous factors must be considered in designing approaches for a particular runway configuration. There is often a tradeoff between the minimum ceiling and visibility that can be achieved and the landing capacity, particularly in determining whether dependent or independent converging IFR approaches can be used. The FAA is actively pursuing ways to increase capacity for a wide variety of configurations while achieving the lowest possible landing minimums. At some airports it might be feasible to increase capacity at Category I landing minimums using technology that reduces the variability between successive operations. Procedural changes are being implemented that widen the range of weather conditions in which higher than previously achievable landing rates may be achieved for intersecting runways.

Technology that reduces the variability between successive operations is being considered to increase capacity at Category I landing minimums.

3.1.5.1 Dependent Converging Instrument Approaches

The landing minima for certain converging runway configurations are currently quite high due to the need to insure that aircraft on each approach are safely separated in the event of simultaneous missed approaches.[6] In return for the high minima, independent landing operations are possible. Typically, independent converging IFR approaches are feasible only when ceilings are above 600 feet depending upon runway geometry. As an alternative precision approach procedure, dependent operations could be conducted to much lower minima, usually down to Category I, expanding the period of time during which the runways can be used. However, in order to conduct these dependent operations efficiently, controllers need an automated method for ensuring that the aircraft on the different approaches remain safely separated. Without such a method, the separation of aircraft would be so large that little capacity would be gained.

Capacity increases of approximately 10 arrivals per hour are achievable using the Converging Runway Display Aid (CRDA) undergoing testing at STL.



Converging Instrument Approaches

A program is underway at St. Louis (STL) to evaluate dependent operations using a controller automation aid, the Converging Runway Display Aid (CRDA) (also called ghosting or mirror imaging and described in Section 4.1.2.1), to maintain aircraft

6. Simultaneous converging approaches are designed using the "TERPS + 3" criteria. This refers to the need for missed approach points to be separated by at least 3 nmi and for missed approach obstacle-free surfaces not to overlap.

stagger on approach. National implementation is planned for late 1992. It is estimated that capacity increases of approximately 10 arrivals per hour over single-runway arrival capacity are achievable with this procedure.

Airport surveys show that there is a high level of interest in the use of the CRDA at the twenty three airports listed in Table 3-2. Not all of these airports would necessarily show a capacity benefit however, because the surveys considered airport-specific needs that might not be directly related to capacity, an improved noise impact, for example.

The CRDA concept may also have applications under VFR. For example, it could be used at airports with intersecting runways that have insufficient length to allow hold short operations. Insufficient runway length between the threshold and the intersection with another runway can be ignored if arrivals are staggered such that one is clear of the intersection before the other crosses its respective threshold.

Twenty-three of the top 100 airports have shown an interest in the use of CRDA.

CRDA may also be used at airports with intersecting runways that have insufficient length to allow hold short operations.

Table 3-2. Candidate Airports for Dependent Approaches Using the Converging Runway Display Aid (CRDA)

Airports with a High Potential for Using the CRDA	
Baltimore (BWI)	Minneapolis-St. Paul (MSP)
Boston (BOS)	New York (JFK)
Chicago Midway (MDW)	New York La Guardia (LGA)
Chicago O'Hare (ORD)	Newark (EWR)
Cleveland (CLE)	Oakland (OAK)
Dallas-Fort Worth (DFW)	Philadelphia (PHL)
Dayton (DAY)	Pittsburgh (PIT)
Denver (DEN)	Portland (PDX)
Houston (HOU)	St. Louis (STL)
Memphis (MEM)	Washington Dulles (IAD)
Miami (MIA)	Windsor Locks (BDL)
Milwaukee (MKE)	

3.1.5.2 Simultaneous Operations on Intersecting Runways (SOIR)

The FAA is currently investigating the capacity ramifications of a number of proposed changes governing simultaneous operations on intersecting runways (SOIRs). Approved SOIRs, which include simultaneous takeoffs and landings and/or simultaneous landings, are authorized when a landing aircraft is able to and is instructed by the controller to hold short of the intersecting runway. Currently, SOIR are permitted only on dry runways. Demonstrations of simultaneous operations on intersecting wet runways (SOIWR) conducted at Boston Logan, Greater Pittsburgh, and Chicago O'Hare airports have pointed out the viability of standardizing these type operations. Procedural development is underway, and a national standard is expected in 1992.

Procedural development is underway for conducting simultaneous operations on intersecting wet runways.

Aircraft are classified into one of six SOIR groups which dictate the minimum landing distance that must be available in order for an aircraft in that group to be eligible to hold short. Proposed restructuring of these groups would more closely match the performance characteristics of aircraft by specifying minimum runway length requirements which differentiate between propeller and jet aircraft, between dry and wet runway conditions, and between different aircraft landing configurations. The runway length available on a hold short runway is currently measured from runway threshold to the nearest edge of the intersecting runway. Additional proposals would reduce this available runway length by requiring aircraft to hold short of Runway Safety Areas and Obstacle Free Zones bordering the intersecting runway.

Efforts are underway to restructure the six SOIR groups. Sixty of the 100 airports would be affected by these changes.

Sixty of the top 100 airports currently conduct hold short operations and would be affected by these changes.The largest capacity benefits would be realized at airports where propeller aircraft use the hold short runway.

3.1.6. Expanded VFR Approach Procedures

It is generally recognized that airport capacities in Instrument Meteorological Conditions (IMC) are well below those achieved in Visual Meteorological Conditions (VMC). However, once weather conditions fall below visual approach vectoring minima, even if conditions are still VFR, an airport whose parallel runways are separated by less than 2,500 feet generally has fewer options for conducting its multiple approaches. For example, San Francisco International (SFO) uses its Runways 28L and 28R about 85 percent of the time for simultaneous visual approaches. These runways are separated by 750 feet. Once the ceiling is less than 500 feet above

Procedures are being developed for instrument approaches to STL and SFO for runways separated by less than 2,500 feet. They consist of an LDA approach to one parallel runway and an ILS approach to the adjacent parallel runway.

the minimum vectoring altitude the airport is forced to go to a single runway operation because aircraft may no longer be vectored for visual approaches to both parallel runways.

A special solution to this problem has been developed and is in use at St. Louis Lambert Field (STL). (STL has parallel runways separated by 1,300 feet.) It involves the use of a Localizer Directional Aid (LDA) approach to one parallel runway and an ILS approach to the adjacent parallel runway. The localizer is offset from the runway centerline to provide increased separation far from the runway. These approaches are conducted simultaneously and utilize the procedures and equipment associated with simultaneous parallel approaches to runways separated by at least 4,300 feet; however, the STL procedure also requires the use of visual separation at or prior to the point where the separation between the final approach courses reaches 4,300 feet (the missed approach point). The minimums for the LDA approach is as low as a 1,200 foot ceiling and 4 miles of visibility.

A similar procedure has been proposed for San Francisco, and procedures are being developed with an anticipated implementation date of August 1992.

Point in space and other approach concepts applicable in marginal VFR conditions may be enhanced through the application of emerging technologies such as Traffic Alert and Collision Avoidance System (TCAS) (Section 4.1.5), Microwave Landing System (MLS) (Section 4.1.4), and the Converging Runway Display Aid (CRDA) (Section 4.1.2.1). These procedures are yet to be developed.

3.1.7 Approach Procedure Applicability at the Top 100 Airports

Table 3-3 shows the applicability of current and proposed procedures for the top 100 airports. The first column shows the current best hourly arrival capacity and the approach procedure utilized to achieve that capacity. The following columns show which of the proposed procedures discussed in the previous sections are applicable. It is important to bear in mind that this table is based on runway approach diagrams; factors such as noise, obstructions, and community concerns were not considered. Some airports may not be using their "current best" approach procedures. For these same reasons, the airports where the PRM might be applicable (Table 3-1) and where significant interest was shown for the CRDA (Table 3-2) are not identical to those shown in Table 3-3. In addition, the actual aircraft fleet mix at each airport was not used; the capacity figures are standard figures which are reasonable approximations of real capacity. The objective of the table is to provide initial information on the applicability of approach procedures being developed by the FAA. The estimated capacities should be used for comparison only.

An asterisk (*) indicates that the proposed approach procedure in the column in question is applicable at a given airport. A "p" indicates that the approach procedure may be applicable if and when proposed construction/extension plans actually take place. Some of this construction is in progress, while other is only at the proposal stage. A blank space indicates either that the runways do not support the proposed procedure, it is a borderline application, or there is not enough information to determine applicability. Finally, in order to highlight new approach procedures that would provide better capacity than any other procedures (current or proposed), an asterisk was replaced by a capacity number wherever the new procedure can provide higher capacity than any other. The number indicates the hourly arrival capacity of the procedure in question. It is easy to identify the most beneficial improvement by looking at the "New Approach Procedure" section in each row.

Table 3-3. Potential Siting of New IFR Approach Procedures and Their Associated IFR Arrival Capacity[1]

Airport Location	Airport Code	Current Best IFR Arrival Capacity (App Procedure)[2]	New Approach Procedures[3] Dependent Parallel	Independent Parallel	CRDA	TERPS+3	Triples
Agana (Guam)	NGM	26 (S)					
Albany	ALB	26 (S)			34		
Albuquerque	ABQ	26 (S)					
Anchorage	ANC	26 (S)				52	
Atlanta	ATL	52 (IP)	*	*p			63p
Austin (new airport)	AUS	52 (IP)					
Baltimore	BWI	26 (S)		52p	*		
Birmingham	BHM	26 (S)					
Boise	BOI	26 (S)					
Boston	BOS	26 (S)	36		*		
Buffalo	BUF	26 (S)			34		
Burbank	BUR	26 (S)			34		
Charleston	CHS	26 (S)			34		
Charlotte	CLT	52 (IP)			*	*	78p
Chicago	MDW	26 (S)					
Chicago	ORD	52 (IP)				*	78
Cleveland	CLE	26 (S)			34		
Colorado Springs	COS	26 (S)		*p	*	52	
Columbia	CAE	26 (S)			34		
Columbus	CMH	36 (DP)		*		52	
Dallas	DAL	36 (DP)		52			
Dallas-Fort Worth	DFW	52 (IP)				*	78p
Dayton	DAY	52 (IP)			*	*	
Denver (new airport)	DVX	52 (IP)	*				78
Des Moines	DSM	26 (S)			34		
Detroit	DTW	52 (IP)	*	*		*	63p
El Paso	ELP	26 (S)	*			52	
Fort Lauderdale	FLL	26 (S)		52	*		
Fort Myers	RSW	26 (S)		52p			
Grand Rapids	GRR	26 (S)		52p			
Greensboro	GSO	26 (S)		52p	*		
Greer	GSP	26 (S)		52p			
Harlingen	HRL	26 (S)		*	*	52	
Hilo	ITO	26 (S)			34		
Honolulu	HNL	52 (IP)			*		

Table 3-3. Potential Siting of New IFR Approach Procedures and Their Associated IFR Arrival Capacity[1] (continued)

Airport Location	Airport Code	Current Best IFR Arrival Capacity (App Procedure)[2]	New Approach Procedures[3] Dependent Parallel	Independent Parallel	CRDA	TERPS+3	Triples
Houston	HOU	26 (S)			34		
Houston	IAH	52 (IP)				*	78p
Indianapolis	IND	36 (DP)			*		
Islip	ISP	26 (S)			34		
Jacksonville	JAX	26 (S)				52	
Kahului	OGG	26 (S)			34		
Kailua-Kona	KOA	26 (S)					
Kansas City	MCI	26 (S)		*p		52	
Knoxville	TYS	26 (S)	36				
Las Vegas	LAS	26 (S)			34		
Lihue	LIH	26 (S)			*	52	
Little Rock	LIT	52 (IP)					
Long Beach	LGB	26 (S)	*	52	*		
Los Angeles	LAX	52 (IP)					
Louisville	SDF	26 (S)		52p	*		
Lubbock	LBB	26 (S)					
Memphis	MEM	36 (DP)		*	*	52	
Miami	MIA	52 (IP)			*	*	
Midland	MAF	26 (S)	*		*	52	
Milwaukee	MKE	26 (S)	*	*	*	52	
Minneapolis-St. Paul	MSP	36 (DP)		52	*		
Nashville	BNA	52 (IP)	*		*		
New Orleans	MSY	26 (S)		*p		52	
New York	JFK	36 (DP)		*	*	52	
New York	LGA	26 (S)			34		
Newark	EWR	26 (S)			*	52	
Norfolk	ORF	26 (S)			34		
Oakland	OAK	26 (S)	*			52	
Oklahoma City	OKC	52 (IP)				*	
Omaha	OMA	26 (S)	36		*		
Ontario	ONT	26 (S)					
Orlando	MCO	52 (IP)	*				78p
Philadelphia	PHL	52 (IC)	*	*p	*		
Phoenix	PHX	26 (S)		52			
Pittsburgh	PIT	52 (IP)	*	*	*		63p
Portland	PDX	36 (DP)		52	*		

Table 3-3. Potential Siting of New IFR Approach Procedures and Their Associated IFR Arrival Capacity[1] (continued)

Airport Location	Airport Code	Current Best IFR Arrival Capacity (App Procedure)[2]	New Approach Procedures[3] Dependent Parallel	Independent Parallel	CRDA	TERPS+3	Triples
Portland	PWM	26 (S)			34		
Providence	PVD	26 (S)	36		*		
Raleigh-Durham	RDU	36 (DP)		*	*		63p
Reno	RNO	26 (S)			34		
Richmond	RIC	26 (S)				52	
Rochester	ROC	26 (S)			*	52	
Sacramento	SMF	52 (IP)					
Salt Lake City	SLC	36 (DP)		*		*	63p
San Antonio	SAT	26 (S)			*	52	
San Diego	SAN	26 (S)					
San Francisco	SFO	26 (S)			34		
San Jose	SJC	26 (S)					
San Juan	SJU	26 (S)				52	
Santa Ana	SNA	26 (S)					
Sarasota-Bradenton	SRQ	26 (S)					
Savannah	SAV	26 (S)		52p	*		
Seattle-Tacoma	SEA	26 (S)	36p				
Spokane	GEG	26 (S)		52p			
St. Louis	STL	26 (S)	*		*	52	
Syracuse	SYR	26 (S)		52p	*		
Tampa	TPA	52 (IP)		*	*	*	
Tucson	TUS	26 (S)					
Tulsa	TUL	52 (IP)			*		78p
Washington	DCA	26 (S)			34		
Washington	IAD	52 (IP)				*	78p
West Palm Beach	PBI	26 (S)			34		
Wichita	ICT	52 (IP)				*	
Windsor Locks	BDL	26 (S)					

1. Generic (not airport-specific) capacities are used here to provide a basis of comparison only. These capacities, derived through the FAA Airfield Capacity Model, use a standard aircraft mix. Generally, runways not suitable for commercial operations were not considered. Also, factors such as winds and noise constraints are not taken into account.

2. Current Best Approach Procedure Abbreviations:
   S - Single runway
   DP - Dependent Parallel runways
   IP - Independent Parallel runways
   IC - Independent Converging runways

- An Asterisk (*) indicates proposed new approach procedures applicable at the airport in question; however, it also means that either the current best procedure, or another proposed approach procedure (under new rules), provides equal or better arrival capacity.
- A number indicates the hourly arrival capacity provided by a new approach procedure, when such capacity is larger than the one provided by other procedures (current or new), applicable at the airport in question.
- A "p" indicates that the approach procedure will be applicable if and when planned runway construction/extensions take place at the airport in question.

3.2 Airspace Planning

Airspace design involves extensive coordination between air traffic controllers and airspace planners. Several efforts are underway to improve the efficiency of the airspace system. Airspace Capacity Design Projects are either completed or underway at 20 major areas in the United States. Annual flight delay savings from the individual projects range into thousands of hours and millions of dollars.

A variety of computer models have been used to analyze a broad spectrum of capacity solutions. Since 1986, the System Capacity and Requirements Office has been applying the SIMMOD model to large scale airspace redesign issues. The first such project was an analysis of the Boston ARTCC in support of the expansion of that facility's airspace. That study identified benefits ranging from $23 million to $123 million depending on demand projections. Similar studies were initiated at the Los Angeles, Fort Worth, and Chicago ARTCCs studying issues as diverse as resectorization, special use airspace restrictions, new routings, complete airspace redesigns, and new runway construction. Computer modeling has been used to quantify delay, travel time, capacity, sector loading, and aircraft operating cost impacts of the proposed solutions.

The most productive solutions have generally involved additional runways. For example, the construction of even one new runway in Chicago would result in savings of up to $54 million per year without considering any increase in traffic. On the other hand, efficiencies have been identified in airspace design. For instance, depending on demand projections, the restructuring of Los Angeles Center airspace will save between $23 million and $41 million per year assuming no growth in runway capacity.

At Dallas-Ft. Worth, effects of the Metroplex plan were studied both with and without new runway construction. Results indicated an immediate savings of $13 million per year resulting from airspace changes alone. By the year 2010, the total plan would have saved a cumulative $5.2 billion in delay; $1.7 billion attributable to airspace, and $3.5 billion to the construction of two new air carrier runways. This demonstrates the "system" nature of the delay problem.

The FAA plans to institutionalize these activities by expanding the capability of its Technical Center in Atlantic City, N.J. Under the guidance of a policy level work group in Washington, the Technical Center, and soon the National Simulation Laboratory, will provide the FAA with the in-house resources to conduct studies using a variety of models.

During 1991, studies were completed at the Kansas City, Houston, and Oakland ARTCCs. What follows are excerpts from

Airspace Capacity Design Projects are either completed or underway at 20 major areas in the United States.

A study of the Boston ARTCC identified benefits ranging from $23 million to $123 million.

The construction of one new runway in Chicago would result in savings of up to $54 million per year.

The restructuring of Los Angeles Center airspace will save between $23 million and $41 million per year.

Studies of the effects of the Metroplex plan on Dallas-Ft. Worth have shown that an immediate savings of $13 million per year are possible from airspace changes alone.

those analyses. It should be noted that the FAA considers alternatives based on technical feasibility. No analysis of political or social considerations are reflected in this data.

3.2.1 Kansas City Area Airspace

The objective of the Kansas City Airspace Capacity Project was to evaluate operational alternatives in the St. Louis Terminal Radar Approach Control (TRACON), Kansas City TRACON and Kansas City ARTCC airspaces, aimed at increasing capacity, reducing delay, and improving the overall efficiency of air traffic operations. To meet this objective, three major simulation analyses were conducted. The first involved evaluating delay and capacity impacts at Lambert-St. Louis Airport associated with relocating arrival fixes based on a four cornerpost VOR system, implementing dual arrival routes over the cornerposts, and developing new departure routes. Table 3-4 illustrates the projected cost and delay savings associated with these changes through 1995.

Table 3-4. Delay and Cost Savings for Lambert-St. Louis Traffic for Alternative Improvement Options

	Improvement Option			Daily Delay Savings in Hours			
Demand Year	Airspace Routes	Flows over Arrival Fixes	Departure Gates	VFR Weather	IFR Weather	Average Day*	Annual Cost Savings**
1990 (base)	Old	Dual	Old	2	0	2	$1 Million
	New	Dual	New	14	0	12	$7 Million
1992 (+8%)	Old	Dual	Old	10	0	9	$5 Million
	New	Dual	New	31	0	26	$15 Million
1995 (+22%)	Old	Dual	Old	23	0	20	$12 Million
	New	Dual	New	137	0	116	$68 Million

* Delay on the average day is calculated based on VFR and IFR conditions occurring 85% and 15% of the time, respectively.

** Marginal aircraft operating cost savings are based on flight costs of $1,600 per hour.

The second analysis evaluated proposed airport/airspace improvements designed to increase capacity at Kansas City International Airport. Improvements included adding an independent parallel north-south runway, establishing a four cornerpost VOR system, realigning airspace, and re-routing traffic around the Truman Military Operations Area (MOA).

The third analysis entailed an evaluation of modifications of Kansas City ARTCC traffic flows to align with the St. Louis and

Kansas City TRACON arrival and departure changes, re-routing of overflight traffic based on specific destination criteria, and raising the ceiling on low altitude sectors from FL230 to FL270. After final analysis in March 1991, Kansas City ARTCC has decided to leave the low altitude sector ceilings at FL230. However, they now have re-stratified the four high altitude sectors which work arrivals and departures into and out of Chicago. The sectors, located in central Illinois and northeastern Missouri, have been redesigned to include two high altitude sectors from FL240 to FL330 (primarily designated for arrivals and departures into and out of Chicago, St. Louis, and Kansas City) and two sectors overlying those from FL350 and above (primarily designated for coast to coast overtraffic). The initial realignment of high altitude sectors was effective in August of 1991. All phases of the resectorization plan should be in effect by March 1, 1992.

3.2.2 Houston/Austin Airspace

To meet the Houston/Austin Airspace Capacity Project objective of quantitatively evaluating the capacity and delay impacts of operational alternatives in the Houston and Fort Worth Centers and in the Austin TRACON, two simulation analyses were conducted. The first involved evaluating the capacity gains and delay reductions that would result from construction of the new Austin airport at Manor, Texas, including redesigning airspace structures, routings, and procedures in the Austin TRACON. The second analysis involved analyzing the impacts of potential re-routing of specific Austin bound traffic from the east coast through the Fort Worth Center instead of via the present routing through the Houston Center.

Delay and cost savings were estimated for these changes under the assumptions that Austin would become a hub airport and that it would not become a hub airport. These results are summarized in Tables 3-5 and 3-6, respectively, for the years 1990 through 2010. The results show substantial benefits under either scenario, but the cumulative cost savings under the hub scenario are more than six times as large as under the non-hub scenario, $2,795 million versus $423 million.

Table 3-5. Delay and Cost Savings for the New Austin Airport/Airspace System at Hub Traffic Demand Levels

Traffic Demand*	Average Daily Delay Savings**	Annual Cost Savings***
1990	11 Hours	$7 Million
2000	122 Hours	$71 Million
2010	700 Hours	$409 Million
	Cumulative Savings 1990 through 2010	$2795 Million

* Traffic demand for Austin is based upon hub scenario forecast levels. Other traffic is assumed to grow at a rate of 4% per annum.

** Delay on the average day is calculated based on VFR and IFR conditions occurring 88% and 12% of the time, respectively.

*** Marginal aircraft operating cost savings based on flight costs of $1,600 per hour.

Table 3-6. Delay and Cost Savings for the New Austin Airport/Airspace System at Non-Hub Traffic Demand Levels

Traffic Demand*	Average Daily Delay Savings**	Annual Cost Savings***
1990	11 Hours	$7 Million
2000	32 Hours	$19 Million
2010	70 Hours	$41 Million
	Cumulative Savings 1990 through 2010	$423 Million

* Traffic demand for Austin is based upon non-hub scenario forecast levels. Other traffic is assumed to grow at a rate of 4% per annum.

** Delay on the average day is calculated based on VFR and IFR conditions occurring 88% and 12% of the time, respectively.

*** Marginal aircraft operating cost savings based on flight costs of $1,600 per hour.

3.2.3 Oakland Area

The following issues were addressed by the Oakland Airspace Project:

- An evaluation of airspace realignment and operational alternatives to alleviate the complexity and saturation problems associated with Oakland ARTCC Sector II.
- An evaluation of air traffic operations under the proposed Northern California Metroplex Control Facility (MCF) airspace redesign, which would consolidate operations in Bay, Sacramento, Stockton, and Travis approach controls.
- An analysis of the impacts on civilian traffic of proposed expansion of special use airspace in the Fallon, Nevada area, which includes Nellis Air Force Base training areas.
- An analysis of the impacts of alternative routes and procedures to alleviate noise problems in the Sacramento area.

The cost savings associated with various combinations of these changes together with the proposed extension of San Jose (SJC) Runway 30R are summarized in Table 3-7 for the years 1991 through 2000.

Table 3-7. Annual Aircraft Operating Cost Savings for MCF Airspace and SJC Runway Options

Improvement Option		Annual Cost Savings*		
Airspace	SJC Rwy 30R	1991	1995	2000
New	Existing	$2.1 M	$4.7 M	$13.7 M
Old	Extended	$3.9 M	$7.2 M	$20.7 M
New	Extended	$7.0 M	$15.6 M	$45.9 M

* Based on marginal aircraft operating costs of $1,600 per hour.

3.2.4 Studies in Progress

Currently, the FAA System Capacity Office is in the process of studying Washington, Cleveland, New York, and Jacksonville Centers and is supporting work in the New York and Atlanta Centers.

Chapter 4

Technology for Capacity Improvement

There are many technological initiatives underway that offer significant promise to improve the capacity of an airport, its surrounding terminal airspace, and the en route airspace. Even when considered individually, these technologies are significant steps in the right direction. However, the impact of each initiative will be enhanced by the integrated approach to capacity improvement that is being maintained through effective coordination of the various programs. At an overall level, this integration will be accomplished through the activities of the National Simulation Laboratory described in Section 4.3.1.

Section 4.1 covers technologies applicable to airport operations and the adjacent terminal airspace. These include the Precision Runway Monitor and the Converging Runway Display Aid that directly support the approach procedure improvements described in Section 3.1. Section 4.2 discusses technologies applicable to the en route airspace, including oceanic airspace. Section 4.3 covers technologies and programs that support planning and integration of the above programs, as well as technologies that will make changes and improvements to the National Airspace System easier and more efficient to implement.

Complete project details, including funding and implementation dates, where appropriate, are given in Appendix F. The projects described there include the key projects discussed in this section plus a large number of other projects that have an impact on capacity, although their primary focus might be different.

4.1 Airport and Terminal Airspace Capacity Technology

There are a number of programs that will improve the capacity of an airport and its surrounding terminal airspace. The Airport Surface Traffic Automation System will provide automation that will make ground operations safer and more efficient. The Precision Runway Monitor and the Converging Runway Display Aid have been discussed in Chapter 3 in connection with procedures for improved landing capacities at airports with multiple runways. The Microwave Landing System will make precision approach procedures available at more runways at more airports by significantly reducing the siting problems and frequency congestion associated with ILS.

The Center-TRACON Automation System will complement the above systems by aiding the controller in merging traffic as it flows into the terminal area. It will also provide enhanced throughput and avoid undesirable bunching and gaps in the traffic flow on the final approach path. This system and the Converging Runway Display Aid have been combined into the Terminal ATC Automation program. Finally, the Traffic Alert and Collision Avoidance System has the potential to expand beyond its current role of providing airborne collision avoidance as an independent system. It has the potential to reduce aircraft spacing in a variety of situations, leading to increased capacity.

Airport Surface Traffic Automation System will provide automation that will make ground operations safer and more efficient.

Microwave Landing System will make precision approach procedures available at more runways at more airports by significantly reducing the siting problems and frequency congestion associated with ILS.

Center-TRACON Automation System will complement the above systems by aiding the controller in merging traffic as it flows into the terminal area.

4.1.1 Airport Surface Traffic Automation Programs

The runway/approach path safety system that will be provided by Airport Surface Traffic Automation (ASTA) programs will include an automated surveillance capability that provides tower controllers with real-time data on the location and movement of all aircraft and vehicles on the airport surface and the final approach path. This capability will eventually provide an integrated display of the runway/approach path situation, that is designed to prevent conflict situations from developing. It will provide for an automatic detection and presentation to controllers of warning and conflict situations and direct automatic communications with the cockpit for ATC clearances, the airport traffic situation, and automatic emergency conflict resolutions messages. This will provide an all-weather, automated capability that allows for safe, high-capacity operations under all conditions.

Airport Surface Traffic Automation programs will provide tower controllers with real-time data on the location and movement of all aircraft and vehicles, automatic detection and presentation to controllers of warning and conflict situations, and direct automatic communications with the cockpit for ATC clearances.

A major portion of these safety benefits can be achieved by the Airport Movement Area Safety System (AMASS), an early runway incursion protection capability. AMASS will add an automation enhancement to the Airport Surface Detection Equipment-3 (ASDE-3) to provide conflict alert algorithms for tower controllers to detect runway incursions. The AMASS would be used by local and ground controllers at the 29 ASDE-3 sites. The system also includes a track data interface with the Automated Radar Terminal System IIIA (ARTS IIIA) to include airborne aircraft on final approach in the conflict alert algorithms.

Airport Movement Area Safety System, an early runway incursion protection capability, would be used at the 29 ASDE-3 sites.

The ASTA system to control and manage airport surface taxi traffic will incorporate the same basic airport surface surveillance system as described above. This system will provide automated tools to monitor and control airport surface traffic taxi flow (in-trail separation, separation at intersections, monitor one-way traffic flow, issue taxi clearance with route and runway assignment, sequence departure queues, etc.). It will also provide automatic aircraft status information for departure sequencing purposes. This system will permit all-weather operations that will reduce ground controller workload while allowing the controller to continue to take advantage of visual observations.

ASTA will also use a data link system that will permit direct digital data communications with pilots and aircraft flight management computers. Services provided by ASTA include delivery of airport traffic situation information to pilots, delivery of aircraft location in relation to an airport map showing runways, taxiways, etc., and, eventually, delivery of detailed guidance to cockpits to guide aircraft on taxiways to their destination. Additionally, a tower workstation will provide automation support for a number of services to aircraft flight crews. Controllers will review and release pre-departure flight plan clearance data and updates for digital delivery to aircraft in the gate area. Automated Terminal Information Service (ATIS) messages, which provide airport status and weather information, will be created for both voice broadcast and digital delivery to aircraft on the airport surface via the ASTA, and to aircraft in flight via Mode S Data Link. Wind shear alerts will be processed by the tower workstation for digital delivery via Mode S Data Link to aircraft approaching the airport.

4.1.2 Terminal ATC Automation (TATCA)

The purpose of the Terminal ATC Automation program (TATCA) is to assist air traffic controllers and supervisors in enhancing the terminal area air traffic management process and to facilitate the early implementation of these aids at busy airports. The TATCA program consists of two projects: the Converging Runway Display Aid (CRDA) and the Center-TRACON Automation System (CTAS). Longer term TATCA activities include the integration of terminal automation techniques with other air traffic control and cockpit automation capabilities.

4.1.2.1 Converging Runway Display Aid

The CRDA uses automation to display an aircraft at its actual location and simultaneously display its image at another location on the controller's scope to assist the controller in assessing the relative position of aircraft that are on different approach paths. The CRDA is compatible with the ARTS system.

Simulations have shown that this aid may be effective in increasing capacity by allowing multiple runways to be used simultaneously in IFR weather. At St. Louis, the FAA is currently conducting an evaluation of this automation aid to facilitate dependent precision converging approaches to Category I minima, approaches which currently can only be used to high IFR ceilings. (This is discussed further in Section 3.1.5.1.)

Simulations have shown that CRDA may be effective in increasing capacity by allowing multiple runways to be used simultaneously in IFR weather.

4.1.2.2 Center-TRACON Automation System

The approach to major terminal areas represents one of the most complex and high-density environments for air traffic control. Arrivals approach from as many as eight directions, with jet arrivals descending from high altitudes while other traffic enters from low altitudes. It is difficult for controllers to foresee how traffic from one approach path will ultimately interact with traffic from other approach paths. This results in traffic arriving either in bunches or with significant gaps, which in turn reduce airport capacity. Speed and space restrictions in the terminal area add to the difficulty of maintaining an orderly flow to the runway. Visibility and wind shifts, variations in aircraft mix, wake vortex considerations, missed approaches, runway/route changes or closings, all add to the difficulty of controlling traffic efficiently and safely in the terminal airspace.

The CTAS is designed to improve system capacity by helping the controller smooth out the traffic flow and eliminate gaps in arrivals. The earliest CTAS products are a Final Approach Spacing Tool (FAST) for the TRACON and a Traffic Management Advisor (TMA) for the ARTCC. The TMA will help en route controllers to coordinate aircraft crossings at arrival fixes so that they can be efficiently merged into the final approach stream by the TRACON controller. The FAST will aid the TRACON controllers in merging arrival traffic into an efficient flow to the final approach path. It will also allow the controller to efficiently merge missed approach and pop-up traffic into the final approach stream. Longer-term CTAS activities focus on integration of terminal automation with other ATC automation and cockpit automation activities.

CTAS is designed to improve system capacity by helping the controller smooth out the traffic flow and eliminate gaps in arrivals.

4.1.3. Precision Runway Monitor (PRM)

Significant capacity gains can be achieved at airports with closely spaced parallel runways if the allowable runway spacing for conducting independent parallel instrument approaches can be reduced. (The benefits associated with reduced spacings are discussed in Section 3.1.3.1.) Current criteria allow independent approaches to parallel runways separated by 4,300 feet or more. This standard was established based on the surveillance rate and accuracy of the airport surveillance radars (ASRs) and the terminal Automated Radar Terminal System (ARTS) capabilities. Analysis and demonstrations have indicated that the separation between parallel runways could be reduced if the surveillance data rate and the radar and display accuracy were improved. Conventional airport surveillance radars update the target position every 4.8 seconds.

The FAA has fielded engineering models of two types of PRM systems to investigate the reduction in separation associated with these improvements. The PRMs consist of improved antenna systems that provide high azimuth and range accuracy and higher data rates than the current terminal ASR radars, a processing system that monitors all approaches and generates controller alerts when an aircraft appears to be entering the no transgression zone between the runways, and a high resolution display system. One version utilizes an electronically scanned antenna that is capable of updating aircraft positions every half second and the other utilizes two mechanically rotating antennas mounted back-to-back that together update aircraft positions every 2.4 seconds.

The PRMs consist of improved antenna systems that provide high azimuth and range accuracy and higher data rates, a processing system that monitors all approaches and generates controller alerts, and a high resolution display system.

Demonstrations have shown that either version of the PRM can allow independent parallel operations for runways as close as 3,400 feet apart. Further research and development, including ATC simulations at the FAA Technical Center, are planned to determine the requirements for conducting independent parallel approaches to runways as close as 2,500 feet apart.

4.1.4 Microwave Landing System (MLS)

Subsequent to the year 2000, the United States intends to completely transition from the Instrument Landing System (ILS) to the MLS. This transition is in accordance with international plans to transition to MLS as the standard precision instrument approach system. By January 1998, all international runways in the U.S. will be equipped with MLS capability.

The ILS has provided dependable precision approach service for many years. However, inherent characteristics of the ILS have caused difficulties in congested terminal areas. Of particular concern from an air traffic perspective is the long straight-in flight path required by ILS. This restriction is not a major concern for isolated airports without obstruction problems, but, for closely spaced airports, ILS finals often create conflicts because flight paths may cross in ways that preclude separation by altitude. In these configurations the airports become interdependent (i.e., preferred operations cannot be conducted simultaneously at the affected airports), causing delays and constraining capacity. In areas such as New York, the curved approach capability provided by MLS will provide a solution to the interdependency of proximate airports.

The curved approach capability provided by MLS will provide a solution to the interdependency of proximate airports.

The MLS will also enable the FAA to provide precision approach capability for runways at which an ILS could not be utilized due to ILS localizer frequency-band congestion or FM radio transmitter interference. For example, it is already difficult to add ILS facilities in congested areas such as Chicago and New York. The MLS has two hundred operational channels, with additional channels available for future growth and development. In addition, there are no nearby frequencies in use to create interference.

It may also be possible to achieve lower minima with MLS than can be achieved with ILS at some sites. Moreover, MLS will relieve surface congestion resulting from restrictions caused by ILS critical area sensitivity to reflecting surfaces such as taxiing and departing aircraft.

Use of MLS back azimuth for missed approach guidance may help support development of approach procedures for converging runway and triple runway configurations. Use of back azimuth for departure guidance will help ease airspace limitations and restrictions on aircraft operations due to noise abatement requirements.

MLS provides for more flexible ground siting of equipment to compensate for terrain irregularities that do not permit a centerline siting. These irregularities include, but are not limited to, mountains, rivers, and valleys. Additionally, MLS does not require as extensive a site preparation as ILS, since MLS does not form guidance signals through ground reflection.

The MLS/RNAV capability with wide-area coverage will provide more flexibility in the terminal airspace. It will permit the design of instrument approach procedures that more closely approximate traffic patterns used during VMC. Typically these result in shorter flight paths, segregation of aircraft by type, reduction of arrival and departure gaps, and avoidance of noise sensitive areas.

MLS/RNAV will provide the capability of computing a centerline approach to secondary runways, both parallel and intersecting, that lie within the coverage volume of the instrumented runway. MLS/RNAV will also allow computing a centerline approach to a primary runway where ground terrain has caused the azimuth station to be offset a considerable distance from the runway centerline.

MLS will relieve surface congestion resulting from restrictions caused by ILS sensitivity to reflecting surfaces such as taxiing and departing aircraft.

The MLS/RNAV capability will permit the design of instrument approach procedures that more closely approximate traffic patterns used during VMC.

4.1.5 Traffic Alert and Collision Avoidance System (TCAS) Applications

TCAS is an airborne system that operates independently of ground-based ATC to provide the pilot with advisories concerning nearby transponder-equipped aircraft. The TCAS II system mandated for use in transport category aircraft provides relative position information and, when necessary, advisories for vertical maneuvers to avoid collisions. This system is expected to be fully implemented on transport carrier aircraft by the end of 1993. Because of the information provided by TCAS and its widespread equipage, it has been identified as having the potential to increase ATC capacity and efficiency and reduce controller workload.

A program is being established to investigate use of TCAS to support reduced spacing on final approach, reduce the stagger requirement for dependent converging approaches using the CRDA, allow departures at reduced spacing, and monitor separation between aircraft on independent approaches. Should these applications prove successful, additional development will be pursued in the areas of wake vortex avoidance, TCAS-based parallel approach monitoring, TCAS-based self-spacing, and other more advanced applications.

The Traffic Alert and Collision Avoidance System is an airborne system that provides the pilot with advisories concerning nearby transponder-equipped aircraft.

A program is being established to investigate use of TCAS to reduce spacings and increase capacity.

4.2 En Route Airspace Capacity Technology

En route airspace congestion is being increasingly identified as a factor in restricting the flow of traffic at certain airports. In 1990, 38 percent of all delays were attributed to limitations in terminal and en route airspace. One cause of en route airspace congestion is that ATC system users want to travel directly from one airport to another at the best altitude for their aircraft, and hundreds of aircraft have similar performance characteristics. Therefore, some portions of airspace are in very high demand, while others are used very little. This non-uniform demand for airspace translates into the need to devise equitable en route airspace management strategies for distributing the traffic when demand exceeds capacity.

Initiatives designed to reduce delays, match traffic flow to demand, and increase users' freedom to fly user-preferred routes are underway. These initiatives have a large technology component as well as significant procedural impacts.

Automated En Route Air Traffic Control (AERA) is a long-term evolutionary program that will increasingly allow aircraft to fly their preferred routes safely with a minimum of air traffic control intervention. The Advanced Traffic Management System (ATMS) will allow air traffic managers to identify in advance when en route

In 1990, 38 percent of all delays were attributed to limitations in terminal and en route airspace.

Initiatives designed to reduce delays, match traffic flow to demand, and increase users' freedom to fly user-preferred routes are underway. These initiatives have a large technology component as well as having significant procedural impacts.

or terminal weather or other factors require intervention to expedite and control the flow of traffic.

The increasingly crowded oceanic airspace is also being addressed. Initiatives that improve the control of this airspace, particularly the more accurate and frequent position reporting resulting from Automatic Dependent Surveillance (ADS) using satellite technology, will make it possible to effect significant reductions in oceanic en route spacing.

Other means of improving en route airspace capacity include reducing the vertical separation requirements at altitudes above FL290 to allow more turbojet aircraft to operate along a given route near their preferred altitudes and reducing the minimum in-trail spacing to increase the flow rate on airways.

4.2.1 Advanced Traffic Management System (ATMS)

The purpose of the ATMS is to minimize the effects of NAS overload on user preferences without compromising safety. This is accomplished by:

- Monitoring the demand on and capacity of ATC resources,
- Developing alternative strategies to balance demand and capacity to prevent critical entities from being overloaded,
- Coordinating and implementing strategies to assure maximum use of critical resources when a demand/capacity imbalance is predicted or detected.

The Traffic Management System will minimize NAS overload effects on user preferences without compromising safety. The capabilities of the TMS consist of the Aircraft Situation Display, Monitor Alert, Automated Demand Resolution, Strategy Evaluation, and Directive Distribution.

The Aircraft Situation Display (ASD) was the first capability developed by ATMS. The ASD generates a graphics display that shows current traffic and flight plans for the entire NAS. The ASD is currently deployed at the Air Traffic Control System Command Center (ATCSCC), all ARTCCs, and selected TRACONs.

The ASD has helped increase system capacity in several ways. It allows Traffic Management specialists to observe approaching traffic across ARTCC boundaries. This has allowed the reduction or elimination of many fixed miles-in-trail restrictions (and the resultant delay of aircraft) that were in effect prior to the deployment of ASD. It allows Traffic Management Specialists to detect and effect solutions to certain congestion problems, such as merging traffic flows, well in advance of problem occurrence and even before the aircraft enter the ARTCC where the congestion problem will occur. Small adjustments to traffic flows made early can avoid large delays associated with last minute solutions.

The ASD also assists Traffic Management specialists in planning arrival flows, especially for airports that are close to ARTCC boundaries. Smoother arrival flows result in better airport utilization.

The second capability developed by ATMS was the Monitor Alert which attempts to predict traffic activity several hours in advance. It compares the predicted traffic level to the threshold alert level for air traffic control sectors, fixes, and airports, and highlights predicted problems. It will aid in detecting congestion problems further in advance, enabling solutions to be implemented earlier. The Monitor Alert has recently been implemented at the ATCSCC, all ARTCCs and several TRACONs.

Three future capabilities that are being developed through ATMS are Automated Demand Resolution, Strategy Evaluation, and Directive Distribution. Automated Demand Resolution will examine problems predicted by Monitor Alert and suggest several alternative problem resolutions. The suggested resolutions are planned to respond to each problem without creating conflicts or additional problems. Strategy Evaluation will provide a tool for the specialist to compare the suggested resolutions. Directive Distribution will automatically distribute the necessary flow directives to implement the selected resolution.

4.2.2 Automated En Route Air Traffic Control (AERA)

AERA is a collection of automation capabilities that will support ATC personnel in the detection and resolution of problems along an aircraft's flight path, and in the planning of traffic flows. AERA will help increase airspace capacity by improving the ATC system's ability to manage more densely populated airspace. AERA will also improve the ability of the ATC system to accommodate user preferences. When the most desirable routes are unavailable because of congestion or weather conditions, AERA will assist the controller in finding the open route closest to the preferred one.

Automated En Route Traffic Control will help increase airspace capacity by improving the ATC system's ability to manage more densely populated airspace.

The most highly automated phase of the AERA program is the aircraft separation assurance function and local flow management function. The ATC specialist becomes a manager of traffic flows, planning and selecting strategies rather than directing the flight paths of individual aircraft. This phase of AERA takes advantage of advanced systems such as flight management systems and data link.

Laboratory facilities for the AERA program were established in 1987. This laboratory has been used for prototyping and analyses of systems and concepts to develop operational and specification requirements, as well as associated supporting technical documentation. These algorithmic and performance specifications and candidate ATC procedures will be completed in 1991.

In the next phase of the AERA program, software will be developed and undergo an operational evaluation at the FAA Technical Center. The AERA software and the ATC procedures will be updated as a result of the operational evaluation. This operational evaluation phase has already begun, and is scheduled to continue through 1997.

In 1989, the AERA program accomplished the first build of a prototype ARTCC in an AERA environment, called the AERA Protocenter, which simulates an integrated automation of the separation and planning functions. The Protocenter has successfully separated aircraft in realistic simulation scenarios consisting of over 100 aircraft. In 1990, the Protocenter was enhanced to include a metering function, so that it will not only keep aircraft separated, but will also develop time schedules and generate clearances to ensure that aircraft meet assigned time constraints, such as metering into terminal areas. Another recent enhancement to the Protocenter is a set of functions to cope with data uncertainties resulting from imperfect knowledge of winds aloft or aircraft speeds. The aggregate of recent enhancements resulted in Build 2 of the Protocenter, capable of successfully separating and metering aircraft in realistic simulation scenarios consisting of over 500 aircraft. In addition to the Protocenter, the AERA program is investigating the human role in a highly automated ATC environment, using a team of controllers, pilots, and specialists in traffic management and meteorology.

4.2.3 Automatic Dependent Surveillance (ADS) and Oceanic ATC

In the ADS system the information generated by an aircraft's onboard navigation system is automatically relayed from the aircraft, via a satellite data link, to air traffic control facilities. The automatic position reports will be displayed to the air traffic controller in nearly real time. This concept will revolutionize ATC in the large oceanic areas that are beyond the range of radar coverage. Currently oceanic air traffic control depends upon hourly reports transmitted via High Frequency (HF) voice radio, which is subject to interference. There is no separate surveillance channel. Oceanic ATC is largely manual and procedural and operates with very little and often delayed information. Because of the uncertainty and infrequency of the position reports, large separations are maintained to assure safety. These large separations effectively restrict available airspace, and cause aircraft to operate on less than optimal routes.

In the ADS system the information generated by an aircraft's onboard navigation system is automatically relayed via a satellite data link to air traffic control facilities. It will be part of an Oceanic ATC System to support flights over the Pacific and Atlantic airspace.

ADS will be a part of an Oceanic ATC System to support transoceanic flights over millions of square miles of Pacific and Atlantic airspace. This Oceanic ATC system will provide an automation infrastructure including oceanic flight data processing, a computer-generated situation display, and a strategic conflict probe for alerting controllers to potential conflicts hours before they would occur. The first phase of the new system, the Oceanic Display and Planning System (ODAPS), became operational in the Oakland Air Route Traffic Control Center (ARTCC) in December 1989 and is scheduled to become operational in the New York ARTCC in 1993. In 1993, real-time position reporting via ADS and a limited set of direct pilot-controller data link messages will be added to the system, and, in 1995, a fully robust satellite data link will be operational.

The new Oceanic ATC System will provide benefits to airspace users in several areas — safety, efficiency, and capacity. The improved position reporting will allow better use of the existing separation standards. Air traffic management can begin the process of reducing those standards, thereby increasing the manageable number of aircraft per route. The strategic conflict probe will allow controllers to evaluate traffic situations hours into the future. Ultimately, controllers will be able to grant more fuel-efficient direct routes. These improvements in efficiency and capacity will have a dramatic impact on fuel costs and delays.

4.3 System Planning, Integration, and Control Technology

The following sections describe technologies that support planning for improvements in the NAS. Both operational improvements and new technologies can be evaluated so that they can be developed and implemented effectively. The National Simulation Laboratory (NSL) will provide the overall framework assuring the integration and interoperability of the elements of the NAS. A large number of models and other technologies will support this integration effort. The National Airspace System Performance Analysis Capability (NASPAC), for example, will help in the identification of demand/capacity imbalances in the NAS, and provide a basis for evaluation of proposed solutions to such imbalances. Computer-graphics tools, such as the Sector Design Analysis Tool and the Terminal Airspace Visualization Tool, will allow airspace designers to quickly and effectively develop alternative airspace sectors and procedures. They will also reduce the time and effort required to implement these alternatives.

Finally, the National Control Facility (NCF) will provide the means to analyze and manage the NAS on an ongoing basis, as well as provide effective training for the requisite personnel.

4.3.1 National Simulation Laboratory

The NSL will be dedicated to assessing the integration and interoperability of elements of the evolving NAS early in the system development process. These assessments will include both pilot and controller human factors considerations. The NSL will be used for interoperability assessments of prototype versions of emerging systems, with an emphasis on the early identification and resolution of cross-system operational and capacity issues. The results of these assessments will be better planning for NAS development and more accurate and achievable system specifications.

The NSL will also provide a means for analyzing and experimenting with alternative concepts for NAS development. It will have the capability to develop prototype alternative NAS configurations at the system design level, so that promising new technologies and concepts can be evaluated and compared at an early stage in their development.

The initial effort has been to establish the Integration and Interaction Laboratory (I-Lab) as a proof-of-concept demonstration. The NSL will begin operation in FY93 by porting I-Lab simulations and prototypes to the more capable processors expected to be available at that time. I-Lab experimentation will continue in parallel.

The NSL will be used to assess the integration and interoperability of elements of the evolving NAS early in the system development process, including both pilot and controller human factors considerations.

The Integration and Interaction Laboratory (I-Lab) has been established, initially, as a proof-of-concept demonstration.

4.3.2 Analysis Tools

A large and growing repertoire of analytical, simulation, and graphical tools and models are being developed and used to help understand and improve the NAS. Some of the more prominent of these are briefly described in the following sections.

4.3.2.1 Computer Simulation Models

The principal objectives of computer simulation models currently in use and under development are to identify current and future problems in the NAS caused by demand/capacity imbalances and to construct and evaluate potential solutions. All of the models rely on a substantial amount of operational data to produce accurate results. The principal models that are being developed and are in use today are described below.

The National Airspace System Performance Analysis Capability (NASPAC) is a simulation of the entire NAS, including detailed modeling of 58 key airports and en route sectors and airspace. It models individual aircraft throughout their daily itineraries, so that it is sensitive to the ripple effects of congestion and delays. It has been used to evaluate significant changes to the airspace system such as new airports, runway closures, and flow control restrictions. A simplified, user-friendly desktop version of the NASPAC that requires only minimal training and preparation will be developed, and the models will be enhanced, as required, for specific FAA applications regarding system performance.

The Airport Network Simulation Model (AIRNET) is a PC-based tool that is designed to assess the impact of changes in airport facilities, operations, and demand. It is a planning tool that can assess the effects of those changes on passenger costs, noise contours, airports, airlines, and aircraft. It addresses macro trends and interactions for use in policy planning and economic analysis.

The Airport and Airspace Simulation Model (SIMMOD) simulates both airports and airspace in a selected geographic area. It aids in the study of en route air traffic, terminal air traffic, and ground operations. It is capable of calculating capacity and delay impacts of a variety of operating alternatives, including runway configurations, airspace routes, sectorization, and separation standards. It is a planning tool for evaluating operational alternatives involving the coordination of airport configurations with airspace configurations. SIMMOD has been used in a number of airspace design studies around major airports. Improvements to SIMMOD include better output displays, automated data-acquisition capability, and a workstation version of the model.

The National Airspace System Performance Analysis Capability (NASPAC), a simulation of the entire NAS, including detailed modeling of 58 key airports and en route sectors and airspace, has been used to evaluate significant changes to the airspace system such as new airports, runway closures, and flow control restrictions

AIRNET is a PC-based tool designed to assess the impact of changes in airport facilities, operations, and demand.

SIMMOD simulates both airports and airspace in a selected geographic area and is capable of calculating capacity and delay impacts of a variety of operating alternatives.

The Aircraft Delay Simulation Model (ADSIM) calculates travel time, delay, and flow rate data to analyze components of an airport, airport operations, and operations in the adjacent airspace. It traces the movement of individual aircraft through gates, taxiways, and runways. The Runway Delay Simulation Model (RDSIM) is a sub-model of ADSIM. RDSIM limits its scope to the final approach, runway, and runway exit.

ADSIM calculates travel time, delay, and flow rate data to analyze components of an airport, airport operations, and operations in the adjacent airspace.

RDSIM is a sub-model of ADSIM that limits its scope to the final approach, runway, and runway exit.

SDAT is an automated tool to be used by airspace designers at the 20 ARTCCs to evaluate proposed changes in the design of airspace sectors, allowing the user to input either the current design or the proposed replacement.

4.3.2.2 Sector Design Analysis Tool (SDAT)

The SDAT is an automated tool to be used by airspace designers at the 20 Air Route Traffic Control Centers (ARTCCs) to evaluate proposed changes in the design of airspace sectors. This computer model will allow the user to input either the current design or the proposed replacement. It will also allow the user to interactively make changes to the design shown graphically on the computer screen.

The model will allow the user to play recorded traffic data against either the actual design or the proposed replacement. It will also allow the user to modify traffic data interactively in order to evaluate alternative designs under postulated future traffic loadings. The model will compute measures of workload for the specified sector or group of sectors. This will allow designers to obtain a better balance in workload between sectors, reducing delays and staffing requirements. The model will also be useful for facility traffic flow managers, for it will display cumulative traffic flows under either historic or anticipated future traffic loadings.

The development of the SDAT has been underway for approximately two years. Procedures for extracting the requisite data from FAA data files and computing the expected demand for separation assurance actions have been developed. A preliminary two-dimensional prototype model has been developed. This model concentrates on only one element of controller workload, the critical element of maintaining safe separation between aircraft.

4.3.2.3 Terminal Airspace Visualization Tool (TVAT)

Terminal airspace differs from en route airspace due to a more varied mix of aircraft and user types, more complicated air traffic rules and procedures, and wider variation in flight paths. A major redesign of terminal airspace currently requires extensive coordination and the effort of a task force lasting many months or even years. The purpose of the TAVT is to provide computer-based assistance to such a task force that will allow the rapid evaluation of many alternatives, e.g., development of new terminal airspace procedures. An effort is currently underway to develop a prototype to model and support the evaluation of terminal airspace.

The purpose of the TAVT is to provide computer-based assistance to airspace planners evaluating the redesign of terminal airspace.

The modeling effort has three goals. First, to display a three-dimensional representation of the airspace on a large computer screen to allow the user/operator to view the airspace from any perspective. The second goal is to provide an easy-to-use interface that permits the user to modify the airspace according to permissible alternatives. The final goal is to develop the capability to quickly evaluate the airspace as displayed to the user in terms of capacity and any other appropriate criteria. A prototype version of the 3-D display is under development at this time on an advanced graphics workstation. The first goal of visualizing a complex terminal airspace has been demonstrated using the proposed Dallas-Fort Worth Metroplex terminal airspace. Development of an interactive, on-screen editing capability is currently underway.

4.3.3 National Control Facility (NCF)

The proposed NCF is intended to provide three major functions to support the goals of the FAA:

The NCF is intended to provide traffic management functions, modeling, and analysis to provide the FAA with tactical recommendations and forecasts, and management development to familiarize users with the capabilities of the air traffic control system.

- The traffic management function, currently the Air Traffic Control System Command Center (ATCSCC), will ensure the viability of, and provide the national direction and airspace management of, the air traffic control system.
- The modeling and analysis function will include the data bases, personnel, and systems required to provide FAA and selected organizations with tactical recommendations and forecasts based on computer simulation and optimization models, as well as studies and analyses of the air traffic system.
- The management development function will provide a structure to familiarize users with the capabilities of the air traffic control system. Specific areas to be addressed in the curriculum include orientation to national airspace management, recurring training in system management techniques for FAA airspace managers, operational review and critique, and demonstration to the airspace system users of potential system problems identified through modeling efforts.

This facility will house the airspace management organization, the National Weather Service Central Flow Weather Service Unit (CFWSU), the National Flight Data Center (NFDC), and the National Maintenance Coordination Complex (NMCC). The systems required to support these organizations will also be housed here.

The traffic management element of the NCF will contain the personnel and systems needed to manage the Nation's air traffic system. A proactive management role using a combination of the data currently available, improved processing, better communications, and additional data is envisioned.

The modeling and analysis element of the NCF will provide the capabilities required to perform in-depth statistical and analytical studies of the airspace system. These studies will enable the examination of solutions to airspace problems and the determination of the maximum utilization of the airspace system on a real-time basis as well as during a long-term planning effort. It will also provide simulations and reconstructions to support the training and refresher activities of the Management Development Facility. The functions required to support this effort include database management, airspace and rules simulations, and system analysis.

To support the modeling element, current capabilities such as NASPAC, AIRNET, and SIMMOD will be enhanced and used to support operational planning as well as the longer-term analysis capabilities they currently provide to support system planning of the NAS. In order to support airspace planners that will use the NCF modeling capabilities, computer-based airspace design tools will be developed. These tools will be designed to address a range of airspace design problems from relatively localized problems affecting a single sector or terminal area to regional or national scale problems.

4.3.4 Traffic Flow Planning

Increasing congestion, delays, and fuel costs require that the FAA take immediate steps to improve airspace use, decrease flight times and controller work loads, and increase fuel efficiency. To achieve these objectives the FAA Traffic Flow Planning program will develop near-term, operational traffic planning models and tools. The program will provide software tools to plan daily air traffic flow, predict traffic problems and probable delay locations, assist in joint FAA-user planning and decision-making, and generate routes and corresponding traffic flow strategies which minimize fuel and time for scheduled air traffic. Benefits include improved aviation safety, airspace use, system throughput, and route flexibility. Working directly with commercial aviation interests and other FAA facilities, the Air Traffic Control System Command Center (ATCSCC) can predict problem areas before they occur and generate alternative reroutings and flow procedures. Overall system capacity will be increased over that of the present fixed route and rigid preferred route systems, and increased fuel efficiency, shorter travel times, and reduced delays will result. Controller workloads will decrease from users' participation in a planned, systematic flow of traffic.

Chapter 5

Marketplace Solutions

Marketplace solutions to airport capacity problems are those that rely primarily on competitive, free-market influences. Some examples, which are discussed below, are the development of new hub airports, the expanded use of existing commercial service airports, the expanded use of reliever airports, and the re-allocation of hourly distribution of demand to reduce demand peaks. Marketplace solutions involve the interests of the airlines, local government and airport authorities, and local communities; both local and national economic factors are involved. This diversity of interests makes predicting and managing these solutions inherently difficult.

5.1 New Hubs at Existing Airports

It is reasonable to assume that as flight delays grow at traditional connecting hub airports, airlines will develop new hubs at existing airports. Hub airports developed since airline deregulation have exhibited the following characteristics:

- Strong origin/destination market,
- Good geographic location,
- Expandable airport facilities,
- Multiple IFR arrival capability,
- Strong economy and availability of balanced work force, and
- Ability to accommodate existing/planned service.

More than two dozen potential new hub airports more than 50 miles from airports with forecast delay problems and with sufficient potential runway capacity to accommodate significantly increased airport operations have been identified. Each has the potential to permit multiple approach streams during IFR conditions. Hence, they meet the first, second, and fourth characteristics. Other airports may meet the third and fourth characteristics through appropriate capital investment. Additional analysis is required to determine which airports have viable economies both from the local and airline perspective, as well as local support for expansion into a hub airport.

More than two dozen potential new hub airports have been identified. Each has the potential to permit multiple approach streams during IFR conditions.

An example of the type of analysis that may be performed to determine the potential conequences of establishing a new hub airport is given for Sacramento Metropolitan airport (SMF). A new connecting hub at Sacramento could produce delay savings by diverting some of the growth that would otherwise occur at San Francisco International (SFO).[1] The following figures illustrate the potential effect on delays at San Francisco in some future period assuming no change in the role Sacramento presently plays in the system. This situation is then compared to a hypothetical one in which Sacramento has become a new connecting hub airport and handles some of the traffic growth that would have connected at San Francisco. Specifically, it assumes that 200 daily operations (100 arrivals and 100 departures) are relocated as a result of establishing a new connecting hub at Sacramento. That number of flights would be "diverted" from the future growth at San Francisco.

FAA forecasts of 1998 demand are used in the analysis. As Figure 5-1 shows, demand at San Francisco is estimated as 673 daily arrivals. This level of activity results in a cumulative level of daily flight delay of 129 hours. If, as a result of Sacramento's potential new hub status, 100 daily arrivals (200 operations) were shifted from future growth at San Francisco to Sacramento, the forecast daily delay at San Francisco would be reduced 90 hours to 39 hours, a 70 percent delay reduction. A diversion of 50 daily arrivals (100 operations) would result in a reduction of 45 hours of forecast daily delay to 84 hours, a 35 percent reduction.

This analysis assumes an hourly arrival capacity of 35 flights per hour at San Francisco under Instrument Meteorological Conditions (IMC). Figure 5-2 shows the relationship between capacity and delay at San Francisco for various arrival capacities. The figure indicates a proportional decrease in benefits if arrival capacity grows (through the use of new approach procedures or new runway layouts). For example, an IMC hourly arrival rate of 40 would result in a daily delay of 15 hours, while an hourly arrival rate of 45 would result in a daily delay of 8 hours. At levels above 45 hourly arrivals, the capacity-delay curve indicates only small improvements in daily delay.

1. *A Case Study of Potential New Connecting Hub Airports, Report to Congress.* The other airports described in that study are Huntsville International Airport, Port Columbus International Airport, and Oklahoma City.

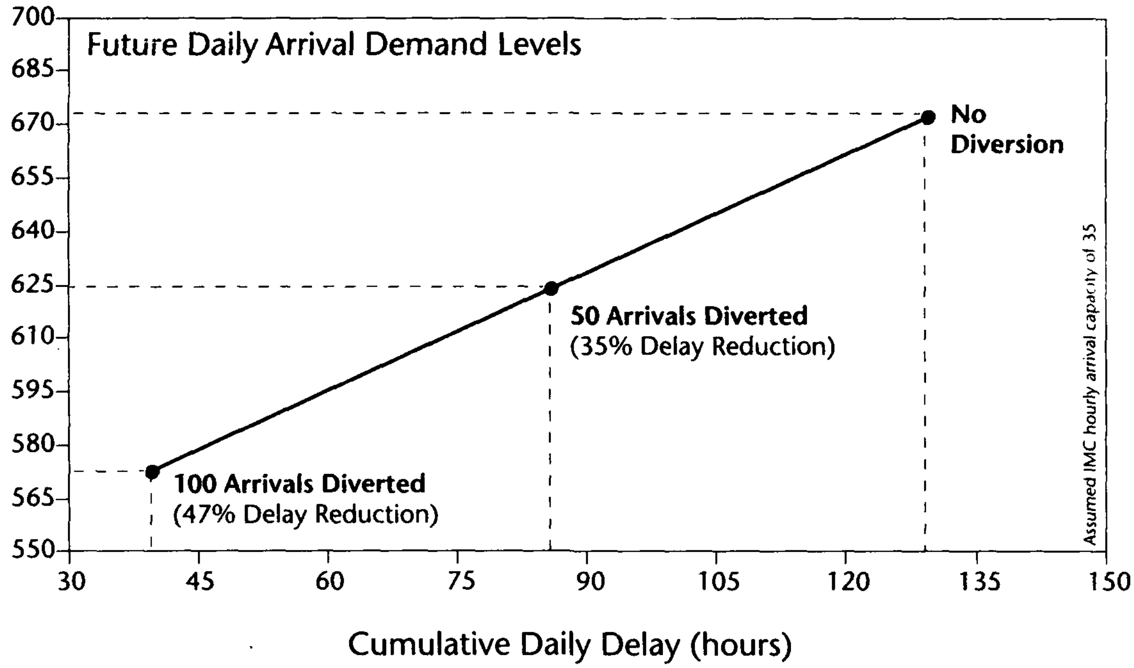


Figure 5-1. Total Delay for Varying Arrival Demand at San Francisco (SFO)

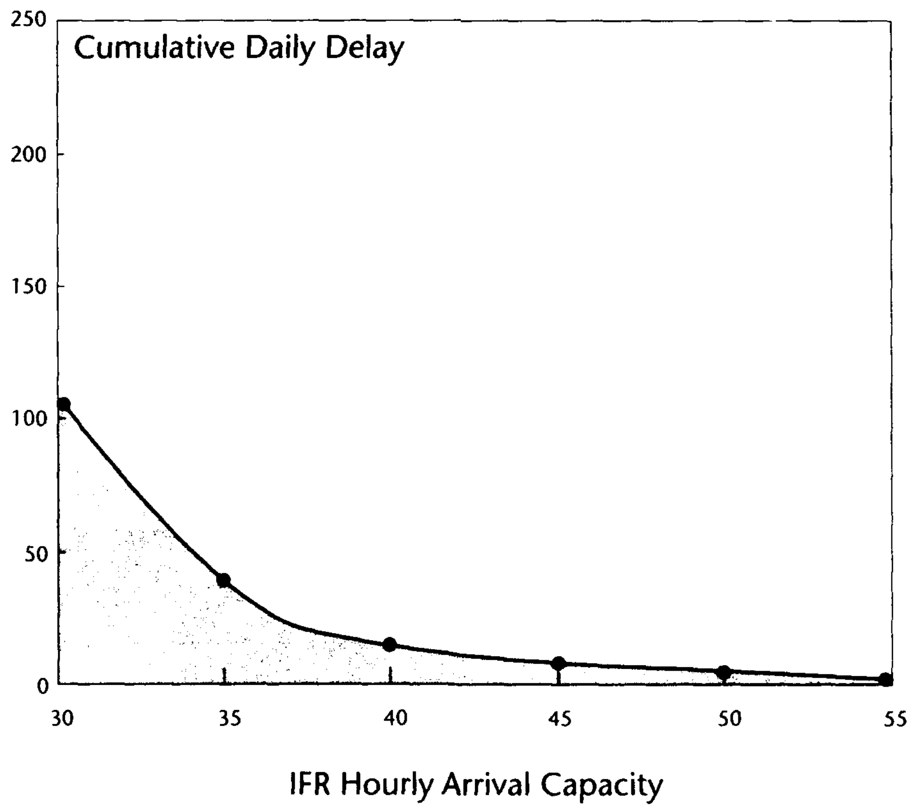


Figure 5-2. Capacity Delay Curve for San Francisco (SFO) Assuming a New Connecting Hub at Sacramento

5.2 New Airports as Hubs

Construction of new airports that would primarily serve as transfer points for passengers flying to and from other airports is being discussed and studied. These new airports could serve to decentralize air service at traditional connecting hub airports and reduce flight delays. Economic, social, and air traffic control factors will help determine if, where, and how fast such "new generation" airports are developed. For example, one factor in siting a new airport might be its impact on existing air traffic patterns. Figure 5-3 shows actual flight tracks for a representative sample of all commercial and general aviation IFR flights within the contiguous United States over a 24-hour period in early 1991. Areas of low traffic density could be investigated further as potential sites for "new generation" airports. Similar studies could be performed for selected regions of interest.

Construction of new airports to primarily serve as transfer points is being studied.

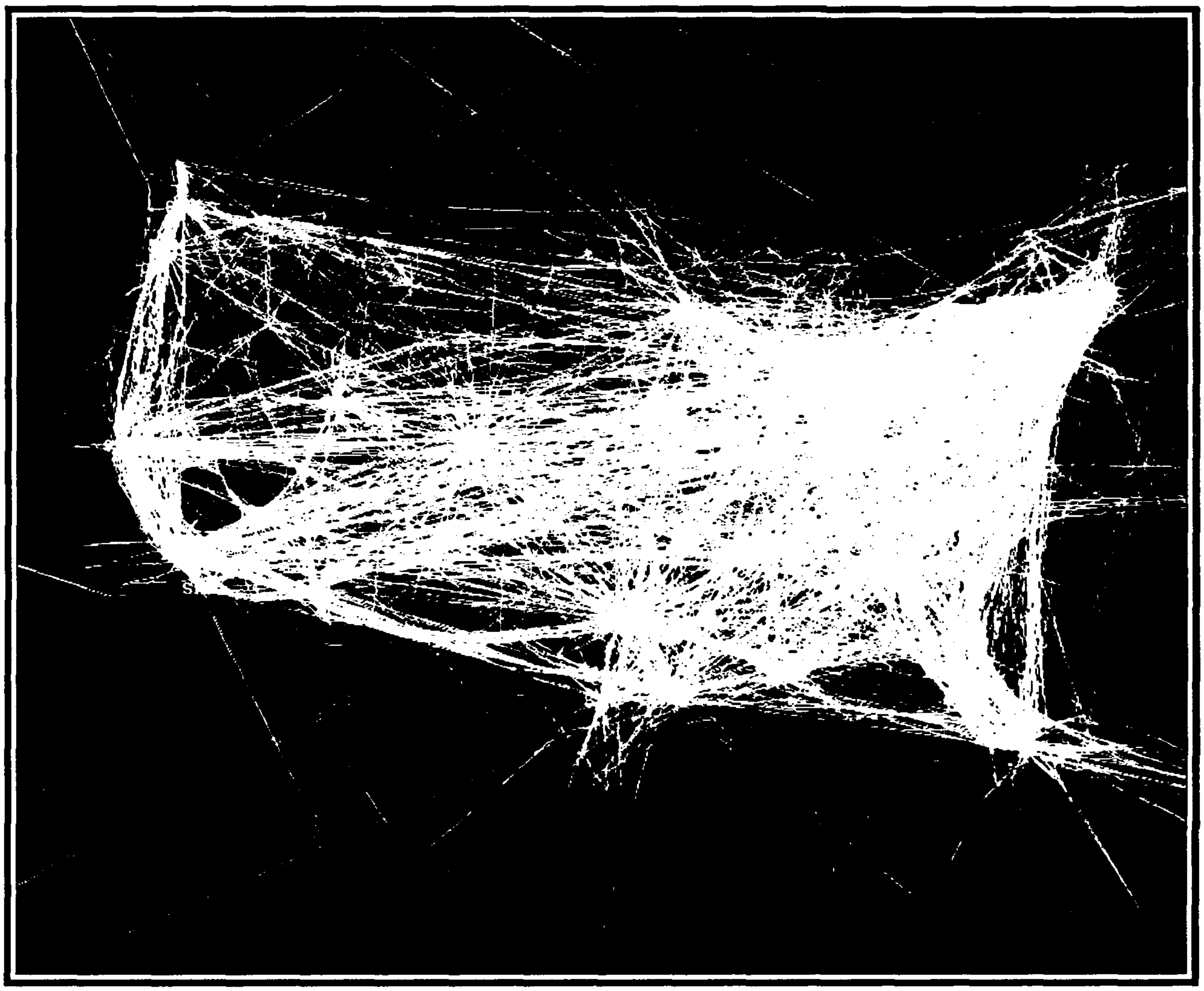


Figure 5-3. Ten Percent of IFR Flight Tracks Within the Contiguous United States Over a 24-Hour Period

5.3 Expanded Use of Existing Commercial Service Airports

Expanded use of existing commercial service airports can ease capacity problems at nearby primary airports by spreading commercial aircraft operations among additional airports near the primary airport.

Existing commercial service airports within 50 miles of current delay-problem airports may provide relief for some of the delay problems.

In contrast to new hubs, the expanded use of existing commercial service airports is primarily intended to relieve congestion in a particular market, not to constitute a market of its own.

For each of the 23 current delay-problem airports, a preliminary list of airports located within 50 miles (or as close as possible) and served by commercial air traffic, was compiled. This is shown in Table 5-1. A number of military airports were added to the list. As congestion becomes greater at the delay-problem airports, passengers may choose to travel to the alternative airports. This traffic diversion would tend to decrease delays at the delay-problem airport.

5.4 Expanded Use of Reliever Airports

Reliever airports ease capacity problems at primary airports by spreading aircraft operations over additional airports near the primary airports. In contrast to the expanded use of commercial service airports, reliever airports are used mainly by smaller general aviation aircraft, while the primary and other commercial use airports serve mostly larger, commercial service aircraft. The segregation of aircraft operations by size increases effective capacity at each airport type because required time and distance separations are reduced between planes of similar size.

Increased use of reliever airports by smaller general aviation aircraft would relieve some of the congestion at the larger, primary airports.

The FAA provides assistance for construction and improvements at reliever airports under the Airport Improvement Program. The objective of this assistance is to increase utilization of reliever airports by building new relievers, improving the facilities and navigational aids at existing relievers, and reducing the environmental impact on neighboring communities. Because they serve primarily general aviation aircraft, reliever airports can be effective with significantly less extensive facilities than commercial service airports.

Reliever airports can be expected to play significant roles in reducing congestion and delay at delay-problem airports, especially those where general aviation constitutes a significant portion of operations.

Of the 40 airports forecasted to exceed 20,000 hours of annual aircraft delay in 2000 without further improvements, about one third have 25 percent or more general aviation operations.

Table 5-1. A Preliminary List of Airports Located Within 50 Miles of the 23 Delay-Problem Airports

Delay-problem Airport[2]	Airport Code	Supplemental Airport
Chicago O'Hare	ORD	Aurora
		Rockford
		Wheeling
		Gary, IN
		Glenview NAS
Atlanta Hartsfield	ATL	Athens
		Macon
		Columbus (100 mi)
		Chattanooga, TN
Dallas-Ft. Worth	DFW	Brownwood (120 mi)
		Killeen (100 mi)
		Longview (100 mi)
		Paris (80 mi)
		Temple (100 mi)
		Waco (80 mi)
		Wichita Falls (100 mi)
Los Angeles	LAX	Burbank
		Irvine
		Long Beach
		Ontario
		Oxnard
		Palmdale
		San Pedro
		Los Angeles NAS
Newark	EWR	Trenton
		White Plains, NY
San Francisco	SFO	Concord
		Hayward
		Oakland
		San Jose
		Santa Rosa
		Moffett Field NAS
		Alameda NAS
		Hamilton AFB
New York	JFK	Farmingdale
		Garden City
		Islip
		Long Island
		White Plains
Boston	BOS	Bedford
		Burlington
		Lawrence
		New Bedford
		Norwood
		Plymouth
		Waltham
		Worcester
		Hanscom AFB
St. Louis	STL	—
Phoenix	PHX	Prescott (80 mi)
Miami	MIA	Ft. Lauderdale
Philadelphia	PHL	Allentown
		Lancaster (70 mi)
		Reading (60 mi)
		Willow Grove NAS
		Trenton, NJ
		Wilmington, DE
Washington	DCA	Baltimore, MD
		Hagerstown, MD (60 mi)
		Charlottesville, VA (100 mi)
		Richmond, VA (100 mi)
		Andrews AFB
Pittsburgh	PIT	Johnstown
		Latrobe
		Morgantown, WV (60 mi)
Detroit	DTW	Flint
		Pontiac
		Lansing (80 mi)
		Toledo, OH (60 mi)
		Selfridge ANG
Orlando	MCO	Daytona Beach
		Ft. Pierce (100 mi)
		Melbourne (60 mi)
		Tampa (70 mi)
		Vero Beach (90 mi)
Minneapolis	MSP	Mankato (70 mi)
		Eau Claire, WI (70 mi)
Charlotte	CLT	Hickory
		Greensboro (90 mi)
		Winston-Salem (60 mi)
Washington	IAD	Baltimore, MD
		Hagerstown, MD (60 mi)
		Charlottesville, VA (100 mi)
		Richmond, VA (100 mi)
		Andrews AFB
Denver	DEN	Colorado Springs (80 mi)
Honolulu	HNL	Kailua
Houston	IAH	Beaumont (60 mi)
		Lufkin (100 mi)
Seattle	SEA	—

2. Airports having greater than 20,000 hours of delay for 1990 as reported by FAA Office of Policy and Plans.

Chapter 6

Summary

The Aviation System Capacity Plan is intended to be a comprehensive "ground-up" view of aviation system requirements and development, starting at the airport level and extending to terminal airspace, en route airspace, and airspace and traffic flow management. The first step in this problem-solving exercise is problem definition. This plan defines the aviation capacity problem in terms of flight delays, rather than dealing with the more abstract "capacity" definition. While it is relatively simple to compute an airport's hourly throughput capacity (the number of flight operations which can be handled in IFR or VFR for a given runway operating configuration), that throughput can change each hour as weather, aircraft mix, and runway configurations change. Annualizing airport capacity is thus a difficult task.

In 1990, 23 of the top 100 airports each exceeded 20,000 hours of airline flight delays. If no improvements in capacity are made, the number of airports which could exceed 20,000 hours of annual aircraft delay in the year 2000 is projected to grow from 23 to 40.

While it is common for demand to exceed hourly capacity at some airports, there are ways of accommodating that demand. For example, air traffic management can regulate departures and slow down en route traffic, so flights are shifted into times of less congestion. This is only a temporary solution because as traffic increases at a given airport, there will be fewer off-peak hours into which flights might be shifted.

There are several techniques that are under investigation to manage the demand at delay-problem airports. One is to encourage small aircraft to use "reliever" airports. There could be significant flight-delay reduction if a percentage of small aircraft operations could be shifted to reliever airports; however, some of the forecasted delay-problem airports have a low percentage of small aircraft operations. Those airports are largely "relieved," and further diversion of operations to reliever airports would be of marginal significance in flight delay reduction.

Having first identified forecasted delay-problem airports, this plan next attempts to document planned or technologically feasible capacity development at those airports. The FAA is co-sponsoring airport capacity design teams (formerly task forces) at major airports to assess how airport development and new technology could "optimize" capacity on a site-specific basis. Airport capacity design team studies were completed at Atlanta, Charlotte, Chicago, Detroit, Kansas City, Los Angeles, Memphis, Miami, Nashville, Oakland, Philadelphia, Phoenix, Pittsburgh, Raleigh-Durham, St. Louis, Salt Lake City, San Francisco, San Jose, San Juan, Seattle-Tacoma, and Washington Dulles.

Moving from the "ground up," this plan identifies new terminal airspace procedures which will increase capacity for existing or new runway configurations. Of the top 100 airports, 30 could benefit from improved independent parallel IFR approaches, 18 could benefit from dependent parallel IFR approaches, 53 could benefit from dependent converging IFR approaches using the Converging Runway Display Aid (CRDA), 32 could benefit from independent converging IFR approaches (TERPS+3), and 14 could benefit from triple IFR approaches. Demonstration programs are underway for these new approach procedures.

Some of the new approach procedures and airport capacity projects require new technology and new systems and equipment. More than three dozen programs are currently under way in FAA's R,E&D and F&E programs to provide that new technology. This plan outlines the progress of those programs.

Many of the technology programs are designed to reduce the capacity differential between IFR and VFR operations. Delays attributable to weather (resulting in large part from the difference in VFR and IFR separation standards) accounted for 70% of all flights delayed 15 minutes or more in 1988. With the use of new technology, that proportion has decreased to 53 percent in 1990. Significant gains in capacity may be achieved with the use of new electronic guidance and control equipment if two or three flight arrival streams can be maintained in IFR, rather than being reduced to one or two arrival streams. These programs are the Precision Runway Monitor (PRM), Converging Runway Display Aid (CRDA), Triple and Quadruple Instrument Approaches, and Microwave Landing System (MLS).

Some of the technology programs are designed to provide more information to air traffic controllers, such as the Center-TRACON Automation System (CTAS), or to pilots, such as the Traffic Alert Collision and Avoidance System (TCAS), with improved visual displays and non-voice communications. Those programs may not show as large an increase in capacity as those programs providing multiple flight arrival and departure streams, but they are significant nonetheless.

Some of the technology programs are designed to improve the efficiency of aircraft movement on the airport urface. The Airport Surface Traffic Automation (ASTA) program, for example, will expedite surface movement while reducing the number of runway incursions.

Some of the technology programs are computer simulation tools to help in airfield and airspace analysis. SIMMOD (Simulation Model), NASPAC (National Airspace Performance Analysis Capability), SDAT (Sector Design Analysis Tool), and TAVT (Terminal Airspace Visualization Tool) will help in the evaluation of various alternatives.

Lastly, some technology programs are designed to "optimize" the aviation system through better planning and improved prediction capability. These include the National Simulation Laboratory (NSL), the National Control Facility (NCF), and Dynamic Special-Use Airspace Management.

The "ground up" view encompasses en route airspace. The plan outlines programs designed to increase en route airspace capacity, including Automated En Route Air Traffic Control (AERA), Advanced Traffic Management System (ATMS), Automatic Dependent Surveillance (ADS), Oceanic Display and Planning System (ODAPS), and Dynamic Ocean Tracking System (DOTS).

Airspace capacity design team projects have been established to analyze and optimize terminal airspace procedures. Projects have been accomplished in Los Angeles, Dallas-Ft. Worth, Chicago, Kansas City, Houston/Austin, and Oakland. Washington, Cleveland, New York, and Jacksonville projects are still in progress. Results or progress reports are included in this plan.

From a "ground up" view, after optimizing existing airport capacity, terminal airspace procedures, and en route airspace capacity using new technology, the next level is adding "reliever" airports and "supplemental" airports for additional aviation system capacity. "Supplemental" airports are existing commercial service airports that could act as reliever airports for delay-problem airports.

Though "supplemental" airports will be helpful, the largest capacity gains come from new airports and new or extended runways at existing airports. One such project is the construction of a new international airport at Denver. Construction began in late 1989. The initial phase will consist of four 12,000-ft runways and a commuter runway and is scheduled to open in the fall of 1993. New parallel runways were put into service at Cincinnati, Indianapolis, and Little Rock prior to mid-1991. A runway extension at Baltimore became operational in 1990 and a runway at Cleveland was reconstructed. Of the top 100 airports, 62 have proposed new runways or extensions to existing runways. Of the 23 delay-problem airports in 1990, 18 are in the process of constructing or planning the construction of new runways or extensions to existing runways. Of the 40 delay-problem airports forecast for the year 2000, 29 propose to build new runways or runway extensions. The total anticipated cost of completing these new runways and runway extensions exceeds $6.5 billion.

The FAA is also pursuing an initiative for the implementation of joint-use military airfields and/or adaptation of former military facilities to civilian use for capacity enhancement to the overall aviation system. The joint-use facilities at Dillingham Army Airfield, Hawaii, and Rickenbacker Air National Guard Base, Columbus, Ohio, have provided congestion relief to the airports at Honolulu and Port Columbus, respectively. Currently, Stewart Air Force Base near Newburgh, New York, and Ellington Air Force Base at Houston, Texas, have been designated for conversion to civilian-use facilities.

System capacity must continue to grow in order to maintain the same level of air service quality. The majority of cities with air service prior to de-regulation in 1978 received more frequent service in 1990. Many smaller cities have benefited from the emphasis on hub-and-spoke airline service in the last decade, receiving more service to connecting hub airports from more than one airline. In the dozen years since airline deregulation, real air fares have declined. System capacity must continue to grow to allow for airline competition if that trend is to continue.

In conclusion, both the quality and cost of air service are strongly tied to aviation system capacity, and will continue to show favorable trends only if aviation system capacity grows.

Appendix A

Activity Statistics at the Top 100 Airports

Table A-1. Airport Operations and Enplanements A-2

Table A-2. Airport Enplanements, 1989 and Forecast 2000 .... A-5

Table A-3. Total Airport Operations, 1989 and Forecast 2000 .... A-8

Table A-4. Growth in Enplanements From 1988 to 1989 .... A-11

Table A-5. Growth in Operations From 1989 to 1990 .... A-14

Table A-6. Growth in Operations and Enplanements A-17

Table A-1. Airport Operations and Enplanements[1]

City-Airport	Airport ID	Rank	Enplanements (000s) CY88	CY89	Operations (000s) FY89	FY90
Chicago O'Hare Int'l	ORD	1	26,597	25,664	789	811
Dallas-Fort Worth Int'l	DFW	2	21,014	22,623	694	725
Atlanta Hartsfield Int'l	ATL	3	21,824	20,398	670	779
Los Angeles Int'l	LAX	4	18,643	18,583	632	669
San Francisco Int'l	SFO	5	13,348	13,326	434	437
Denver Stapleton Int'l	DEN	6	14,442	12,320	468	475
New York LaGuardia	LGA	7	11,322	10,840	356	365
Phoenix Sky Harbor Int'l	PHX	8	9,455	10,166	480	497
New York Kennedy Int'l	JFK	9	10,660	10,081	337	342
Newark Int'l	EWR	10	10,838	9,822	377	384
Detroit Metro Wayne County	DTW	11	9,214	9,739	369	391
Boston Logan Int'l	BOS	12	10,141	9,661	417	448
St. Louis Lambert Int'l	STL	13	9,554	9,396	425	443
Honolulu Int'l	HNL	14	8,396	8,944	406	407
Miami Int'l	MIA	15	9,462	8,592	378	463
Minneapolis-St. Paul	MSP	16	8,171	8,460	376	382
Pittsburgh Int'l	PIT	17	8,379	7,941	379	385
Orlando Int'l	MCO	18	7,473	7,373	286	278
Seattle-Tacoma	SEA	19	6,826	7,060	328	426
Houston Intercontinental	IAH	20	6,872	7,030	294	310
Las Vegas McCarran	LAS	21	6,865	7,027	378	395
Charlotte Douglas Int'l	CLT	22	6,620	6,903	424	452
Washington National	DCA	23	7,259	6,896	316	320
Philadelphia Int'l	PHL	24	6,634	6,247	383	405
San Diego Lindbergh	SAN	25	5,181	5,317	207	212
Salt Lake City Int'l	SLC	26	4,730	5,244	293	302
Washington Dulles Int'l	IAD	27	4,327	4,544	235	240
Baltimore-Washington Int'l	BWI	28	4,370	4,446	307	304
Tampa Int'l	TPA	29	4,495	4,409	217	227
Kansas City Int'l	MCI	30	4,470	4,357	239	162
Raleigh-Durham Int'l	RDU	31	3,518	4,117	273	283
Memphis Int'l	MEM	32	4,533	3,990	334	330
Houston Hobby	HOU	33	3,840	3,927	257	267
Cincinnati Int'l	CVG	34	3,543	3,771	265	285
Nashville Metro	BNA	35	3,244	3,746	276	259

1. At the top 100 airports, ranked by 1989 enplanements

Table A-1. Airport Operations and Enplanements (continued)[2]

City-Airport	Airport ID	Rank	Enplanements (000s) CY88	CY89	Operations (000s) FY89	FY90
Cleveland Hopkins Int'l	CLE	36	3,547	3,722	257	273
Fort Lauderdale Int'l	FLL	37	3,899	3,646	217	224
Chicago Midway	MDW	38	3,174	3,410	316	322
San Juan Luis Muñoz Marín Int'l	SJU	39	3,264	3,269	194	205
New Orleans Int'l	MSY	40	3,200	3,171	139	152
San Jose Int'l	SJC	41	2,774	3,094	318	320
Portland (OR) Int'l	PDX	42	2,823	3,055	268	272
Dallas Love	DAL	43	2,475	2,774	214	214
Ontario Int'l	ONT	44	2,354	2,609	143	151
Indianapolis Int'l	IND	45	2,406	2,523	203	225
San Antonio Int'l	SAT	46	2,392	2,493	204	219
West Palm Beach Int'l	PBI	47	2,361	2,404	234	239
Albuquerque Int'l	ABQ	48	2,113	2,337	231	226
Windsor Locks Bradley Int'l	BDL	49	2,322	2,270	174	182
Santa Ana John Wayne	SNA	50	2,156	2,174	534	523
Kahului	OGG	51	2,026	2,133	182	179
Dayton Int'l	DAY	52	2,140	2,083	205	197
Oakland Metro Int'l	OAK	53	1,826	2,031	403	389
Austin Robert Mueller	AUS	54	1,922	2,022	185	193
Milwaukee Mitchell Int'l	MKE	55	1,779	1,872	197	209
Sacramento Metro	SMF	56	1,792	1,800	177	177
El Paso Int'l	ELP	57	1,427	1,672	188	179
Columbus Int'l	CMH	58	1,759	1,662	233	224
Buffalo Int'l	BUF	59	1,780	1,629	136	140
Oklahoma City Will Rogers World	OKC	60	1,493	1,540	137	145
Fort Myers SW Florida Regional	RSW	61	1,460	1,526	57	113
Tulsa Int'l	TUL	62	1,362	1,441	187	195
Reno Cannon Int'l	RNO	63	1,452	1,360	163	164
Lihue	LIH	64	1,264	1,341	111	114
Burbank	BUR	65	1,458	1,320	246	235
Tucson Int'l	TUS	66	1,407	1,311	222	229
Norfolk Int'l	ORF	67	1,492	1,298	158	161
Syracuse Hancock Int'l	SYR	68	1,474	1,272	180	183
Jacksonville Int'l	JAX	69	1,288	1,249	153	148
Anchorage	ANC	70	1,052	1,159	212	252

2.At the top 100 airports, ranked by 1989 enplanements

Table A-1. Airport Operations and Enplanements (concluded)[3]

City-Airport	Airport ID	Rank	Enplanements (000s)		Operations (000s)	
			CY88	CY89	FY89	FY90
Rochester Monroe County	ROC	71	1,242	1,149	205	184
Omaha Eppley	OMA	72	1,052	1,007	158	153
Birmingham Municipal	BHM	73	983	989	187	199
Kailua-Kona Keahole	KOA	74	837	982	57	59
Providence Green State	PVD	75	945	952	200	180
Little Rock Adams	LIT	76	880	947	148	149
Louisville Standiford	SDF	77	1,014	910	151	160
Greensboro Regional	GSO	78	994	894	143	151
Albany	ALB	79	817	838	165	184
Richmond Int'l	RIC	80	851	827	154	160
Sarasota-Bradenton	SRQ	81	843	794	164	168
Spokane Int'l	GEG	82	744	727	119	121
Des Moines	DSM	83	708	669	160	146
Long Beach	LGB	84	579	662	462	483
Grand Rapids Kent County Int'l	GRR	85	597	649	151	169
Lubbock Int'l	LBB	86	583	628	120	133
Guam Agana Field	NGM	87	487	624	59	n/a
Hilo General Lyman	ITO	88	553	611	93	100
Colorado Springs Municipal	COS	89	641	600	168	177
Charleston (SC) AFB Int'l	CHS	90	662	597	130	132
Midland Int'l	MAF	91	602	597	103	97
Wichita Mid-Continent	ICT	92	602	593	167	175
Harlingen Rio Grande Int'l	HRL	93	510	535	63	60
Boise	BOI	94	526	534	160	168
Savannah Int'l	SAV	95	531	499	107	109
Greer Greenville-Spartanburg	GSP	96	507	493	67	69
Columbia (SC) Metro	CAE	97	531	487	116	113
Knoxville McGhee-Tyson	TYS	98	532	482	162	167
Harrisburg	MDT	99	421	444	59	64
Amarillo/Borger	AMA	100	433	442	85	86
Total			**410,652**	**408,794**	**24,960**	**25,749**

Sources:
Enplanement data: *Airport Activity Statistics of Certificated Route Air Carriers*, 1988 and 1989 data.
Operations data: *FAA Air Traffic Activity*, FY89 and FY90 data.

3. At the top 100 airports, ranked by 1989 enplanements

Table A-2. Airport Enplanements, 1989 and Forecast 2000 [4]

City-Airport	Airport ID	Rank	Enplanements (000s) FY89	FY2000	% Growth
Chicago O'Hare Int'l	ORD	1	28,386	41,722	47.0
Dallas-Fort Worth Int'l	DFW	2	23,820	36,434	53.0
Los Angeles Int'l	LAX	3	22,752	30,347	33.4
Atlanta Hartsfield Int'l	ATL	4	21,652	33,164	53.2
New York Kennedy Int'l	JFK	5	14,874	20,396	37.1
San Francisco Int'l	SFO	6	14,782	23,905	61.7
Denver Stapleton Int'l*	DEN	7	13,732	—	—
New Denver Int'l	DVX	—	—	21,990	60.1
Miami Int'l	MIA	8	11,454	18,525	61.7
New York LaGuardia	LGA	9	11,195	13,887	24.0
Boston Logan Int'l	BOS	10	11,088	16,459	48.4
Newark Int'l	EWR	11	10,455	17,934	71.5
Phoenix Sky Harbor Int'l	PHX	12	10,269	19,098	86.0
Detroit Metro Wayne County	DTW	13	10,212	16,409	60.7
Honolulu Int'l	HNL	14	10,202	14,758	44.7
St. Louis Lambert Int'l	STL	15	9,941	16,135	62.3
Minneapolis-St. Paul	MSP	16	9,149	14,442	57.9
Pittsburgh Int'l	PIT	17	8,581	14,815	72.6
Orlando Int'l	MCO	18	8,391	13,704	63.3
Las Vegas McCarran	LAS	19	7,799	16,066	106.0
Seattle-Tacoma	SEA	20	7,580	12,700	67.5
Charlotte Douglas Int'l	CLT	21	7,546	11,239	48.9
Houston Intercontinental	IAH	22	7,496	13,163	75.6
Washington National	DCA	23	7,269	7,799	7.3
Philadelphia Int'l	PHL	24	7,241	13,097	80.9
Salt Lake City Int'l	SLC	25	5,517	8,791	59.3
San Diego Lindbergh	SAN	26	5,467	9,494	73.7
Baltimore-Washington Int'l	BWI	27	5,098	8,044	57.8
Washington Dulles Int'l	IAD	28	4,879	10,350	112.1
Kansas City Int'l	MCI	29	4,598	7,813	70.0
Tampa Int'l	TPA	30	4,586	9,241	101.5
Cincinnati Int'l	CVG	31	4,431	9,396	112.0
Raleigh-Durham Int'l	RDU	32	4,315	8,786	104.0
Fort Lauderdale Int'l	FLL	33	4,309	8,016	86.0
Memphis Int'l	MEM	34	4,270	7,006	64.1
Cleveland Hopkins Int'l	CLE	35	3,993	5,556	39.1

4. At the top 100 airports, ranked by 1989 enplanements

* DEN projected to close by 2000.

Table A-2. Airport Enplanements, 1989 and Forecast 2000 (continued) [5]

City-Airport	Airport ID	Rank	Enplanements (000s) FY89	FY2000	% Growth
San Juan Luis Muñoz Marín Int'l	SJU	36	3,991	7,536	88.8
Nashville Metro	BNA	37	3,965	6,389	61.1
Houston Hobby	HOU	38	3,931	6,929	76.3
Chicago Midway	MDW	39	3,562	5,898	65.6
New Orleans Int'l	MSY	40	3,240	6,000	85.2
San Jose Int'l	SJC	41	3,217	6,566	104.1
Portland (OR) Int'l	PDX	42	3,200	5,361	67.5
Dallas Love	DAL	43	2,781	5,688	104.5
Indianapolis Int'l	IND	44	2,671	3,959	48.2
Ontario Int'l	ONT	45	2,623	8,097	208.7
San Antonio Int'l	SAT	46	2,593	4,037	58.0
West Palm Beach Int'l	PBI	47	2,526	4,382	73.5
Albuquerque Int'l	ABQ	48	2,448	4,107	67.8
Windsor Locks Bradley Int'l	BDL	49	2,422	4,199	73.4
Dayton Int'l	DAY	50	2,304	3,300	43.2
Santa Ana John Wayne	SNA	51	2,232	3,805	70.5
Kahului	OGG	52	2,183	3,575	63.8
Milwaukee Mitchell Int'l	MKE	53	2,097	3,947	88.2
Oakland Metro Int'l	OAK	54	2,094	4,649	122.0
Austin Robert Mueller	AUS	55	2,033	4,720	132.2
Sacramento Metro	SMF	56	1,853	3,474	87.5
Columbus Int'l	CMH	57	1,773	3,102	75.0
Buffalo Int'l	BUF	58	1,696	2,621	54.5
El Paso Int'l	ELP	59	1,677	2,607	55.5
Anchorage	ANC	60	1,588	2,456	54.7
Oklahoma City Will Rogers World	OKC	61	1,561	2,707	73.4
Fort Myers SW Florida Regional	RSW	62	1,548	4,005	158.7
Tulsa Int'l	TUL	63	1,445	2,321	60.6
Reno Cannon Int'l	RNO	64	1,435	2,251	56.9
Norfolk Int'l	ORF	65	1,394	2,218	59.1
Syracuse Hancock Int'l	SYR	66	1,380	2,456	78.0
Lihue	LIH	67	1,350	2,028	50.2
Burbank	BUR	68	1,343	2,596	93.3
Tucson Int'l	TUS	69	1,338	2,523	88.6
Jacksonville Int'l	JAX	70	1,314	2,480	88.7

5. At the top 100 airports, ranked by 1989 enplanements

Table A-2. Airport Enplanements, 1989 and Forecast 2000 (concluded) [6]

City-Airport	Airport ID	Rank	Enplanements (000s) FY89	FY2000	% Growth
Rochester Monroe County	ROC	71	1,234	2,140	73.4
Providence Green State	PVD	72	1,107	1,619	46.3
Albany	ALB	73	1,078	1,727	60.2
Omaha Eppley	OMA	74	1,052	1,435	36.4
Birmingham Municipal	BHM	75	1,002	1,557	55.4
Kailua-Kona Keahole	KOA	76	991	1,849	86.6
Louisville Standiford	SDF	77	983	1,619	65.0
Little Rock Adams	LIT	78	961	1,474	53.3
Richmond Int'l	RIC	79	917	1,653	80.2
Greensboro Regional	GSO	80	911	1,747	92.0
Guam Agana Field	NGM	81	906	1,395	54.0
Sarasota-Bradenton	SRQ	82	816	1,261	55.0
Spokane Int'l	GEG	83	774	1,685	100.2
Des Moines	DSM	84	716	1,080	51.0
Grand Rapids Kent County Int'l	GRR	85	690	1,037	50.2
Long Beach	LGB	86	665	1,576	100.4
Charleston (SC) AFB Int'l	CHS	87	640	1,123	75.4
Lubbock Int'l	LBB	88	629	845	34.3
Colorado Springs Municipal	COS	89	623	955	53.2
Wichita Mid-Continent	ICT	90	620	1,031	66.2
Hilo General Lyman	ITO	91	613	961	57.0
Harrisburg	MDT	92	609	1,101	80.8
Midland Int'l	MAF	93	597	829	39.0
Boise	BOI	94	572	1,054	84.2
Knoxville McGhee-Tyson	TYS	95	562	878	56.2
Greer Greenville-Spartanburg	GSP	96	560	837	49.4
Harlingen Rio Grande Int'l	HRL	97	538	1,019	89.4
Columbia (SC) Metro	CAE	98	528	966	83.0
Savannah Int'l	SAV	99	510	790	55.0
Amarillo/Borger	AMA	100	458	782	70.7
Total			**448,999**	**731,695**	

Sources:
Enplanement data: *FAA Airport Activity Statistics*
Forecast: *APO Terminal Area Forecasts*

6. At the top 100 airports, ranked by 1989 enplanements

Table A-3. Total Airport Operations, 1990 and Forecast 2000 [7]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY2000	% Growth
Chicago O'Hare Int'l	ORD	1	811	827	2.0
Atlanta Hartsfield Int'l	ATL	2	779	931	19.5
Dallas-Fort Worth Int'l	DFW	3	725	1068	47.3
Los Angeles Int'l	LAX	4	669	800	19.6
Santa Ana John Wayne	SNA	5	523	674	28.9
Phoenix Sky Harbor Int'l	PHX	6	497	602	21.1
Long Beach	LGB	7	483	517	7.0
Denver Stapleton Int'l	DEN	8	475	586	23.4
Miami Int'l	MIA	9	463	586	26.6
Charlotte Douglas Int'l	CLT	10	452	531	17.5
Boston Logan Int'l	BOS	11	448	505	12.7
St. Louis Lambert Int'l	STL	12	443	508	14.7
San Francisco Int'l	SFO	13	437	624	42.8
Honolulu Int'l	HNL	14	407	515	26.5
Philadelphia Int'l	PHL	15	405	542	33.8
Las Vegas McCarran	LAS	16	395	548	38.7
Detroit Metro Wayne County	DTW	17	391	514	31.5
Oakland Metro Int'l	OAK	18	389	544	39.8
Pittsburgh Int'l	PIT	19	385	510	32.5
Newark Int'l	EWR	20	384	439	14.3
Minneapolis-St. Paul	MSP	21	382	510	36.5
New York LaGuardia	LGA	22	365	381	4.4
Seattle-Tacoma Int'l	SEA	23	354	427	20.6
New York Kennedy Int'l	JFK	24	342	380	11.1
Memphis Int'l	MEM	25	330	458	38.8
Chicago Midway	MDW	26	322	383	18.9
Washington National	DCA	27	320	374	16.9
San Jose Int'l	SJC	28	320	493	54.1
Houston Intercontinental	IAH	29	310	411	32.6
Baltimore-Washington Int'l	BWI	30	304	406	33.6
Salt Lake City Int'l	SLC	31	302	383	26.8
Cincinnati Int'l	CVG	32	285	464	62.8
Raleigh-Durham Int'l	RDU	33	283	407	43.8
Orlando Int'l	MCO	34	278	481	73.0
Cleveland Hopkins Int'l	CLE	35	273	301	13.6

7. At the top 100 airports, ranked by 1990 total operations

Table A-3. Total Airport Operations, 1990 and Forecast 2000 (continued) [8]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY2000	% Growth
Portland (OR) Int'l	PDX	36	272	338	24.3
Houston Hobby	HOU	37	267	343	28.5
Nashville Metro	BNA	38	259	349	34.7
Washington Dulles Int'l	IAD	39	240	451	87.9
West Palm Beach Int'l	PBI	40	239	243	0.2
Burbank	BUR	41	235	306	30.2
Tucson Int'l	TUS	42	229	440	92.1
Tampa Int'l	TPA	43	227	320	41.0
Albuquerque Int'l	ABQ	44	226	405	79.2
Indianapolis Int'l	IND	45	225	316	40.4
Columbus Int'l	CMH	46	224	274	22.3
Fort Lauderdale Int'l	FLL	47	224	344	53.6
San Antonio Int'l	SAT	48	219	332	51.6
Anchorage	ANC	49	219	271	23.7
Dallas Love	DAL	50	214	349	63.1
San Diego Lindbergh	SAN	51	212	304	43.4
Milwaukee Mitchell Int'l	MKE	52	209	243	16.3
Islip Long Island MacArthur	ISP	53	209	289	38.3
San Juan Luis Muñoz Marín Int'l	SJU	54	205	267	30.2
Birmingham Municipal	BHM	55	199	258	29.6
Dayton Int'l	DAY	56	197	284	44.1
Tulsa Int'l	TUL	57	195	271	39.0
Austin Robert Mueller	AUS	58	193	345	78.8
Rochester Monroe County	ROC	59	184	277	50.5
Albany	ALB	60	184	237	28.8
Syracuse Hancock Int'l	SYR	61	183	246	34.4
Windsor Locks Bradley Int'l	BDL	62	182	321	76.4
Providence Green State	PVD	63	180	216	2.0
El Paso Int'l	ELP	64	179	290	62.0
Kahului	OGG	65	179	267	49.2
Colorado Springs Municipal	COS	66	177	213	20.3
Wichita Mid-Continent	ICT	67	175	291	66.3
Grand Rapids Kent County Int'l	GRR	68	169	195	15.4
Boise	BOI	69	168	366	117.8
Sarasota-Bradenton	SRQ	70	168	208	23.8

8. At the top 100 airports, ranked by 1990 total operations

Table A-3. Total Airport Operations, 1990 and Forecast 2000 (concluded) [9]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY2000	% Growth
Knoxville McGhee-Tyson	TYS	71	167	200	23.4
Reno Cannon Int'l	RNO	72	164	304	85.4
Kansas City Int'l	MCI	73	162	340	109.9
Sacramento Metro	SMF	74	162	279	72.2
Norfolk Int'l	ORF	75	161	230	42.9
Richmond Int'l	RIC	76	160	205	28.1
Louisville Standiford	SDF	77	160	208	12.5
Omaha Eppley	OMA	78	153	187	22.2
New Orleans Int'l	MSY	79	152	220	44.7
Greensboro Regional	GSO	80	151	203	34.4
Ontario Int'l	ONT	81	151	316	109.3
Little Rock Adams	LIT	82	149	241	61.7
Jacksonville Int'l	JAX	83	148	182	23.0
Des Moines	DSM	84	146	248	69.9
Oklahoma City Will Rogers World	OKC	85	145	222	53.1
Harrisburg Int'l	CXY	86	140	188	34.3
Buffalo Int'l	BUF	87	140	175	25.0
Lubbock Int'l	LBB	88	133	189	42.1
Charleston (SC) AFB Int'l	CHS	89	132	170	28.8
Spokane Int'l	GEG	90	121	167	38.0
Lihue	LIH	91	114	159	39.5
Columbia (SC) Metro	CAE	92	113	183	61.9
Fort Myers SW Florida Regional	RSW	93	69	134	94.2
Portland (ME) Int'l Jetport	PWM	94	112	139	24.1
Savannah Int'l	SAV	95	109	166	52.3
Hilo General Lyman	ITO	96	100	116	16.0
Midland Int'l	MAF	97	97	160	64.9
Amarillo	AMA	98	86	119	38.4
Greer Greenville-Spartanburg	GSP	99	69	100	44.9
Guam Agana Field	NGM	100	67	72	7.5
Total			25,870	34,921	36.1

Sources:
APO Terminal Area Forecasts.
FAA Air Traffic Activity FY90 data.

9. At the top 100 airports, ranked by 1990 total operations

Table A-4. Growth in Enplanements From 1988 to 1989 [10]

City-Airport	Airport ID	Rank	Enplanements (000s) CY88	CY89	% Growth
Guam Agana Field	NGM	1	487	624	28.1
Kailua-Kona Keahole	KOA	2	837	982	17.3
El Paso Int'l	ELP	3	1,427	1,672	17.2
Raleigh-Durham Int'l	RDU	4	3,518	4,117	17.0
Nashville Metro	BNA	5	3,244	3,746	15.5
Long Beach	LGB	6	579	662	14.3
Dallas Love	DAL	7	2,475	2,774	12.1
San Jose Int'l	SJC	8	2,774	3,094	11.5
Oakland Metro Int'l	OAK	9	1,826	2,031	11.2
Salt Lake City Int'l	SLC	10	4,730	5,244	10.9
Ontario Int'l	ONT	11	2,354	2,609	10.8
Albuquerque Int'l	ABQ	12	2,113	2,337	10.6
Hilo General Lyman	ITO	13	553	611	10.5
Anchorage	ANC	14	1,052	1,159	10.2
Grand Rapids Kent County Int'l	GRR	15	597	649	8.7
Portland (OR) Int'l	PDX	16	2,823	3,055	8.2
Dallas-Fort Worth Int'l	DFW	17	21,014	22,623	7.7
Lubbock Int'l	LBB	18	583	628	7.7
Little Rock Adams	LIT	19	880	907	7.6
Phoenix Sky Harbor Int'l	PHX	20	9,455	10,166	7.5
Chicago Midway	MDW	21	3,174	3,410	7.4
Honolulu Int'l	HNL	22	8,396	8,944	6.5
Cincinnati Int'l	CVG	23	3,543	3,771	6.4
Lihue	LIH	24	1,264	1,341	6.1
Tulsa Int'l	TUL	25	1,362	1,441	5.8
Detroit Metro Wayne County	DTW	26	9,214	9,739	5.7
Harrisburg	MDT	27	421	444	5.5
Kahului	OGG	28	2,026	2,133	5.3
Austin Robert Mueller	AUS	29	1,922	2,022	5.2
Milwaukee Mitchell Int'l	MKE	30	1,779	1,872	5.2
Washington Dulles Int'l	IAD	31	4,327	4,544	5.0
Cleveland Hopkins Int'l	CLE	32	3,547	3,722	4.9
Indianapolis Int'l	IND	33	2,406	2,523	4.9
Harlingen Rio Grande Int'l	HRL	34	510	535	4.9
Fort Myers SW Florida Regional	RSW	35	1,460	1,526	4.5

10. Top 100 airports ranked by growth in total enplanements.

Table A-4. Growth in Enplanements From 1988 to 1989 (continued) [11]

City-Airport	Airport ID	Rank	Enplanements (000s) CY88	CY89	% Growth
Charlotte Douglas Int'l	CLT	36	6,620	6,903	4.3
San Antonio Int'l	SAT	37	2,392	2,493	4.2
Minneapolis-St. Paul	MSP	38	8,171	8,460	3.5
Seattle-Tacoma	SEA	39	6,826	7,060	3.4
Oklahoma City Will Rogers World	OKC	40	1,493	1,540	3.2
San Diego Lindbergh	SAN	41	5,181	5,317	2.6
Albany	ALB	42	817	838	2.6
Las Vegas McCarran	LAS	43	6,865	7,027	2.4
Houston Intercontinental	IAH	44	6,872	7,030	2.3
Houston Hobby	HOU	45	3,840	3,927	2.3
Amarillo/Borger	AMA	46	433	442	2.1
West Palm Beach Int'l	PBI	47	2,361	2,404	1.8
Baltimore-Washington Int'l	BWI	48	4,370	4,446	1.7
Boise	BOI	49	526	534	1.5
Santa Ana John Wayne	SNA	50	2,156	2,174	0.8
Birmingham Municipal	BHM	51	983	990	0.7
Providence Green State	PVD	52	945	952	0.7
Sacramento Metro	SMF	53	1,792	1,800	0.5
San Juan Luis Muñoz Marín Int'l	SJU	54	3,264	3,269	0.1
San Francisco Int'l	SFO	55	13,348	13,326	-0.2
Los Angeles Int'l	LAX	56	18,643	18,583	-0.3
Midland Int'l	MAF	57	602	597	-0.8
New Orleans Int'l	MSY	58	3,200	3,171	-0.9
Orlando Int'l	MCO	59	7,473	7,373	-1.3
Wichita Mid-Continent	ICT	60	602	593	-1.5
St. Louis Lambert Int'l	STL	61	9,554	9,396	-1.7
Tampa Int'l	TPA	62	4,495	4,409	-1.9
Windsor Locks Bradley Int'l	BDL	63	2,322	2,270	-2.2
Spokane Int'l	GEG	64	744	727	-2.3
Kansas City Int'l	MCI	65	4,470	4,357	-2.5
Dayton Int'l	DAY	66	2,140	2,083	-2.7
Richmond Int'l	RIC	67	851	827	-2.8
Greer Greenville-Spartanburg	GSP	68	507	493	-2.8
Jacksonville Int'l	JAX	69	1,288	1,249	-3.1
Chicago O'Hare Int'l	ORD	70	26,597	25,664	-3.5

11. Top 100 airports ranked by growth in total enplanements.

Table A-4. Growth in Enplanements From 1988 to 1989 (concluded) [12]

City-Airport	Airport ID	Rank	Enplanements (000s) CY88	CY89	% Growth
New York LaGuardia	LGA	71	11,322	10,840	-4.3
Omaha Eppley	OMA	72	1,052	1,007	-4.3
Boston Logan Int'l	BOS	73	10,141	9,661	-4.7
Washington National	DCA	74	7,259	6,896	-5.0
Pittsburgh Int'l	PIT	75	8,379	7,941	-5.2
New York Kennedy Int'l	JFK	76	10,660	10,081	-5.4
Columbus Int'l	CMH	77	1,759	1,662	-5.5
Des Moines	DSM	78	708	669	-5.5
Philadelphia Int'l	PHL	79	6,634	6,247	-5.8
Sarasota-Bradenton	SRQ	80	843	794	-5.8
Savannah Int'l	SAV	81	531	499	-6.0
Reno Cannon Int'l	RNO	82	1,452	1,360	-6.3
Colorado Springs Municipal	COS	83	641	600	-6.4
Atlanta Hartsfield Int'l	ATL	84	21,824	20,398	-6.5
Fort Lauderdale Int'l	FLL	85	3,899	3,646	-6.5
Tucson Int'l	TUS	86	1,407	1,311	-6.8
Rochester Monroe County	ROC	87	1,242	1,149	-7.5
Columbia (SC) Metro	CAE	88	531	487	-8.3
Buffalo Int'l	BUF	89	1,780	1,629	-8.5
Miami Int'l	MIA	90	9,462	8,592	-9.2
Newark Int'l	EWR	91	10,838	9,822	-9.4
Knoxville McGhee-Tyson	TYS	92	532	482	-9.4
Burbank	BUR	93	1,458	1,320	-9.5
Charleston (SC) AFB Int'l	CHS	94	662	597	-9.8
Greensboro Regional	GSO	95	994	894	-10.1
Louisville Standiford	SDF	96	1,014	910	-10.3
Memphis Int'l	MEM	97	4,533	3,990	-12.0
Norfolk Int'l	ORF	98	1,492	1,298	-13.0
Syracuse Hancock Int'l	SYR	99	1,474	1,272	-13.7
Denver Stapleton Int'l	DEN	100	14,442	12,320	-14.7
Total			**410,652**	**408,755**	**1.3**

Sources: Enplanement data: *Airport Activity Statistics of Certificated Route Air Carriers*, 1988 and 1989 data.

12. Top 100 airports ranked by growth in total enplanements.

Table A-5. Growth in Operations From 1989 to 1990 [13]

City-Airport	Airport ID	Rank	Operations (000s) FY89	FY90	% Growth
Fort Myers SW Florida Regional	RSW	1	57	113	49.6
Seattle-Tacoma	SEA	2	328	426	29.9
Miami Int'l	MIA	3	378	463	22.5
Greer Greenville-Spartanburg	GSP	4	67	82	22.3
San Diego Lindbergh	SAN	5	207	259	20.1
Atlanta Hartsfield Int'l	ATL	6	670	779	16.3
Guam Agana Field	NGM	7	59	67	13.6
Grand Rapids Kent County Int'l	GRR	8	151	169	11.9
Albany	ALB	9	165	184	11.5
Indianapolis Int'l	IND	10	203	225	10.4
Lubbock Int'l	LBB	11	120	133	9.8
New Orleans Int'l	MSY	12	103	97	9.3
Boston Logan Int'l	BOS	13	417	448	7.5
Cincinnati Int'l	CVG	14	265	285	7.5
Hilo General Lyman	ITO	15	93	100	7.0
San Antonio Int'l	SAT	16	204	219	6.9
Charlotte Douglas Int'l	CLT	17	424	452	6.6
Cleveland Hopkins Int'l	CLE	18	257	273	6.2
Milwaukee Mitchell Int'l	MKE	19	197	209	6.1
Birmingham Municipal	BHM	20	187	199	6.1
Detroit Metro Wayne County	DTW	21	369	391	6.0
Los Angeles Int'l	LAX	22	632	669	5.6
Oklahoma City Will Rogers World	OKC	23	137	145	5.6
Philadelphia Int'l	PHL	24	383	405	5.5
San Juan Luis Muñoz Marín Int'l	SJU	25	194	205	5.4
Greensboro Regional	GSO	26	143	151	5.3
Ontario Int'l	ONT	27	143	151	5.3
Houston Intercontinental	IAH	28	294	310	5.2
Colorado Springs Municipal	COS	29	168	177	5.1
Boise	BOI	30	160	168	4.9
Tampa Int'l	TPA	31	217	227	4.6
Windsor Locks Bradley Int'l	BDL	32	174	182	4.6
Wichita Mid-Continent	ICT	33	167	175	4.6
Dallas-Fort Worth Int'l	DFW	34	694	725	4.5
Long Beach	LGB	35	462	483	4.5

13. At the top 100 airports, ranked by growth in total operations.

Table A-5. Growth in Operations From 1989 to 1990 (continued) [14]

City-Airport	Airport ID	Rank	Operations (000s) FY89	FY90	% Growth
Las Vegas McCarran	LAS	36	378	395	4.4
Tulsa Int'l	TUL	37	187	195	4.2
Austin Robert Mueller	AUS	38	185	193	4.2
St. Louis Lambert Int'l	STL	39	425	443	4.1
Richmond Int'l	RIC	40	154	160	3.9
Louisville Standiford	SDF	41	151	157	3.9
Houston Hobby	HOU	42	257	267	3.8
Raleigh-Durham Int'l	RDU	43	273	283	3.6
Phoenix Sky Harbor Int'l	PHX	44	480	497	3.5
Fort Lauderdale Int'l	FLL	45	217	226	3.4
Kailua-Kona Keahole	KOA	46	57	59	3.4
Anchorage	ANC	47	212	219	3.3
Tucson Int'l	TUS	48	222	229	3.1
Salt Lake City Int'l	SLC	49	293	302	3.0
Knoxville McGhee-Tyson	TYS	50	162	167	3.0
Buffalo Int'l	BUF	51	136	140	2.9
Chicago O'Hare Int'l	ORD	52	789	811	2.7
Lihue	LIH	53	111	114	2.7
New York LaGuardia	LGA	54	356	365	2.5
Sarasota-Bradenton	SRQ	55	164	168	2.4
Washington Dulles Int'l	IAD	56	235	240	2.1
West Palm Beach Int'l	PBI	57	234	239	2.1
Newark Int'l	EWR	58	377	384	1.9
Chicago Midway	MDW	59	316	322	1.9
Norfolk Int'l	ORF	60	158	160	1.9
Savannah Int'l	SAV	61	107	109	1.8
Syracuse Hancock Int'l	SYR	62	180	183	1.7
Pittsburgh Int'l	PIT	63	379	385	1.6
Minneapolis-St. Paul	MSP	64	376	382	1.6
Charleston (SC) AFB Int'l	CHS	65	130	132	1.5
Denver Stapleton Int'l	DEN	66	468	475	1.5
Portland (OR) Int'l	PDX	67	268	272	1.5
New York Kennedy Int'l	JFK	68	337	342	1.5
Washington National	DCA	69	316	320	1.3
Amarillo/Borger	AMA	70	85	86	1.2

14. At the top 100 airports, ranked by growth in total operations.

Table A-5. Growth in Operations From 1989 to 1990 (concluded) [15]

City-Airport	Airport ID	Rank	Operations (000s) FY89	FY90	% Growth
San Francisco Int'l	SFO	71	434	437	0.7
San Jose Int'l	SJC	72	318	320	0.7
Little Rock Adams	LIT	73	148	149	0.7
Reno Cannon Int'l	RNO	74	163	164	0.6
Honolulu Int'l	HNL	75	406	407	0.2
Dallas Love	DAL	76	214	214	0.0
Sacramento Metro	SMF	77	177	177	0.0
Baltimore-Washington Int'l	BWI	78	307	304	-1.0
Memphis Int'l	MEM	79	334	330	-1.2
Kahului	OGG	80	182	179	-1.7
Santa Ana John Wayne	SNA	81	534	523	-2.1
Albuquerque Int'l	ABQ	82	231	226	-2.2
Columbia (SC) Metro	CAE	83	116	113	-2.6
Orlando Int'l	MCO	84	286	278	-2.8
Omaha Eppley	OMA	85	158	153	-3.2
Jacksonville Int'l	JAX	86	153	148	-3.3
Oakland Metro Int'l	OAK	87	403	389	-3.5
Columbus Int'l	CMH	88	233	224	-3.9
Burbank	BUR	89	246	235	-4.5
Dayton Int'l	DAY	90	205	197	-4.7
El Paso Int'l	ELP	91	188	179	-4.8
Harrisburg Int'l	MDT	92	147	140	-4.8
Harlingen Rio Grande Int'l	HRL	93	63	60	-4.8
Nashville Metro	BNA	94	276	259	-6.2
Midland Int'l	MAF	95	103	97	-5.9
Des Moines	DSM	96	160	146	-9.5
Providence Green State	PVD	97	200	180	-11.1
Rochester Monroe County	ROC	98	205	184	-12.0
Kansas City Int'l	MCI	99	239	162	-32.2
Spokane Int'l	GEG	100	119	87	-36.7
Total			**24,960**	**25,749**	**3.42**

Sources:
APO Terminal Area Forecasts. FAA Air Traffic Activity FY89 and FY90.

15. At the top 100 airports, ranked by growth in total operations.

Table A-6. Growth in Operations and Enplanements [16]

City-Airport	Airport ID	Rank	% Growth in Enplanements CY88 to CY89	% Growth in Operations FY89 to FY90
Albany	ALB	1	2.6	11.5
Albuquerque Int'l	ABQ	2	10.6	-2.2
Amarillo/Borger	AMA	3	2.1	1.2
Anchorage	ANC	4	10.2	18.9
Atlanta Hartsfield Int'l	ATL	5	-6.5	16.3
Austin Robert Mueller	AUS	6	5.2	4.3
Baltimore-Washington Int'l	BWI	7	1.7	-0.1
Birmingham Municipal	BHM	8	0.7	6.4
Boise	BOI	9	1.5	5.0
Boston Logan Int'l	BOS	10	-4.7	7.4
Buffalo Int'l	BUF	11	-8.5	2.9
Burbank	BUR	12	-9.5	-4.7
Charleston (SC) AFB Int'l	CHS	13	-9.8	1.5
Charlotte Douglas Int'l	CLT	14	4.3	6.6
Chicago Midway	MDW	15	7.4	1.9
Chicago O'Hare Int'l	ORD	16	-3.5	2.8
Cincinnati Int'l	CVG	17	6.4	7.5
Cleveland Hopkins Int'l	CLE	18	4.9	6.2
Colorado Springs Municipal	COS	19	-6.4	5.4
Columbia (SC) Metro	CAE	20	-8.3	-2.7
Columbus Int'l	CMH	21	-5.5	-4.0
Dallas Love	DAL	22	12.1	0
Dallas-Fort Worth Int'l	DFW	23	7.7	4.5
Dayton Int'l	DAY	24	-2.7	-4.0
Denver Stapleton Int'l	DEN	25	-14.7	1.5
Des Moines	DSM	26	-5.5	-9.6
Detroit Metro Wayne County	DTW	27	5.7	6.0
El Paso Int'l	ELP	28	17.2	-5.0
Fort Lauderdale Int'l	FLL	29	-6.5	3.2
Fort Myers SW Florida Regional	RSW	30	4.5	98.2
Grand Rapids Kent County Int'l	GRR	31	8.7	11.9
Greensboro Regional	GSO	32	-10.1	5.6
Greer Greenville-Spartanburg	GSP	33	-2.8	3.0
Guam Agana Field	NGM	34	28.1	13.6
Harlingen Rio Grande Int'l	HRL	35	4.9	-5.0

16. At the top 100 airports, in alphabetical order.

Table A-6. Growth in Operations and Enplanements (continued) [17]

City-Airport	Airport ID	Rank	% Growth in Enplanements CY88 to CY89	% Growth in Operations FY89 to FY90
Harrisburg	MDT	36	5.5	8.5
Hilo General Lyman	ITO	37	10.5	7.5
Honolulu Int'l	HNL	38	6.5	0.2
Houston Hobby	HOU	39	2.3	3.9
Houston Intercontinental	IAH	40	2.3	5.4
Indianapolis Int'l	IND	41	4.9	10.8
Jacksonville Int'l	JAX	42	-3.1	-3.4
Kahului	OGG	43	5.3	-1.7
Kailua-Kona Keahole	KOA	44	17.3	3.5
Kansas City Int'l	MCI	45	-2.5	-47.5
Knoxville McGhee-Tyson	TYS	46	-9.4	3.1
Las Vegas McCarran	LAS	47	2.4	4.5
Lihue	LIH	48	6.1	2.7
Little Rock Adams	LIT	49	7.6	0.7
Long Beach	LGB	50	14.3	4.5
Los Angeles Int'l	LAX	51	-0.3	5.9
Louisville Standiford	SDF	52	-10.3	6.0
Lubbock Int'l	LBB	53	7.7	10.8
Memphis Int'l	MEM	54	-12.0	-1.2
Miami Int'l	MIA	55	-9.2	22.5
Midland Int'l	MAF	56	-0.8	-6.2
Milwaukee Mitchell Int'l	MKE	57	5.2	6.1
Minneapolis-St. Paul	MSP	58	3.5	1.6
Nashville Metro	BNA	59	15.5	-6.6
New Orleans Int'l	MSY	60	-0.9	9.4
New York Kennedy Int'l	JFK	61	-5.4	1.5
New York LaGuardia	LGA	62	-4.3	2.5
Newark Int'l	EWR	63	-9.4	1.9
Norfolk Int'l	ORF	64	-13.0	1.9
Oakland Metro Int'l	OAK	65	11.2	-3.6
Oklahoma City Will Rogers World	OKC	66	3.2	5.8
Omaha Eppley	OMA	67	-4.3	-3.3
Ontario Int'l	ONT	68	10.8	5.6
Orlando Int'l	MCO	69	-1.3	-2.9
Philadelphia Int'l	PHL	70	-5.8	5.7

17.At the top 100 airports, in alphabetical order.

Table A-6. Growth in Operations and Enplanements (concluded) [18]

City-Airport	Airport ID	Rank	% Growth in Enplanements CY88 to CY89	% Growth in Operations FY89 to FY90
Phoenix Sky Harbor Int'l	PHX	71	7.5	3.5
Pittsburgh Int'l	PIT	72	-5.2	1.6
Portland (OR) Int'l	PDX	73	8.2	1.5
Providence Green State	PVD	74	0.7	-11.1
Raleigh-Durham Int'l	RDU	75	17.0	3.7
Reno Cannon Int'l	RNO	76	-6.3	0.6
Richmond Int'l	RIC	77	-2.8	3.9
Rochester Monroe County	ROC	78	-7.5	-11.4
Sacramento Metro	SMF	79	0.5	0
Salt Lake City Int'l	SLC	80	10.9	3.1
San Antonio Int'l	SAT	81	4.2	7.4
San Diego Lindbergh	SAN	82	2.6	2.4
San Francisco Int'l	SFO	83	-0.2	0.7
San Jose Int'l	SJC	84	11.5	0.6
San Juan Luis Muñoz Marín Int'l	SJU	85	0.1	5.7
Santa Ana John Wayne	SNA	86	0.8	-2.1
Sarasota-Bradenton	SRQ	87	-5.8	2.4
Savannah Int'l	SAV	88	-6.0	1.9
Seattle-Tacoma	SEA	89	3.4	29.9
Spokane Int'l	GEG	90	-2.3	1.7
St. Louis Lambert Int'l	STL	91	-1.7	4.2
Syracuse Hancock Int'l	SYR	92	-13.7	1.7
Tampa Int'l	TPA	93	-1.9	4.6
Tucson Int'l	TUS	94	-6.8	3.2
Tulsa Int'l	TUL	95	5.8	4.3
Washington Dulles Int'l	IAD	96	5.0	2.1
Washington National	DCA	97	-5.0	1.3
West Palm Beach Int'l	PBI	98	1.8	2.1
Wichita Mid-Continent	ICT	99	-1.5	4.8
Windsor Locks Bradley Int'l	BDL	100	-2.2	4.6

Sources:
Ennlanement data: *Airport Activity Statistics of Certificated Route Air Carriers*, 1988 and 1989 data.
O ·ions data: *FAA Air Traffic Activity* FY89 and FY90 data.

18. At the top 100 airports, in alphabetical order.

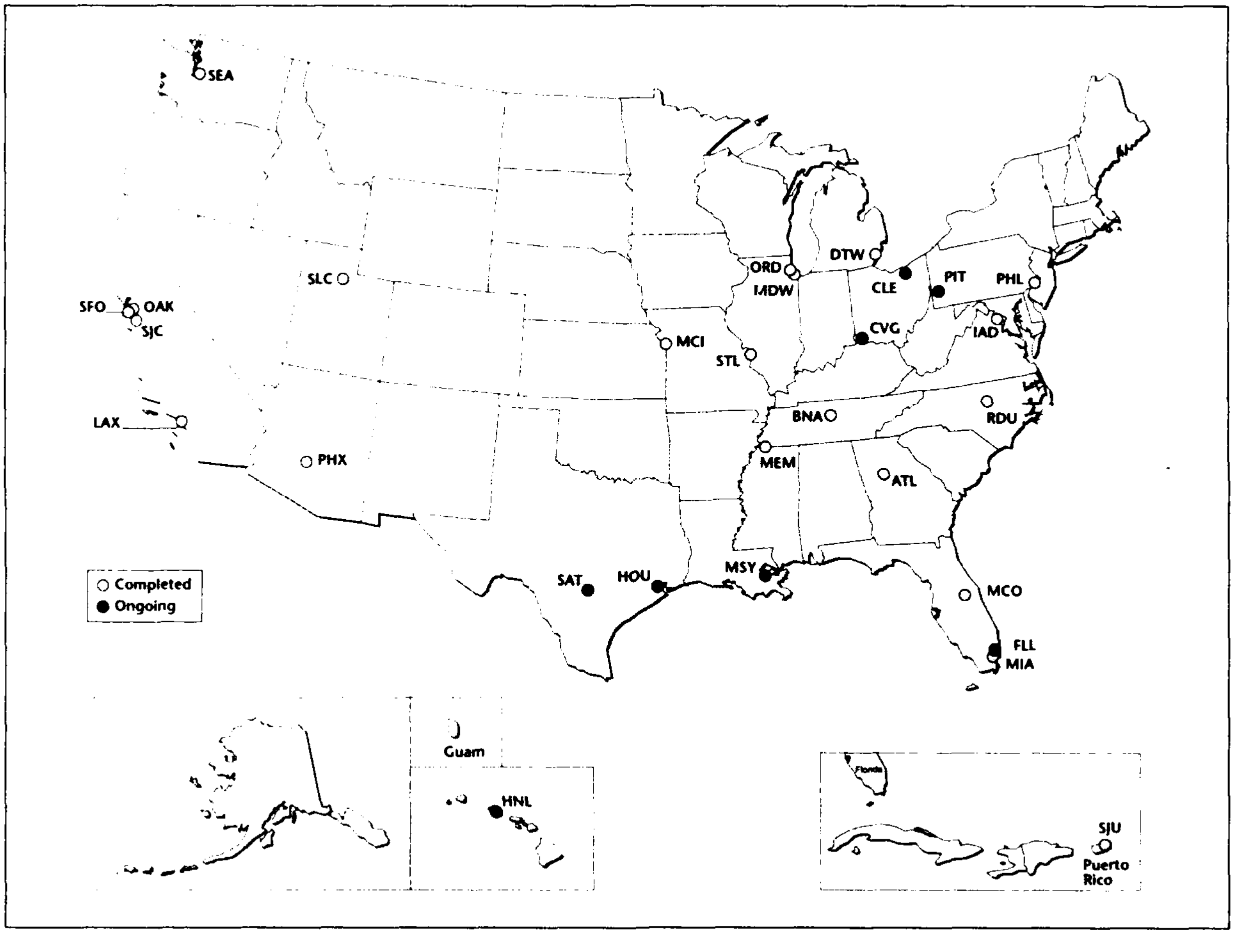
Appendix B

Airport Capacity Design Team Project Summaries

The Airport Capacity Design Teams identify and evaluate various actions, which, if implemented, would increase capacity, improve operational efficiency, and reduce delay at the airports under study. The Capacity Teams examine proposed alternatives to determine their technical merit. Environmental, socioeconomic, and political issues are not assessed. These issues will be addressed in other airport planning efforts, like the master planning process.

For those airports where the Airport Capacity Design Team has completed its study, the project summaries and airport layouts contained in this appendix document the capacity improvement alternatives included in the final report. They have not been updated to include any subsequent changes at the airports. For those airports where the Capacity Team's analysis is still in progress, the proposed capacity improvement alternatives listed may well change as the study evolves.

The following capacity teams were recently initiated, and initial recommendations had not been finalized at press time: Cincinnati, Honolulu, New Orleans, San Antonio, Ft. Lauderdale, Houston, and Cleveland.


SEA
SFO
OAK
SJC
LAX
SLC
PHX
MCI
STL
ORD
MDW
DTW
CLE
PIT
PHL
CVG
IAD
BNA
RDU
MEM
ATL
SAT
HOU
MSY
MCO
FLL
MIA
Guam
HNL
SJU
Puerto Rico
Completed
Ongoing

Atlanta-Hartsfield International Airport B-5
Charlotte/Douglas International Airport B-7
Chicago Midway Airport B-9
Chicago O'Hare International Airport B-11
Detroit Metropolitan Wayne County Airport B-13
Greater Pittsburgh International Airport B-15
Kansas City International Airport B-17
Los Angeles International Airport B-19
Memphis International Airport B-21
Miami International Airport B-23
Nashville International Airport B-25
Oakland International Airport B-27
Orlando International Airport B-29
Philadelphia International Airport B-31
Phoenix-Sky Harbor International Airport B-33
Raleigh-Durham International Airport B-35
Salt Lake City International Airport B-37
San Francisco International Airport B-39
San Jose International Airport B-41
San Juan Luis Muñoz Marín International Airport B-43
Seattle-Tacoma International Airport B-45
Lambert-St. Louis International Airport B-47
Washington Dulles International Airport B-49

Legend

Existing Runway

Existing Taxiway/Apron

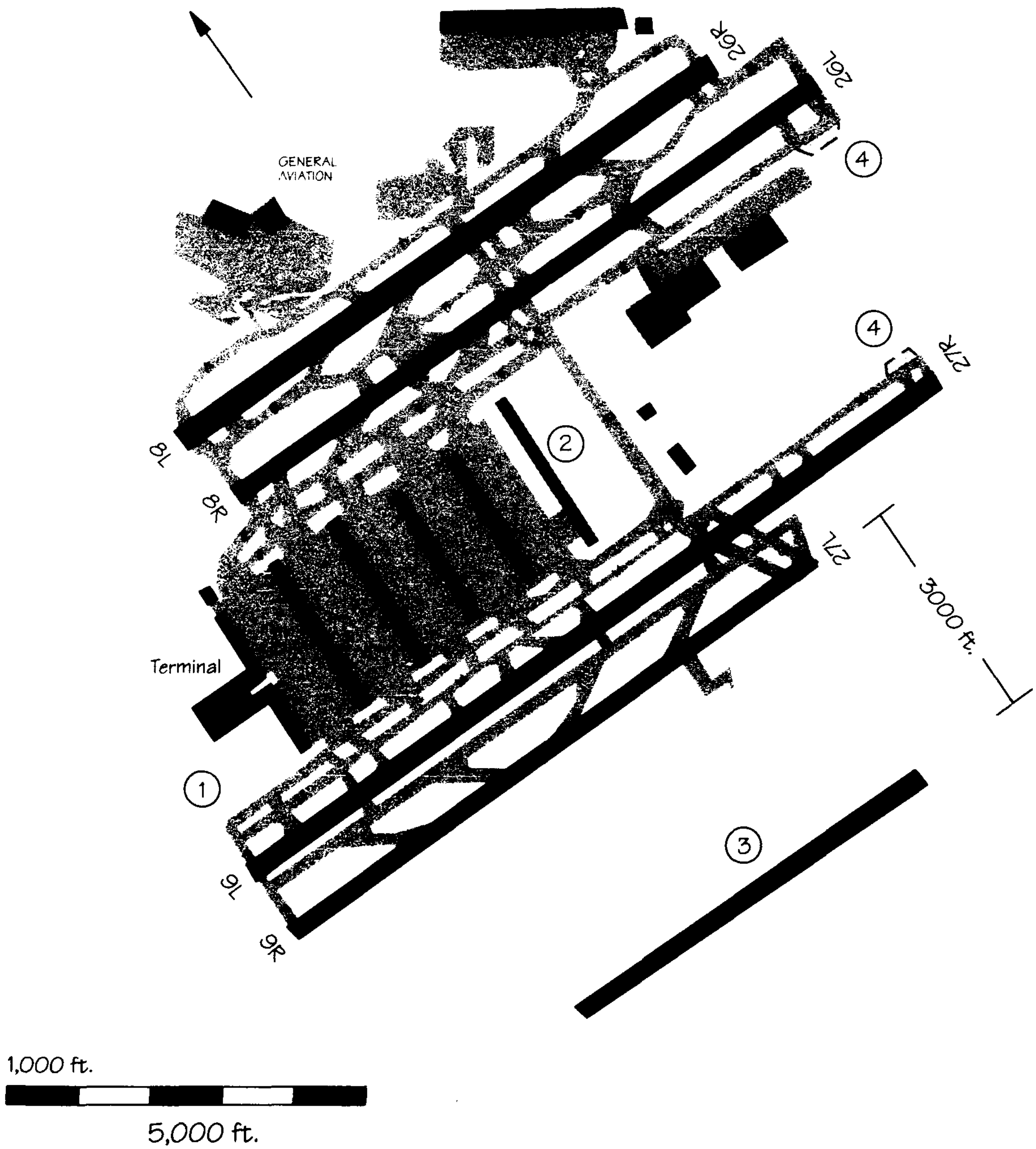
Proposed Runway/Runway Extension

Proposed Taxiway/Apron/Facility Improvements

Buildings

5 Numbers are keyed to alternatives listed in Airport Project Summary

Note: Some buildings/structures may have been removed for clarity.



GENERAL AVIATION
26R
26L
4
4
27R
2
8L
8R
27L
3000 ft.
Terminal
1
3
9L
9R
1,000 ft.
5,000 ft.

Atlanta-Hartsfield International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. International concourse
2. Fifth concourse
3. Commuter/GA terminal and runway complex south of Runway 9R/27L
4. Three hold pads/bypass taxiways at end of departure runways
5. Taxiway C parallel to the west of Taxiway D

Facilities and Equipment Improvements

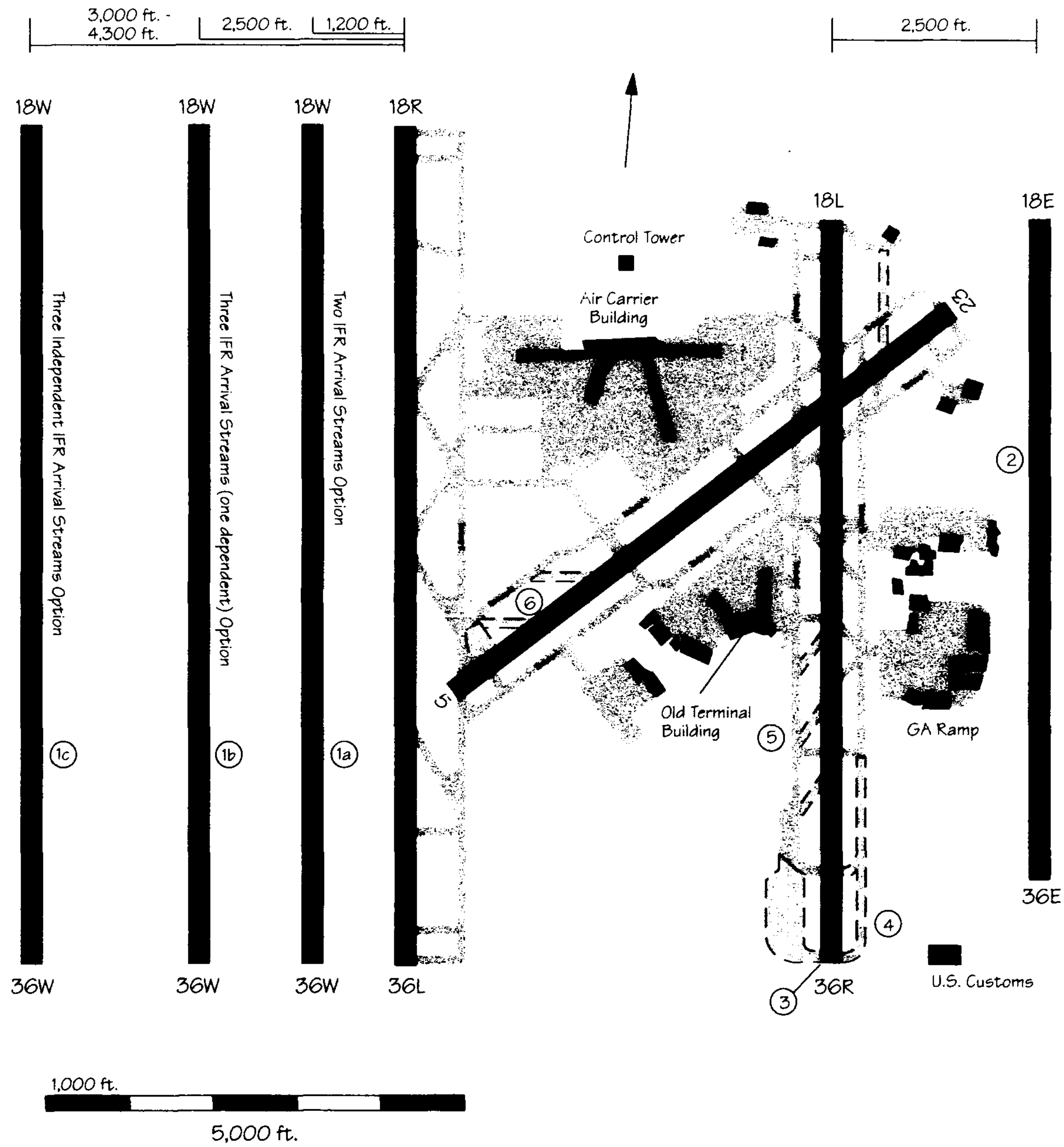
7. Expedite development and installation of wake vortex forecasting and avoidance systems
8. Upgrade NAVAIDs and approach lights on Runway 26R and 27L to Category II
9. Update terminal approach radar
10. Upgrade RVR system to CAT IIIB and ICAO standards
11. Install ASDE-3 with tracking
12. Install touchdown zone lights on Runway 27L
13. Precision Runway Monitor (PRM)
14. CAT III ILS

Operational Improvements

15. Reduce arrival separations to 2.5 nm
16. Enhance traffic management procedures

User Improvements

17. Depeak airline schedules within the hour


3,000 ft. - 4,300 ft.
2,500 ft.
1,200 ft.
2,500 ft.
18W
18W
18W
18R
18L
18E
Control Tower
Air Carrier Building
Three Independent IFR Arrival Streams Option
Three IFR Arrival Streams (one dependent) Option
Two IFR Arrival Streams Option
1c
1b
1a
2
3
4
5
6
5
23
Old Terminal Building
GA Ramp
U.S. Customs
36W
36W
36W
36L
36R
36E
1,000 ft.
5,000 ft.

Charlotte/Douglas International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Build third parallel runway, Runway 18W/36W
   - 1a. Two IFR arrival streams
   - 1b. Three IFR arrival streams (one dependent)
   - 1c. Three IFR independent arrival streams
2. Build fourth parallel runway, Runway 18E/36E
3. Extend Runway 36R further south
4. Extend Taxiway D full Runway 18L/36R length
5. Build angled exits off Runway 18L
6. Build angled exits off Runway 23
7. Construct departure sequencing pads at runway ends
8. Install centerline lights on Runway 5

Facilities and Equipment Improvements

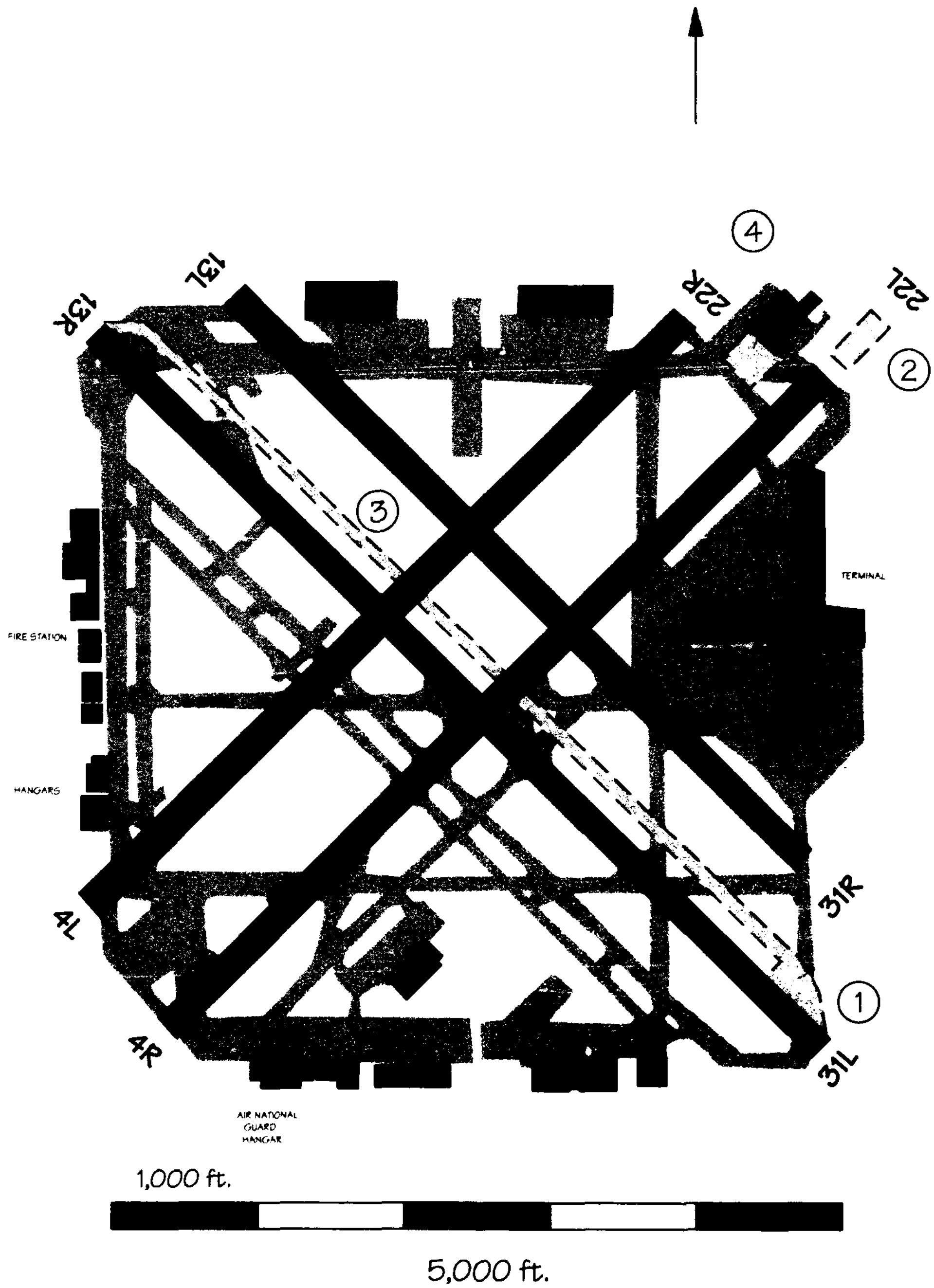
9. Install Category I ILS on Runway 23
10. Install Category II/III ILS on Runway 18R
11. Install Category II/III ILS on Runway 18L
12. Install Category II/III ILS on Runway 36R
13. Install Airport Surface Detection Equipment (ASDE)
14. Expand the Charlotte TRACON and ARTS-IIIA
15. Acquire the Aircraft Situation Display (ASD)
16. Install Precision Runway Monitor (PRM)
17. Install approach light system on Runway 18L and Runway 23

Operational Improvements

18. Waiver to conduct intersecting runway operations with wet runways
19. Increase Charlotte tower satellite control positions for departures
20. Identify departure restrictions

Other Improvements

21. Improve reliever airports (reduce GA by 50%)


④
13L
13R
22R
22L
②
③
TERMINAL
FIRE STATION
HANGARS
31R
①
4L
4R
31L
AIR NATIONAL GUARD HANGAR
1,000 ft.
5,000 ft.

Chicago Midway Airport
Capacity Design Team Project Summary

Recommendations

Airfield Improvements

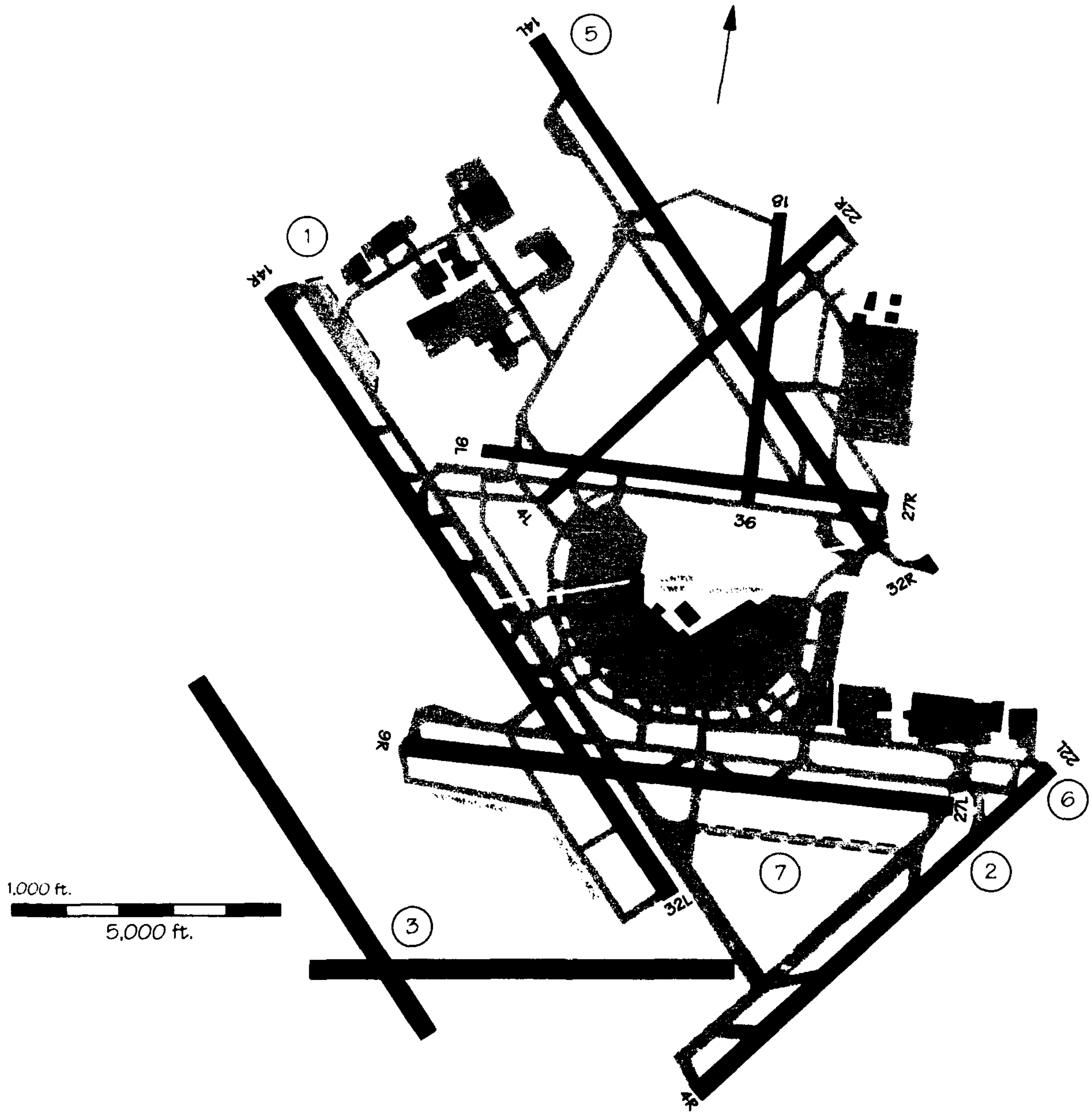
1. Runway 31L hold pad
2. Extension to Runway 22L
3. Parallel taxiway between Runways 13R/31L and 13L/31R
4. Runway 22L hold pad
5. Expand apron/gate area
6. Rehabilitation of Runway 13L/31R
7. Reduce arrival minimums for Runways 4R and 31L
8. Commission general aviation Runway 13/31

Air Traffic Control Operational Improvements

9. Intersecting runway operations
10. Silent release departures
11. Dual approach procedures to Runways 31L, 31R, 4L, and 4R
12. Straight-in approach to Runway 22L
13. Meig's instrument approach capability

Research/New Technology Improvements

1. Reduce/eliminate miles-in-trail restrictions
2. Examine flow control procedures
3. Reduce aircraft separation criteria
4. Examine Chicago airspace organization


14L
5
18
22R
1
14R
9L
4L
36
27R
32R
9R
22L
6
27L
7
2
1,000 ft.
5,000 ft.
3
32L
4R

Chicago O'Hare International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

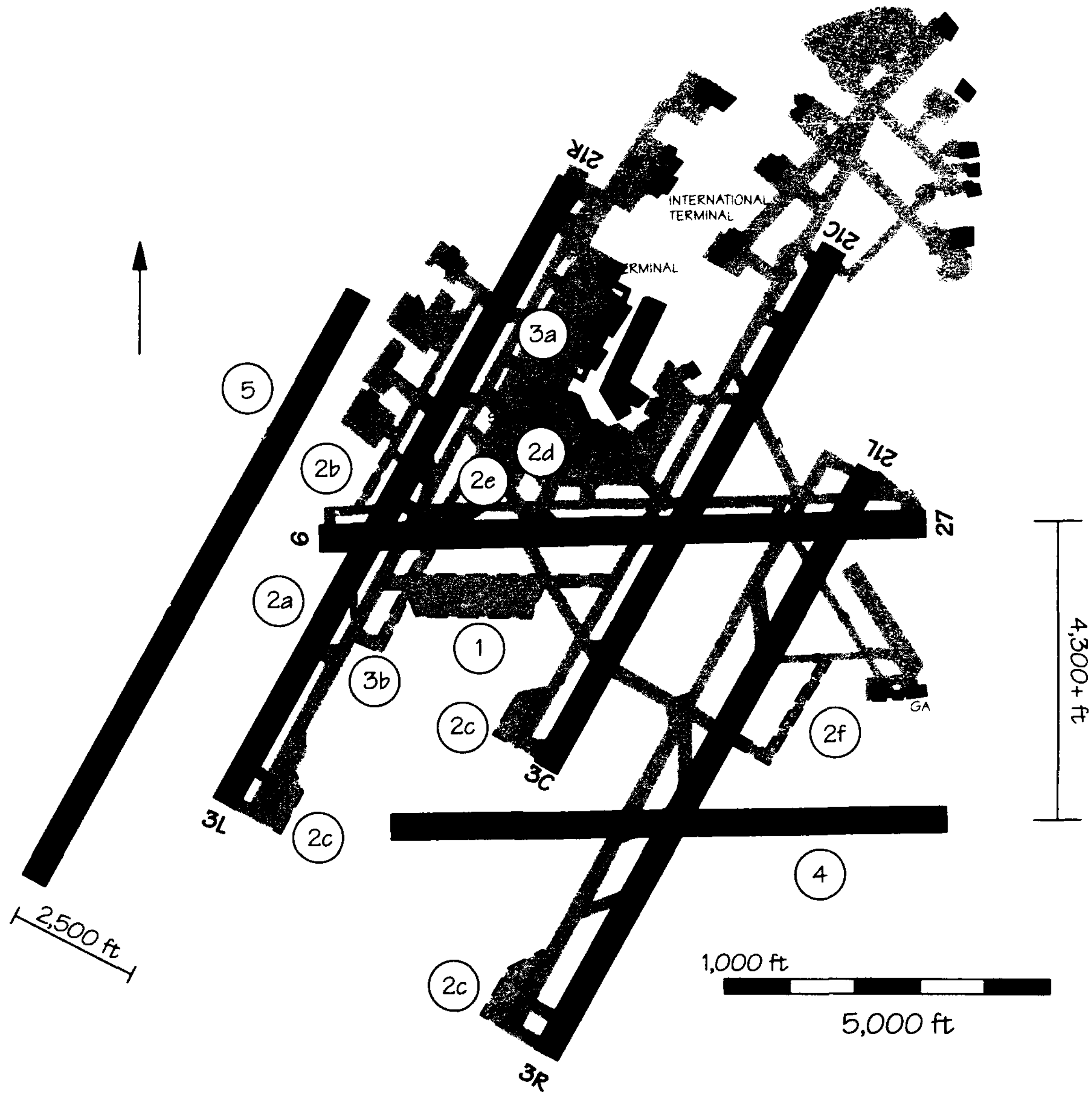
1. Large flow-through aircraft holding areas ("Chicago hold pads")
2. Runway 4R angled exit
3. New Runways 14/32 and 9/27
4. Northward relocation of Runways 9L/27R and 4L/22R
5. Extension to Runway 14L
6. Extension to Runway 22L
7. Southern Runway 9R/27L parallel taxiway
8. Additional Category II/III approach capability

Air Traffic Control Operational Improvements

9. Triple converging instrument approach procedures
10. Intersecting wet runway operations on Runway 14L
11. Independent triple IFR approach procedures

Research/New Technology Improvements

1. Reduce/eliminate miles-in-trail restrictions
2. Examine flow control procedures
3. Reduce aircraft separation criteria
4. Examine Chicago airspace organization


INTERNATIONAL
TERMINAL
RMINAL
21R
21C
21L
3L
3C
3R
9
27
1
2a
2b
2c
2c
2c
2d
2e
2f
3a
3b
4
5
GA
2,500 ft
4,300+ ft
1,000 ft
5,000 ft

Detroit Metropolitan Wayne County Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Holding apron and taxiway south
2. Runway and taxiway improvements
   - 2a. High-speed exit taxiway - Runway 21R to Taxiway Y
   - 2b. Extend Taxiway Z to Taxiway V
   - 2c. Construct and expand holding aprons at Runways 3C, 3L, and 3R
   - 2d. Extend inner taxiway parallel to Taxiway H
   - 2e. Construct exit taxiway - Runway 9/27 to Taxiway H
   - 2f. Construct Taxiway S to east GA area
3. Terminal improvements
   - 3a. Terminal expansion
   - 3b. Mid-field terminal
4. Construct independent crosswind Runway 9R/27L
5. Construct independent fourth north/south runway

Facilities and Equipment Improvements

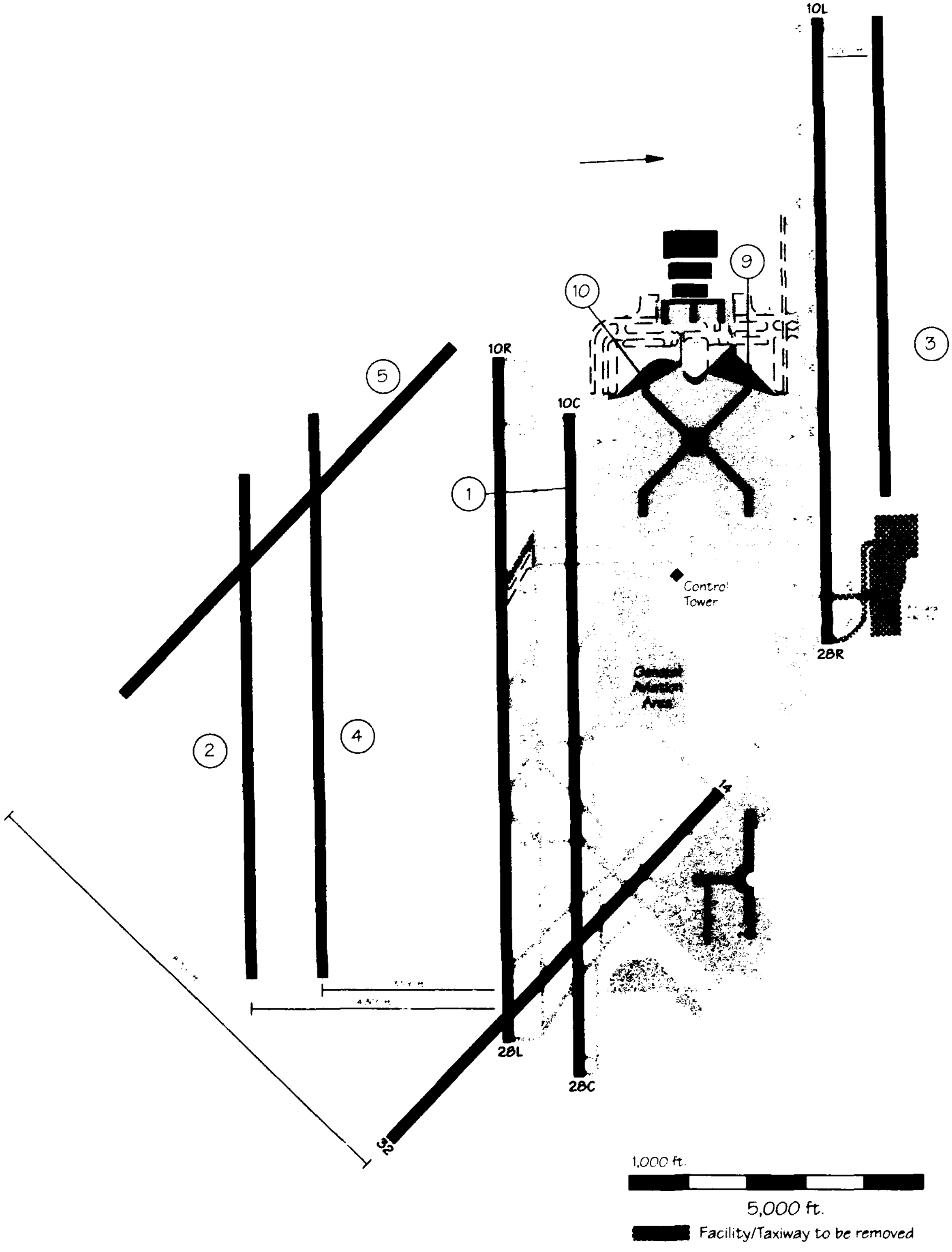
7. Upgrades on Runway 3C
   - 7a. ILS, MLS, and approach lights on existing Runway 3C
   - 7b. RVR for existing Runway 3C
8. ASDE
9. Terminal Doppler Weather Radar (TDWR)
11. RVR and centerline lights on Runway 27
12. Expedite development and installation of wake vortex forecasting and avoidance system
13. Install an airport VOR

Air Traffic Control Improvements

14. Independent converging VFR/IFR approaches to Runways 27 and 21R, hold short of Runway 21R
15. Add controller positions, establish STAR routes, relocate MOTER intersection
16. Use departure corridors
17. Realign Cleveland Center sector airspace
18. Expand tower en route program
19. Reduce arrival longitudinal separation to 2.5nmi
   - 19a. Runway occupancy time reduced 10%
   - 19b. Runway occupancy time reduced 20%
   - 19c. Runway occupancy time reduced 30%

User Improvements

20. Relocate general aviation traffic users
21. More uniform distribution of scheduled operations within the hour


10L
10R
10C
28L
28C
28R
14
32
1
2
3
4
5
9
10
Control Tower
General Aviation Area
1,000 ft.
5,000 ft.
Facility/Taxiway to be removed

Greater Pittsburgh International Airport Capacity Design Team Project Summary

Recommendations

Airfirld Improvements

Runway Extension

1. Extend Runway 10C/28C 2,000 feet west

One New Runway

2. Build 8,500 foot independent south parallel runway 4,300 feet south of Runway 10R/28R
3. Build 8,200 foot north parallel runway 1,000 feet north of Runway 10L/28R
4. Build 8,500 foot dependent south parallel runway 3,100 feet south of Runway 10R/28L
5. Build 9,000 foot crosswind Runway 14R/32L 8,700 feet west of Runway 14/32

Two New Runways

6. Build north and south parallel runways
7. Build two south parallel runways, 3,100 and 4,300 feet south of Runway 10R/28L
8. Build south parallel and crosswind runways

Terminal Area Improvements

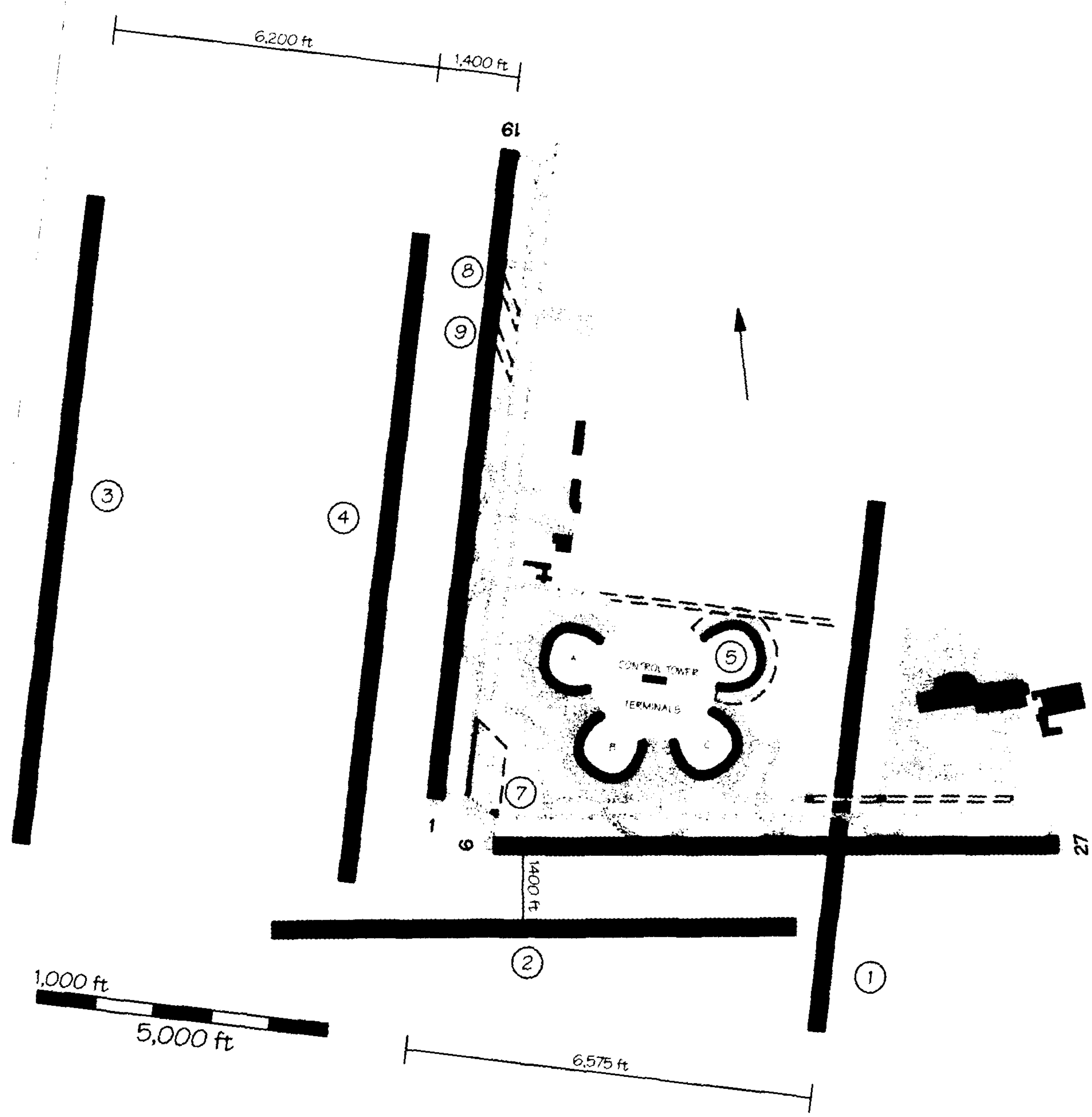
9. Add new gates to northwest finger of new Midfield Terminal and improve Taxiway H to Taxiway R
10. Add new gates to southwest finger of new Midfield Terminal and improve Taxiway K from Taxiway W to A

Facilities and Equipment Improvements

11. Upgrade Runway 10R to CAT II/III ILS
12. Install Precision Runway Monitor (PRM)

Operational Improvements

13. Conduct an airspace capacity design project and re-structure terminal airspace


6,200 ft
1,400 ft
19
8
9
3
4
CONTROL TOWER
TERMINALS
5
7
1
9
27
1400 ft
2
1
1,000 ft
5,000 ft
6,575 ft

Kansas City International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Independent 9500' Runway 1R/19L
2. Dependent 10,000' parallel Runway 9R/27L
3. Independent 10,000 parallel Runway 18R/36L
4. Dependent 10,000 parallel Runway 18L/36R
5. Add fourth terminal
6. Extend Taxiways B and D to Taxiway H
7. Build holding aprons west of Terminal B
8. High speed exit at A2 for Runway 1L
9. High speed exit at A3 for Runway 19R
10. Extend Taxiway B5 to Runway 19R for GA
11. High speed exit between C5 and C7 for Runway 27R

Facilities and Equipment Improvements

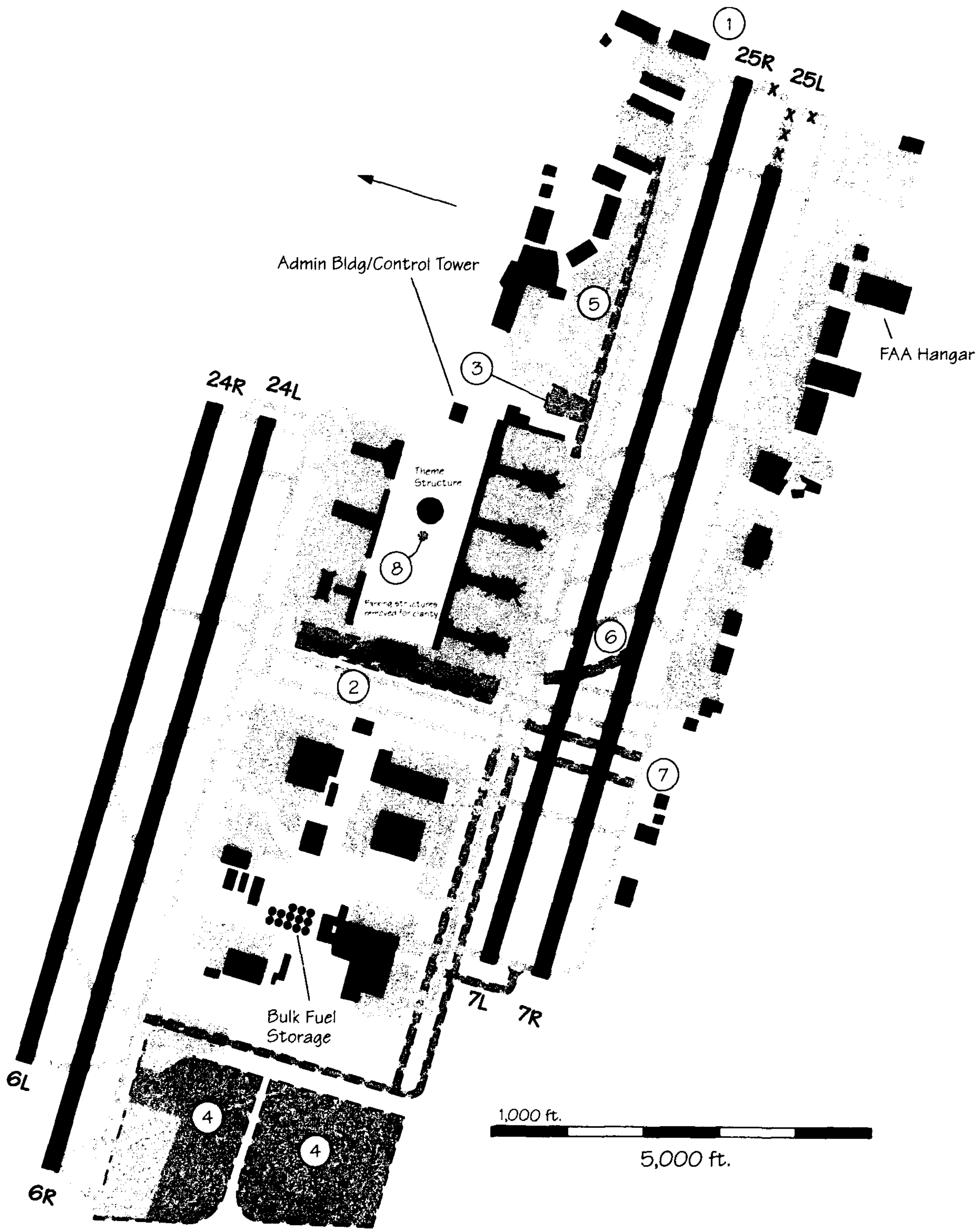
12. CAT III ILS on Runway 1R
13. CAT I ILS on Runway 19L
14. Install ILS/MLS for Runway 27R
15. DME for Runways 1L/19R and 1R/19L
16. RVR for Runway 1R/19L
17. Upgrade Runway 1L ILS to CAT III
18. Benefit of ASDE

Operational Improvements

19. Simultaneous converging instrument approaches
20. Impact of terminal service road
21. Impact of perimeter service road
22. Effect of noise restrictions
23. Effect of ARSA separations within the TCA

User Improvements

24. Uniformly distribute scheduled commercial operations within the hour
25. Reduce ROT through pilot and controller education
26. Reduce longitudinal separations to 2.5 nm


1
25R
25L
Admin Bldg/Control Tower
5
FAA Hangar
3
24R
24L
Theme Structure
8
6
2
7
7L
7R
Bulk Fuel Storage
6L
6R
4
4
1,000 ft.
5,000 ft.

Los Angeles International Airport
Capacity Design Team Project Summary

Recommendations

Airfield Improvements

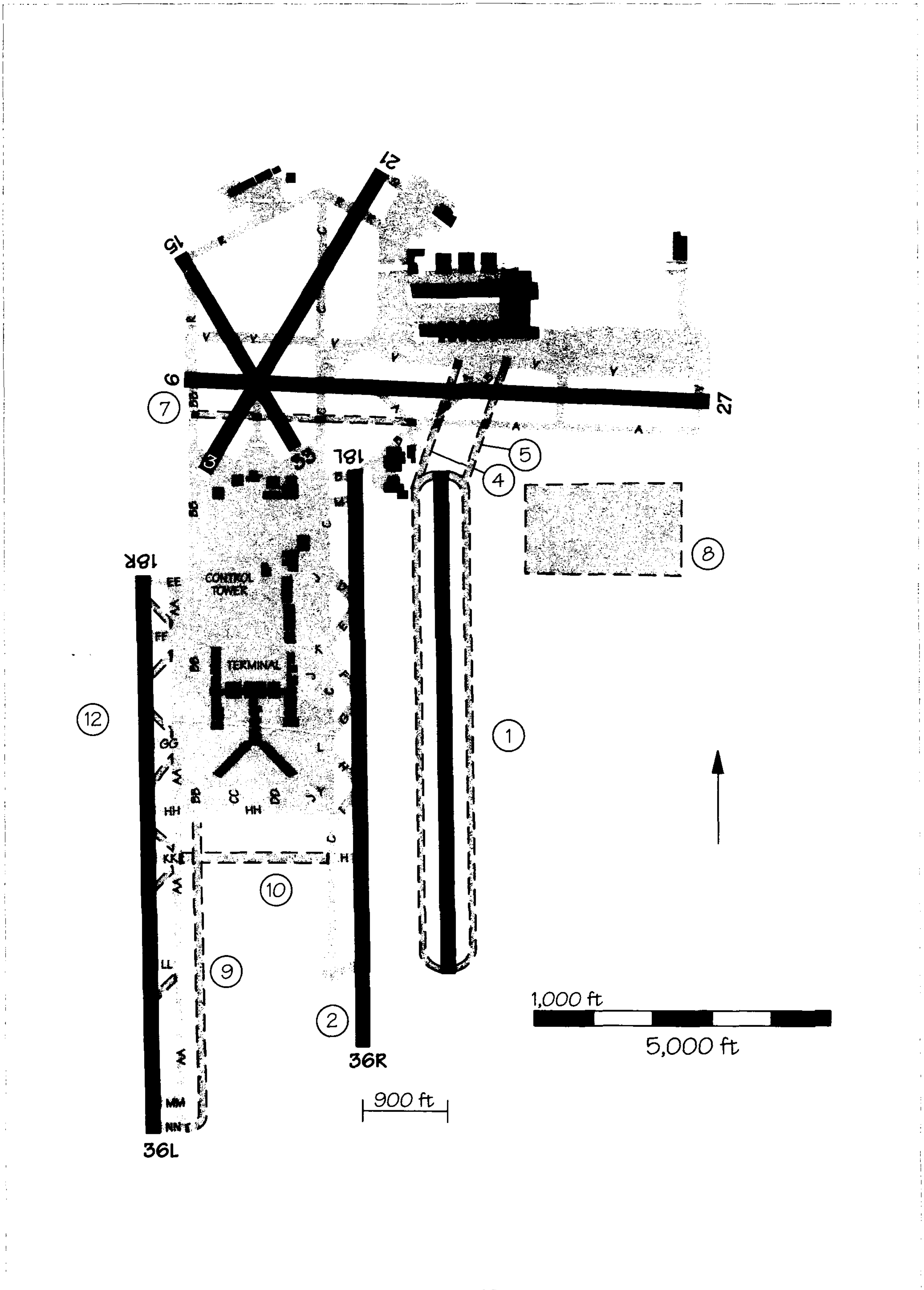
1. Construct departure pads (staging areas) at ends of runways
2. Construct new gates west side of Tom Bradley International Terminal (TBIT)
3. Construct 11-gate domestic terminal (east of Sepulveda) and 24-gate international terminal on the west end
4. West end development
   4a. Construct 24 remote gates (no terminal) for domestic and international operations
   4b. Construct 24-gate passenger terminal for domestic and/or international operations
5. Extend Taxiway K to the east
6. Construct high-speed Taxiway 43
7. Extend Taxiways 48 and 49 to Taxiway F

Facilities and Equipment Improvements

8. Construct new air traffic control tower
9. Upgrade ILS on Runway 25L to CAT III

Procedures Improvements

10. Taxi aircraft versus towing from remote parking areas to gates
11. Restructure Los Angeles Basin airspace


21
15
9
27
3
33
18L
18R
36R
36L
CONTROL TOWER
TERMINAL
1
2
4
5
7
8
9
10
12
1,000 ft
5,000 ft
900 ft

Memphis International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Construct Runway 18E/36E, dual departures
2. Construct Runway 18E/36E, triple departures in VFR-1
3. Construct Runway 18E/36E, triple departures in all weather conditions (waiver required)
4. Extend inner parallel taxiway north to Taxiway V
5. Extend outer Taxiway P north to Taxiway V
6. Extend Runway 18L/36R south
7. Extend Taxiway A from B to BB
8. Large freight ramp, east of Runway 18E, south of Runway 27
9. Extend Taxiway BB to approach end of Runway 36L
10. New crossover Taxiway KK, south of Taxiway HH
11. Terminal expansion
12. Angled exits on Runway 18R/36L (reduce occupancy times by 10%)

Facility and Equipment Improvements

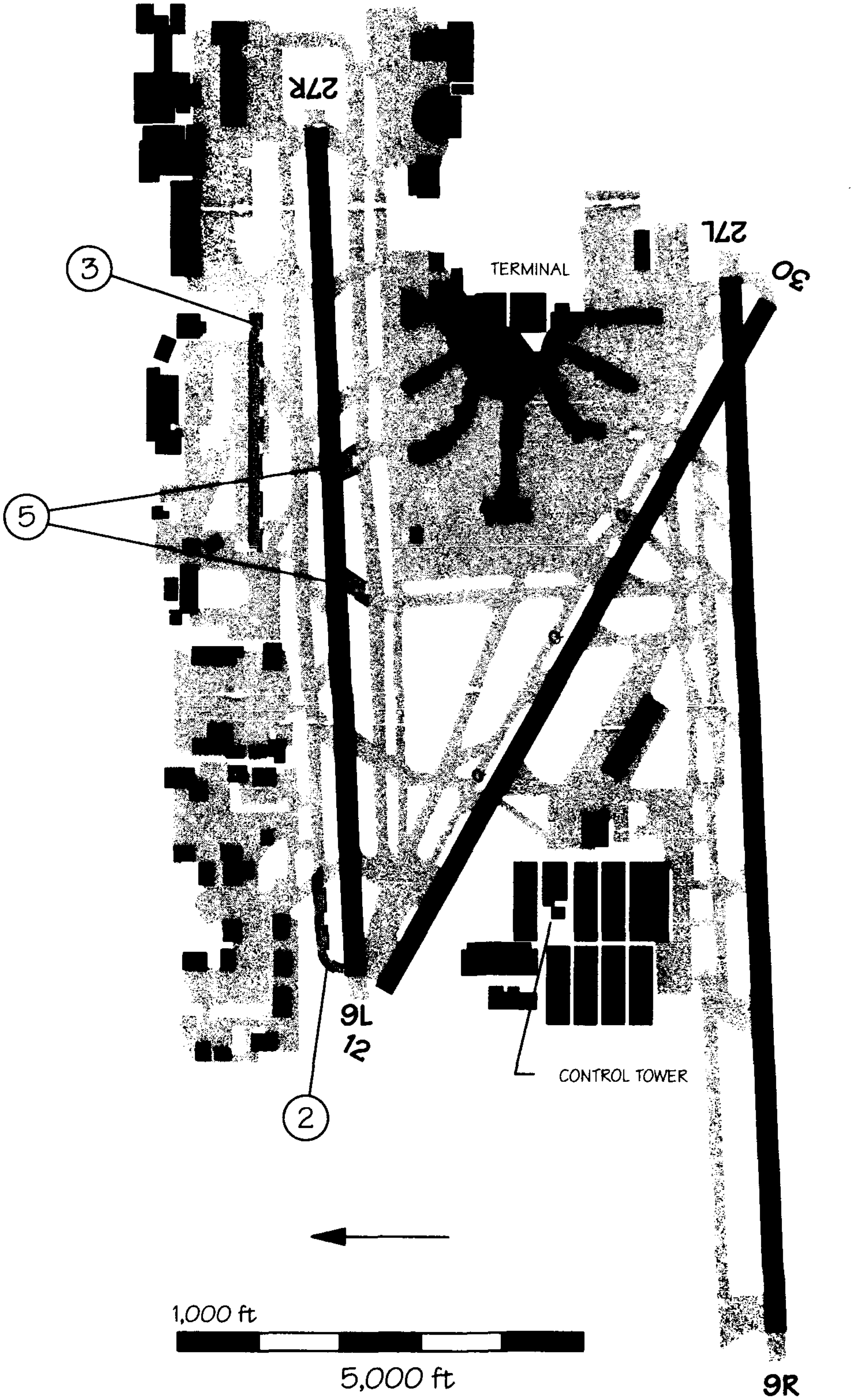
13. CAT II/III ILS on Runway 36R
14. CAT II/III ILS on Runway 36E
15. CAT II/III ILS on Runways 18R, 18L, and 18E
16. Install Airport Surface Detection Equipment (ASDE)
17. Re-route high altitude traffic away from MEM VORTAC

Operational Improvements

18. Reduce longitudinal spacing to 2.5 nm between similar class, non-heavy arrivals
19. Reduce lateral spacing (simultaneous ILS approaches to existing parallels)
20. Small aircraft hold short of Runways 3/21 and 15/33 when landing Runway 27 (regardless of wind)
21. 1.5 mile staggered ILS approach to existing parallels
22. Relief from airspace criteria

User Improvements

23. Reduce small-slow aircraft by 10 %; by 25 %
24. Uniformly distribute traffic within the hour
25. Increase GA forecast by 20%
26. Relocate Air Guard off airport


27R
27L
30
TERMINAL
3
5
9L
12
CONTROL TOWER
2
1,000 ft
5,000 ft
9R

Miami International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

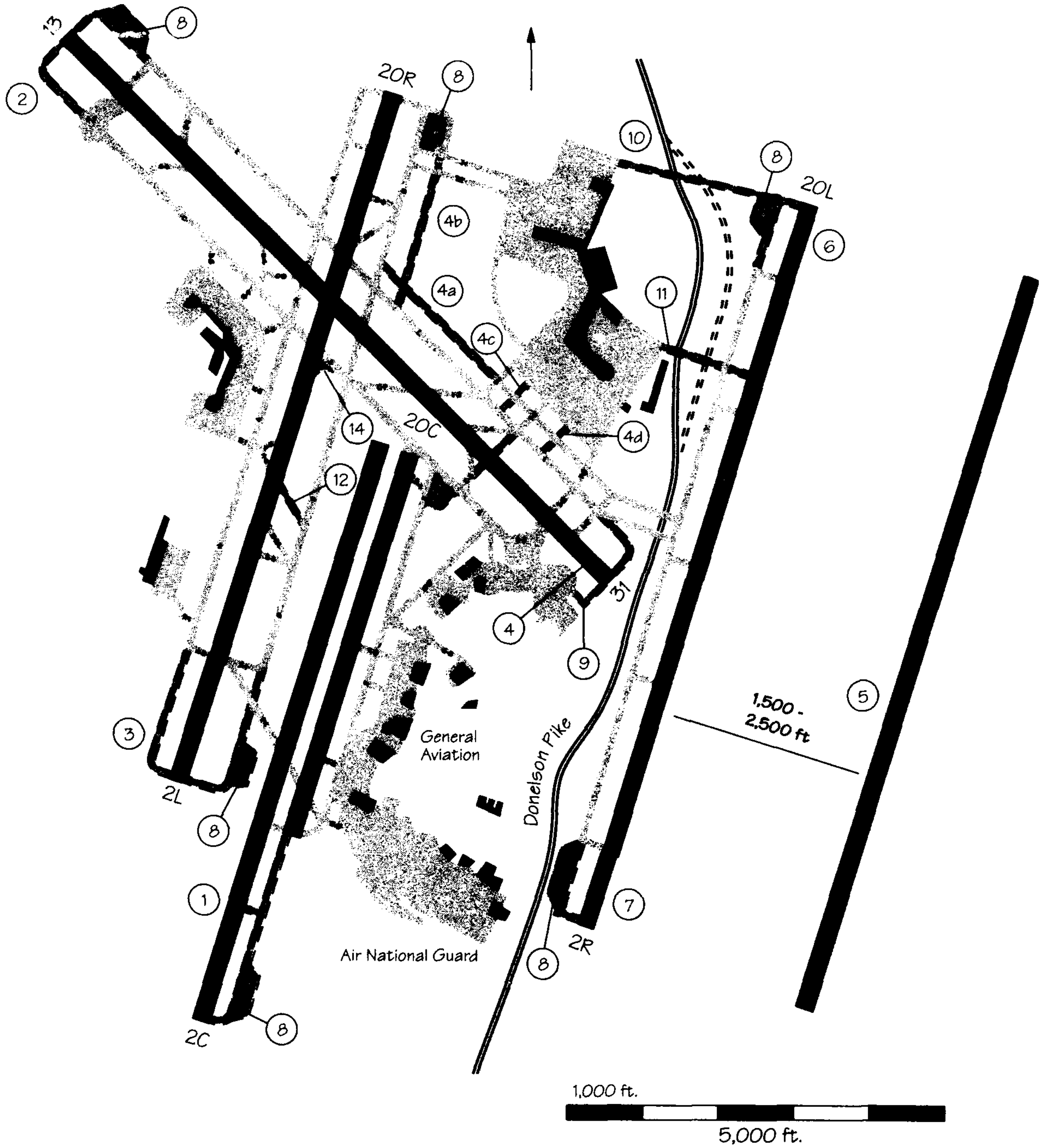
1. Dual taxiway around Concourse H (remove 2 end gates)
2. Extend Taxiway L to Runway 9L end
3. Construct new partial dual Taxiway K
4. Develop improved exits for Runway 9L/27R northside
   4a. Strengthen/reconstruct Runway 9L/27R
5. Improve Exits M4 and M5 on Runway 9L/27R

Facility and Equipment Improvements

6. CAT II on Runway 9L
7. CAT II on Runway 9R
8. Install touchdown and midpoint RVRs on Runway 9R
10. Glideslope, MALSR, and middle marker on Runway 30
11. ASDE
12. Benefits of MLS
13. Install midpoint and rollout RVRs on Runway 9L

Operational Improvements

14. Independent converging IFR approaches to Runways 12 and 9R
15. Independent converging IFR approaches to Runways 27R and 30
16. 2.5 mile in-trail longitudinal approach separation (IFR)


13
2
8
20R
8
10
8
20L
6
4b
4a
11
4c
14
20C
4d
12
31
4
9
5
1,500 -
2,500 ft
3
General
Aviation
Donelson Pike
2L
8
1
7
Air National Guard
8
2R
2C
8
1,000 ft.
5,000 ft.

Nashville International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

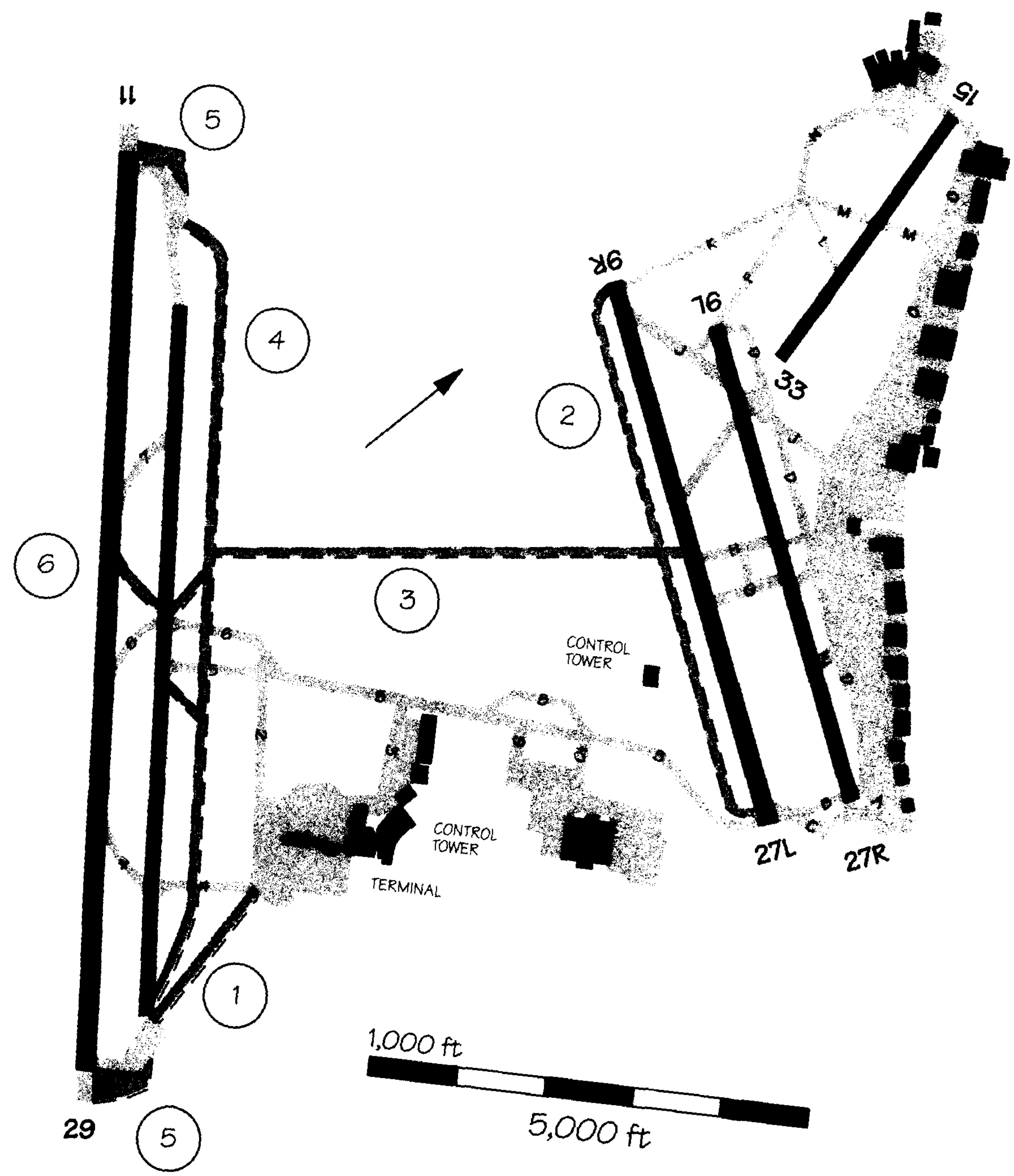
1. Relocate Runway 2C and extend to 8,000 ft
2. Extend Runway 13 to the northwest
3. Extend Runway 2L 1,300 ft. or more to the south
4. Improve terminal taxiways and ramp
   - 4a. Extend Taxiway I
   - 4b. Extend Taxiway B hold
   - 4c. Construct dual lane at Taxiway T-4
   - 4d. Construct dual lane at Taxiway T-6
5. Construct new Runway 2E/20E 1,500 to 3,000 ft. east of existing Runway 2R/20L
   - 5a. Less than 2,500 ft. east of Runway 2R/20L
   - 5b. 2,500 ft. east of Runway 2R/20L (dependent)
6. Extend existing Runway 20L 1,000 ft. north
7. Extend existing Runway 2R 1,000 ft. south
8. Construct holding (departure sequencing) pads on all runway ends (bypass capability)
9. Construct taxiway from GA area to Runway 31 departure end
10. Construct crossover taxiway from ramp to Runway 20L
11. Construct connecting taxiway from Concourse D to Runway 2R/20L
12. Construct new exit for commuters east off Runway 20R at 5,000 ft
13. Expand existing terminal
14. Round off fillet at Taxiway C and Runway 2L

Facilities and Equipment Improvements

15. Upgrade ILS on all existing and future runways
16. Install wake vortex advisory system

Operational Improvements

17. Encourage GA use of reliever airports
18. Conduct IFR dependent converging approaches to Runways 13 and 20L
19. Conduct an airspace capacity design project and re-structure terminal and en route airspace
   - 19a. Evaluate airspace restrictions
   - 19b. Revise low-altitude airway structure
20. Establish a terminal control area (TCA)


11
5
4
9R
16
15
33
2
6
3
CONTROL TOWER
CONTROL TOWER
TERMINAL
27L
27R
1
1,000 ft
5,000 ft
29
5

Oakland International Airport Capacity Design Team Project Summary

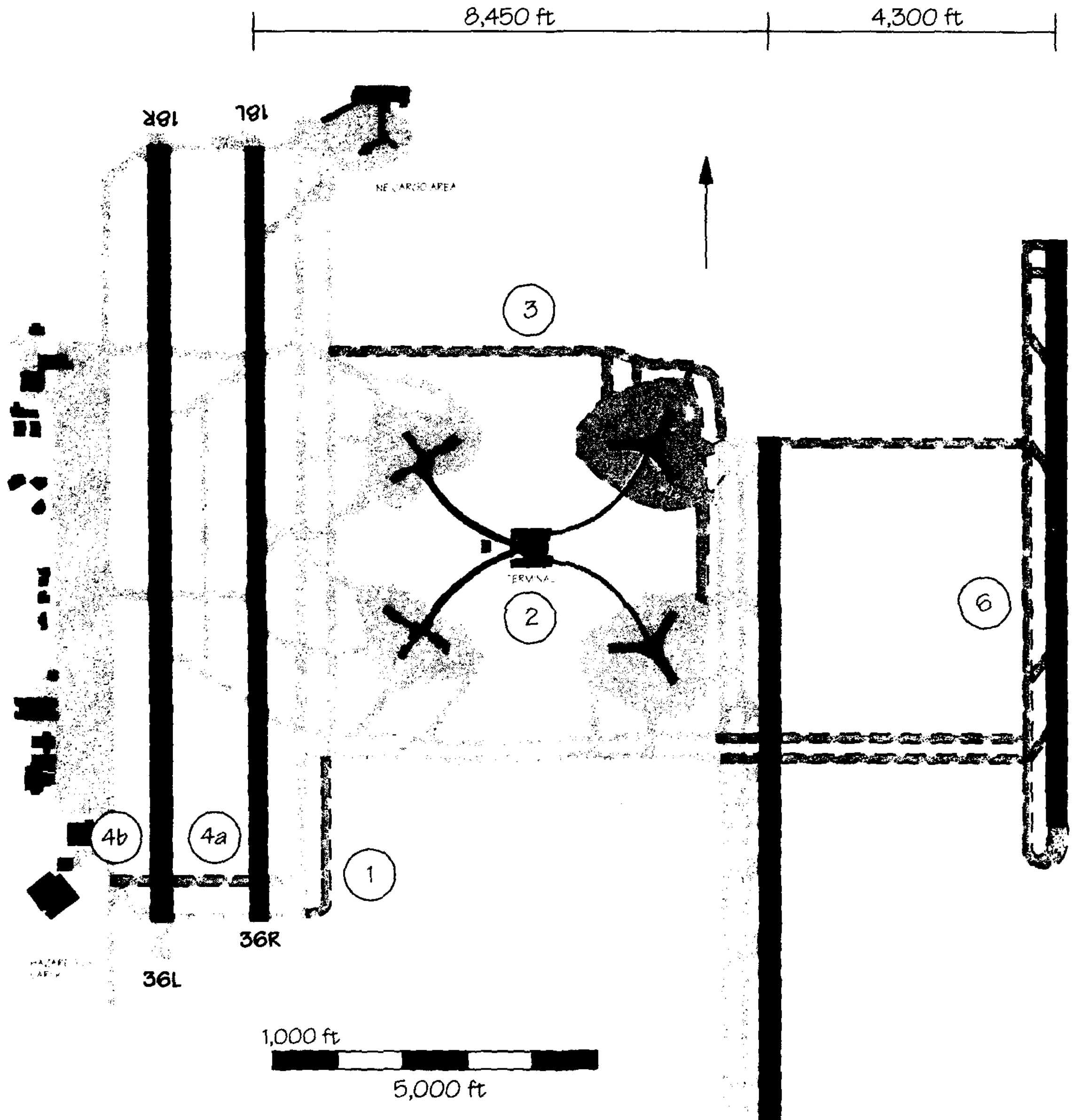
Recommendations

Airfield Improvements

1. Construct taxiway from southeast corner of terminal to Runway 29 approach threshold
2. Build taxiway parallel to Runway 27L
3. Add taxiway between north and south complexes
4. Convert Taxiway 1 to air carrier Runway 29 and add parallel taxiway
5. Enlarge staging pads at entrances to Runway 11/29
6. Construct additional angled exit off Runway 11
7. Build penalty box on south side of approach end of Runway 29

Facilities and Equipment Improvements

8. Install MLS on Runways 29 and 27
9. Install a non-directional beacon approach to Runway 29


8,450 ft
4,300 ft
18R
18L
3
2
6
4b
4a
1
36R
36L
1,000 ft
5,000 ft

Orlando International Airport
Capacity Design Team Project Summary

Recommendations

Airfield Improvements
1. Extend Taxiway C to threshold of Runway 36R
2. Construct new heliport
3. Construct north crossfield taxiway

4a. Construct new Taxiway B9 from Runway 36R to Runway 36L

4b. Construct new Taxiway B9 from Taxiway A to threshold of Runway 36L

5. Construct staging areas on all runways
6. Construct fourth runway and associated taxiways

Facilities and Equipment Improvements
7. Install VOR at OIA

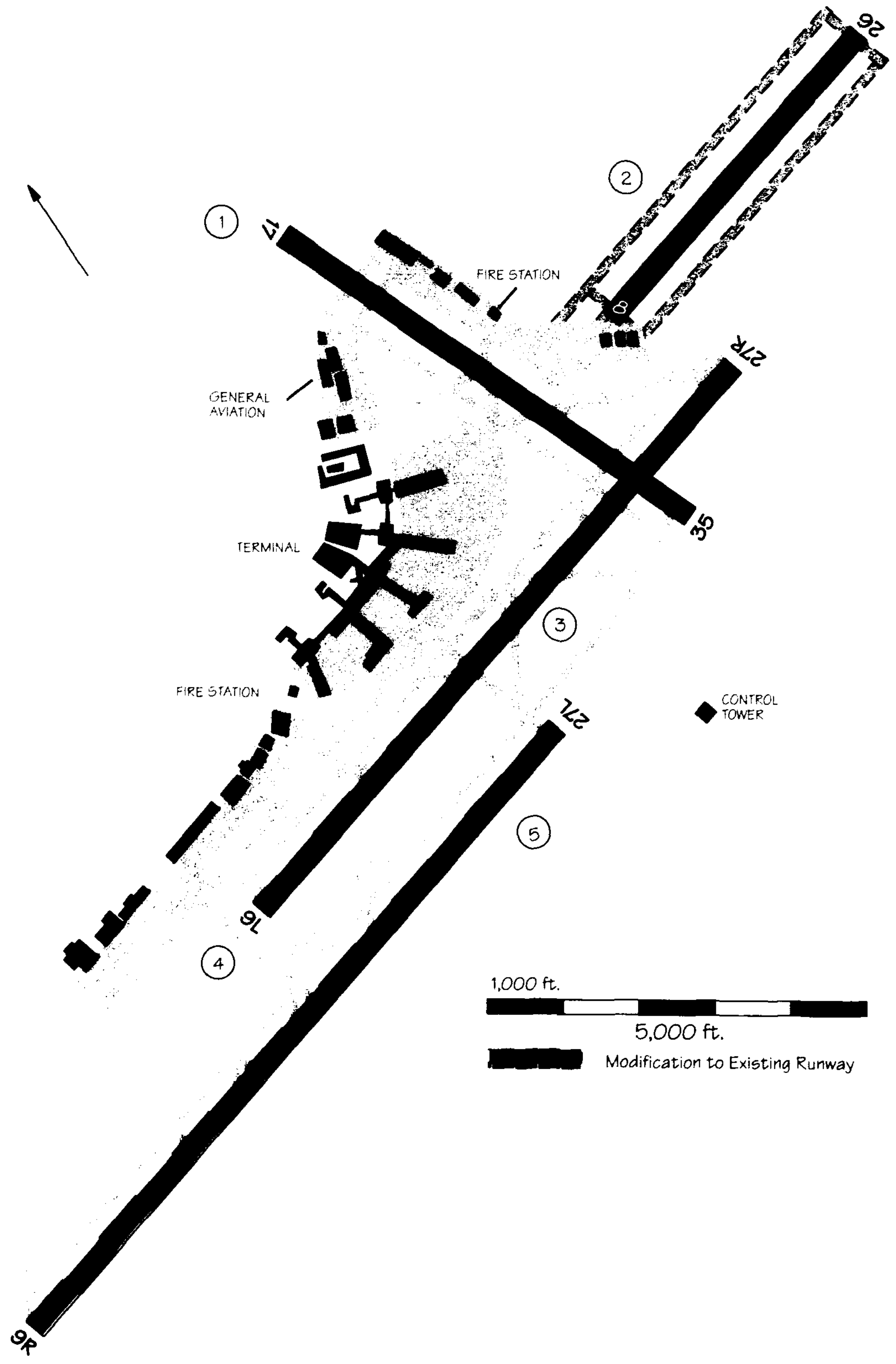
8a. Install CAT III ILS on Runway 18R

8b. Install CAT III ILS on all runways

9. Install ASDE
10. Install PRM

Operational Improvements
11. Implement ramp control by users
12. Implement triple parallel approaches (four-runway configuration using PRM)
13. Modifications to terminal airspace
14. Restructure airways
15. Use ground crossovers versus air crossovers
16. Segregate GA and helicopter operations from turbojets

User Improvements
17. Encourage GA use of alternative airports by providing new east and west reliever airports



1
2
3
4
5
17
35
26
8
27R
27L
9L
9R
FIRE STATION
GENERAL AVIATION
TERMINAL
FIRE STATION
CONTROL TOWER
1,000 ft.
5,000 ft.
Modification to Existing Runway

Philadelphia International Airport
Capacity Design Team Project Summary

Recommendations

Airfield Improvements

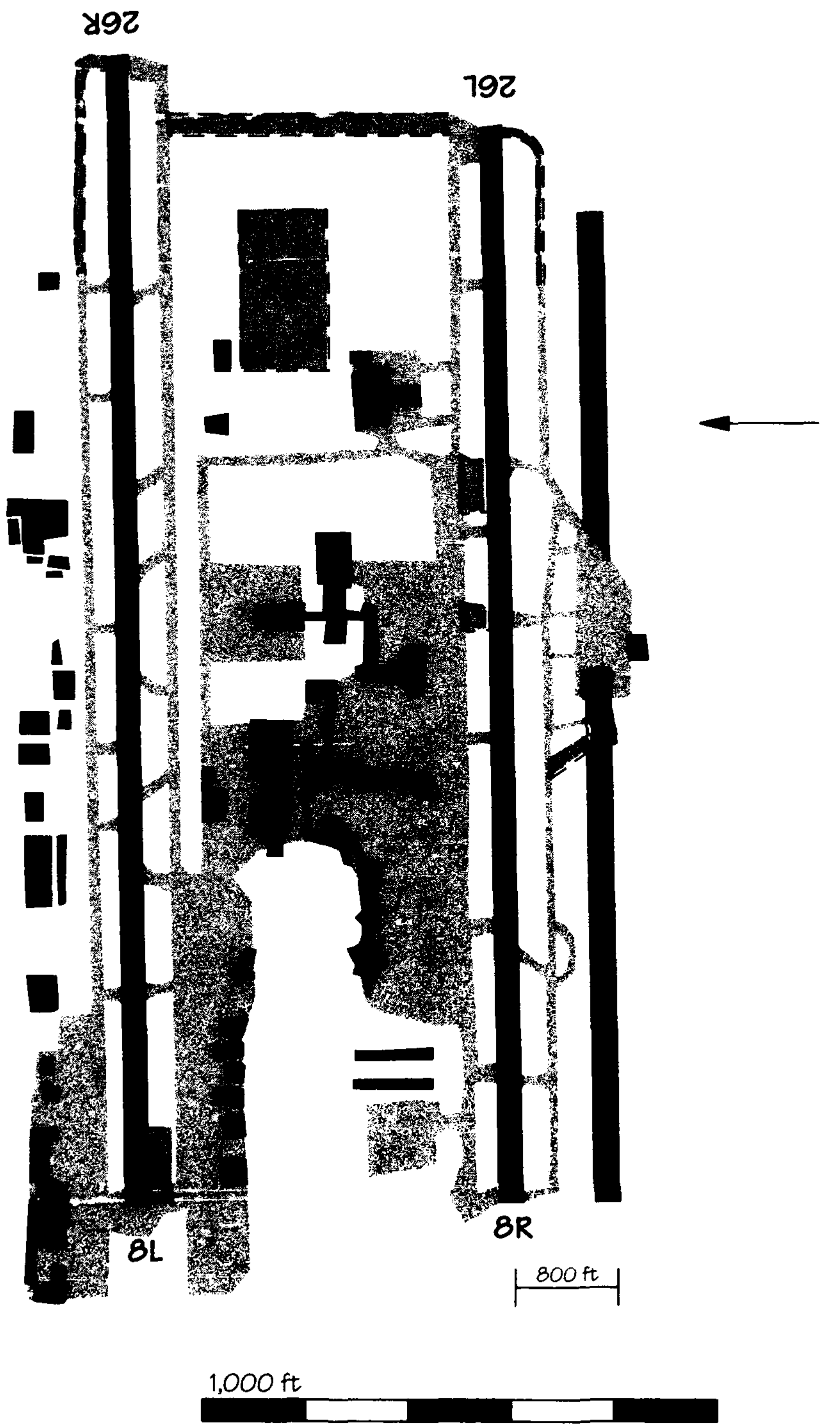
1. Extend Runway 17/35 600 ft. to the north
2. Construct new 5,000-ft commuter Runway 8/26 3,000 ft. north of Runway 9R/27L
3. Relocate Runway 9L/27R (laterally) 400 ft. to the south with associated parallel and apron taxiways
4. Relocate Runway 9L/27R (longitudinally) 2,735 ft. to the west
5. Relocate Runway 9R/27L (longitudinally) 1,000 ft. to the east.

Facilities and Equipment Improvements

6. Install localizer directional aid (LDA) on Runways 9L and 27L
   - 6a. LDA approach to Runway 27L with ILS arrivals on Runway 27R
   - 6b. LDA approach to Runway 9L with ILS arrivals on Runway 9R
7. Install Precision Runway Monitor (PRM)

Operational Improvements

8. Allow restricted air carrier use on Runway 17/35 with arrivals on Runway 35 and departures on Runway 17
9. Implement preferential taxiway routing
10. Conduct dependent instrument approaches to Runways 27L and 17
11. Conduct dependent instrument approaches to Runways 27R and 17
12. Implement a steep-angle MLS approach to Runway 27L
13. Conduct an airspace capacity design project and re-structure terminal airspace
    - 13a. Remove departure fix restrictions
    - 13b. Install terminal ATC automation (TATCA) enhancements


26R
26L
8L
8R
800 ft
1,000 ft
5,000 ft

Phoenix-Sky Harbor International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Construct new Runway 8S/26S south of Runway 8R/26L with associated taxiways
2. Construct holding aprons at two runway ends
3. Widen fillets at Taxiways C5 and C7 off of Runway 8R/26L
4. Holding area southeast of Terminal 3
5. New angled exit off of Runway 8R/26L to Taxiway C
6. New angled exit off of Runway 8S/26S to Taxiway D
7. Second midfield crossover Taxiway Y adjacent to Taxiway X
8. Crossover Taxiway W and associated taxiways at approach ends of Runway 26R and Runway 26L
9. Crossover Taxiway Z from Taxiways B3 to C3
10. Construct Terminal 4 and remove Terminal 1

11a. Extend Taxiway A to end of Runway 26R

11b. Extend Taxiway D to end of Runway 26L

12. Complete northside taxilane (parallel to and north of Taxiway C)
13. Relocation of 161st Air Refueling Group

Facilities and Equipment Improvements

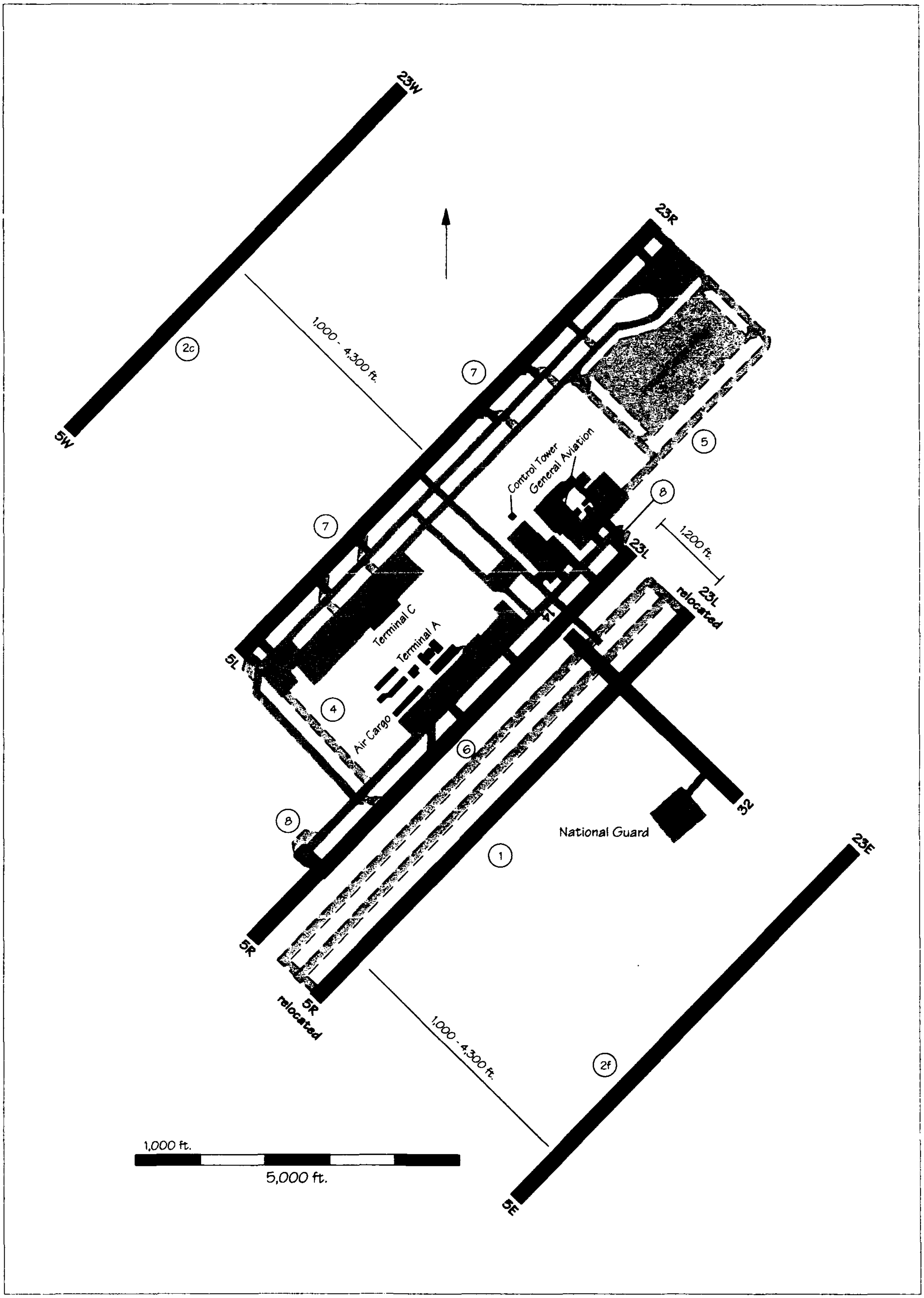
14. TVOR/VORTAC (Carefree) in northern valley
15. ILS (CAT I) for Runway 26R
16. Precision approach for Runway 8L
17. Precision approach for Runway 8S/26S
18. Potential benefits of MLS at Sky Harbor
19. VORTAC near airport

Operational Improvements

20. Reduce in-trail separations to 2.5 miles
21. Reduce runway occupancy times
22. IFR dependent parallel approaches
23. IFR independent parallel approaches
24. Segregate fast and slow aircraft
25. Reduce arrival to intersection departure separation
26. Reduce in-trail departure restrictions to allow simultaneous departures
27. Reduce noise restrictions to utilize special turboprop corridors

User Improvements

28. Uniformly distribute scheduled commercial operations within the hour
29. Provide attractive alternative facilities for GA at other airports
30. Pilot education for reduced runway occupancy times


23W
5W
2c
1,000 - 4,300 ft.
7
7
23R
5
Control Tower
General Aviation
8
1,200 ft.
23L
23L
relocated
14
Terminal C
Terminal A
5L
4
Air Cargo
6
8
32
National Guard
1
5R
5R
relocated
1,000 - 4,300 ft.
23E
2f
5E
1,000 ft.
5,000 ft.

Raleigh-Durham International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Relocate Runway 5R/23L 1,200 ft. southeast and extend to 9,000 ft. in length
2. Construct new 8,000 ft. third parallel Runway 5W/23W

   Runway 5W/23W

   2a. 1,000 to 2,400 ft. from Runway 5L/23R

   2b. 2,500 ft. from Runway 5L/23R

   2c. 3,000 to 4,300 ft. from Runway 5L/23R

   Runway 5E/23E

   2d. 8,000 ft. runway 1,000 to 2,400 ft. from relocated Runway 5R/23L

   2e. 8,000 ft. runway 2,500 ft. from relocated Runway 5R/23L

   2f. 8,000 ft. runway 3,000 to 4,300 ft. from relocated Runway 5R/23L
3. Construct new fourth parallel Runway 5E/23E (assumes Runway 5W/23W in place)

   3a. Triple independent/dependent arrivals

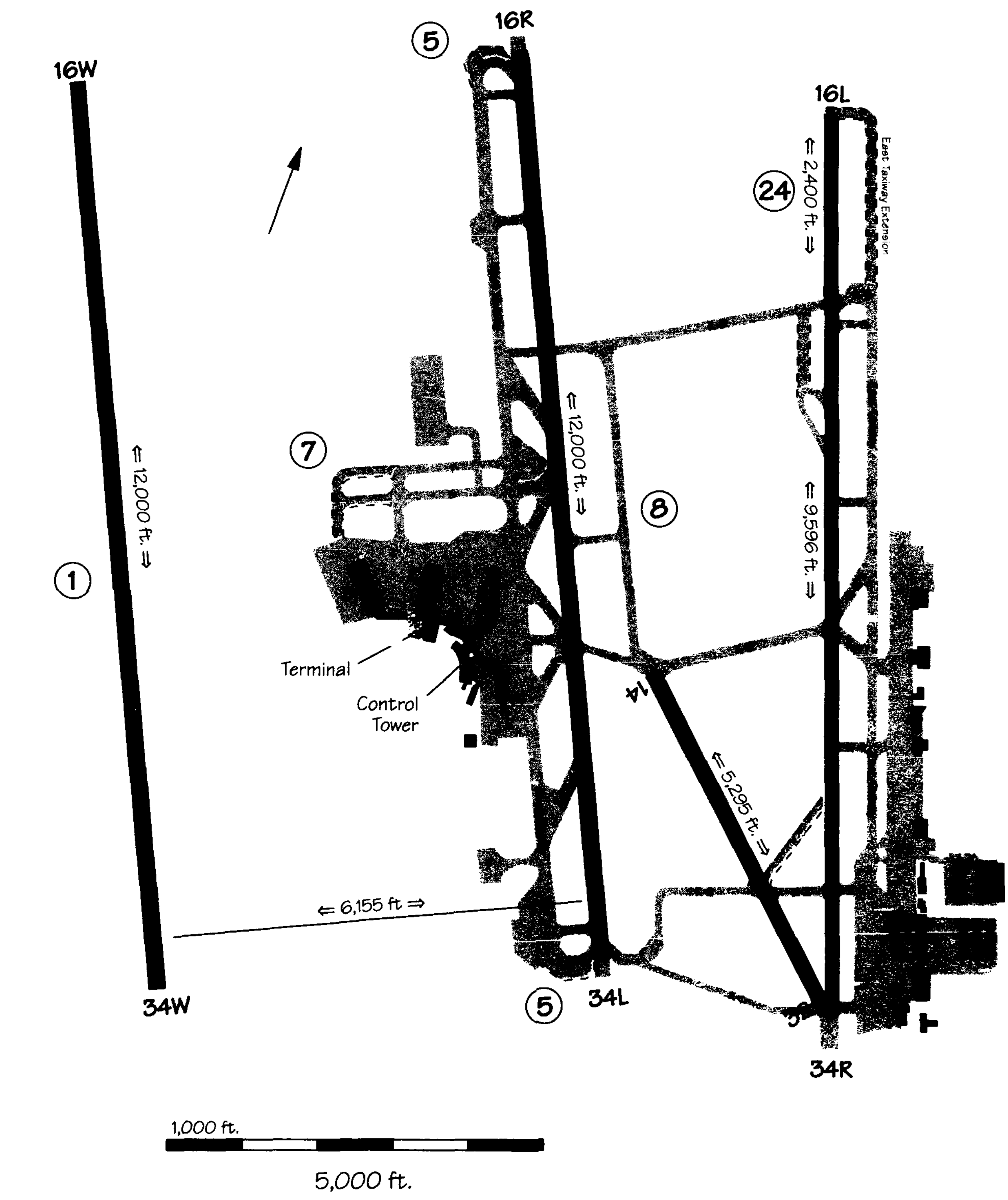
   3b. Triple independent arrivals
4. Construct dual parallel taxiway near feeder Taxiway E
5. Construct taxiway from new cargo complex to Runway 5R/23L
6. Construct full-length dual parallel taxiways for Runway 5R
7. Construct angled exits on Runway 5L/23R
8. Expand holding and sequencing pads and bypass taxiways on Runway 5R/23L and all future runways

Facilities and Equipment Improvements

9. Install CAT II/III ILS on existing and future runways
10. Install runway visual range (RVR) on Runway 23L and future runways
11. Install wake vortex advisory system
12. Install airport surface detection equipment (ASDE)

Operational Improvements

13. Implement staggered approaches with 1.5 nm separation
14. Implement independent approaches to existing runways (Precision Runway Monitor (PRM))
15. Implement 2.5 nm spacing between similar class, non-heavy aircraft arrivals in IFR
16. Establish a terminal control area (TCA)
17. Study noise abatement procedures
18. Conduct an airspace capacity design project and restructure terminal and en route airspace


16R
5
16W
16L
⇑ 2,400 ft. ⇓
East Taxiway Extension
24
7
⇑ 12,000 ft. ⇓
⇑ 12,000 ft. ⇓
8
⇑ 9,596 ft. ⇓
1
Terminal
Control Tower
14
⇐ 5,295 ft. ⇒
⇐ 6,155 ft ⇒
34W
5
34L
34R
1,000 ft.
5,000 ft.

Salt Lake City International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Construct a parallel runway to the west with independent IFR capability (CAT III ILS on both ends)
2. Taxiway to Delta Air Lines hangar
3. Relocate tower
4. Revised taxiway exit layout
5. Construct staging areas for Runway 16R/34L at runway entrances
6. Terminal expansion
7. Extend Taxiways S and T to west boundary of the terminal ramp
8. Rehabilitate Taxiways X and Y
9. Improve aircraft access to cargo facilities

Facilities and Equipment Improvements

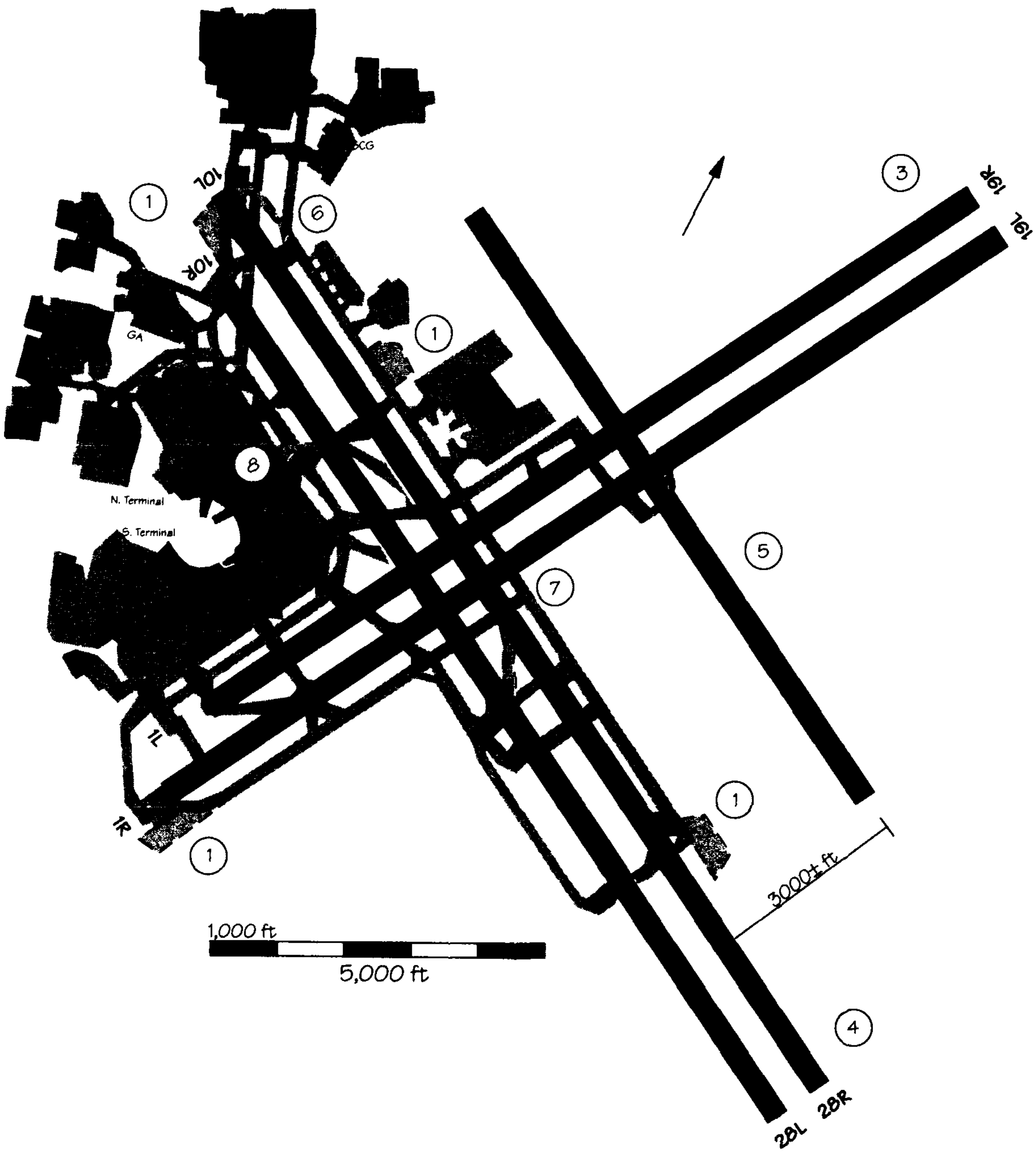
10. CAT I ILS on Runway 34R
11. LDA approach to Runway 34R
12. CAT III ILS on Runway 16R
13. Install Precision Runway Monitor (PRM)
14. Install Microwave Landing System (MLS)
15. Install runway visual range (RVR) equipment on Runway 34R
16. Install Airport Surface Detection Equipment (ASDE)
17. Install taxiway centerline lights

Operational Improvements

18. Make Bonneville routing one-way
19. Reduce in-trail arrival separation standard to 2.5 nm (like class aircraft only)
20. IFR independent converging approaches

User Improvements

21. Reduce runway occupancy times through pilot education (10%, 20%, or 30% runway occupancy time reduction)
22. Improve reliever airports (reduce general aviation operations by 10%, 20%, or 30%)
23. Delta Air Lines ramp control tower


10L
10R
1
6
3
19R
19L
GA
CG
1
8
N. Terminal
S. Terminal
5
7
1L
1R
1
1
3000± ft
1,000 ft
5,000 ft
4
28L
28R

San Francisco International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Create holding areas near Runways 10L, 10R, 1R, and 28R
2. Improve noise barrier for Runway 1R
3. Extend Runway 19L/19R
4. Extend Runway 28L/28R
5. Construct independent parallel Runway 28
6. Extend Taxiway C to threshold of Runway 10L
7. Create high speed exit from Runway 10L between Taxiways L and P
8. Extend Taxiway T to Taxiway A

Air Traffic Control Improvements

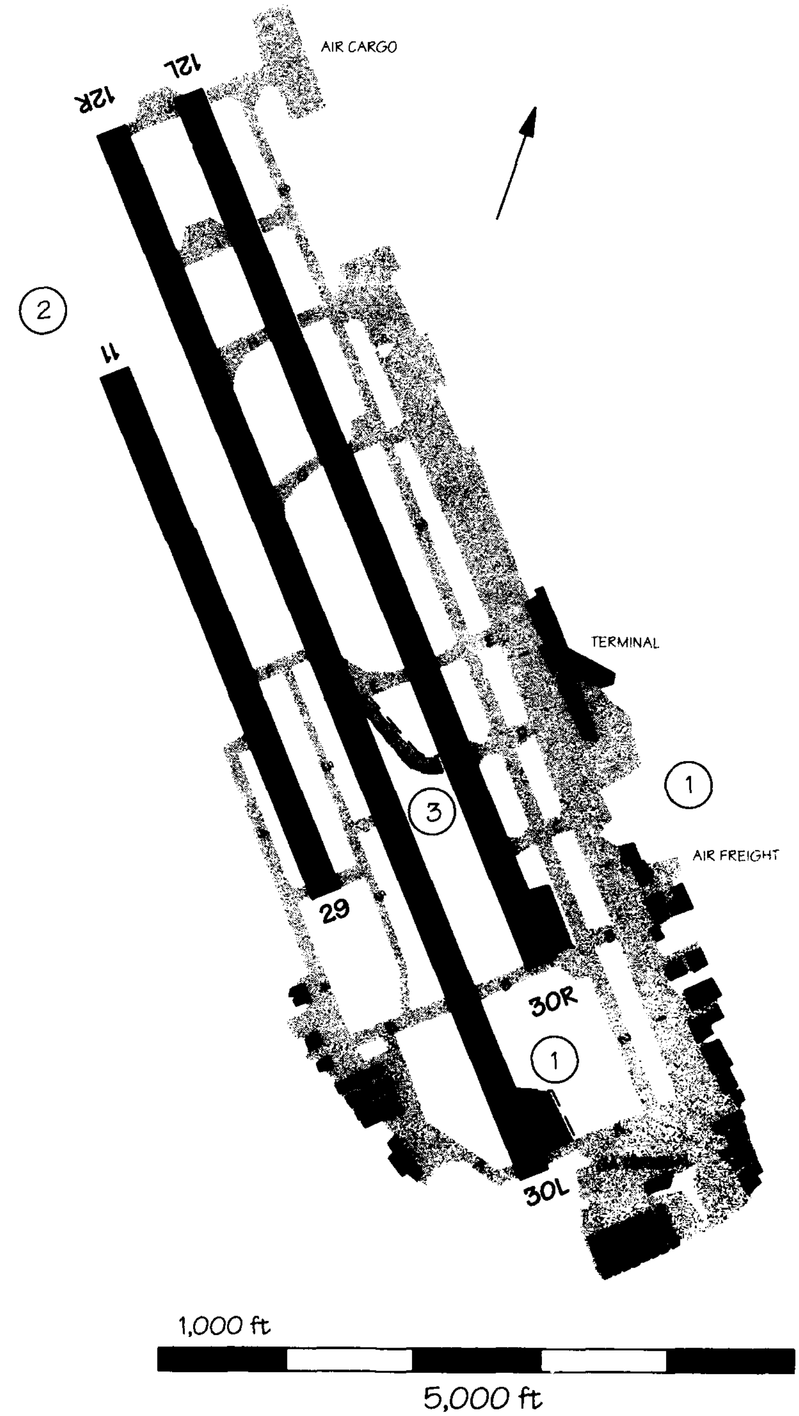
9. Expand visual approach procedures
10. Offset instrument approach to Runway 28R
11. Use staggered 1-mile divergent IFR departures on Runway 10L/10R

Facilities and Equipment

12. Install Microwave Landing System (MLS) on Runways 28 and 19

User Improvements

13. Taxi aircraft across active runways instead of towing
14. Distribute airline traffic more evenly among three airports
15. Distribute traffic uniformly within the hour
16. Divert 50% general aviation to reliever airports


AIR CARGO
12R
12L
2
11
TERMINAL
1
3
AIR FREIGHT
29
30R
1
30L
1,000 ft
5,000 ft

San Jose International Airport
Capacity Design Team Project Summary

Recommendations

Airfield Improvements

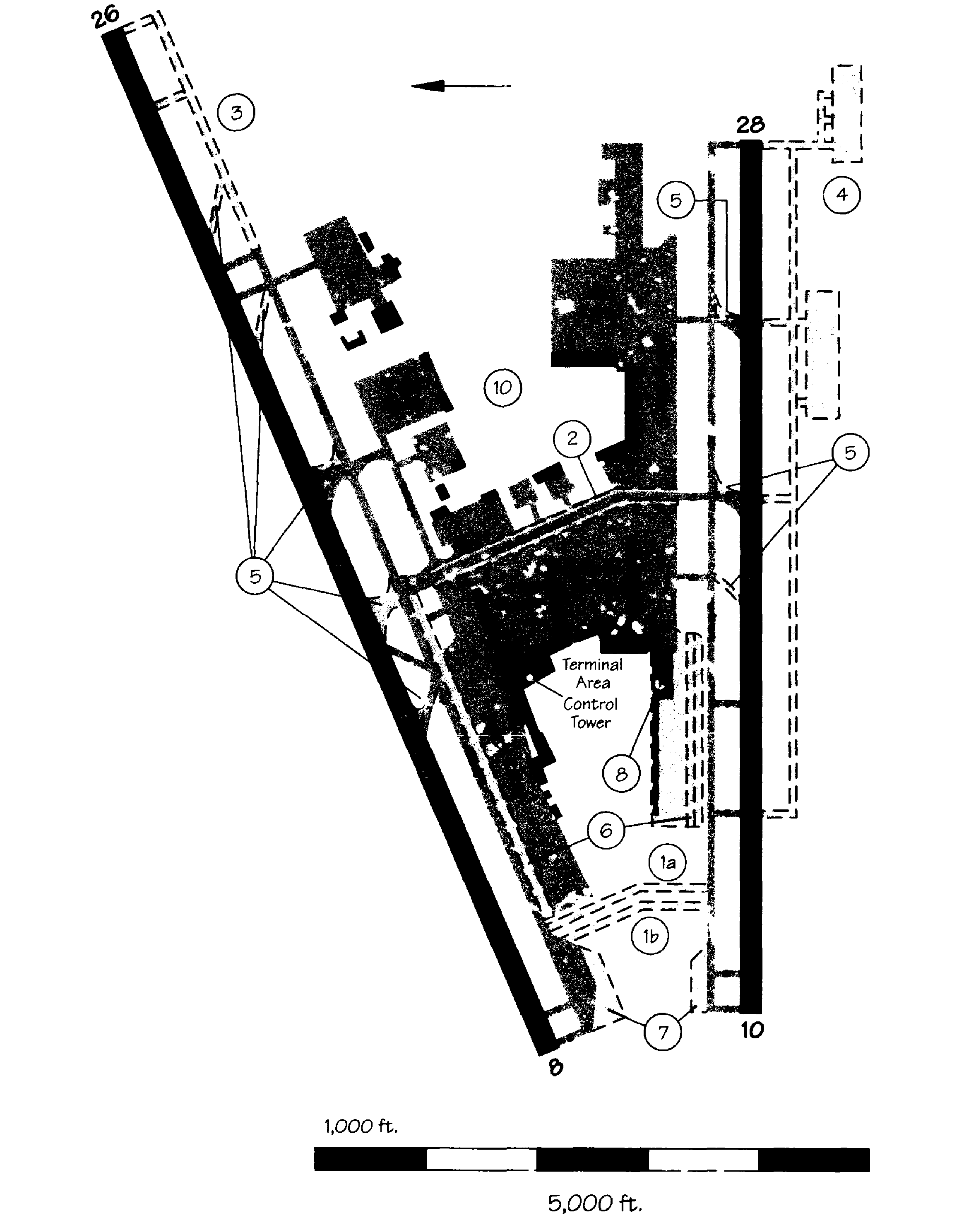
1. Create staging area at Runway 30L
1. Create staging area at Runway 30R
2. Extend and upgrade Runway 11/29
   2a. Extension of Runway 30R
3. Create angled exits for Runway 12R

Facilities and Equipment Improvements

4. Promote use of reliever ILS training facility
5. Install MLS on Runway 30L

Air Traffic Control Improvements

6. Implement simultaneous departure with Moffett Field


26
28
3
4
5
10
2
5
5
Terminal
Area
Control
Tower
8
6
1a
1b
7
10
8
1,000 ft.
5,000 ft.

San Juan Luis Muñoz Marín International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Construct new north/south taxiway complex at the west end
   1a. Single one-way taxiway
   1b. Two-directional taxiway
2. Expand existing north/south taxiway to provide two-directional capability
3. Extend Taxiway S
4. Construct new ramp area on south side of airport
5. Construct new/improve existing exits on Runways 8 and 10
6. Expand existing Taxiways S and H to dual taxiways adjacent to north and south ramps
7. Construct holding pads (staging areas) on Runways 8 and 10
   7a. With three hold positions
   7b. With five hold positions
8. Construct new international passenger terminal

Facilities and Equipment Improvements

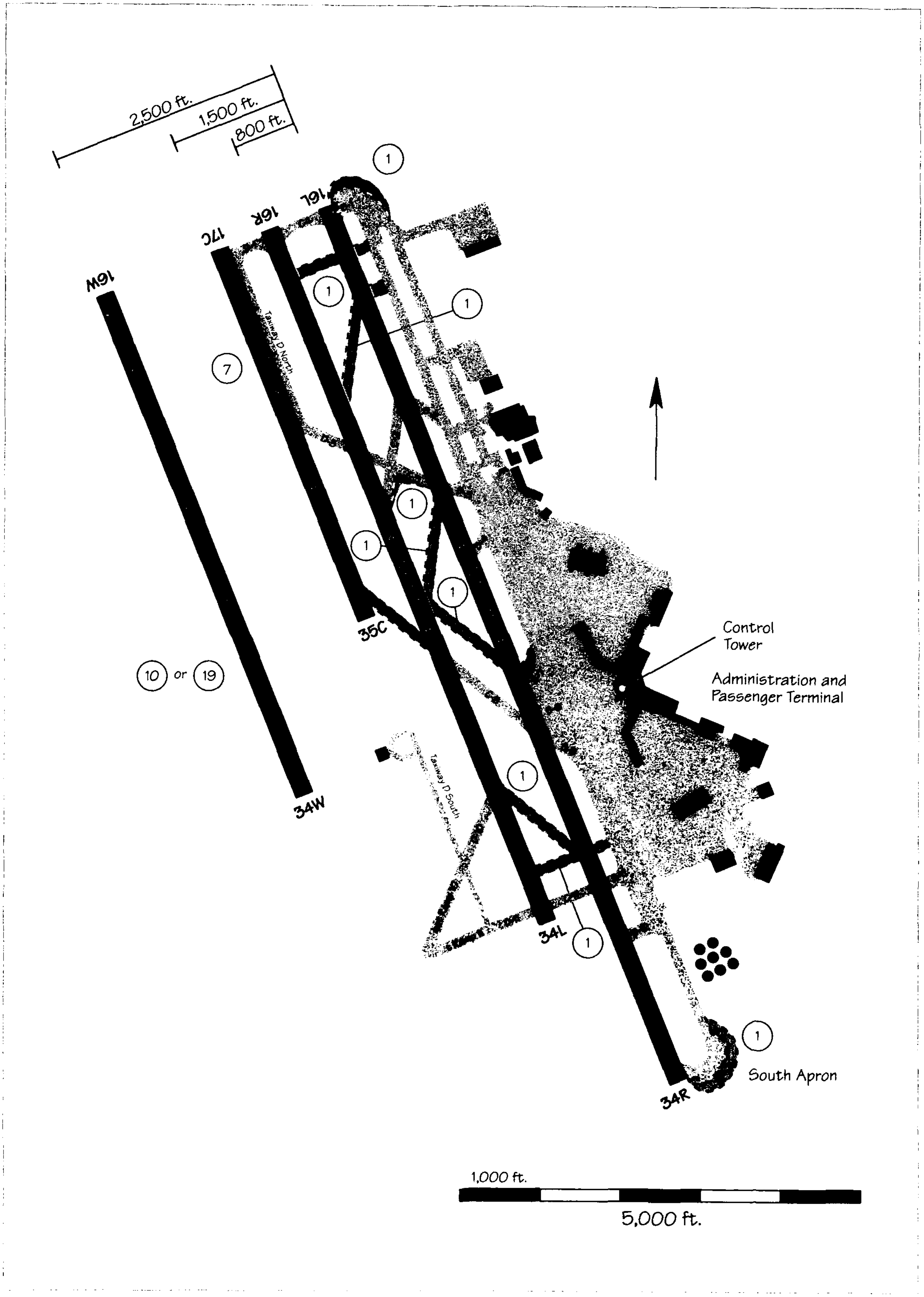
9. Upgrade VOR to include doppler
10. Construct new air traffic control tower
11. Install wake vortex advisory system
12. Install terminal ATC automation (TATCA) enhancements
13. Install improved approach aids on Runway 26
    13a. Install Precision Approach Path Indicator (PAPI)

Operations Improvements

14. Implement improved oceanic separations (no fix restrictions)
15. Use 2.5 nm separations on final approach
16. Unrestricted use of Runway 10

User Improvements

17. Remove military operations
18. Enhance general aviation (GA) reliever airports and reduce GA activity by 50 %


2,500 ft.
1,500 ft.
800 ft.
16W
17C
16R
16L
Taxiway D North
Taxiway D South
35C
34W
34L
34R
1
7
10 or 19
Control Tower
Administration and Passenger Terminal
South Apron
1,000 ft.
5,000 ft.

Seattle-Tacoma International Airport Capacity Design Team Project Summary

Recommendations

Improvements to Existing Airfield

1. Improved exit and taxiway construction
2. Reduce in-trail spacing to 2.5 nm
3. CAT I ILS on Runway 16L (IFR-1)
4. LDA approach to Runway 16L/34R and ILS to Runway 16R/34L
5. Noise abatement effect on departures
6. Install wake vortex advisory system

New Runway Improvements

Commuter Runway

7. Commuter Runway 17C/35C (converted Taxiway D)
8. LDA to Runways 17C/35C and ILS to Runway 16L/34R
9. Install wake vortex advisory system

Dependent Runway

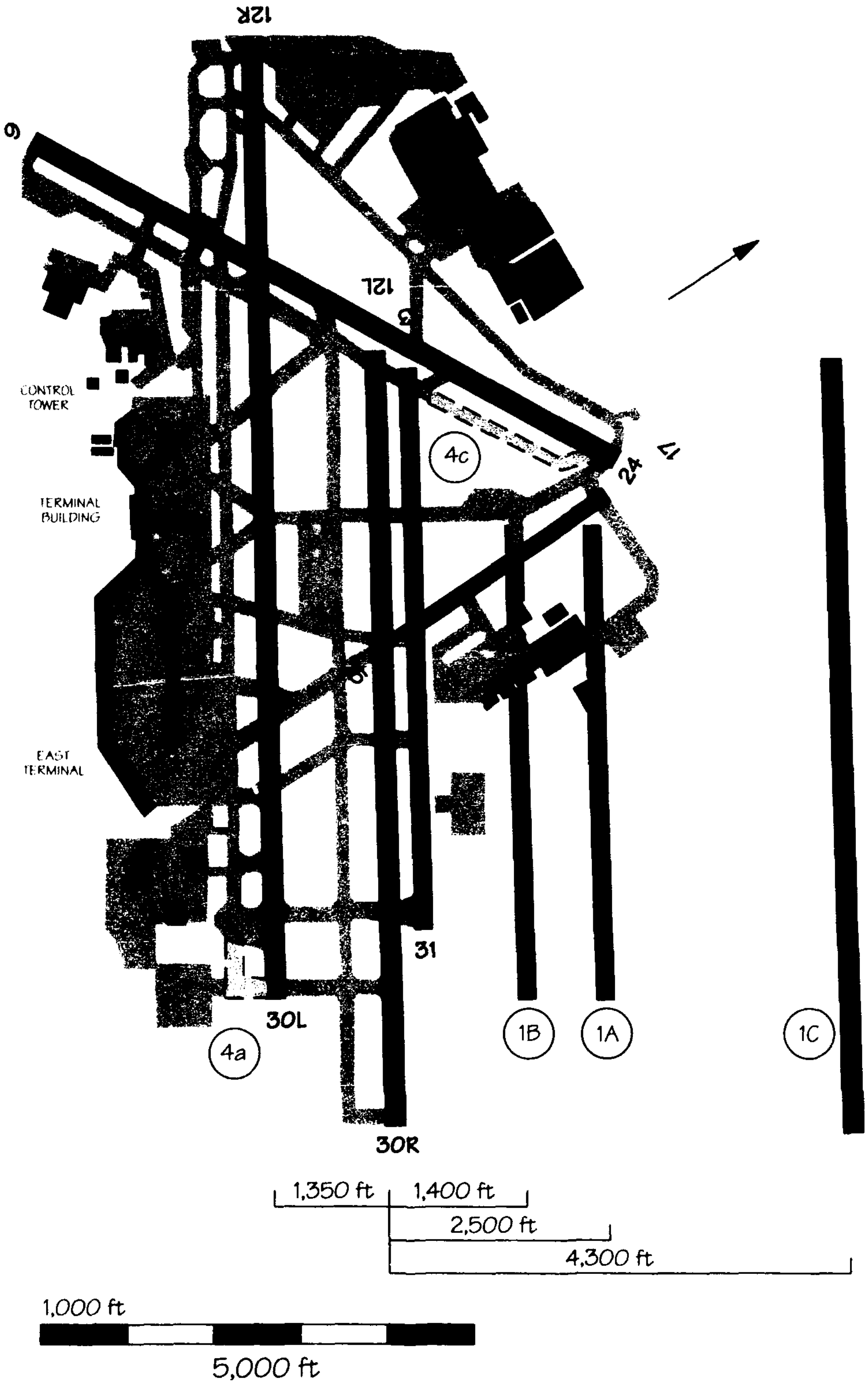
10. Air carrier (dependent) Runway 16W/34W
11. LDA approaches to Runway 16W/34W
12. CAT I ILS on Runway 16W (IFR-1)
13. CAT II ILS on Runway 16W (over CAT I)
14. CAT I ILS on Runway 34W (IFR-1)
15. Staggered approaches to Runways 16L/16W and 34R/34W - 2.0 nm stagger
16. Staggered approaches to Runways 16L/16W and 34R/34W - 1.5 nm stagger
17. Operate Runway 16R/34L as primary runway versus Runway 16L/34R with Runway 16W/34W
18. Install wake vortex advisory system

Independent Runway

19. Air carrier (independent) Runway 16W/34W
20. CAT II on Runway 16W (only)

Demand Management

21. Uniformly distribute scheduled commercial operations


12R
9
12L
3
CONTROL TOWER
TERMINAL BUILDING
EAST TERMINAL
4c
24
21
31
30L
4a
30R
1B
1A
1C
1,350 ft
1,400 ft
2,500 ft
4,300 ft
1,000 ft
5,000 ft

Lambert-St. Louis International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. New runway parallel to Runway 12L/30R
   1a. Alternate 1: new independent commuter runway 2500' from Runway 12L/30R
   1b. Alternate 2: new dependent commuter runway 1400' from Runway 12L/30R
   1c. Alternate 3: new independent air carrier runway parallel to Runway 12L/30R
2. Convert Taxiway F to VFR Runway 13/31
3. Angled exits on Runway 12L/30R
4. Taxiway extensions
   4a. Extend Taxiway A south to end of Runway 30L
   4b. Extend Taxiway P from Taxiway C to Taxiway M
   4c. Extend Taxiway C from Taxiway F to end of Runway 24
5. Realign Taxiway B off Taxiway A to Runway 12R/30L
6. Establish queuing areas to various runway ends
7. Relocate cargo area
8. Relocate mid coast aviation to northeast

Facilities and Equipment Improvements

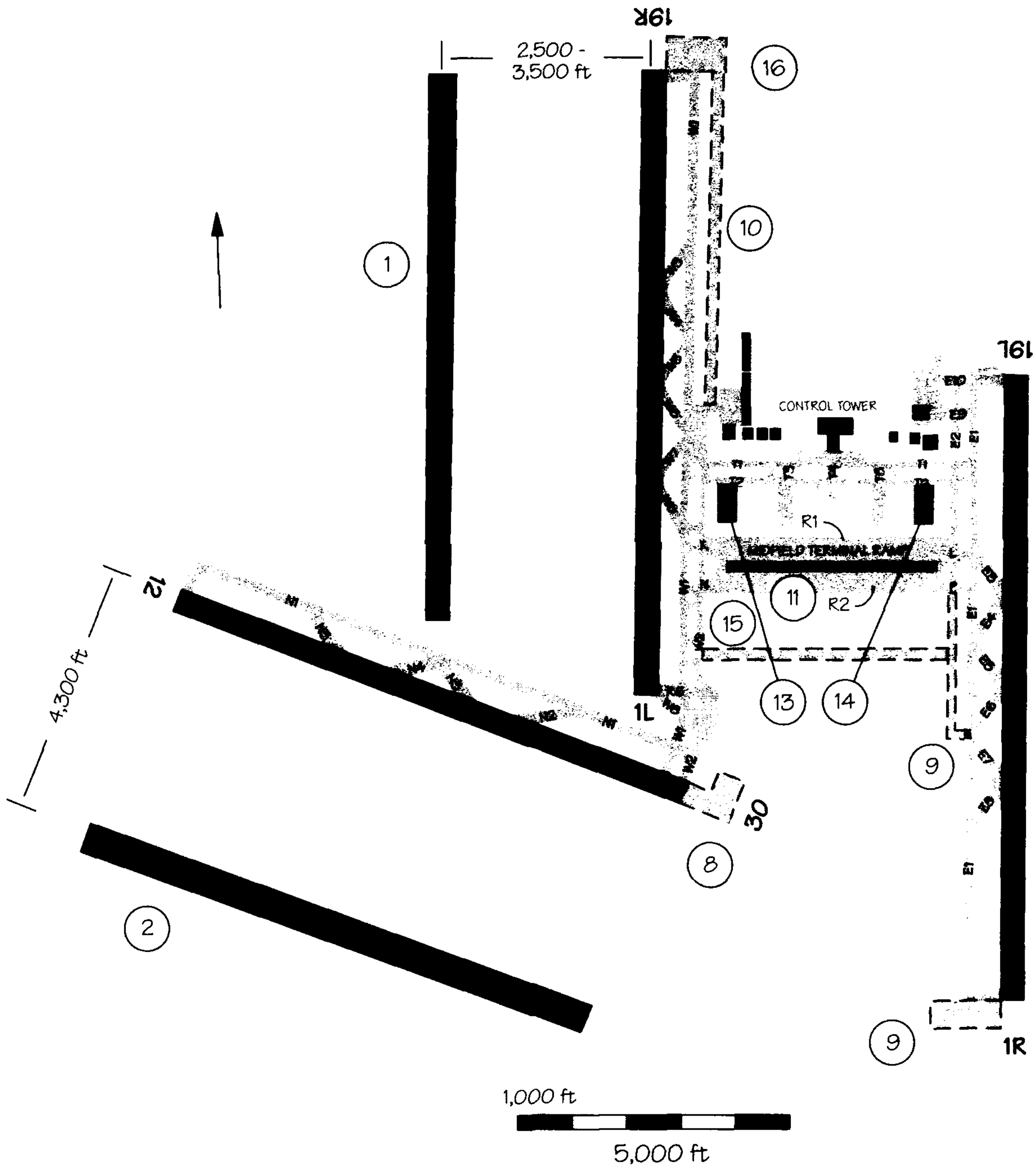
9. Install marker lights and parking lanes in center field remote holding area
10. Install wake vortex advisory system
11. Install CAT III ILS to reduce approach minima on Runways 12L and 12R
12. IFR approaches with additional instrumentation on Runway 6
13. IFR approaches with additional instrumentation on Runway 24
14. LDA approaches support
    14a. Equipment installation on Runway 30L
    14b. Equipment installation on Runway 12L
15. Install light systems at taxiway and runway intersections
16. Install ASDE

Operational Improvements

17. Reduce IFR parallel approach stagger to 2 nm
18. Reduce IFR in-trail separations to 2.5 nm
19. Converging IFR approaches to
    19a. Runways 6 and 30R
    19b. Runways 6 and 30L
20. Converging IFR approaches to
    20a. Runways 24 and 30R
    20b. Runways 24 and 30L
21. Simultaneous approaches to ILS Runway 30R, LDA Runway 30L, and ILS Runway 24

User Improvements

22. Change fleet mix
    22a. Relocate GA 25%
    22b. Relocate GA 50%
    22c. Relocate GA 75%
23. Distribute scheduled commercial operations within the hour
24. Relocate Air National Guard



19R
2,500 -
3,500 ft
16
10
1
19L
CONTROL TOWER
R1
MIDFIELD TERMINAL RAMP
11
R2
15
12
4,300 ft
1L
13
14
9
30
8
2
9
1R
1,000 ft
5,000 ft

Washington Dulles International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Construct Runway 1W/19W 3,500 ft west of Runway 1L/19R
2. Construct Runway 12R/30L south of Runway 12/30
3. Widen turnback fillets on Runway 1L (at Exits W-3, W-5)
4. Widen turnback fillets on Runway 19L (at Exits E-6, E-8) (not pictured)
5. Complete construction of east/west Taxiway R-2
6. Add GA exits to Runways 19R (north of Exit W-3) and 19L (north of Exit E-3)
7. Extend Runway 12/30 southeast and enlarge Runway 30's holding pads
8. Add Runway 1R holding pad and extend Taxiway E-2 south (to south of Exit E-7)
9. Runway 19R staging improvements: extension of Taxiway W-2 north, Runway 19R holding pad, and Runway 19R bypass taxiway
10. Add midfield ramp
11. Add centerfield north/south taxiway
12. Midfield Terminal — Phase 1A (24 gates)
13. Midfield Terminal — Phase 1B (48 gates)
14. Add east/west Taxiway R-3, south of R-2, with 2 north/south stubs
15. Additional FBO, east of Runway 19R threshold

Facilities and Equipment Improvements

16. Touchdown RVR and touchdown zone lights on Runway 1L
17. Touchdown RVR and centerline lights on Runways 12 and 30 and touchdown zone lights on Runway 12

Operational Improvements

18. Simultaneous ILS approaches to existing parallel runways
19. Simultaneous converging instrument approaches to Runways 12 and 19R or 12 and 19L
20. 2.5 nm longitudinal spacing inside outer marker (between similar class, non-heavy arrivals)

User Improvements

21. Redistribute traffic more uniformly within the hour
22. Improve reliever airports: reduce small-slow aircraft by 25%; by 50%

Appendix C

New Runway Construction Projects at Major U.S. Airports

Albany (ALB) C-2
Albuquerque (ABQ) C-3
Amarillo (AMA) C-4
Atlanta (ATL) C-5
Austin (AUS) C-6
Baltimore-Washington (BWI) C-7
Birmingham (BHM) C-8
Boston (BOS) C-9
Buffalo (BUF) C-10
Charlotte (CLT) C-11
Chicago (ORD) C-12
Cincinnati (CVG) C-13
Cleveland (CLE) C-14
Colorado Springs (COS) C-15
Columbus (CMH) C-16
Dallas-Fort Worth (DFW) C-17
Dayton (DAY) C-18
New Denver (DVX) C-19
Detroit (DTW) C-20
Fort Lauderdale (FLL) C-21
Fort Myers (RSW) C-22
Grand Rapids (GRR) C-23
Greensboro (GSO) C-24
Greer Greenville-Spartanburg (GSP) C-25
Harlingen (HRL) C-26
Houston (IAH) C-27
Indianapolis (IND) C-28
Jacksonville (JAX) C-29
Kansas City (MCI) C-30
Knoxville (TYS) C-31
Las Vegas (LAS) C-32
Little Rock (LIT) C-33
Los Angeles (LAX) C-34
Louisville (SDF) C-35
Lubbock (LBB) C-36
Memphis (MEM) C-37
Midland (MAF) C-38
Milwaukee (MKE) C-39
Minneapolis (MSP) C-40
Nashville (BNA) C-41
New Orleans (MSY) C-42
New York (JFK) C-43
Newark (EWR) C-44
Norfolk (ORF) C-45
Oakland (OAK) C-46
Oklahoma City (OKC) C-47
Orlando (MCO) C-48
Philadelphia (PHL) C-49
Phoenix (PHX) C-50
Pittsburgh (PIT) C-51
Raleigh-Durham (RDU) C-52
Rochester (ROC) C-53
St. Louis (STL) C-54
Salt Lake City (SLC) C-55
San Jose (SJC) C-56
Sarasota (SRQ) C-57
Savannah (SAV) C-58
Seattle-Tacoma (SEA) C-59
Spokane (GEG) C-60
Syracuse (SYR) C-61
Tampa (TPA) C-62
Tucson (TUS) C-63
Tulsa (TUL) C-64
Washington (IAD) C-65
West Palm Beach (PBI) C-66

Legend

Existing Runway

Existing Taxiway/Apron

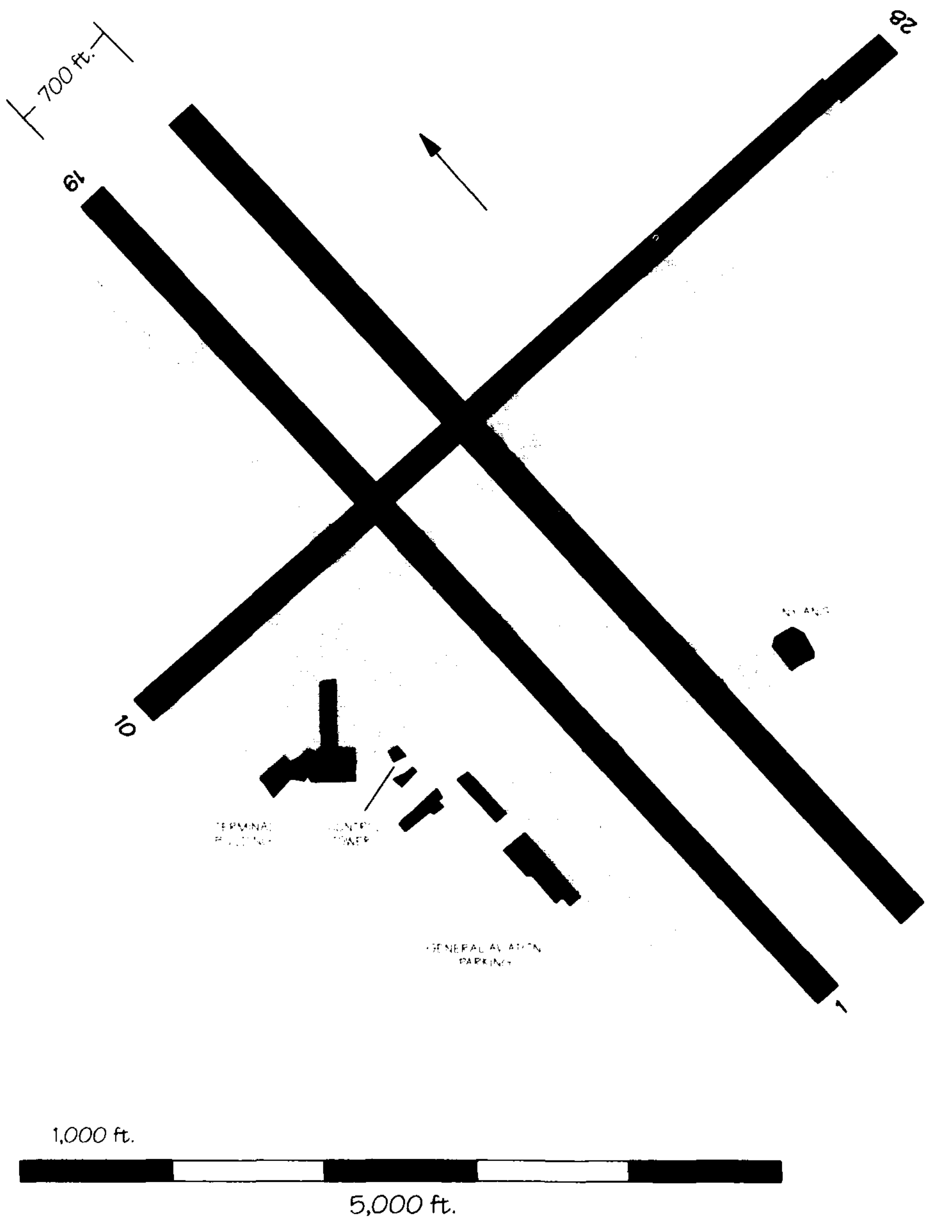
Proposed Runway/Runway Extension

Proposed Taxiway/Apron/Facility Improvements

Buildings

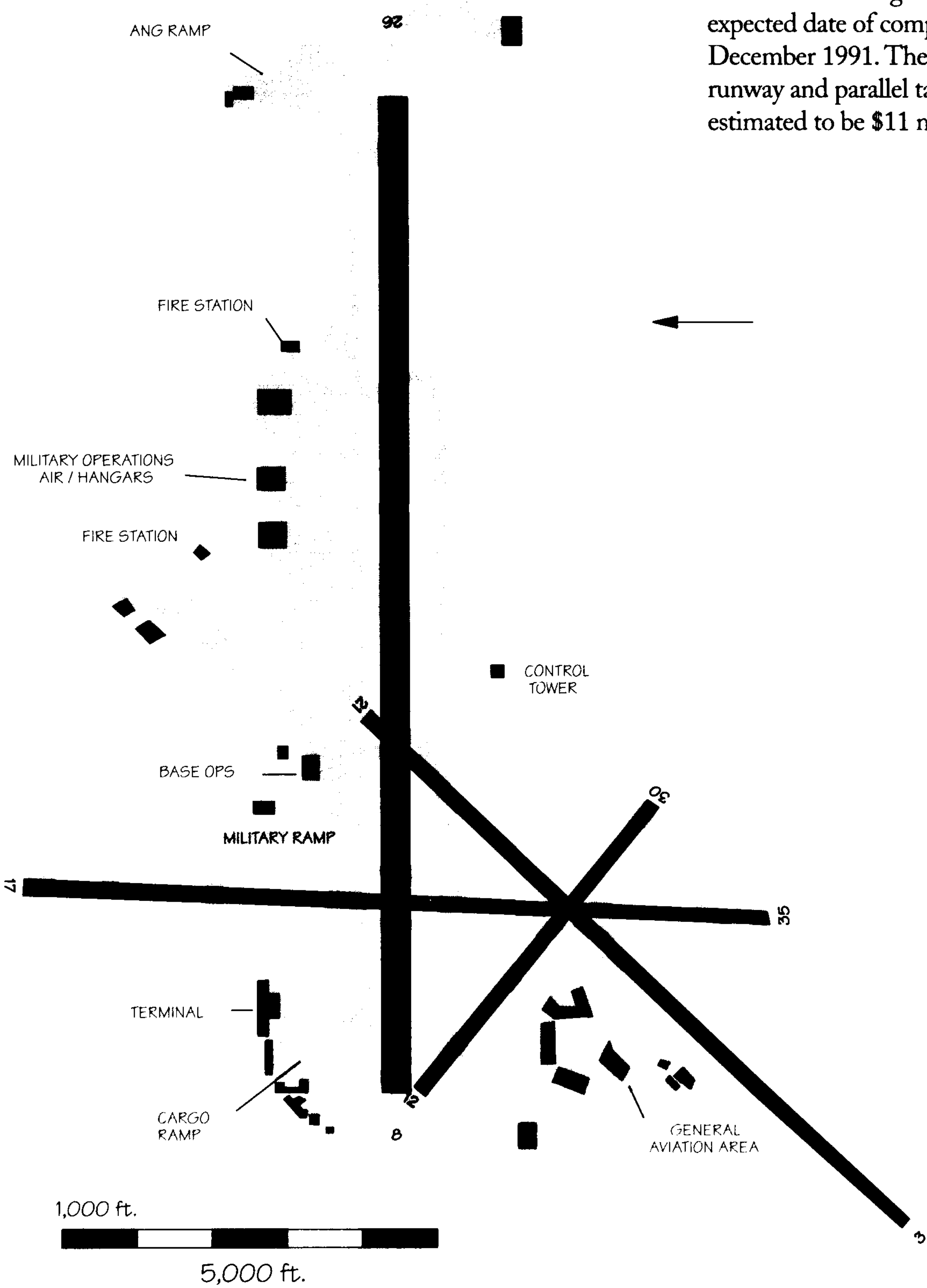
Albany (ALB)

An extension to Runway 10/28 is expected to begin in 1996 and should be completed sometime in 1997. The cost of constructing the extension is estimated to be $2 million. Albany is also planning a new parallel Runway 1R/19L to begin in 1997 and should be operational in 1999. Cost of construction is estimated to be $15 million.



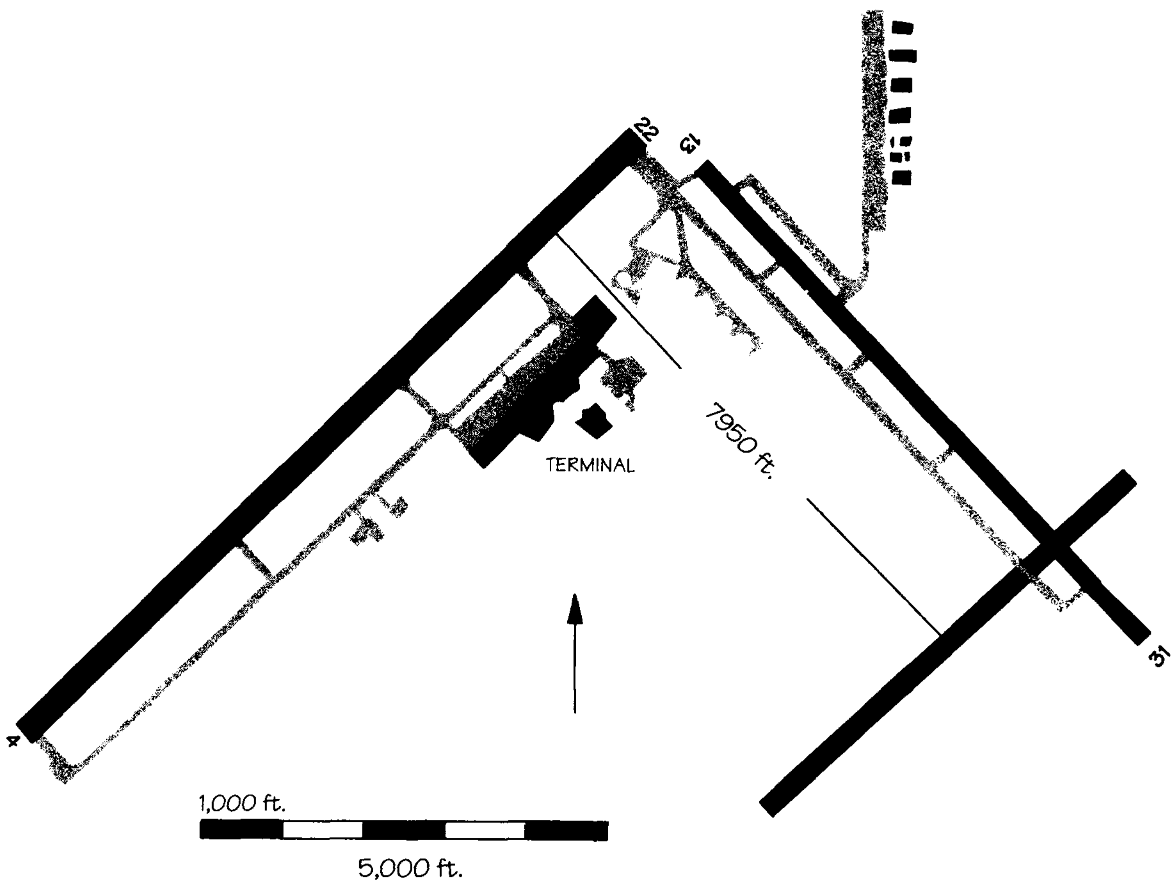
Albuquerque (ABQ)

A 3,200 foot extension to Runway 3/21 is underway. The work will provide an 8,800 foot runway, eliminating the intersection with Runway 8/26. Construction started in August 1989. The expected date of completion is December 1991. The cost of the runway and parallel taxiway is estimated to be $11 million.



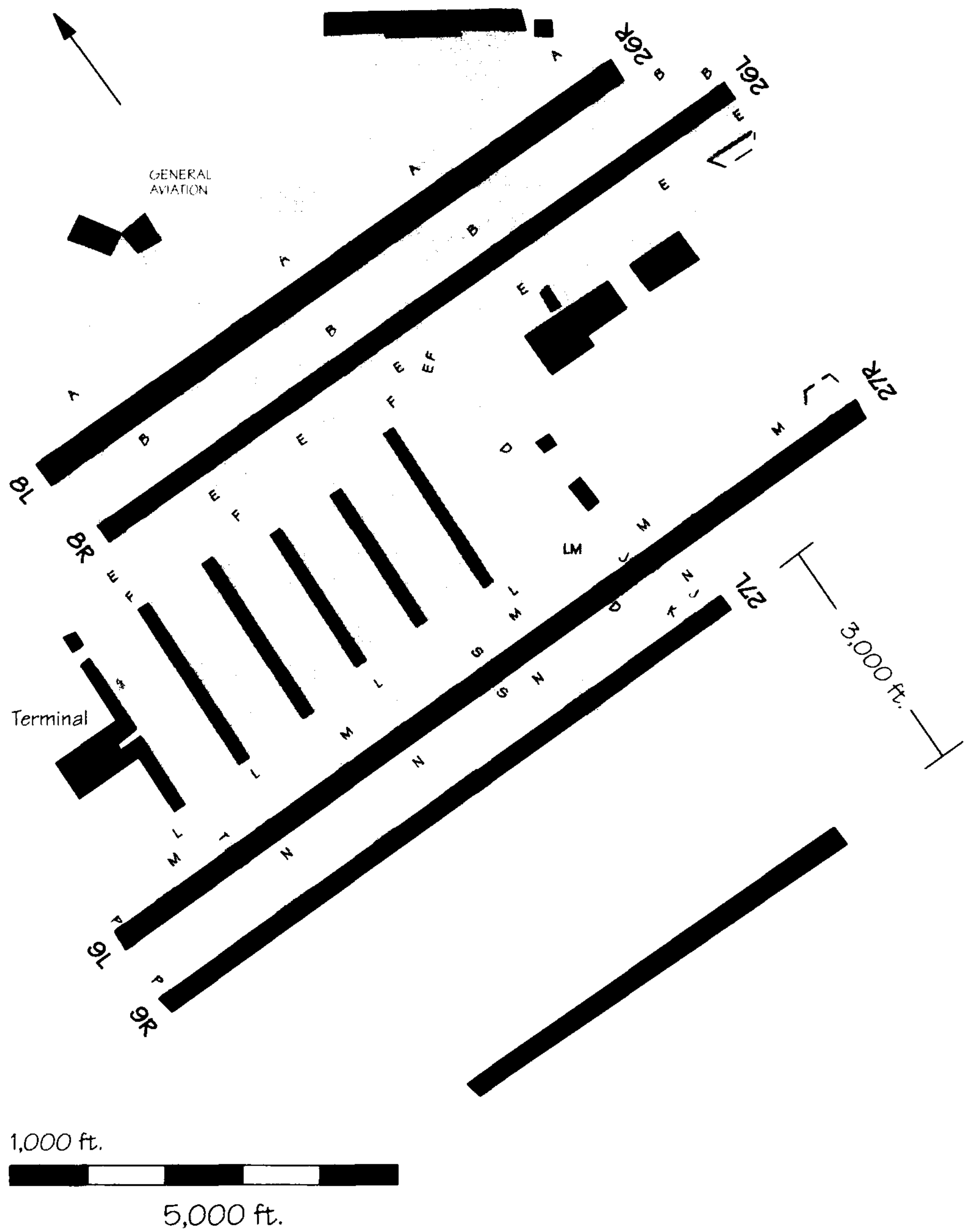
Amarillo (AMA)

An extension to Runway 13/31 is expected to be completed by late 1997.



Atlanta (ATL)

A fifth parallel runway, 5,500 feet long and 3,000 feet south of Runway 9R/27L, is being planned at Atlanta. The total estimated cost is $130 million. Construction is estimated to start in 1992; the estimated operational date is 1995.



Austin (AUS)

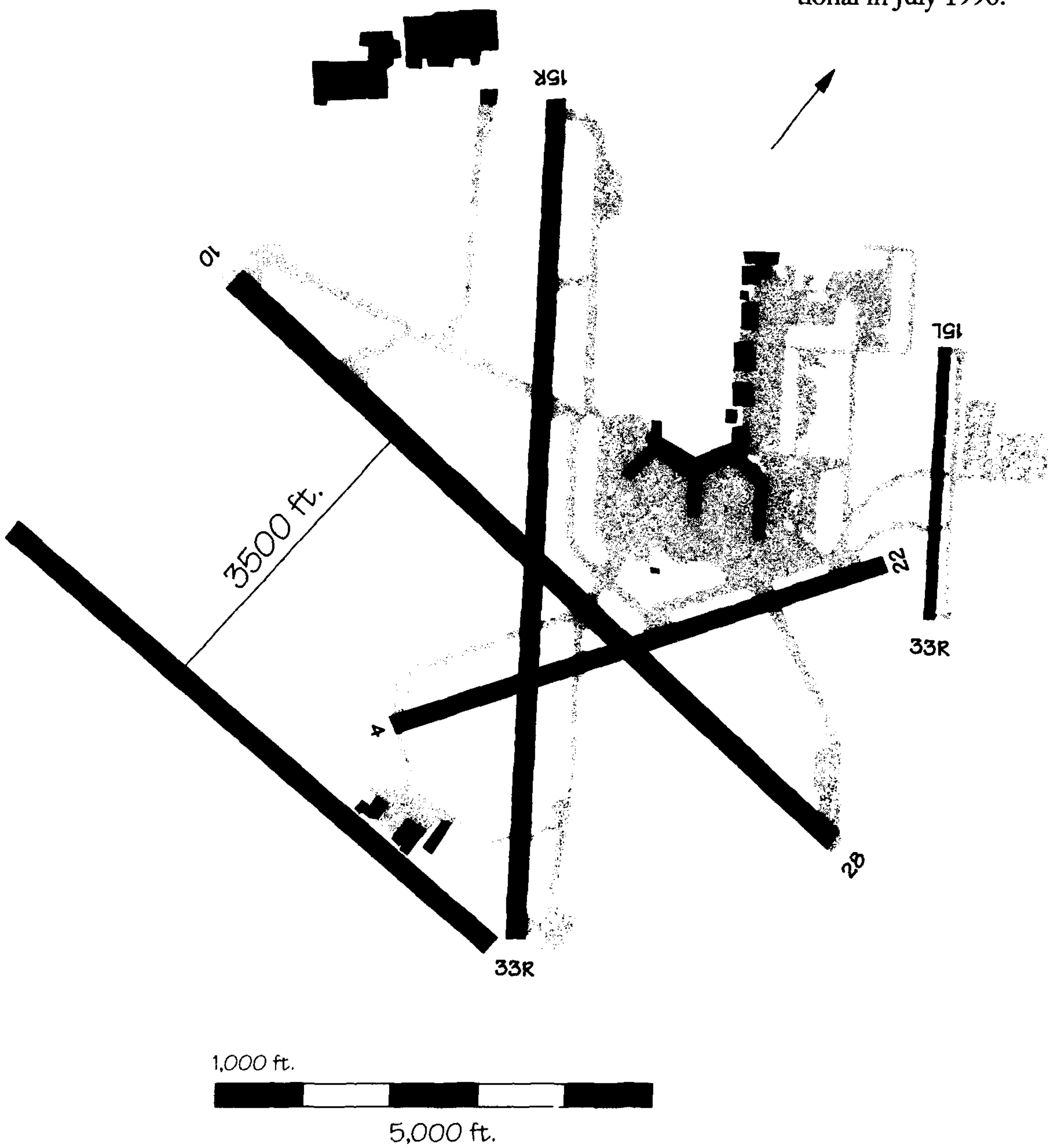
The community has approved the sale of revenue bonds for the development of a new airport. The environmental assessment for the new airport site has been approved. The present airport cannot be expanded. The new airport site will accommodate dual parallel runways that support simultaneous instrument approaches, which will potentially double the IFR arrival capacity from 26 (at Robert Mueller Airport) to 52 per hour. The cost of construction of Phase 1 of the new airport, including the land, terminal, and two runways, is $550 million. The estimated operational date is January 1997. Since Robert Mueller Airport will close upon completion of the new airport, no capacity enhancements are planned at Mueller.

Development activities have recently been suspended pending a decision by the Air Force regarding the closing of Bergstrom AFB. Should Bergstrom AFB close, it could potentially be available for development as a civil airport for the Austin area.

No layout of the new Austin airport was available at press time.

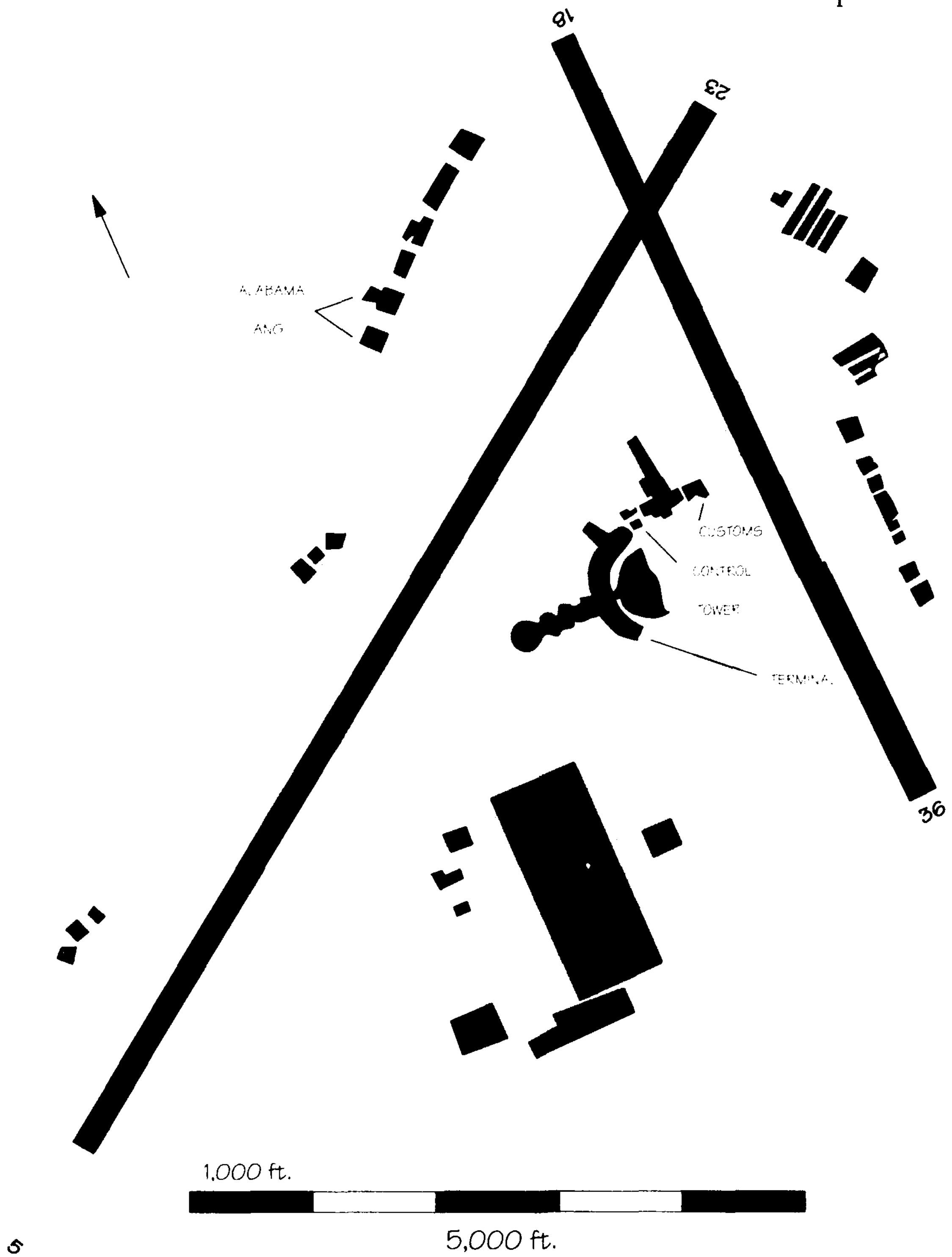
Baltimore-Washington (BWI)

A new 7,800-foot runway, Runway 10R/28L, will be constructed 3,500 feet south of Runway 10/28. Construction is expected to begin in 1994, and the runway is planned to be completed in 1996 at a cost of $38 million. When Runway 10R/28L is constructed, Runway 4/22 will convert to a taxiway. A runway extension of Runway 15L/33R to 5,000 feet long and 100 feet wide, was operational in July 1990.



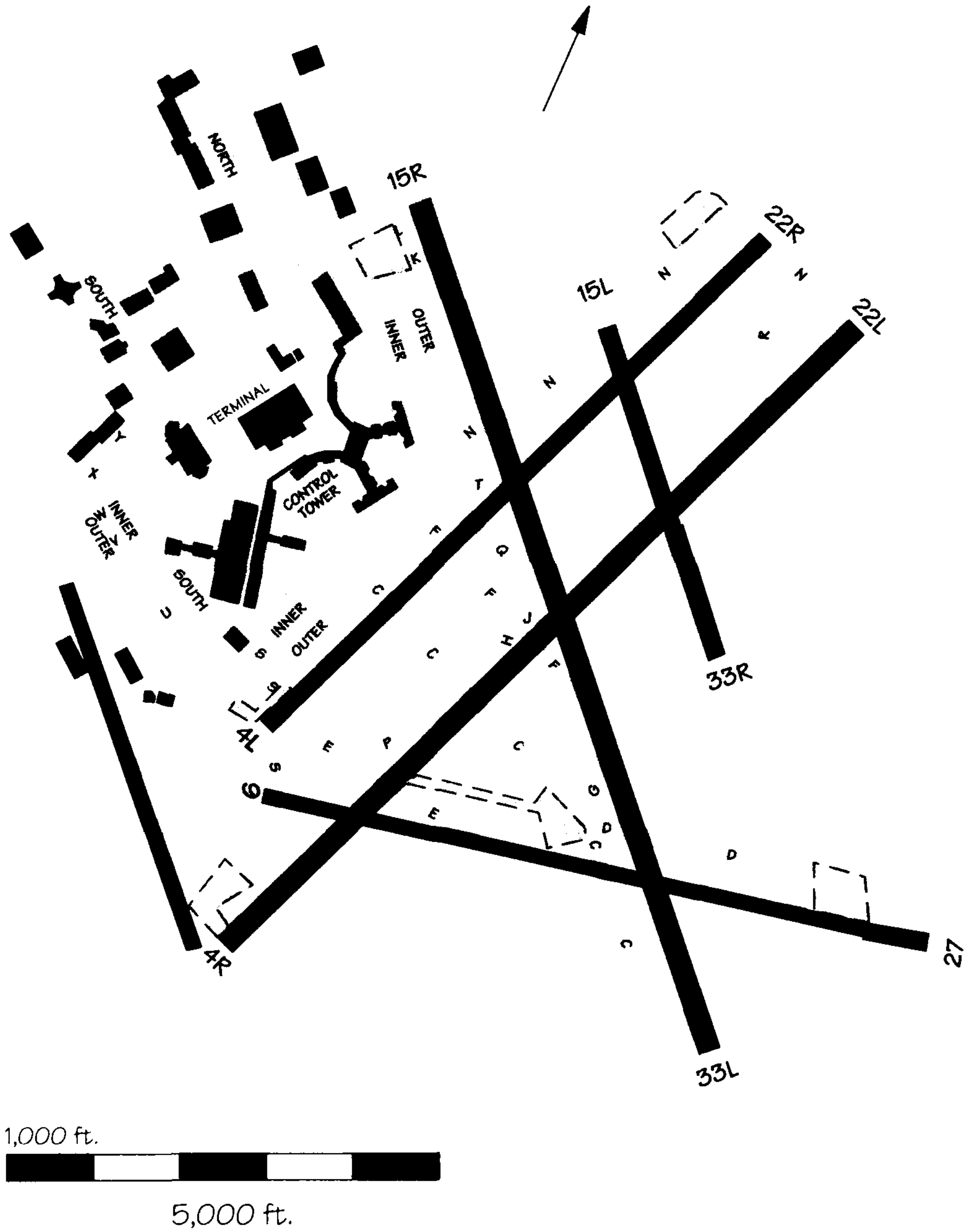
Birmingham (BHM)

Runway 18/36 will be extended from 4,800 feet to 7,500 feet. The environmental process was completed in May 1990. The estimated cost of construction is $42.5 million. The extension is expected to be completed in 1996.



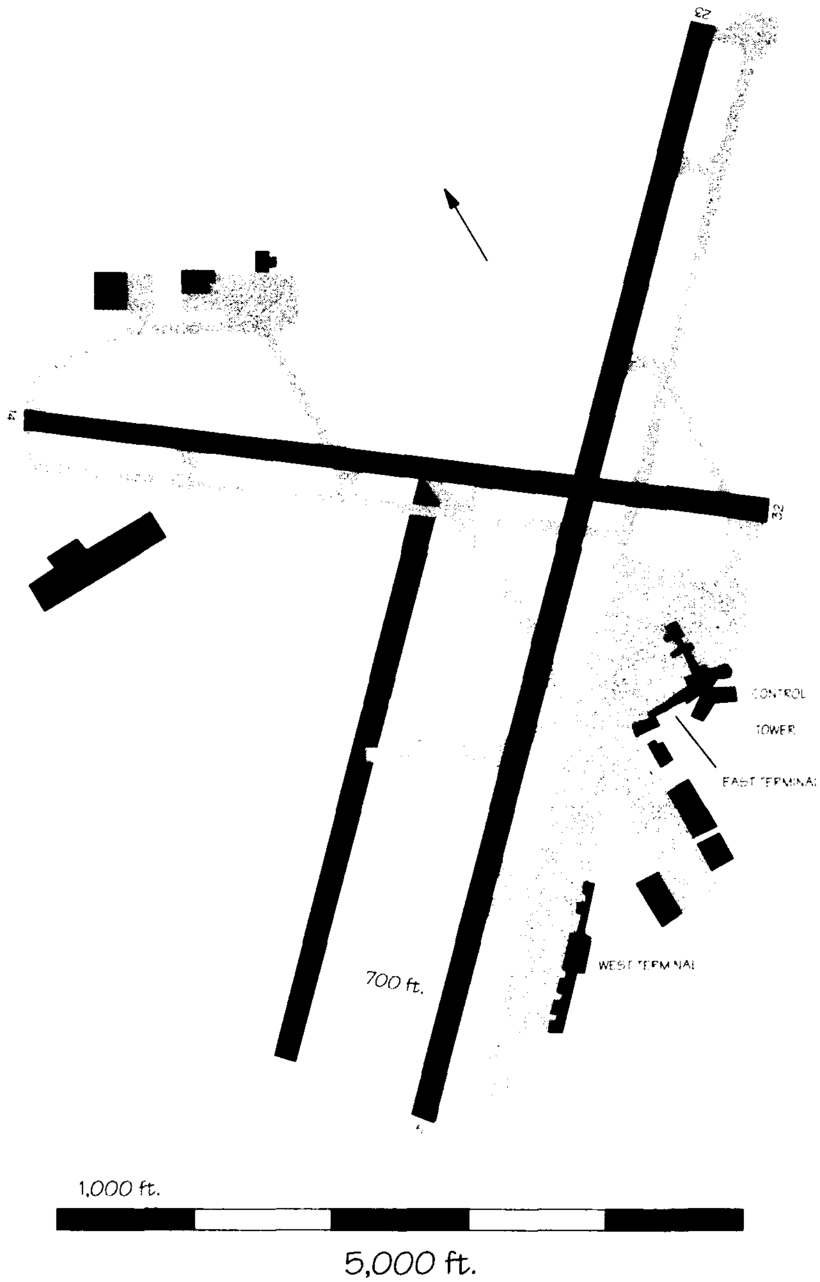
Boston (BOS)

A new Runway 14/32 and extension of Runway 15L/33R have been considered.



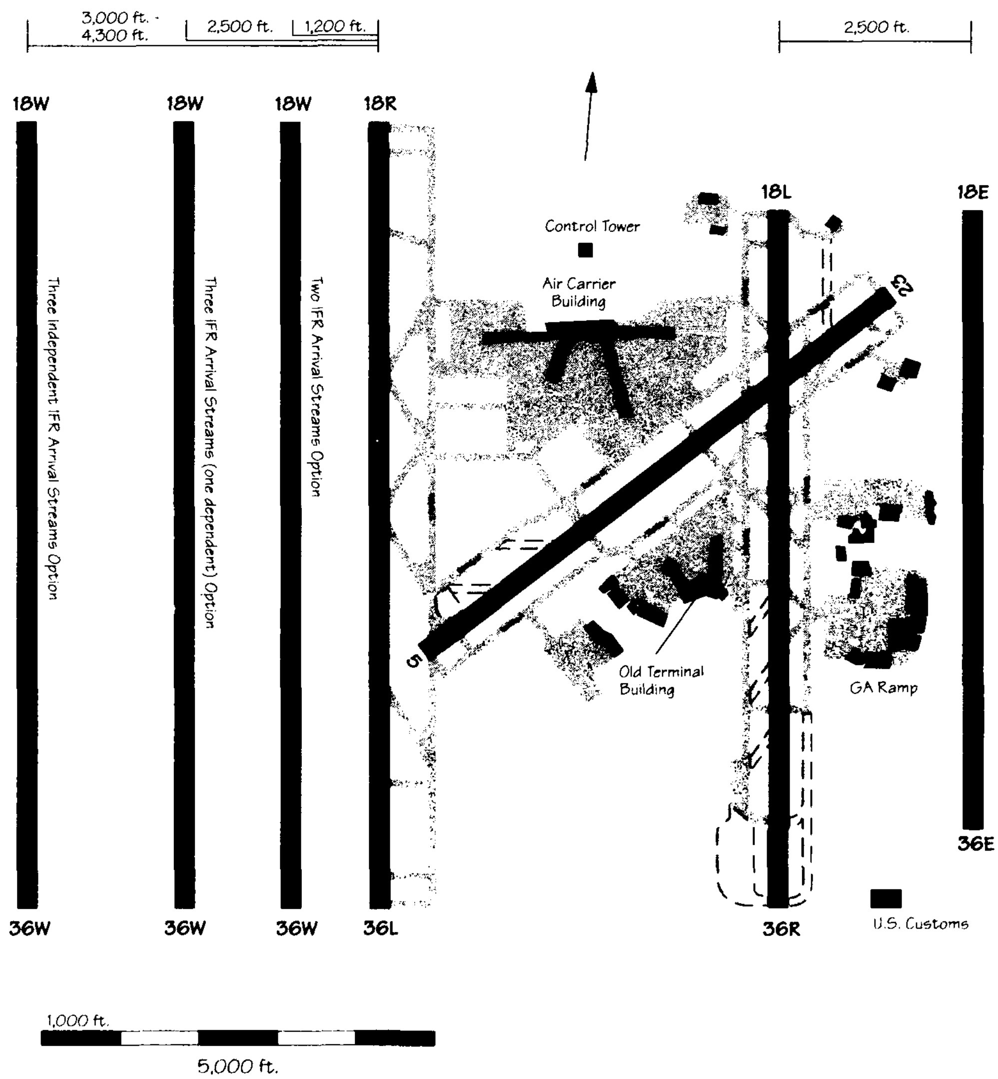
Buffalo (BUF)

Runway 14/32 is planned to be extended. Construction is expected to start in 1992 with completion estimated for 1993 at a cost of $4 million. A draft Master Plan shows a new parallel runway, Runway 5L/23R, 3,800 feet by 75 feet, located 700 feet northwest of Runway 5/23. It is planned for 1999-2000. No increase in IFR arrival capacity will be provided, but departure capacity will increase.



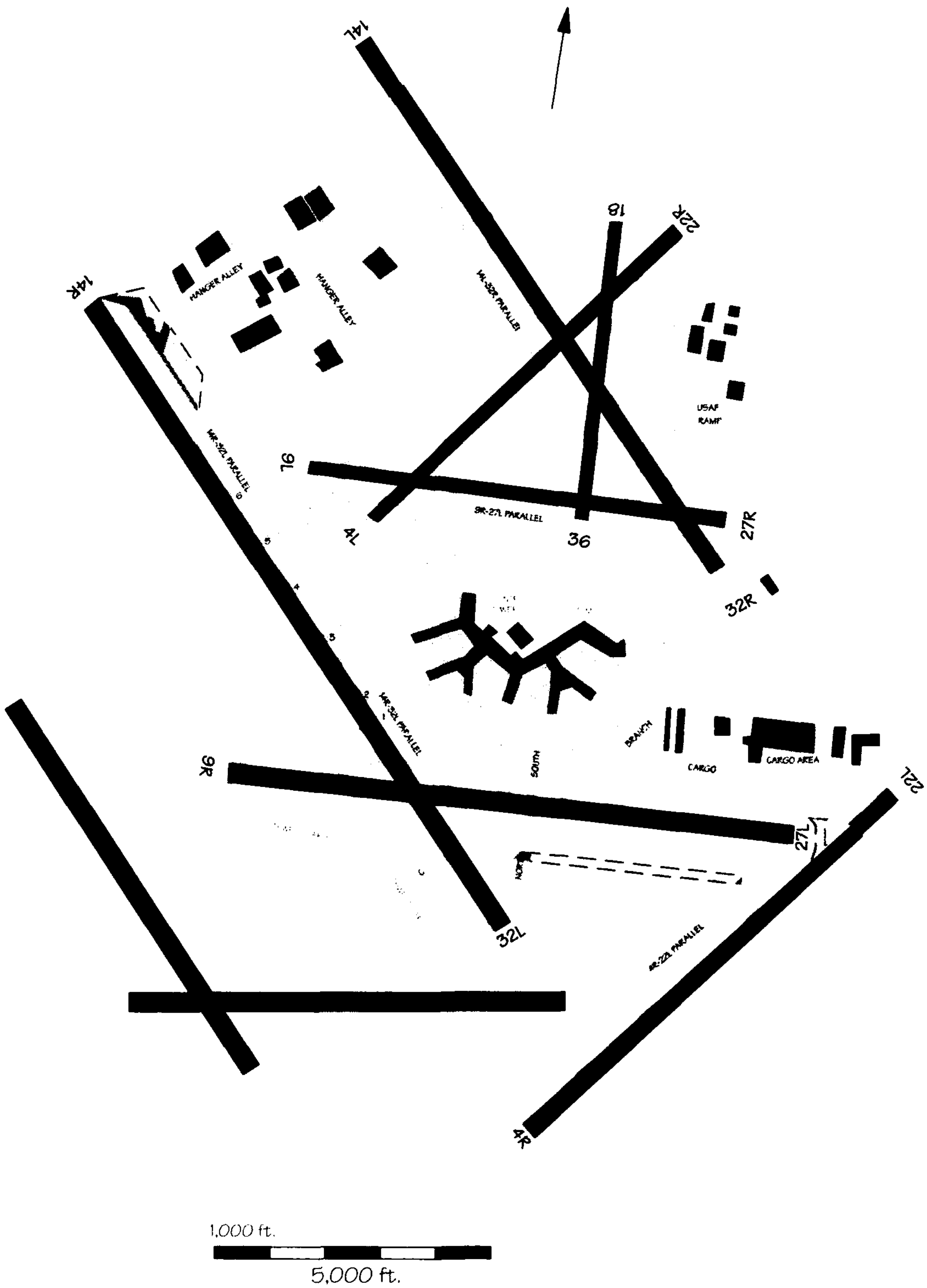
Charlotte (CLT)

Construction is scheduled to begin in October 1991 to extend Runway 36R 1,000 feet south to provide simultaneous approach capability during noise abatement hours. Completion is expected in 1993. A third parallel 8,000 foot runway west of Runway 36L is being planned to open in 1996 that would permit independent IFR arrivals. Construction is planned to start in 1993. The task force also recommended another parallel runway east of 18L/36R. Triple or quadruple IFR approaches could become available with the construction of this runway.



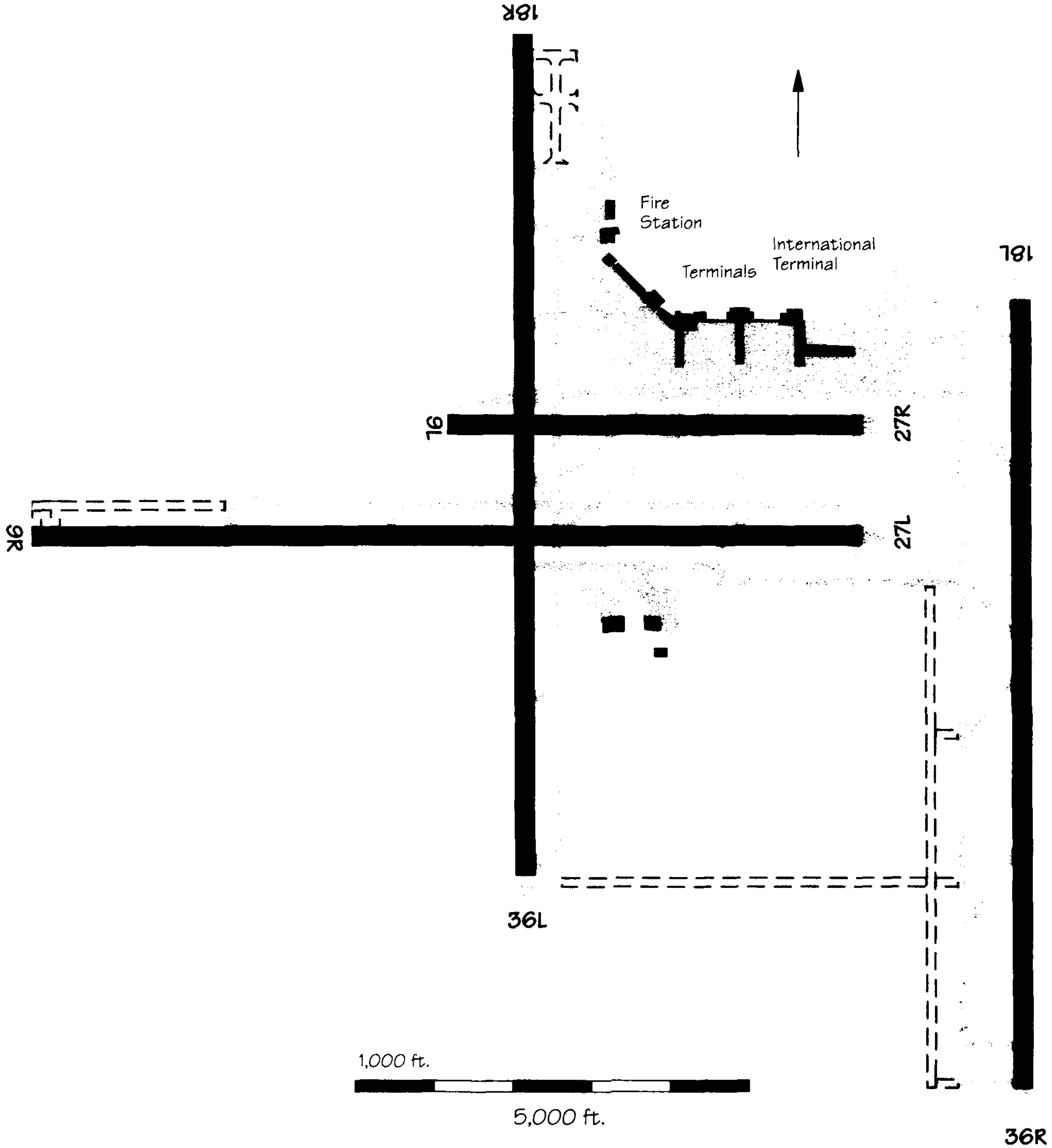
Chicago (ORD)

New Runways 9/27 and 14/32 have been recommended by the Chicago Airport Capacity Design Team.



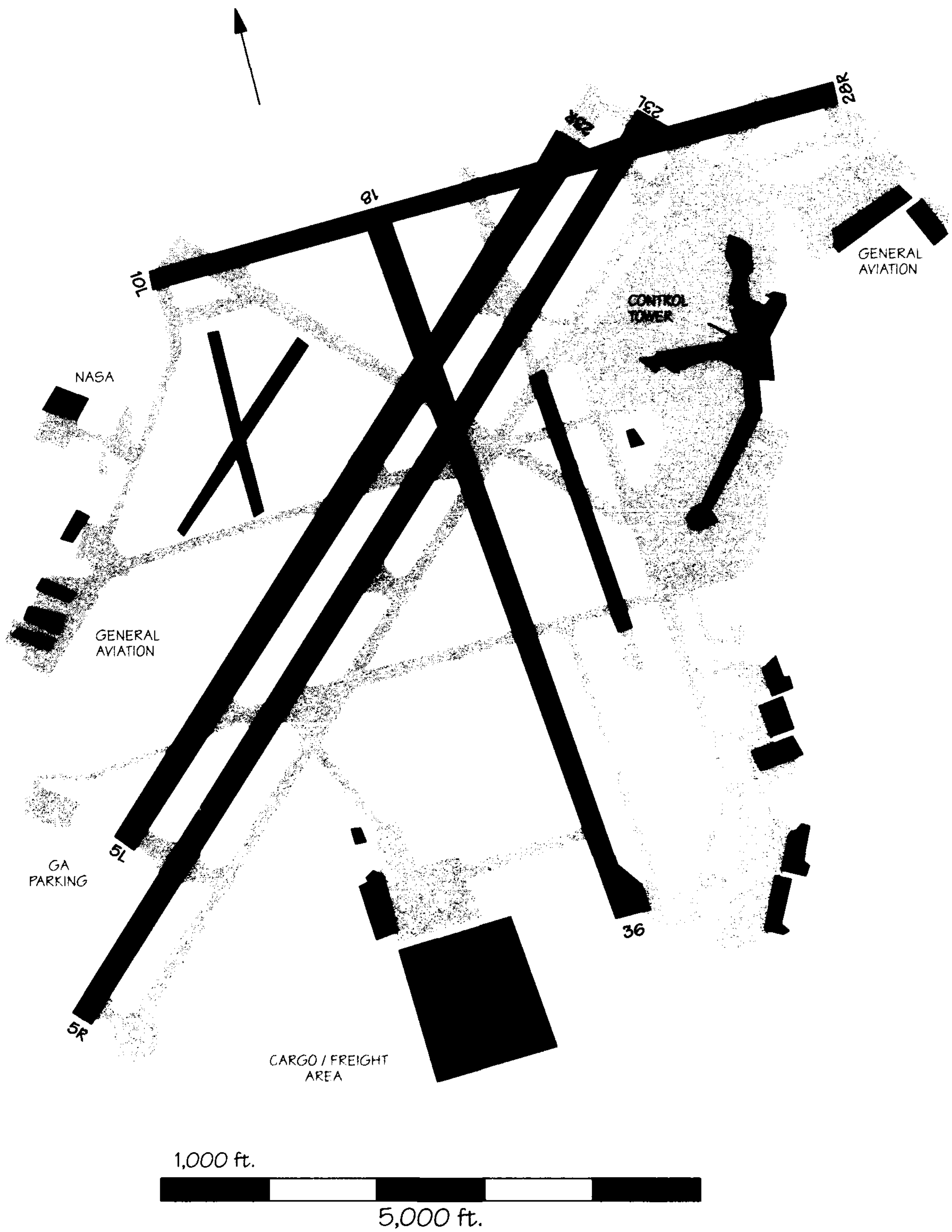
Cincinnati (CVG)

New Runway 18L/36R, parallel to and 6,200 feet away from Runway 18R/36L, became operational in January 1991. This runway provides the potential for independent IFR configurations, doubling IFR arrival capacity.



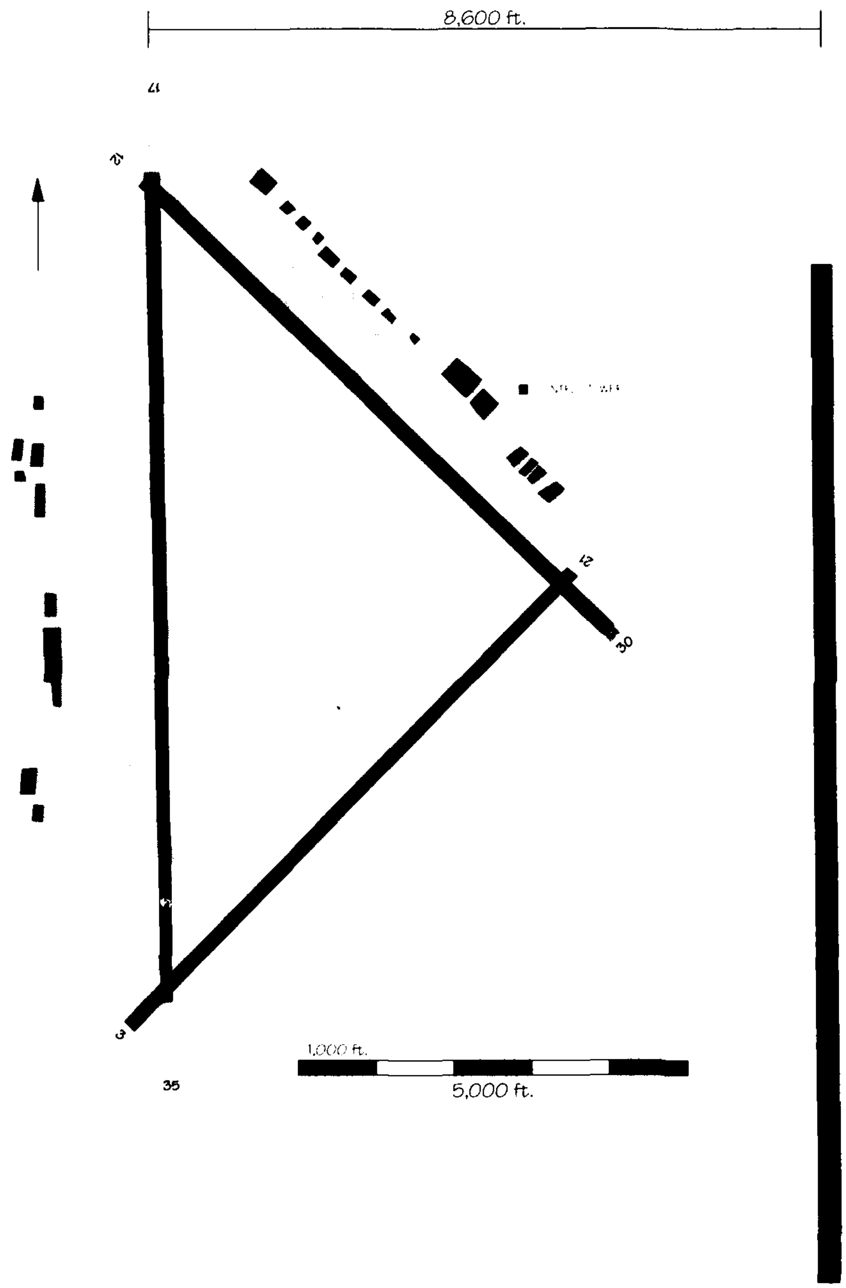
Cleveland (CLE)

The reconstruction of Runway 5R/23L began on 23 April 1990. It was completed in November 1990 at a total construction cost of $16.5 million.



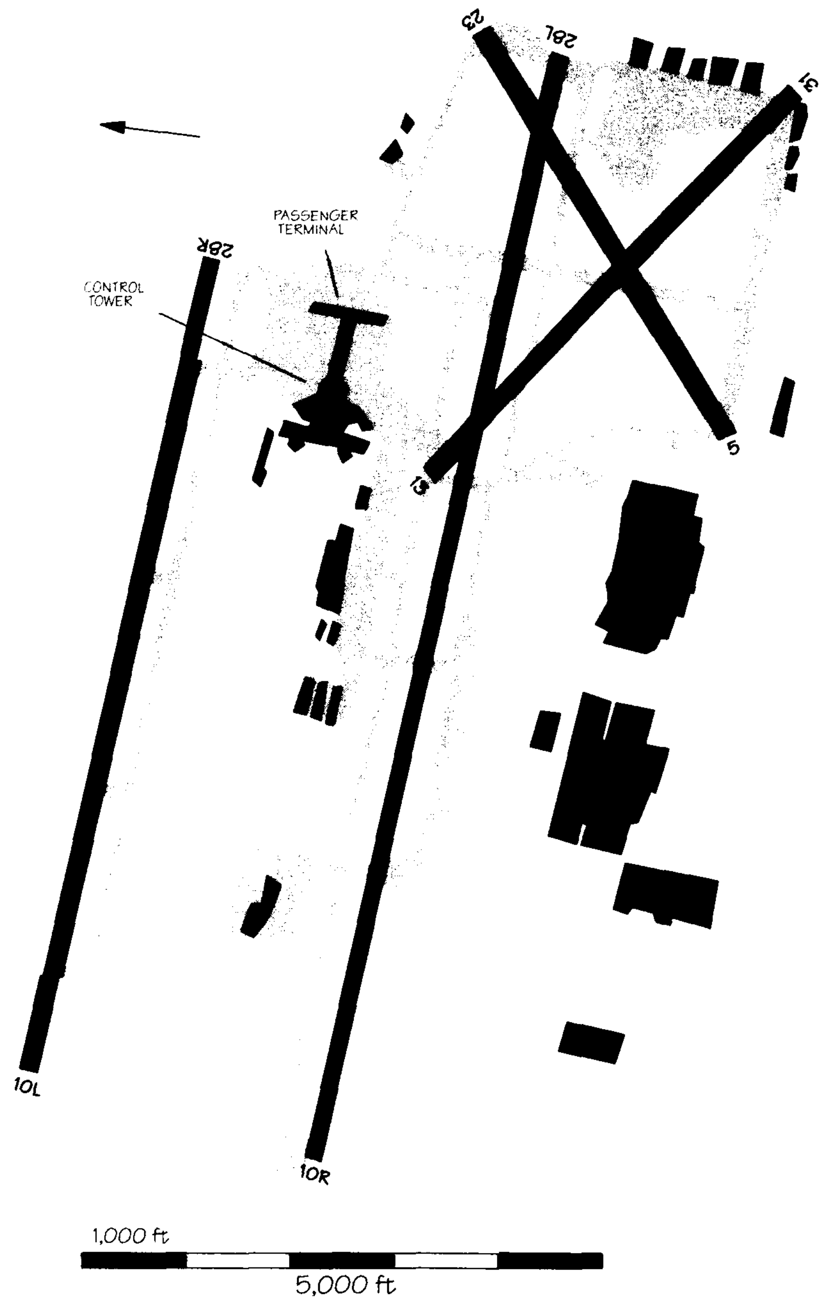
Colorado Springs (COS)

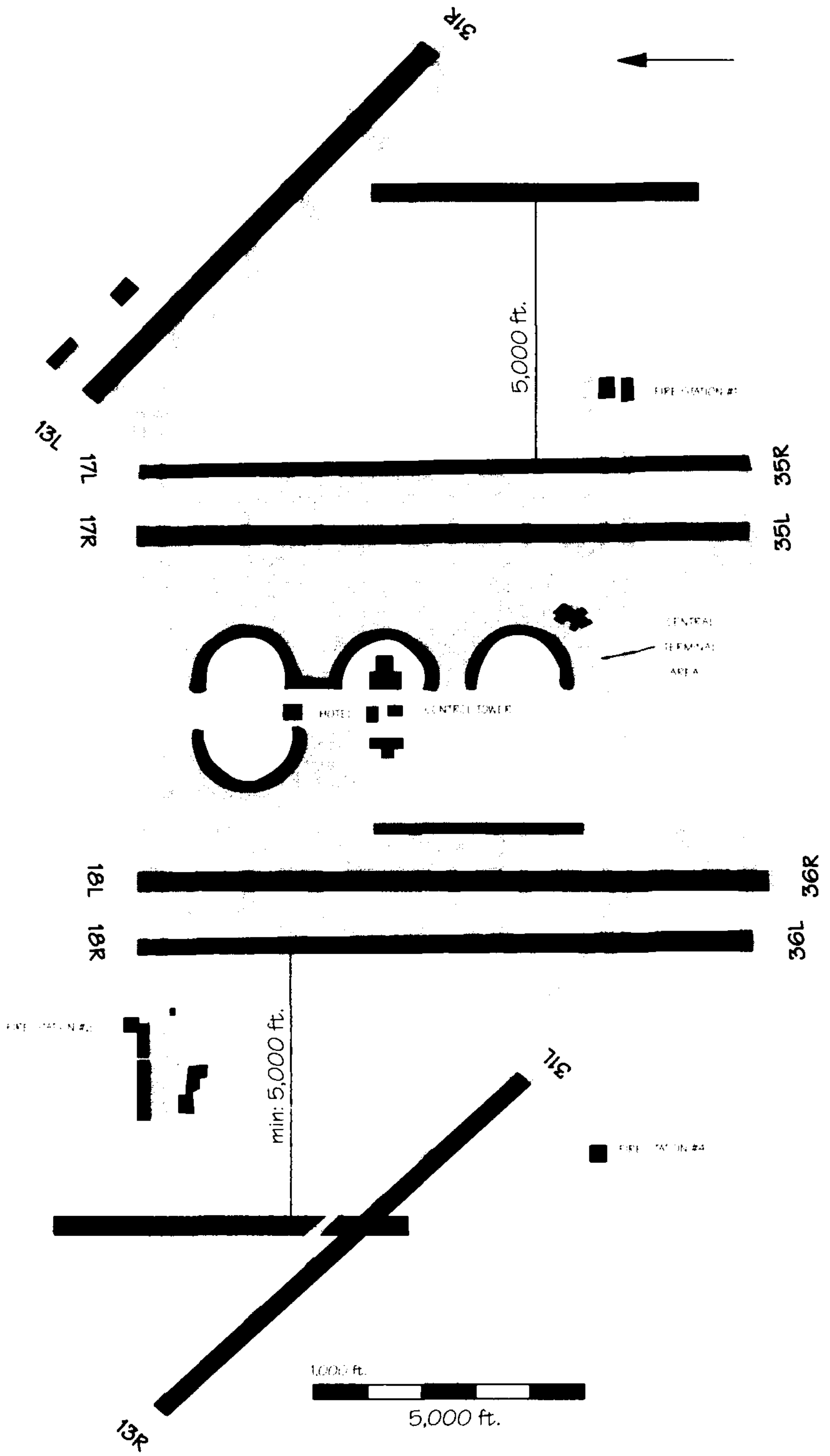
Runway 17L/35R will be constructed 8,600 feet east of existing Runway 17/35. This should permit two instrument approaches during IFR conditions, doubling arrival capacity. Construction began in 1990. The runway is scheduled to be operational in 1992, at a construction cost of $38 million.



Columbus (CMH)

An update to the current ALP is being coordinated. It includes 1,000-foot extensions to each end of Runway 10L/28R. Construction on the extension to Runway 10L is expected to begin in 1994 and should be completed in 1995. The estimated cost of construction is $8.1 million. The extension to Runway 28R is expected to begin in early 1994, and be operational late that year. The estimated cost of construction of this extension is $3.2 million.



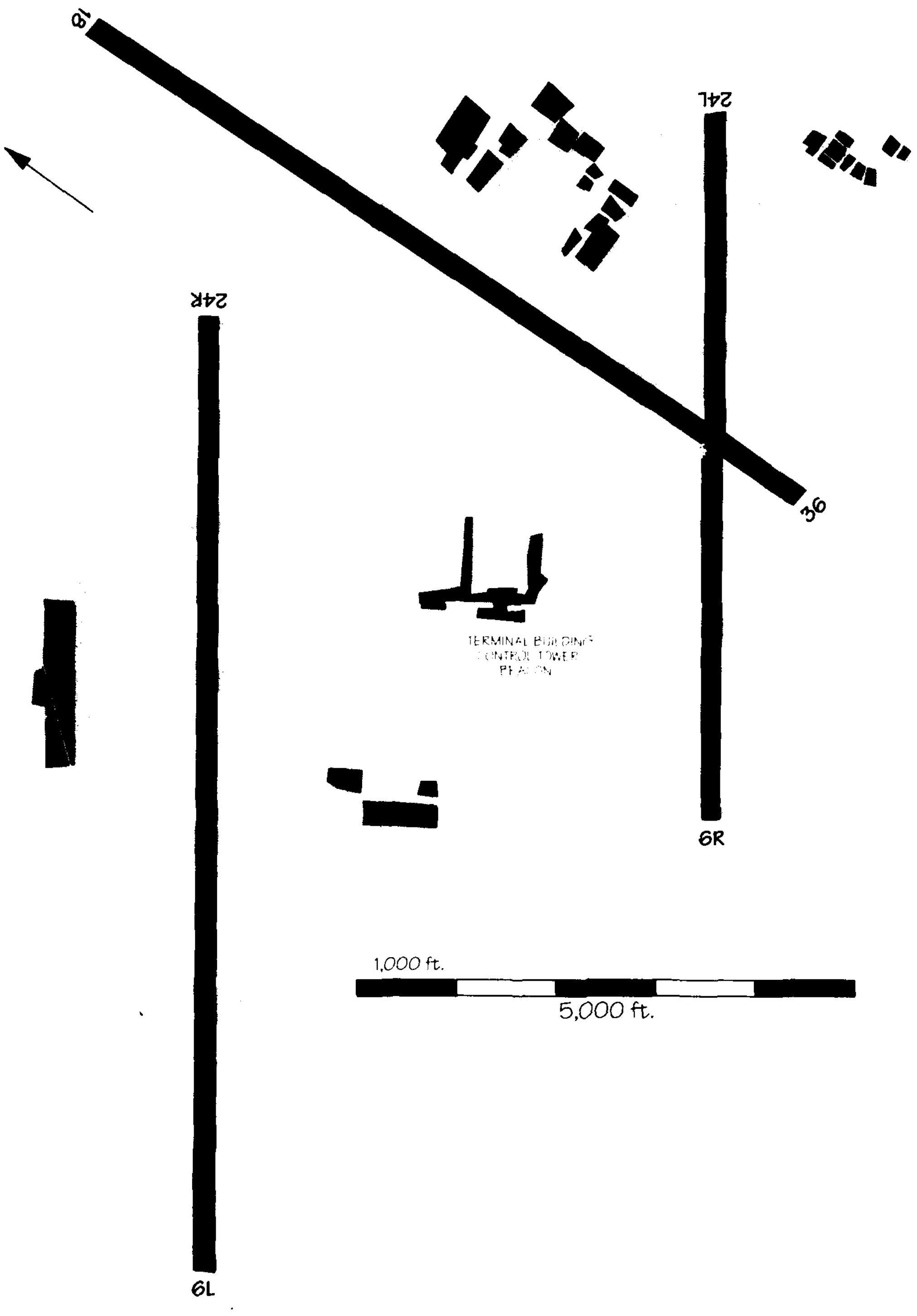


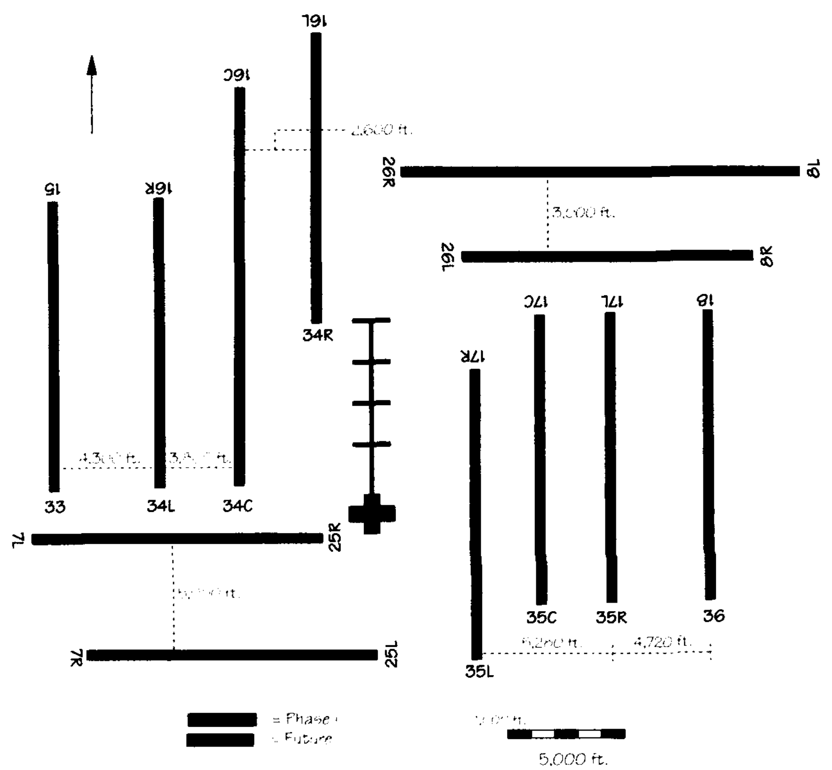
Dallas-Fort Worth (DFW)

Planned 2,000-foot extensions to Runways 35L and 36R will provide an overall length of 13,400 feet for each. Each extension is estimated to cost $24 million. The tentative date of completion of Runway 35L is 1992 with Runway 32R scheduled to start construction in late 1993. Also planned are two more parallel runways, Runway 16L/34R and Runway 16R/34L. The east runway, Runway 16L/34R, encompasses a two-stage action. Initially, a 6,000-foot runway will be constructed for ultimate phased extension to 8,500 feet. It will be located 5,000 feet east of and parallel to Runway 17L/35R. The estimated cost is $100 million. It is anticipated that the 6,000-foot runway will be operational by 1993. Construction on the west runway, Runway 16R/34L, should begin in 1993 and is expected to be completed in 1997. The estimated cost is $95 million. It will be located west of Runway 18R/36L. These runways could potentially permit triple or quadruple IFR arrival operations (78 and 104 hourly IFR arrivals, respectively) if the multiple approach concepts are approved.

Dayton (DAY)

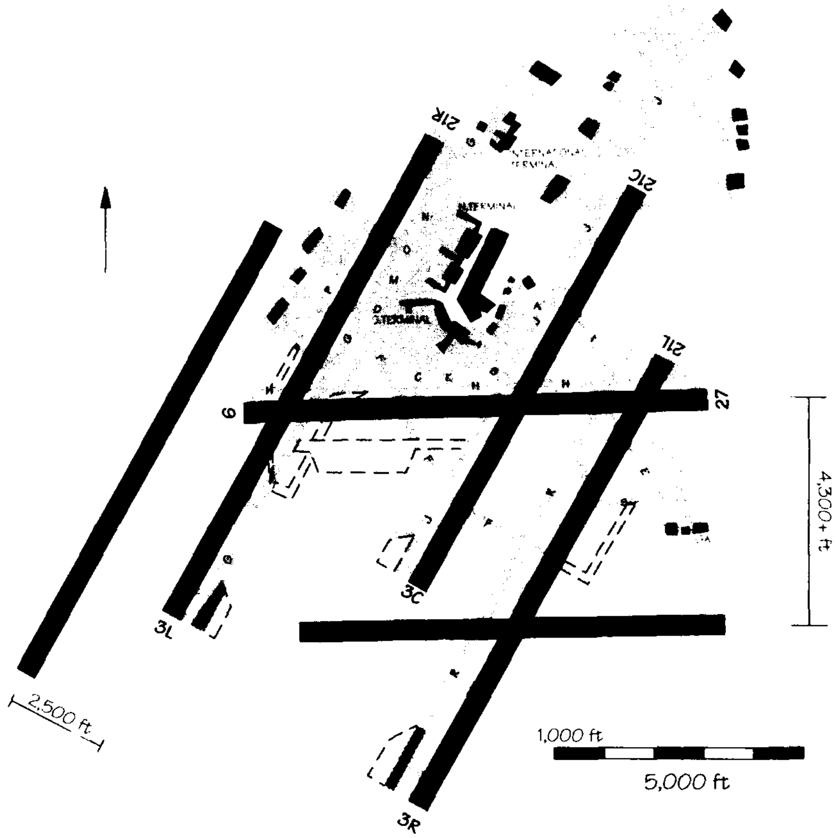
A Master Plan shows an extension of Runway 6L/24R to 11,000 feet to accommodate overseas departures.





New Denver (DVX)

The initial phase of the new Denver airport will consist of six runways. The current plan involves four north-south parallels and two east-west parallels. Runway 17C/35C will initially be the farthest west of the four north-south parallels. It will be located 3,100 feet west of Runway 16L/34R and 10,700 feet west of Runway 17R/35L. Runway 17R/35L and Runway 18L/36R will be separated by 5,700 feet. East-west parallels, Runways 7L/25R and 8R/26L, will have centerlines 13,500 feet apart. Runway 7L/25R is south of Runways 16C/34C and 16L/34R. Runway 8R/26L is north of Runways 18R/36L and 18L/36R. Construction began in late 1989. The total estimated cost of construction is $2.5 billion. The new airport is expected to be operational in October 1993. The airport could potentially operate independent triple or quadruple IFR approaches, if approved (quadruple approaches under this configuration would require one dependent pair or use of the PRM). This could increase Denver hourly IFR arrival capacity from 52 to 78 (triples) or more (quadruples) per hour. A second future phase proposes the construction of six more runways.

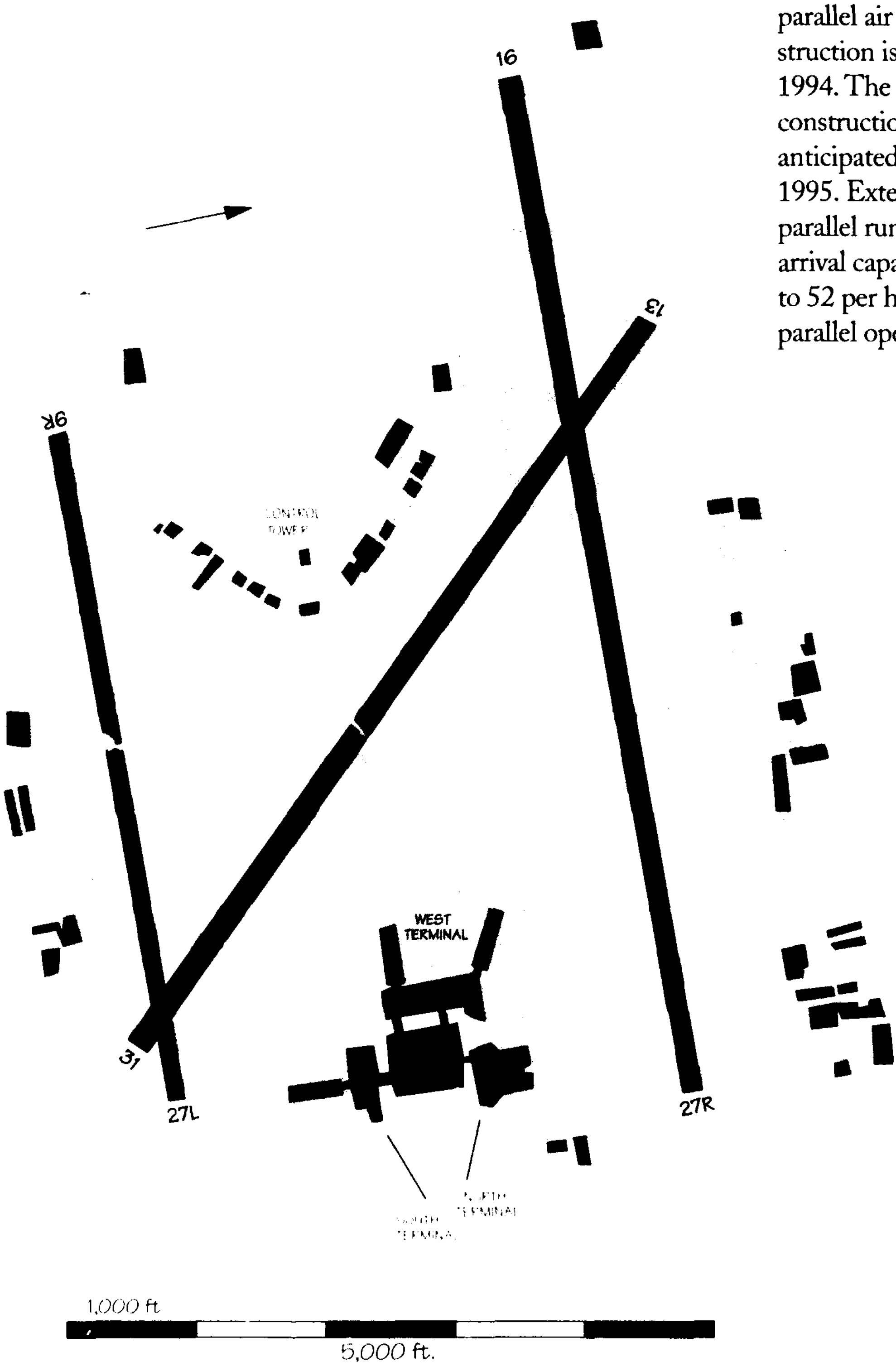


Detroit (DTW)

Runway 9R/27L is planned, located more than 4,300 feet from and parallel to existing Runway 9/27. The estimated cost is $69.1 million. This new runway will allow DTW to run independent parallel IFR approaches in an east-west configuration, thus matching its current north-south IFR arrival capabilities. Construction is to begin in 1991 and should be completed in late 1992. A fourth north-south parallel, Runway 4/22, 2,500 feet west of Runway 3L/21R, is also planned. Construction is expected to begin in 1994 and should be completed in 1995. The estimated cost of construction is $58.2 million. This runway could potentially permit triple IFR arrivals with one dependent and one independent pairing. If approved, hourly IFR arrival capacity could increase from 52 to 63. An environmental assessment was submitted in September 1989, and a record of decision was issued in March 1990 for all three projects.

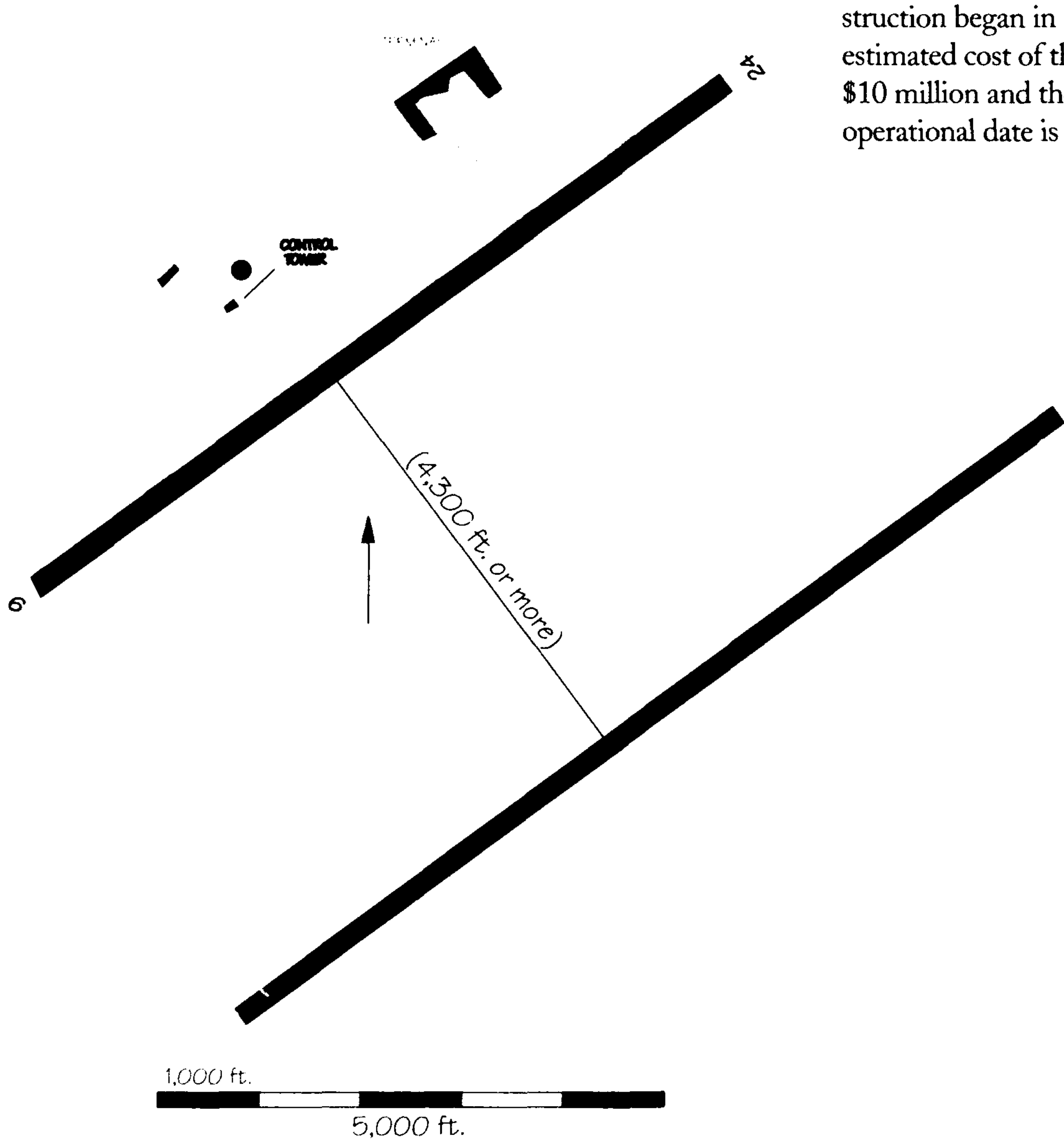
Fort Lauderdale (FLL)

An extension of the short parallel Runway 9R/27L to 6,000 feet by 150 feet is planned to provide the airport with a second parallel air carrier runway. Construction is expected to begin in 1994. The estimated cost of construction is $26 million, and the anticipated operational date is 1995. Extension of this short parallel runway would permit IFR arrival capacity to increase from 26 to 52 per hour in an independent parallel operation.

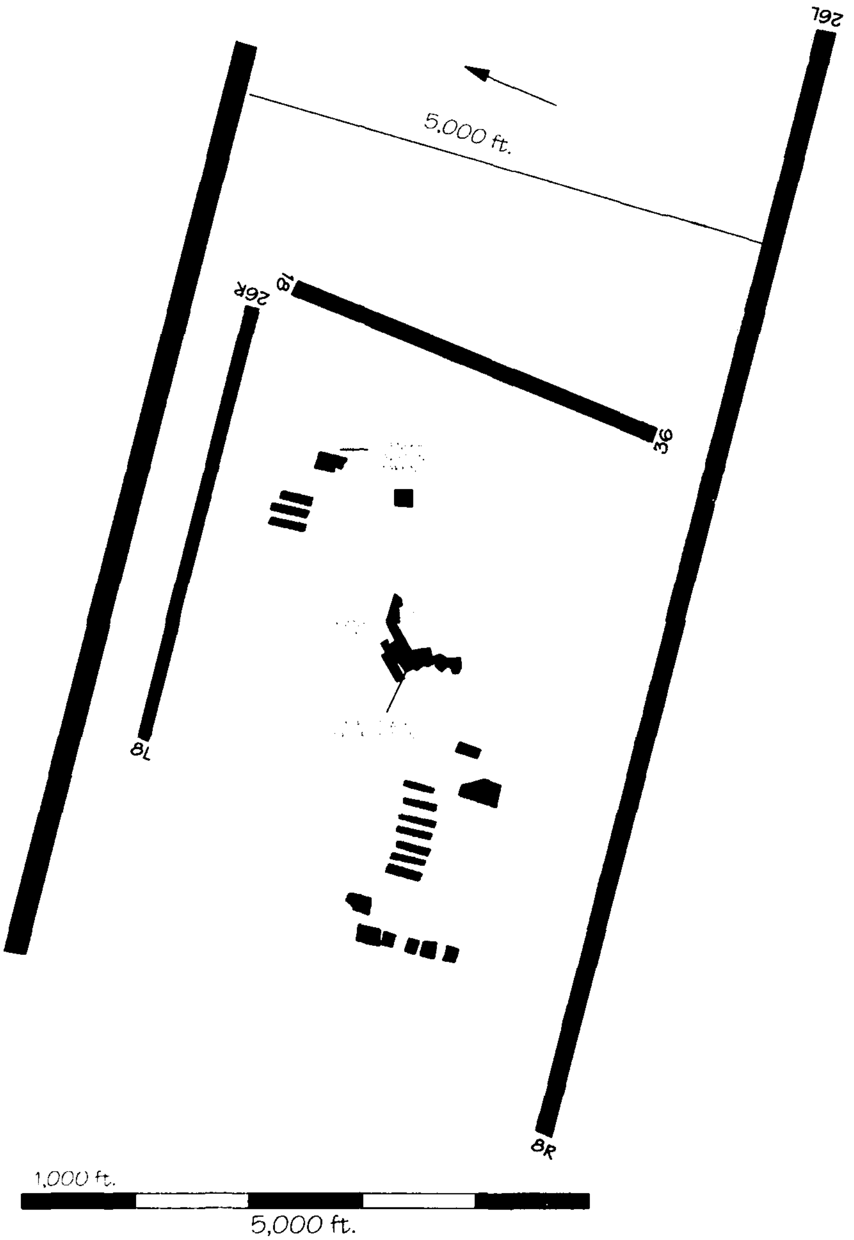


Fort Myers (RSW)

Planning has begun for a 9,000-10,000 foot new parallel runway, Runway 6R/24L, 4,300 feet or more from the existing air carrier runway. Construction is expected to begin in 1996. It is estimated to be operational by 1999 at a cost of $123 million. This would provide independent parallel operations with potential to increase IFR hourly arrival capacity from 26 to 52. An environmental assessment is underway for an extension of Runway 6/24 from 8,400 feet to 10,600 feet. Construction began in 1991. The estimated cost of the extension is $10 million and the estimated operational date is 1992.



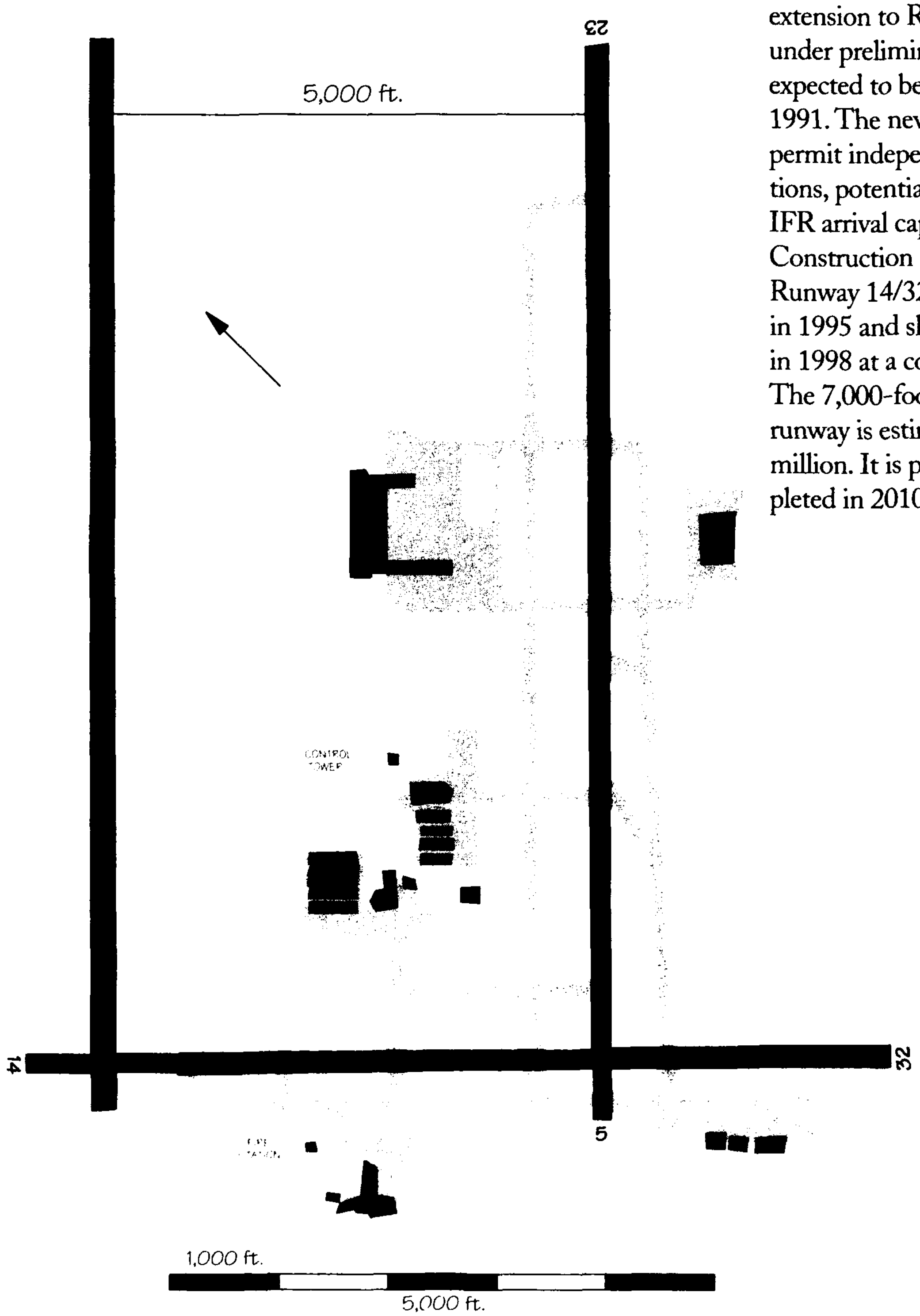
Grand Rapids (GRR)



A new 7,000-foot parallel runway, Runway 8L/26R, 5,000 feet from Runway 8R/26L, is being considered. The current 3,918 foot Runway 8L/26R would become a taxiway. An environmental assessment is underway and is expected to be submitted in November 1991. Construction is scheduled to start in 1993 and should be completed by late 1994. The estimated cost of construction is $25 million. This runway will potentially double hourly IFR arrival capacity from 26 to 52.

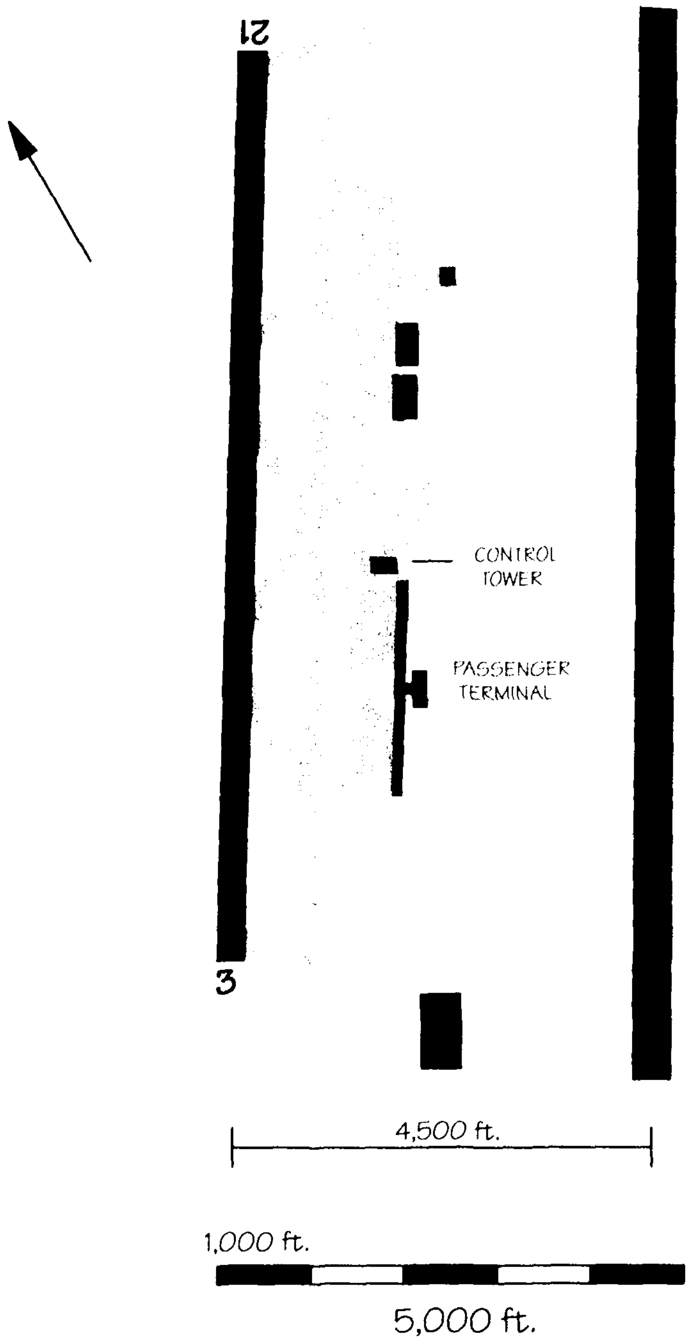
Greensboro (GSO)

An airport layout plan shows a new parallel Runway 5/23, 5,000 feet northwest of the existing Runway 5/23, and a 1,200 foot extension to Runway 14/32 is under preliminary review and is expected to be approved in late 1991. The new runway would permit independent parallel operations, potentially doubling hourly IFR arrival capacity from 26 to 52. Construction on the extension to Runway 14/32 is expected to begin in 1995 and should be completed in 1998 at a cost of $14 million. The 7,000-foot long parallel runway is estimated to cost $20 million. It is planned to be completed in 2010.



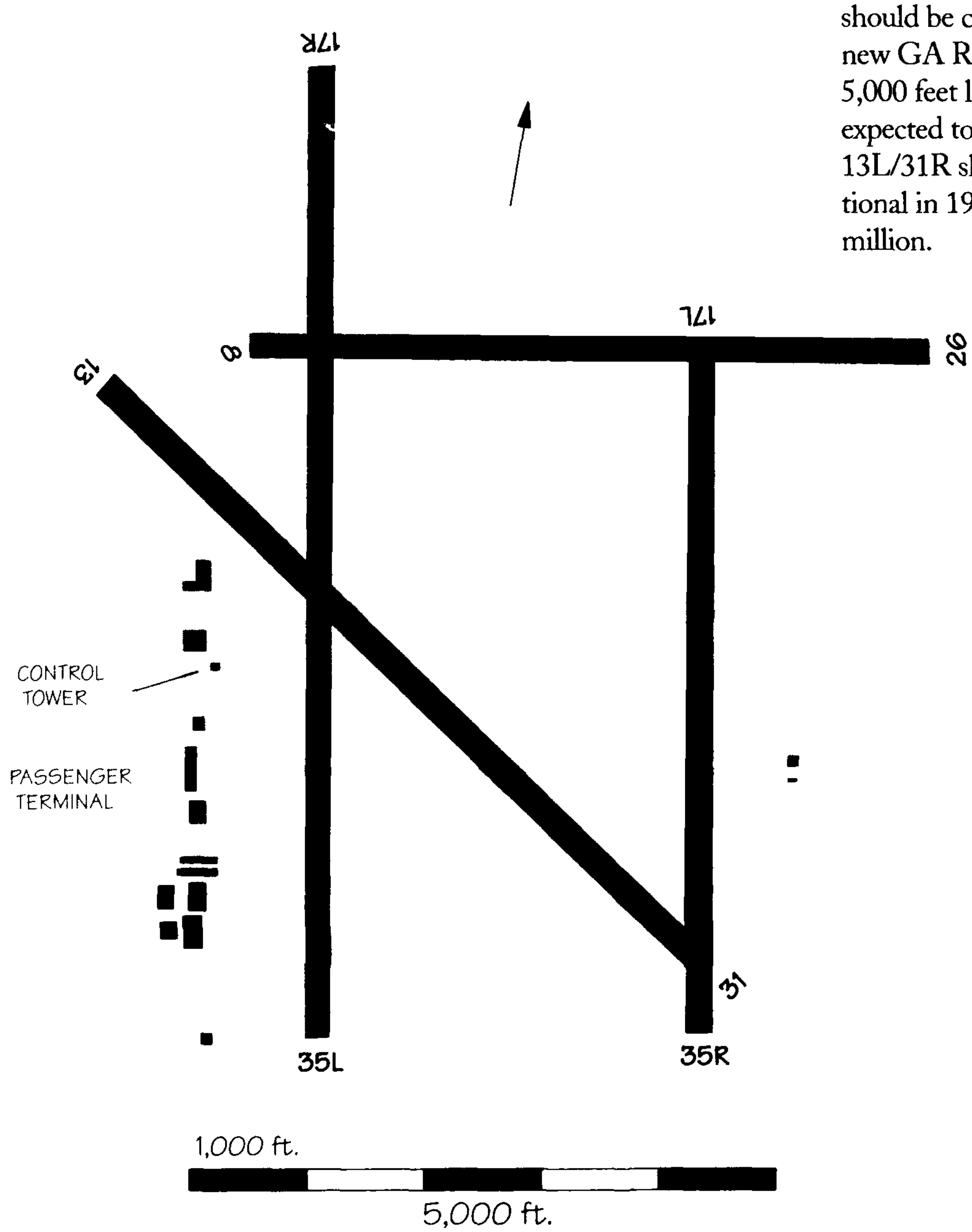
Greer Greenville-Spartanburg (GSP)

A new parallel runway, Runway 3R/21L, is anticipated in 1995 at a cost of $25 million. Presently, its planned length is 5,900 feet with a 4,500 foot separation from Runway 3/21. This would potentially double hourly IFR arrival capacity from 26 to 52.



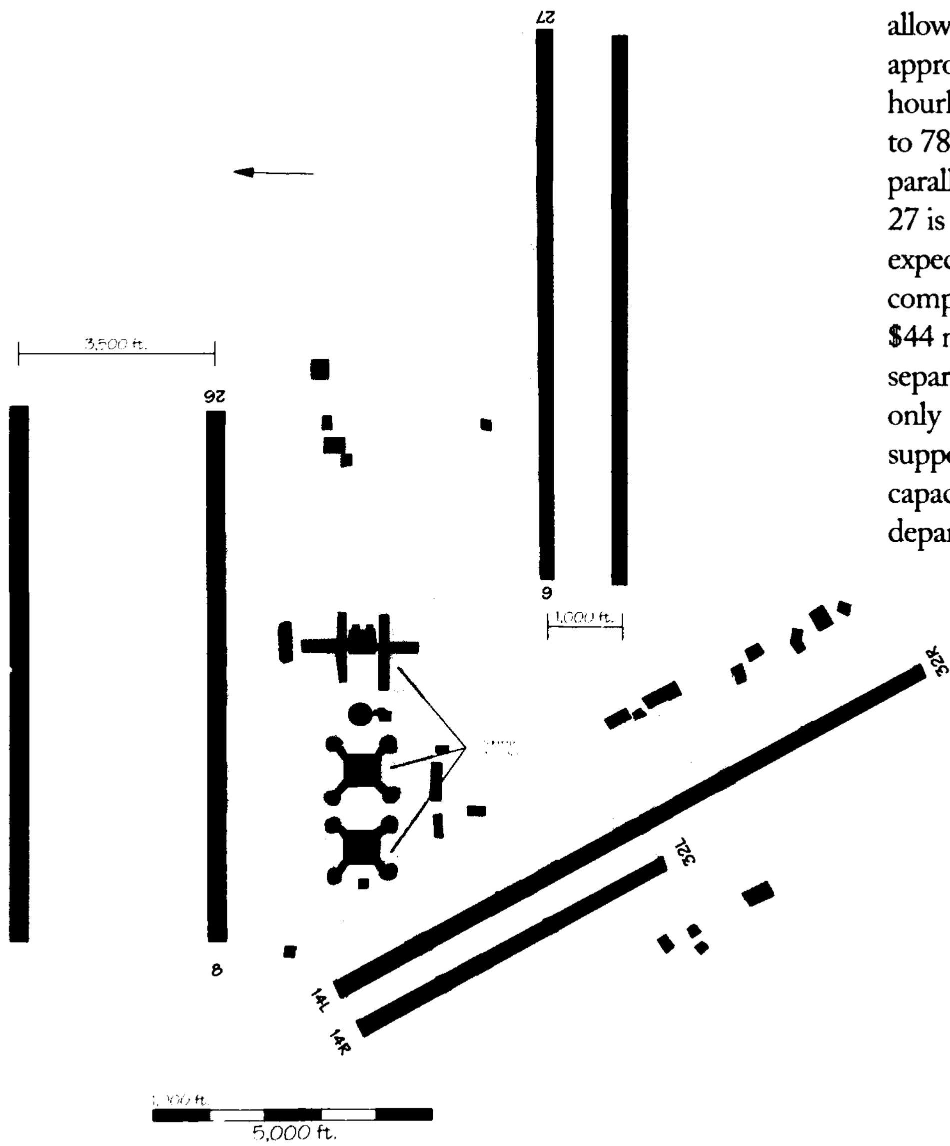
Harlingen (HRL)

An approved airport layout plan is anticipated in late 1991, which will include an extension to Runway 13/31 and a new parallel GA runway, Runway 13L/31R. The extension to Runway 13/31 will bring the runway length to 9,500 feet at an estimated cost of $6.7 million. A noise study and environmental assessment are expected in 1992. Construction is anticipated to begin in 1994 and should be completed in 1995. The new GA Runway 13L/31R will be 5,000 feet long. Construction is expected to begin in 1994. Runway 13L/31R should also be operational in 1995 at a cost of $5 million.



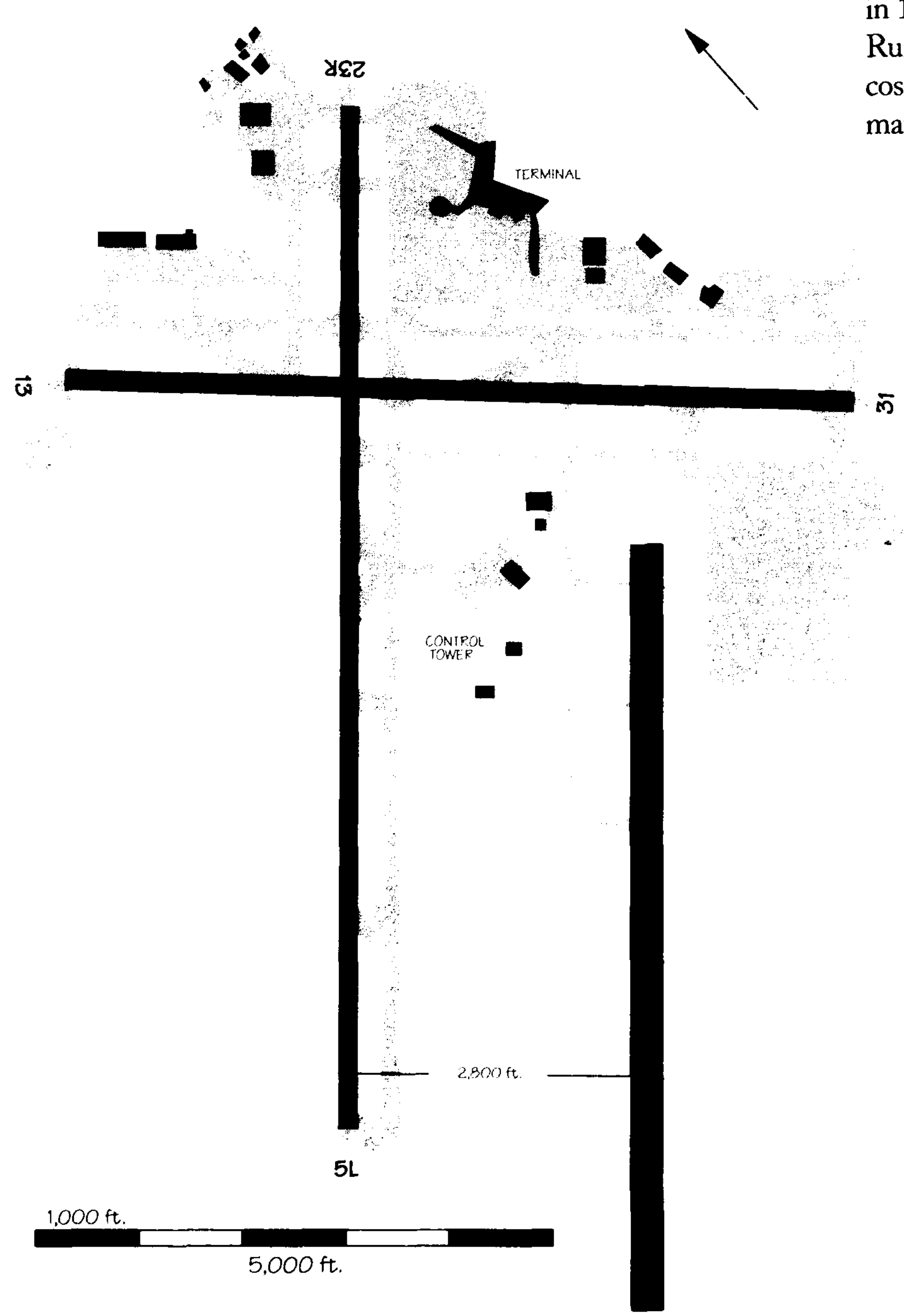
Houston (IAH)

An $8 million, 2,000 foot extension to Runway 14R/32L is planned to be operational in 1997. Construction is expected to begin in 1996 with completion in 1997. A new runway, Runway 8L/26R, is planned to be completed sometime in 1999. Construction should begin in 1997 and is estimated to cost $44 million. This runway will be parallel to and north of existing Runway 8/26. The spacing between these two runways will be 3,500 feet. Runway 8L/26R, in conjunction with Runways 9/27 and 8/26, has the potential for allowing triple IFR approaches, if approved, which could increase hourly IFR arrival capacity from 52 to 78. Another new runway, parallel to and south of Runway 9/27 is also planned. Construction is expected to begin in 1999 and be completed in 2002, also at a cost of $44 million. This runway will be separated from Runway 9/27 by only 1,000 feet, which, while not supporting additional IFR arrival capacity, would increase available departure capacity.



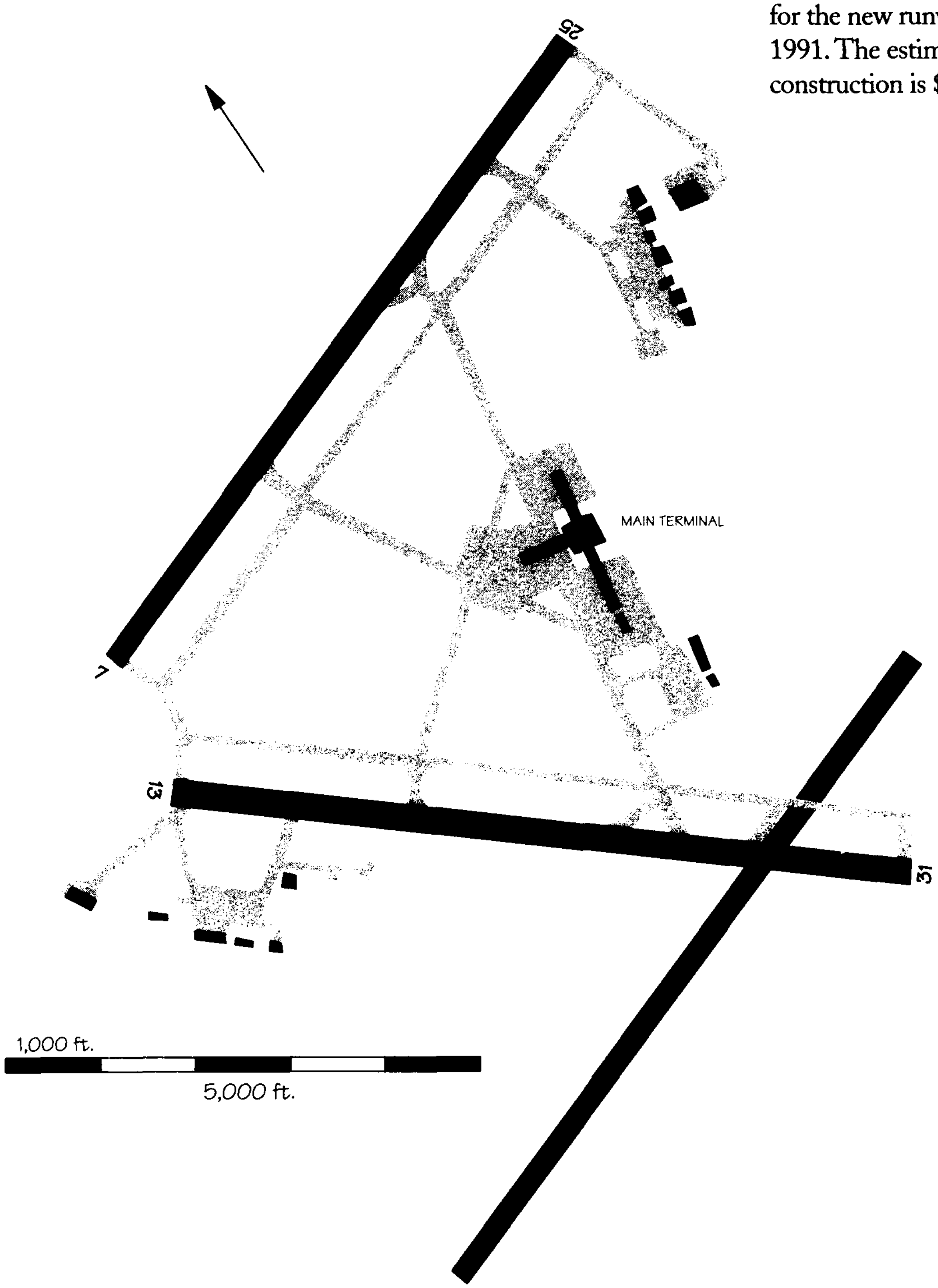
Indianapolis (IND)

A new runway, Runway 5R/ 23L, parallel to and 2,800 feet away from the existing Runway 5L/23R, became operational in July 1990. The runway dimensions are 10,000 feet by 150 feet. A CAT I ILS was installed in December 1990. This will permit dependent parallel operations, increasing hourly IFR arrival capacity from 26 to 36. Construction is scheduled to begin in 1993 for a replacement for Runway 5L/23R. The estimated cost is $42 million and the estimated operational date is 1996.



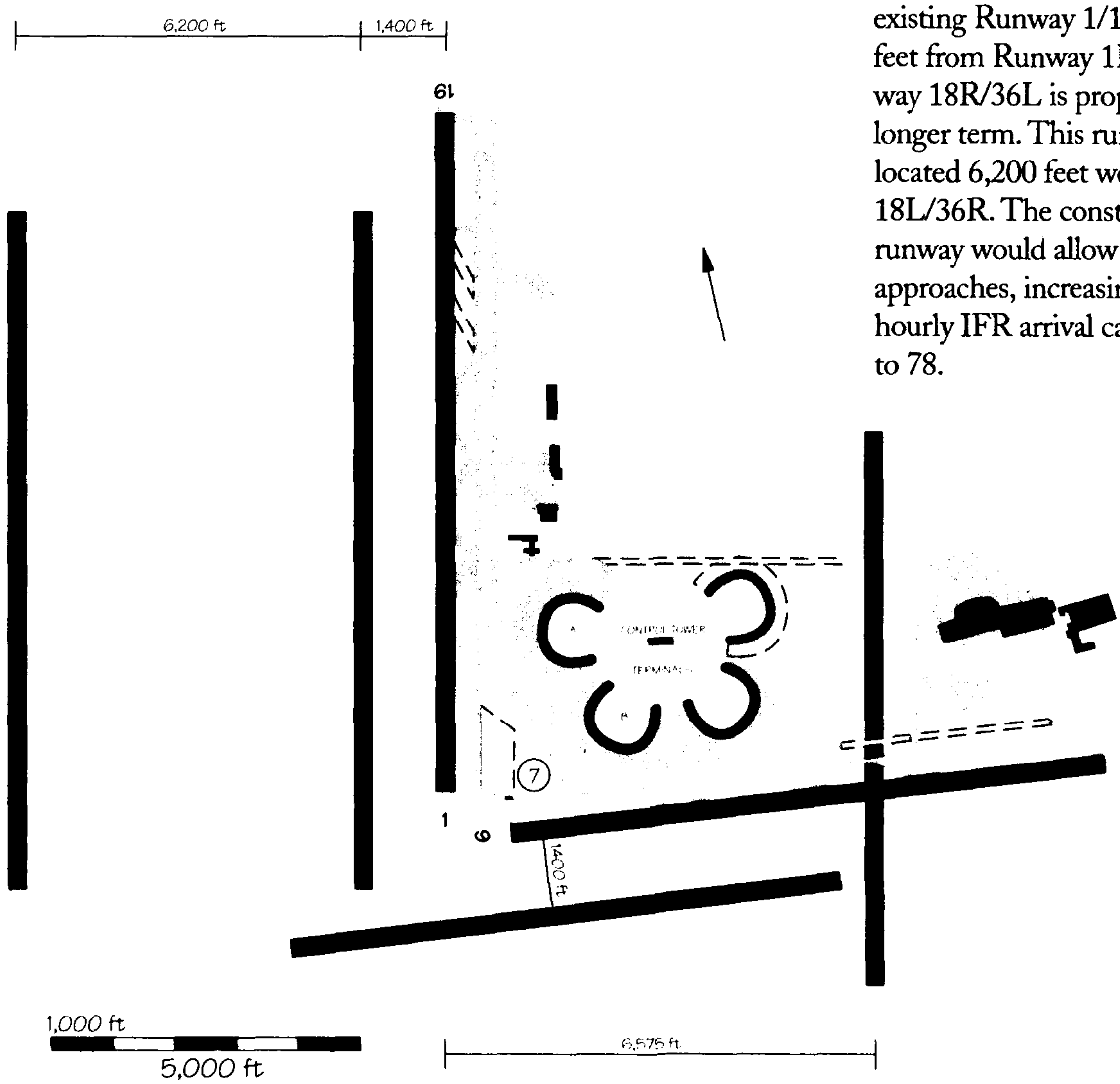
Jacksonville (JAX)

Runway 7R/25L is planned. It will be 6,500 feet south of the existing Runway 7/25, permitting independent parallel IFR operations and potentially doubling Jacksonville's hourly IFR arrival capacity. Plans and specifications for the new runway will start in 1991. The estimated cost of construction is $37 million.



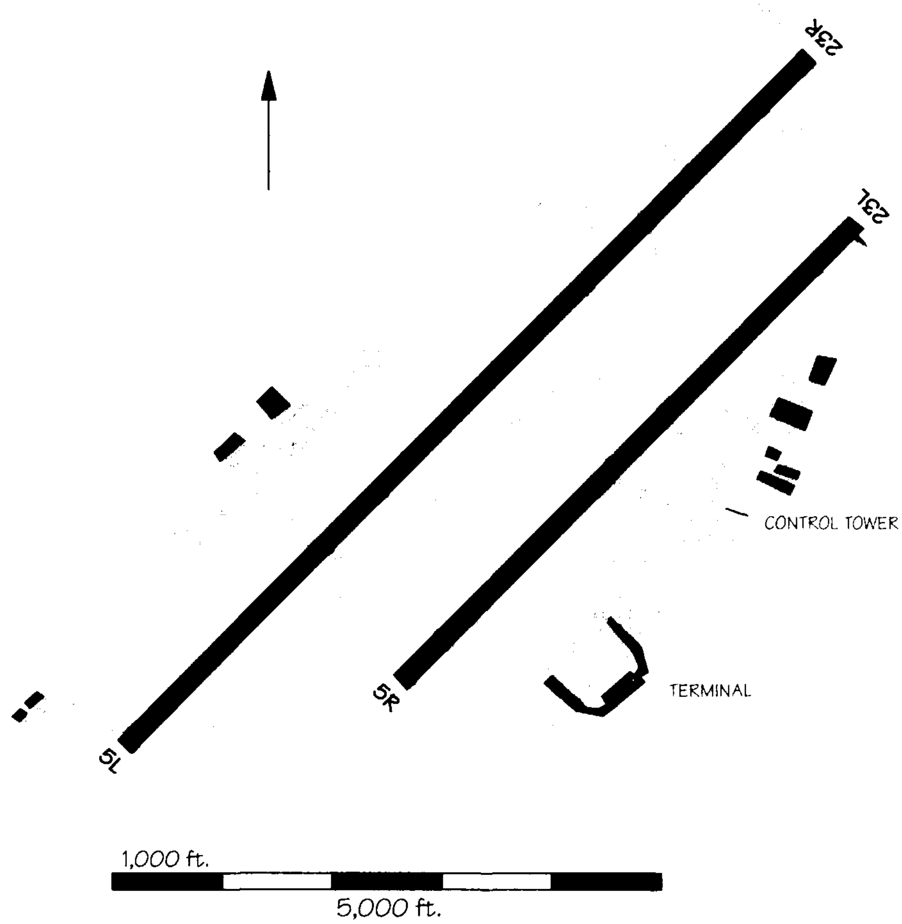
Kansas City (MCI)

A new north-south parallel runway, Runway 1R/19L, is currently under construction. It will be located 6,575 feet east of existing Runway 1/19, permitting independent parallel IFR operations. Construction began in October 1989 and should be completed in 1992. The estimated cost of construction is $46.2 million. A new runway, Runway 9R/27L, is proposed to be located 1,400 feet south of existing Runway 9/27. Runway 18L/36R is proposed to be constructed after 2000. This runway will be 1,400 feet away, parallel to and west of existing Runway 1/19, and 7,975 feet from Runway 1R/19L. Runway 18R/36L is proposed for the longer term. This runway would be located 6,200 feet west of Runway 18L/36R. The construction of this runway would allow triple IFR approaches, increasing average hourly IFR arrival capacity from 52 to 78.



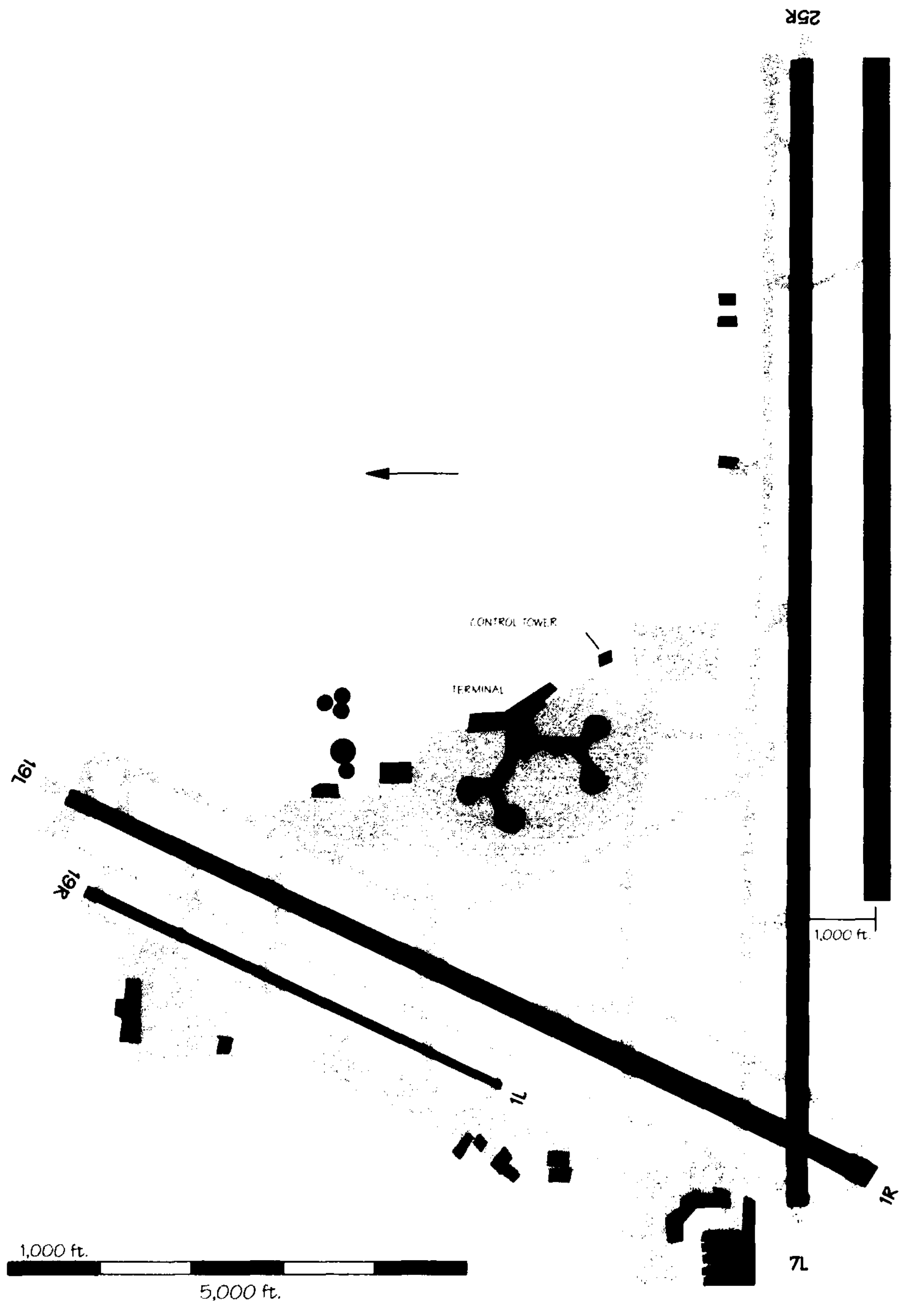
Knoxville (TYS)

A 3,000 foot extension of Runway 5R/23L from 6,000 to 9,000 feet is under multi-year grant. Construction began in June 1989. The projected date of commissioning is 1992. The estimated cost of construction is $17.4 million.



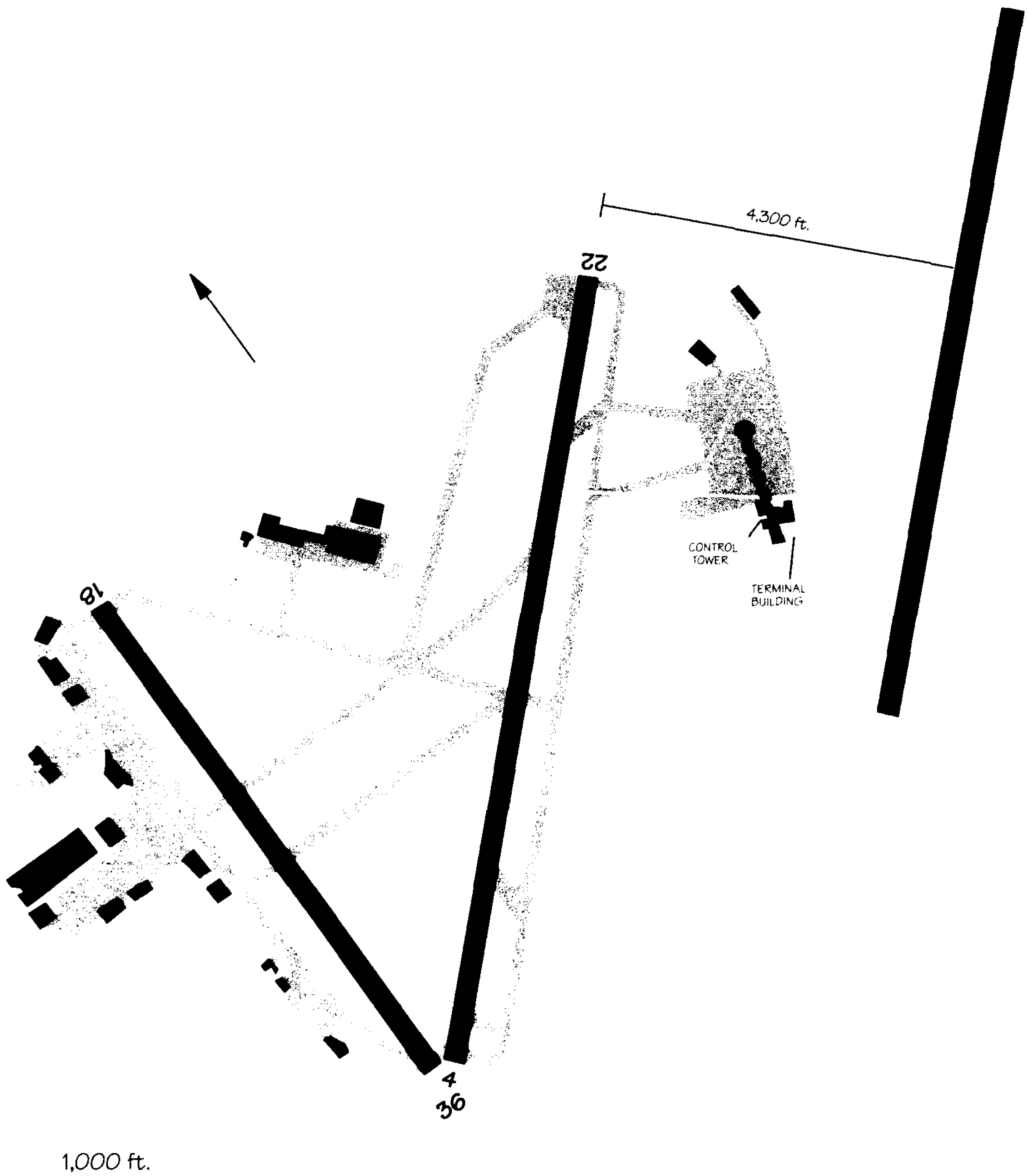
Las Vegas (LAS)

A new 8,900-foot runway, Runway 7R/25L, was constructed parallel to and 1,000 feet south of Runway 7/25. Construction began in 1990. The runway became operational in January 1991. While this will increase departure capacity, no increase in hourly IFR arrival capacity is provided.



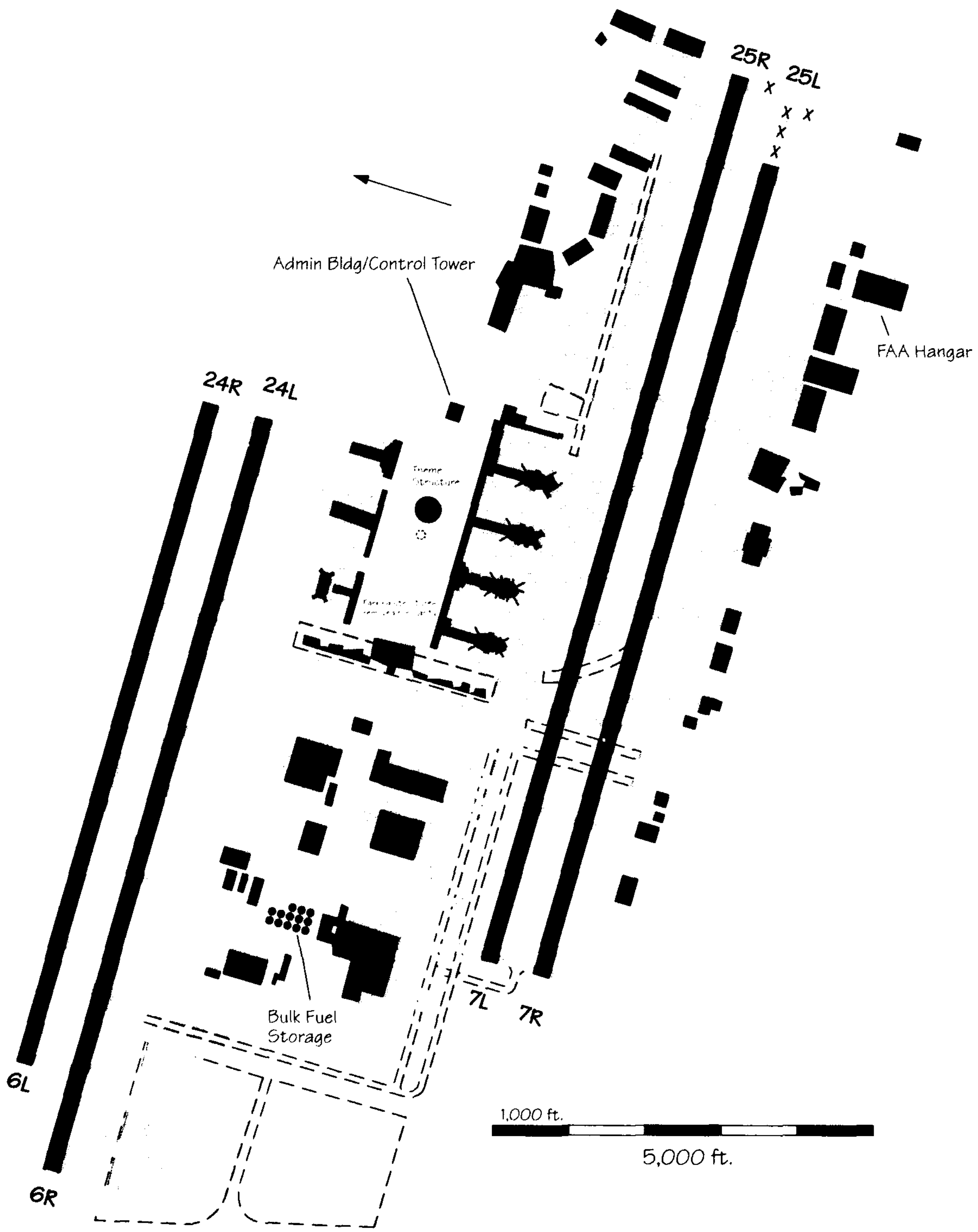
Little Rock (LIT)

Parallel runway 4R/22L, separated from Runway 4/22 by 4,300 feet, became operational in May 1991. This should allow independent parallel IFR operations, increasing hourly IFR arrival capacity from 26 to 52.



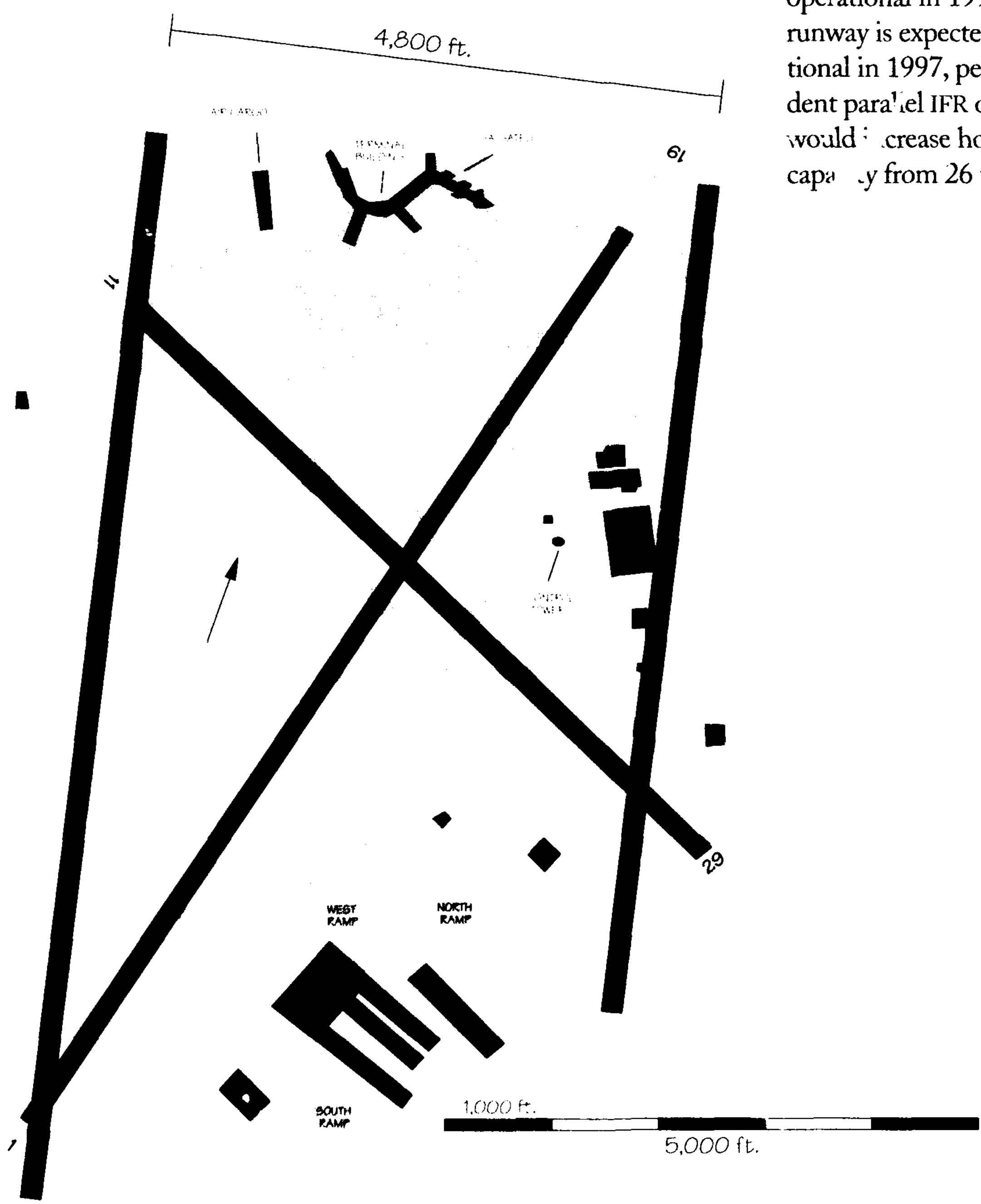
Los Angeles (LAX)

Runway 6L/24R is planned to be extended 1,360 feet to the west, to a length of 10,285 feet. This will improve the take-off capability of Runway 24R to equal that of Runway 24L. The estimated cost of construction is approximately $4 million.



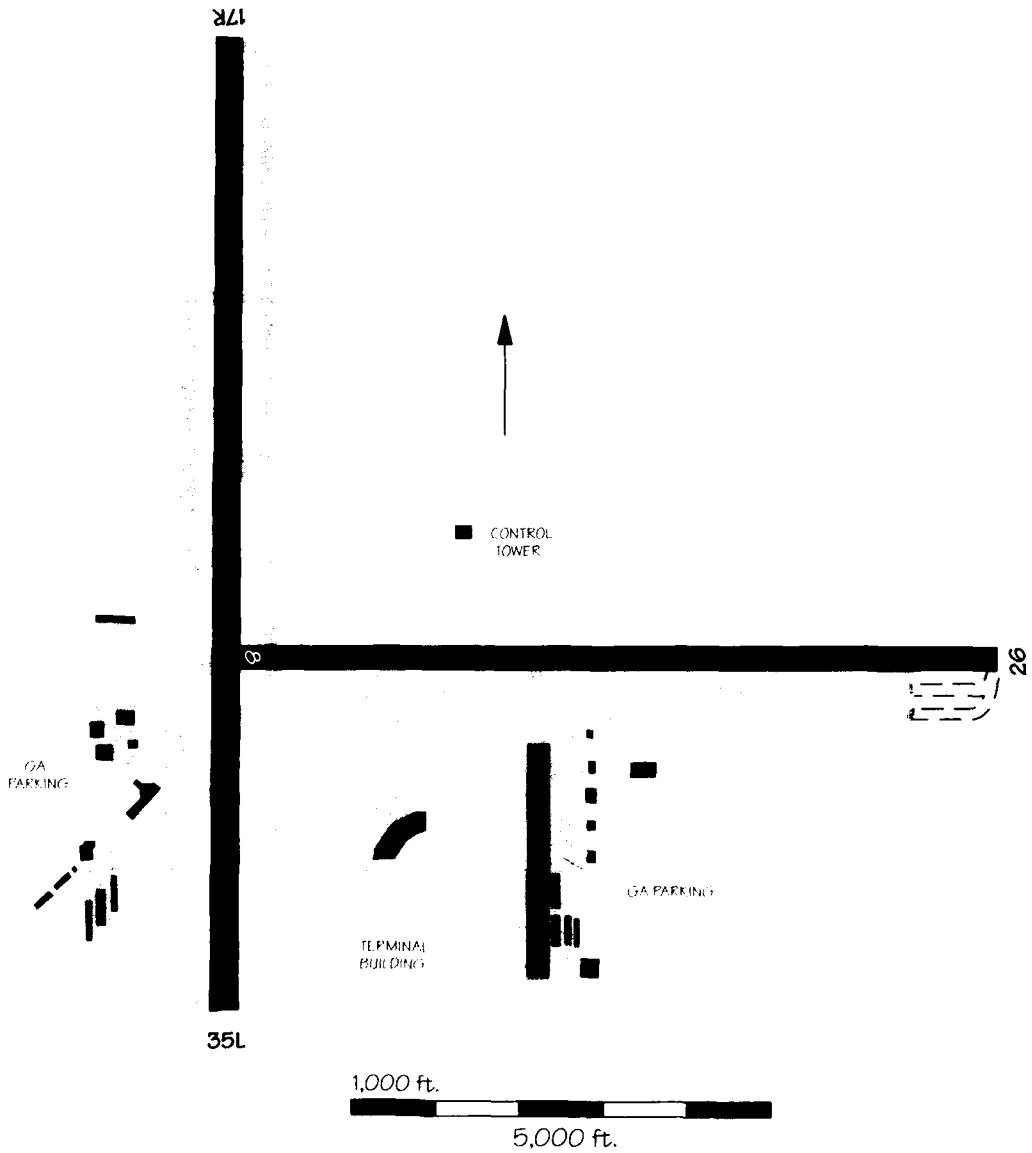
Louisville (SDF)

Plans have begun for two new parallel runways, 4,950 feet apart. They will be numbered Runways 17R/35L and 17L/35R, and will be 10,000 and 7,800 feet long, respectively. They will replace Runway 1/19 which will be closed. The estimated cost of construction is $350 million. Construction is scheduled to begin in 1991. The east runway is expected to be operational in 1995. The west runway is expected to be operational in 1997, permitting independent parallel IFR operations that would increase hourly IFR arrival capacity from 26 to 52.

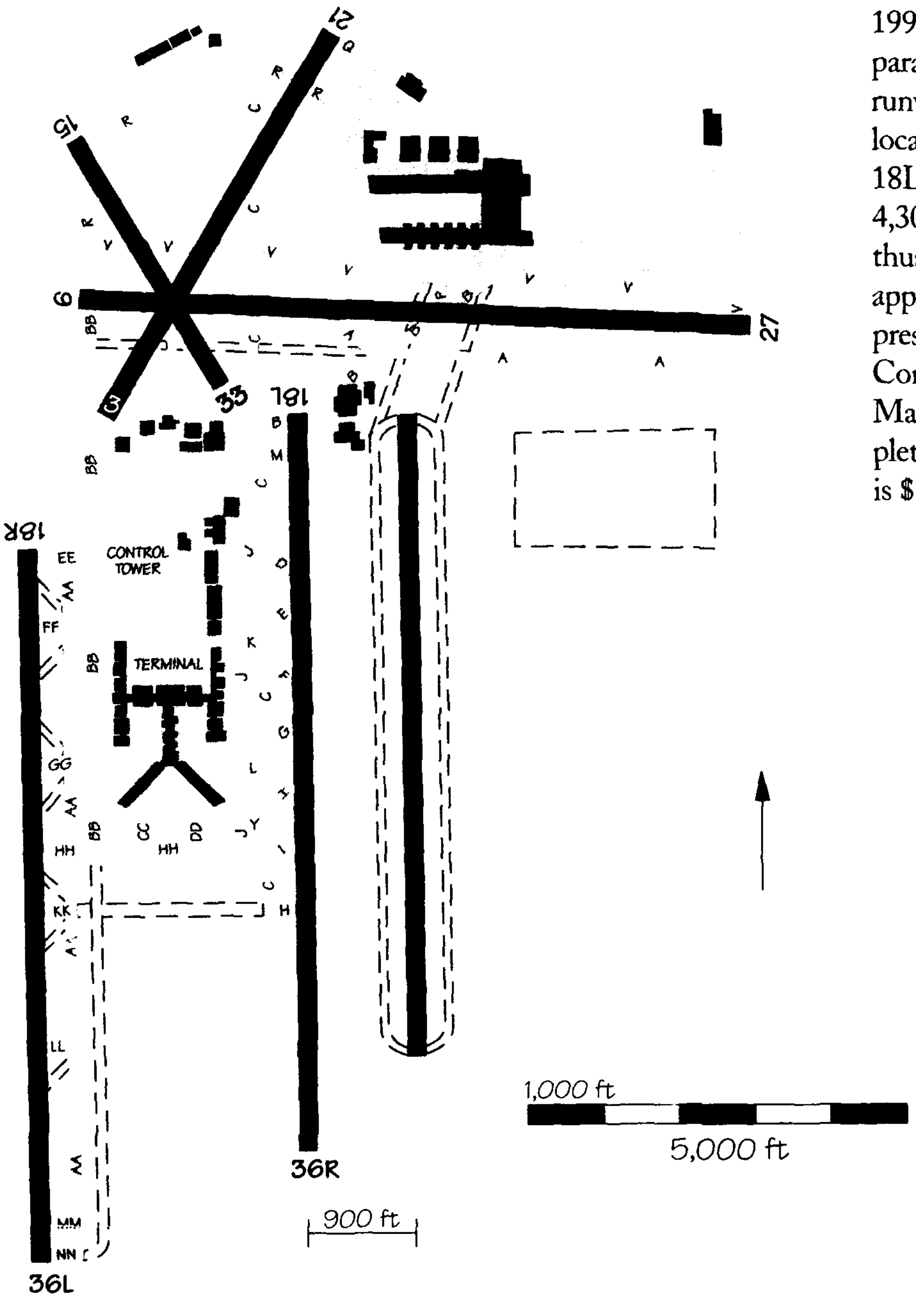


Lubbock (LBB)

An extension to Runway 8/26 is planned. The expected start of construction is 1994 at a cost of $6.2 million. It is anticipated that the extension will become operational in 1995.



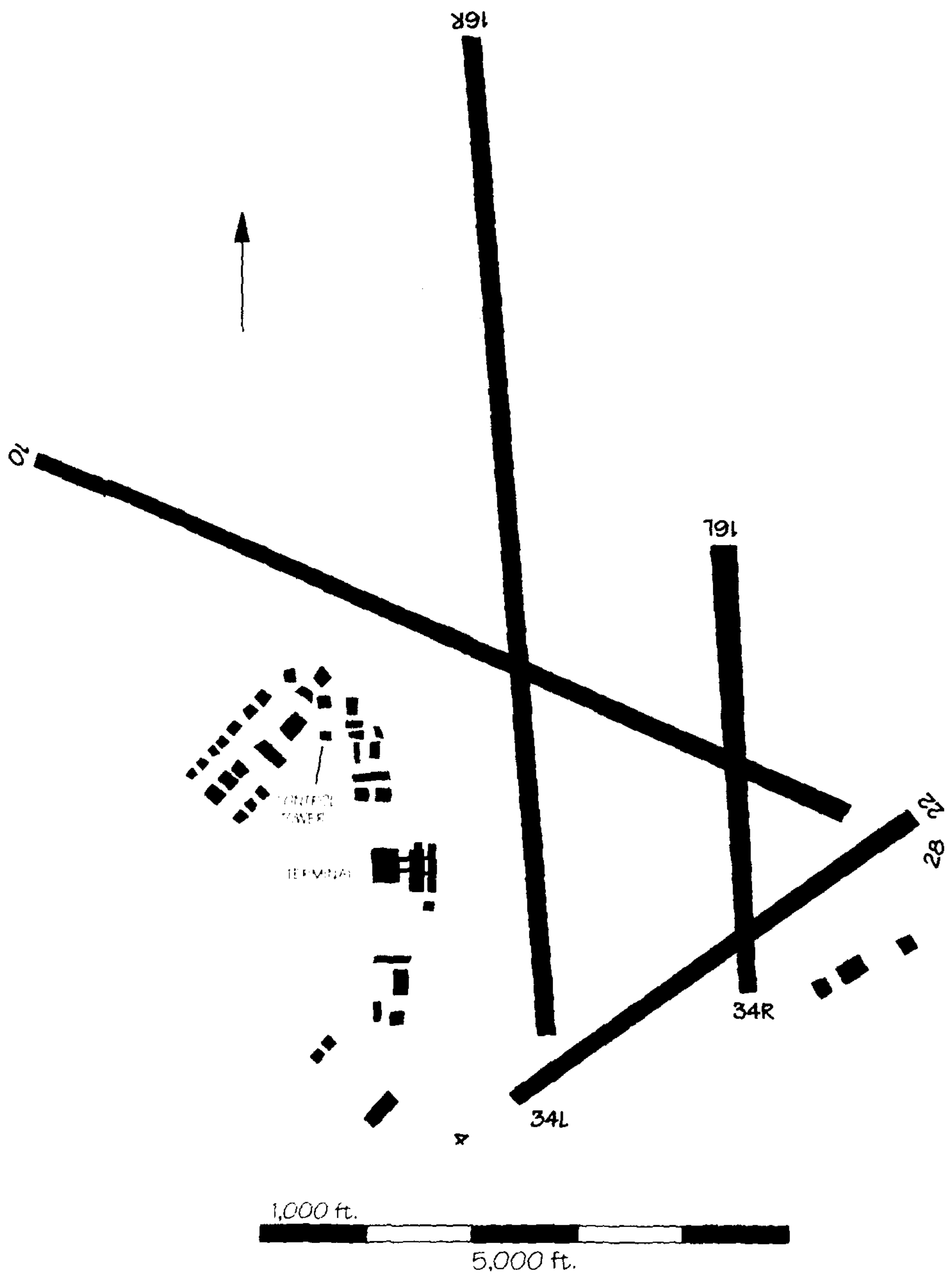
Memphis (MEM)



A new north-south runway, Runway 18L/36R, is planned, as noted in an ALP approved in June 1990. This new runway will be parallel to the existing pair of runways. It will tentatively be located 927 feet east of Runway 18L/36R; this puts the runway 4,300 feet from Runway 18R/36L, thus allowing independent parallel approaches. This would double present hourly IFR arrival capacity. Construction will be started in March 1992 and should be completed in 1994. The estimated cost is $105 million.

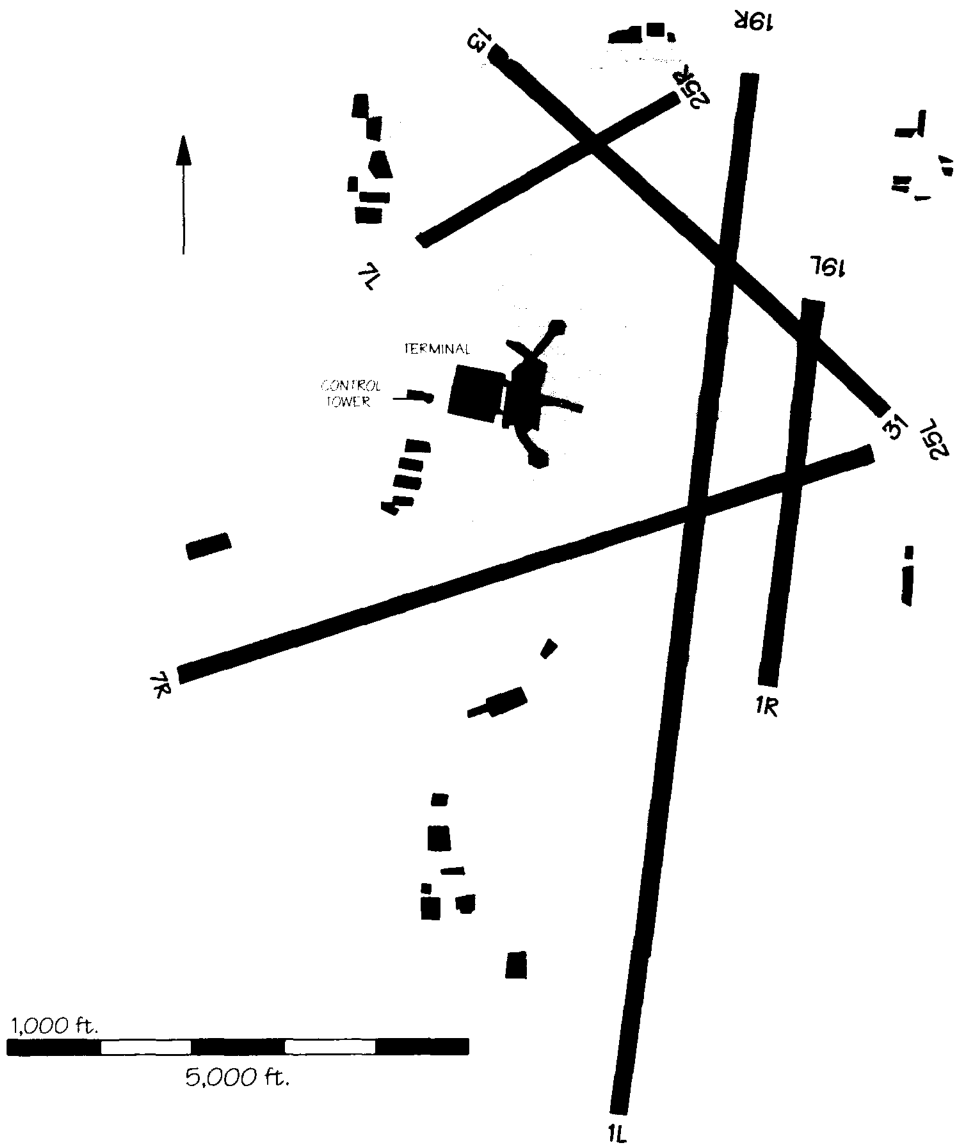
Midland (MAF)

An extension to Runway 10/28 is planned. Construction is planned to begin in 1991. The extension is estimated to be commissioned in March 1992. The estimated cost of construction is $6 million.



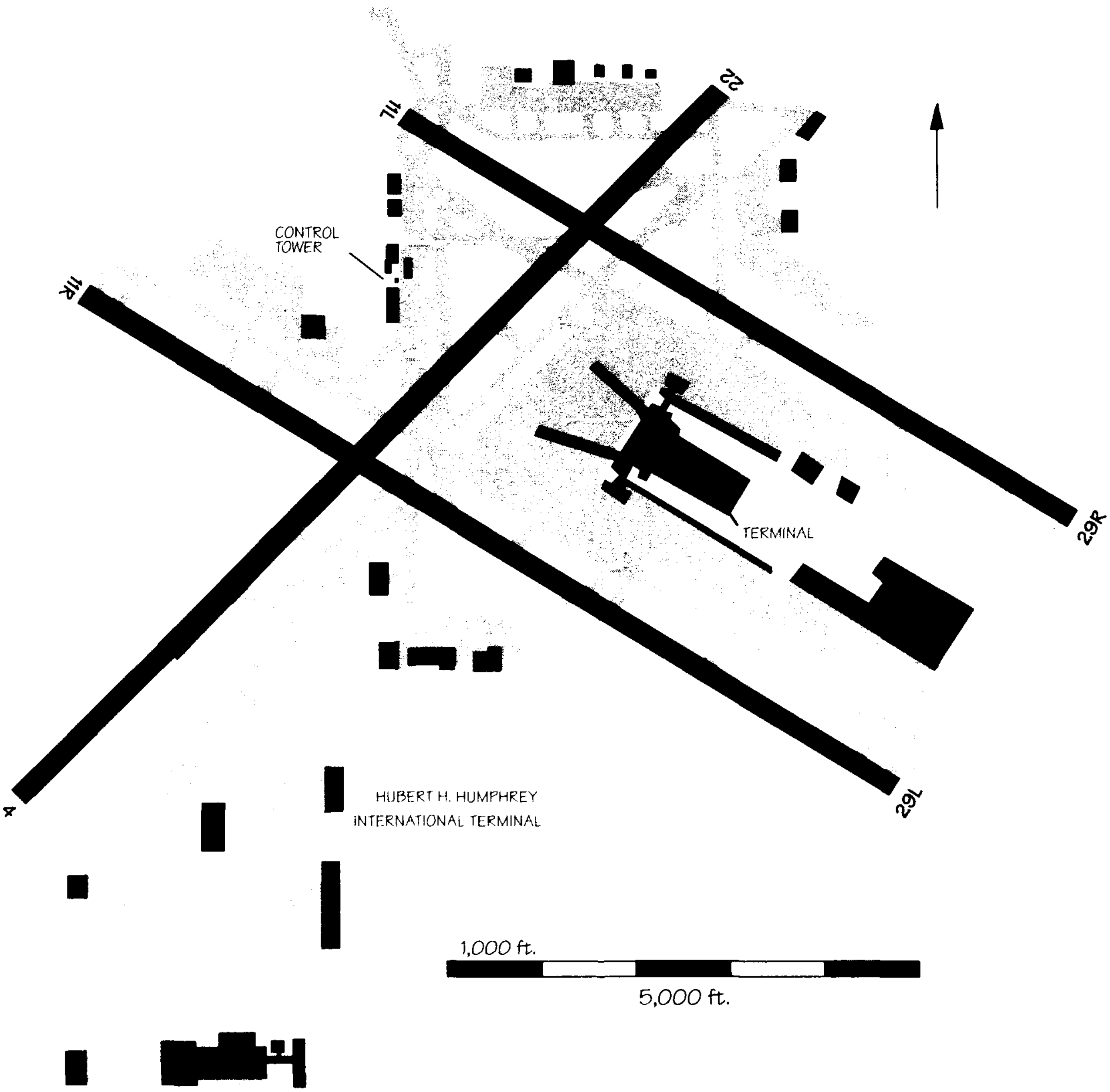
Milwaukee (MKE)

Runway 1L/19R is proposed to be extended 2,000 feet to the south for a total length of 11,600 feet. Construction is scheduled to begin in June 1992 and should be completed in August 1993 at a cost of $13 million. A new parallel Runway 7L/25R is planned in the future.



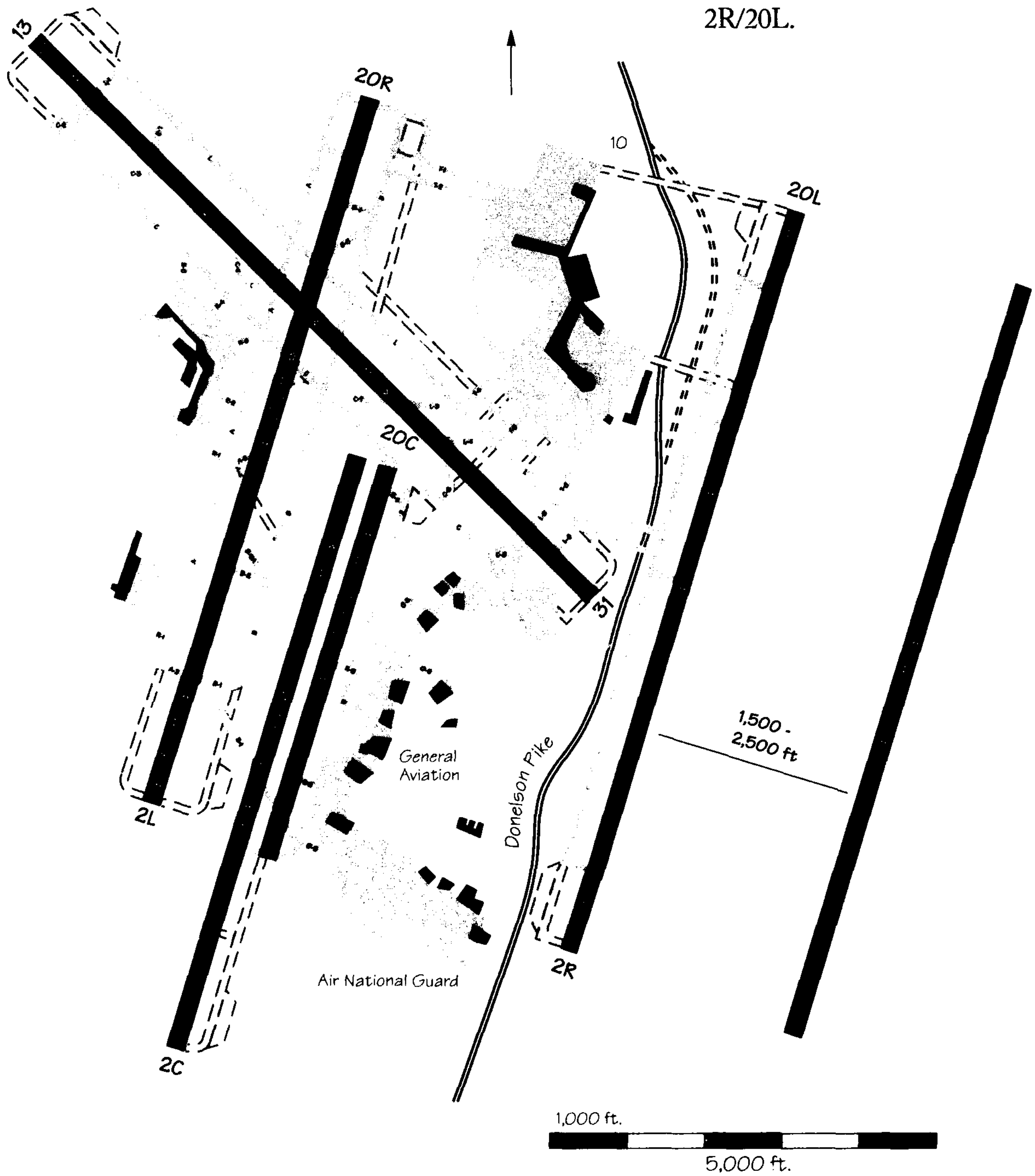
Minneapolis (MSP)

An extension of Runway 4/22 2,750 feet to the southwest is proposed. This will bring the runway length to 11,000 feet. Construction began in January 1991 and the extension should be operational in 1992. The estimated cost of construction is $11 million.



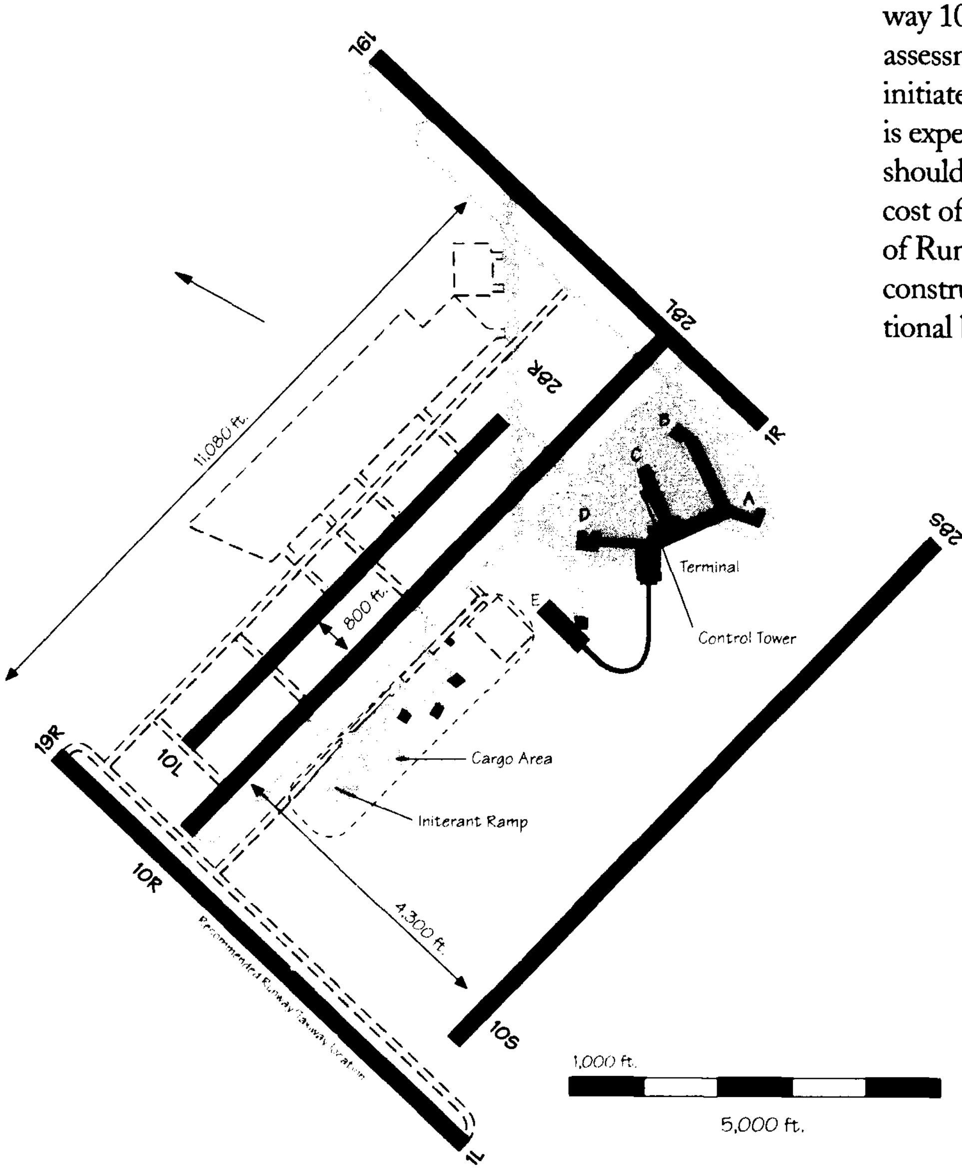
Nashville (BNA)

Plans exist to extend Runway 2L/20R and the Runway 2C/20C taxiway. Construction is expected to start in 1991 and the runway should be operational in the summer of 1995. The cost of the extension is estimated at $34 million. A new Runway 2E/20E is planned for the future between 1,500 and 3,000 feet from Runway 2R/20L.



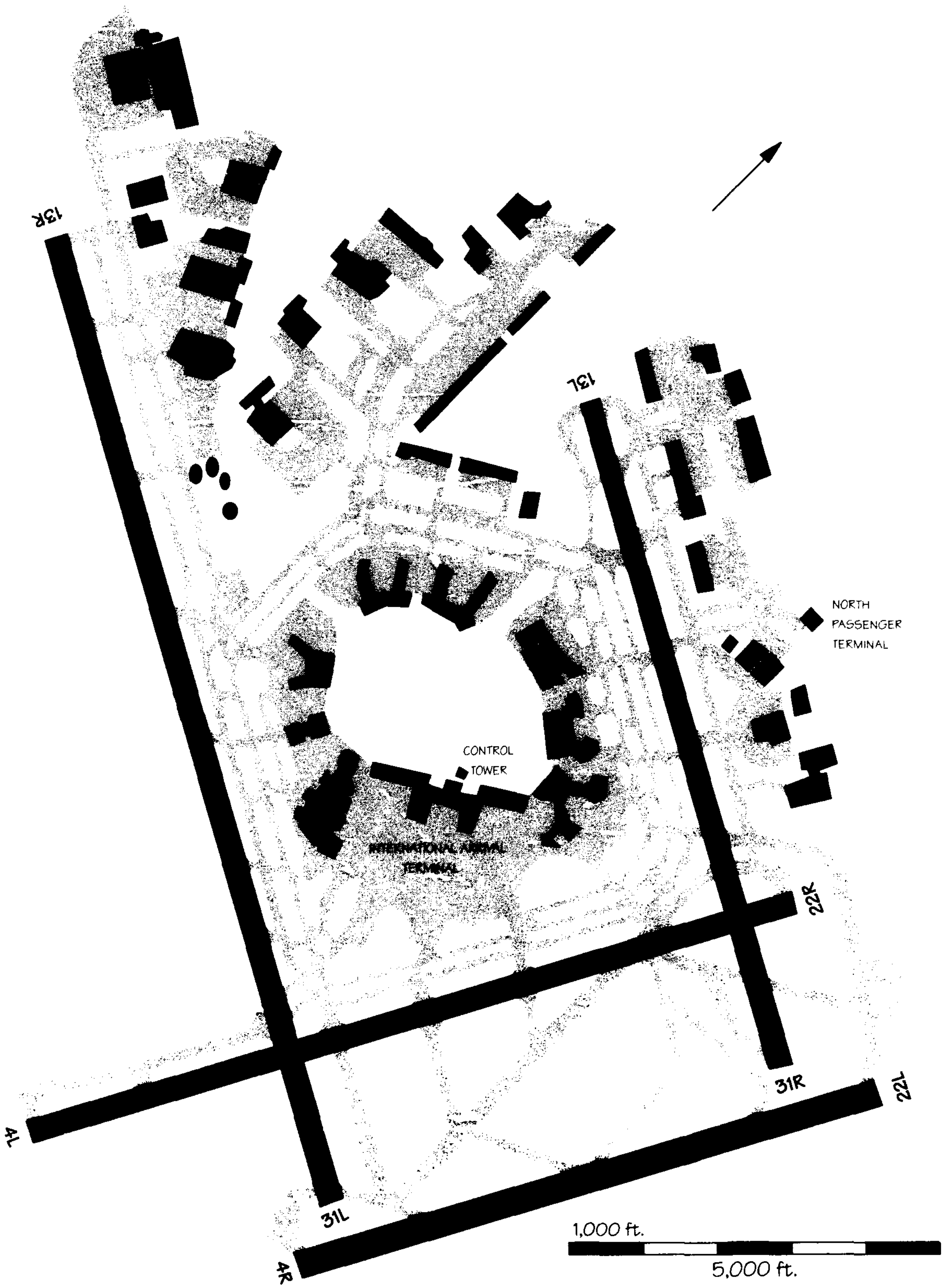
New Orleans (MSY)

A new north-south runway is planned. This new runway will be parallel to existing Runway 1/19 and will be located beyond the threshold of Runway 10, 8,000 feet away from Runway 1/19. This will allow independent parallel operations, doubling IFR hourly arrival capacity. Construction is planned to begin in January 1995 and be completed in 2000 at a cost of $180 million. The airport is also considering construction of a 6,000-foot runway approximately 10,000 feet north of and parallel to Runway 10/28. An environmental assessment is expected to be initiated in FY 1992. Construction is expected to begin in 1994 and should be completed in 1995 at a cost of $40 million. An extension of Runway 10/28 is currently being constructed and should be operational by late 1991.



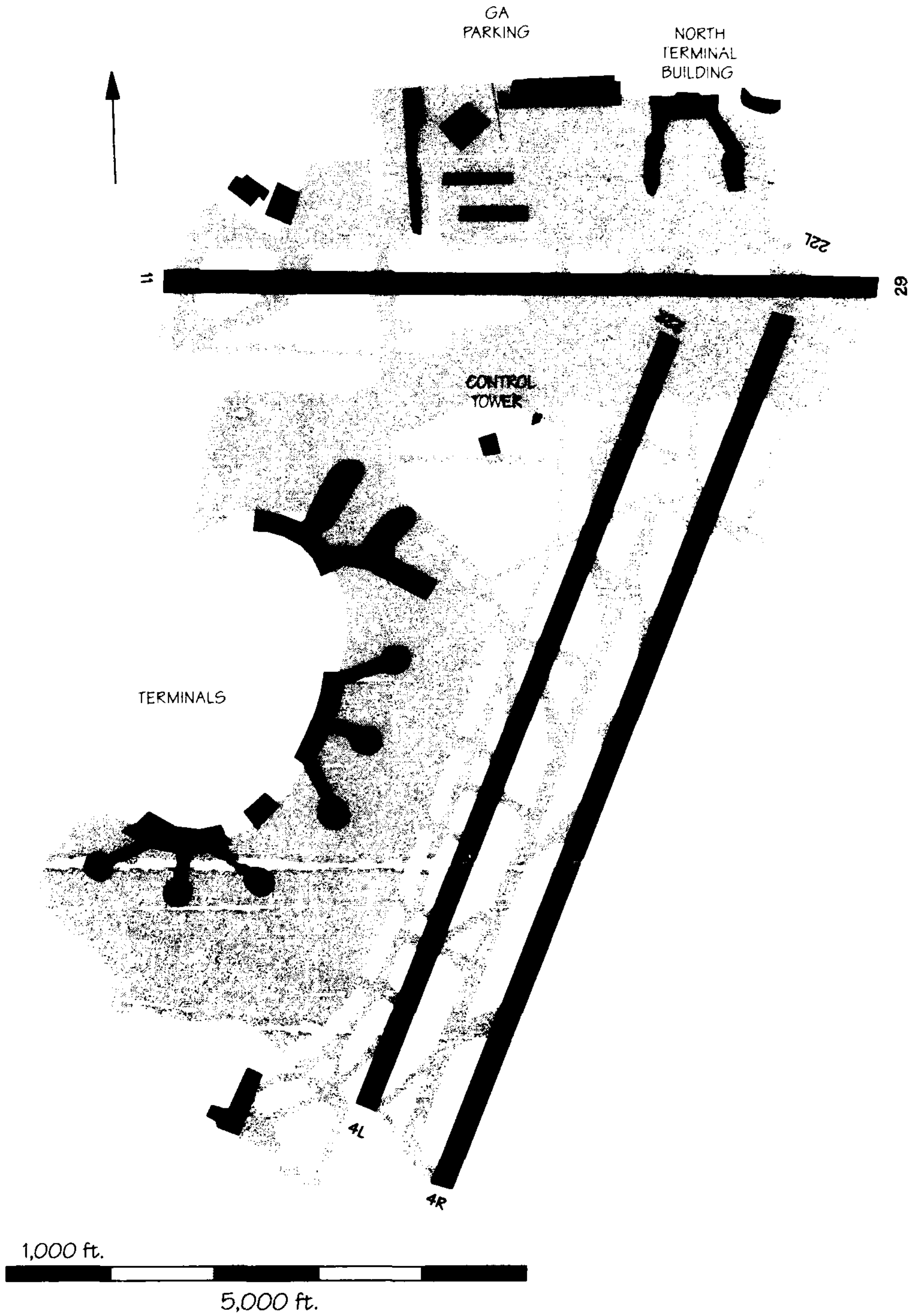
New York (JFK)

An extension of Runway 4L/22R is planned.



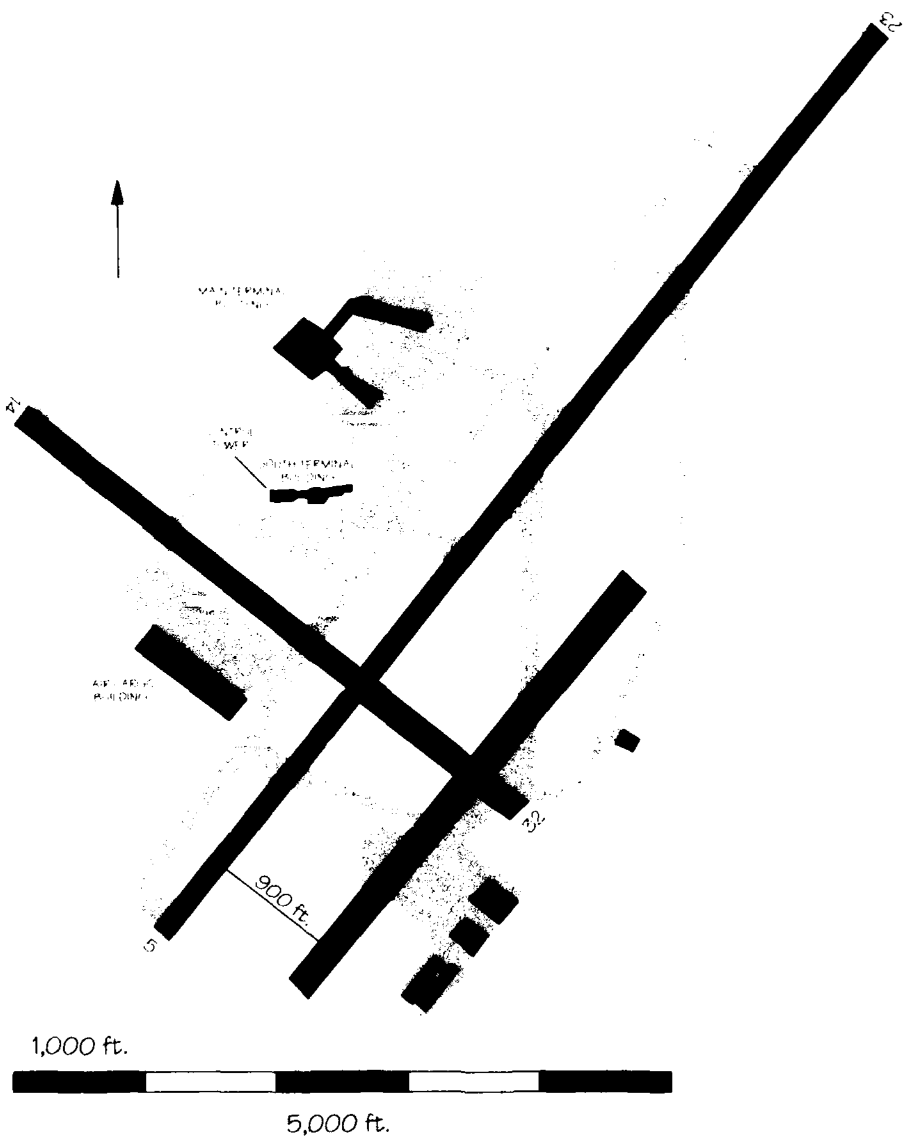
Newark (EWR)

A 500 foot extension to Runway 11/29 is planned.



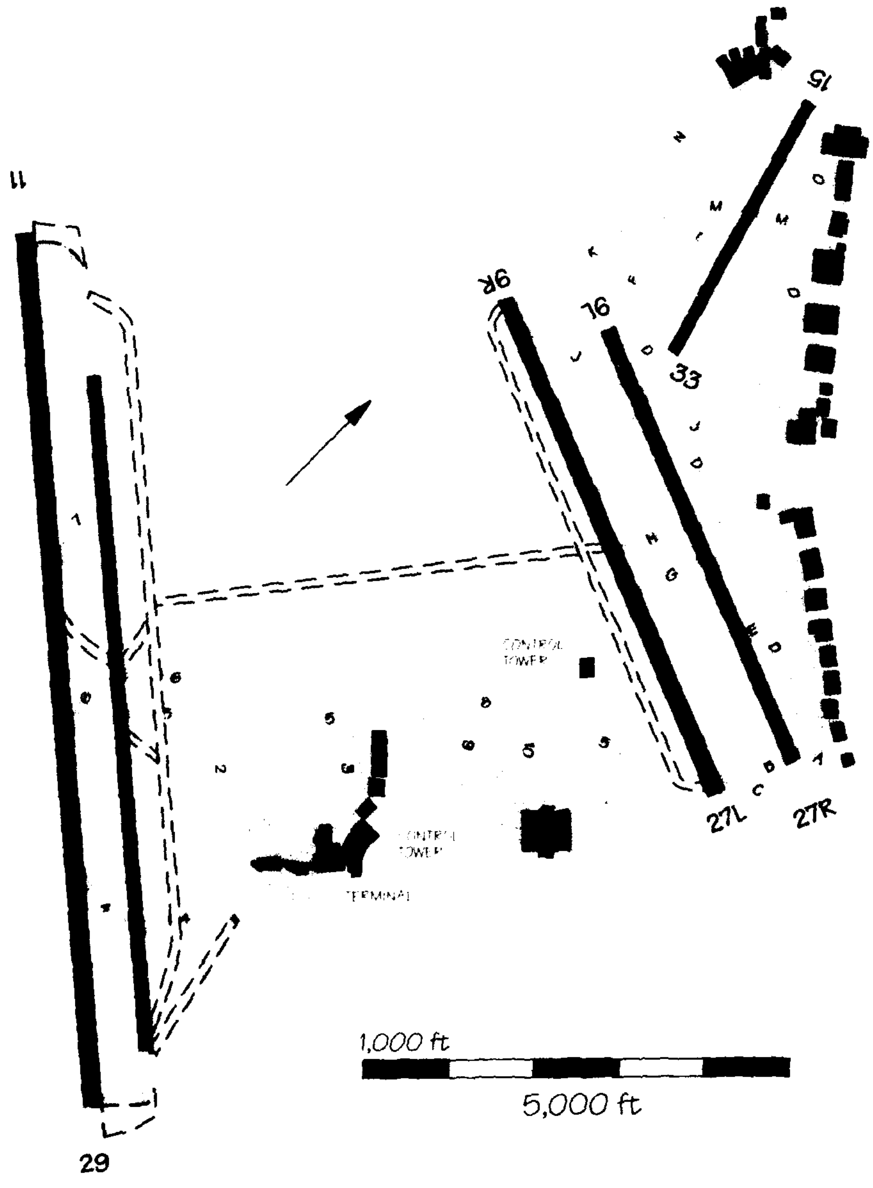
Norfolk (ORF)

Runway 5R/23L, parallel to and 900 feet southeast of the main Runway 5/23, is being planned. Completion of this new parallel would not increase hourly IFR arrival capacity, but would add additional departure capacity. It is estimated that the runway will be operational in 1994 at a cost of $13 million with construction starting in July 1992. An extension to Runway 14/32 is also planned. The estimated cost is $2 million and the runway is expected to be operational in October 1996.

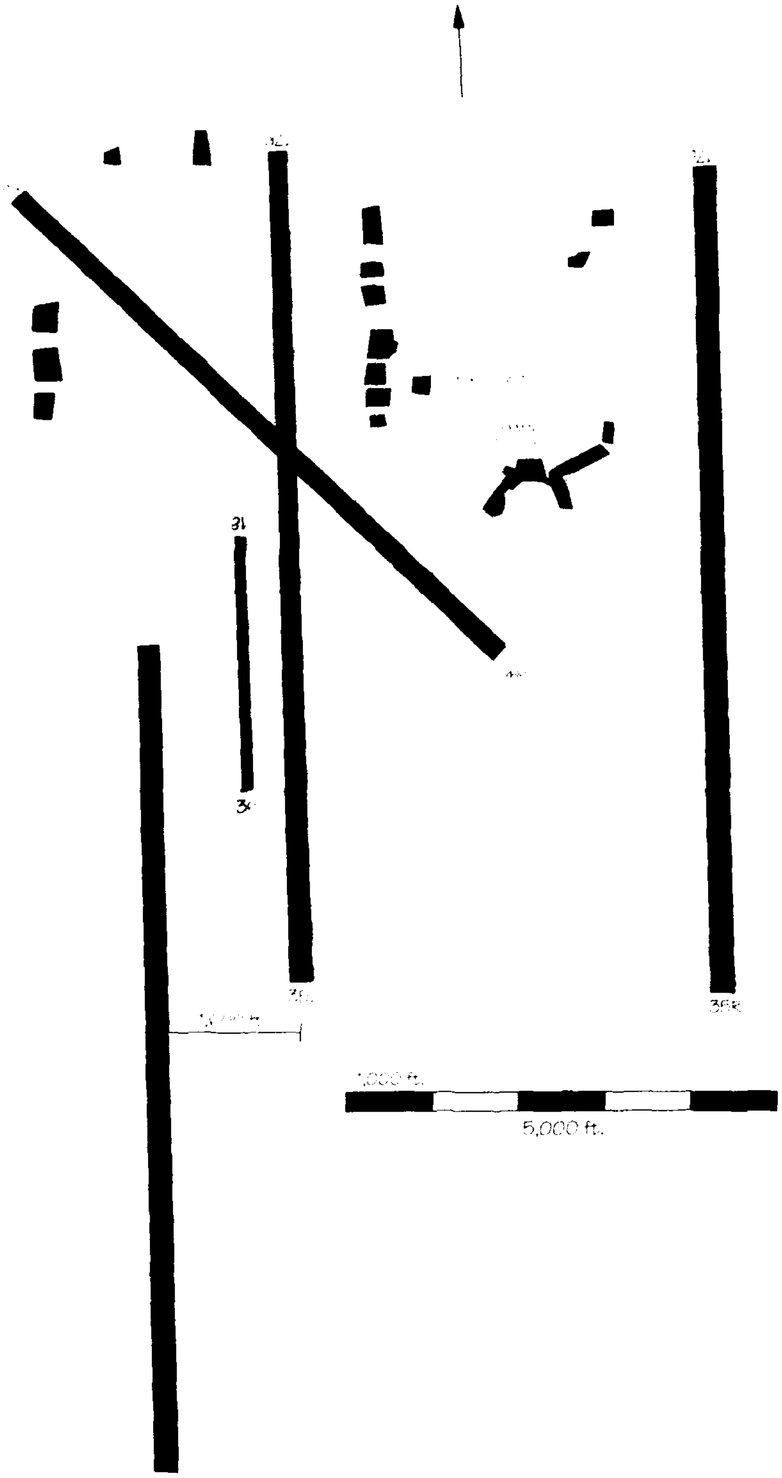


Oakland (OAK)

A new Master Plan is underway considering construction of a new air carrier runway, Runway 11R/29L. The estimated cost of construction is $143 million.



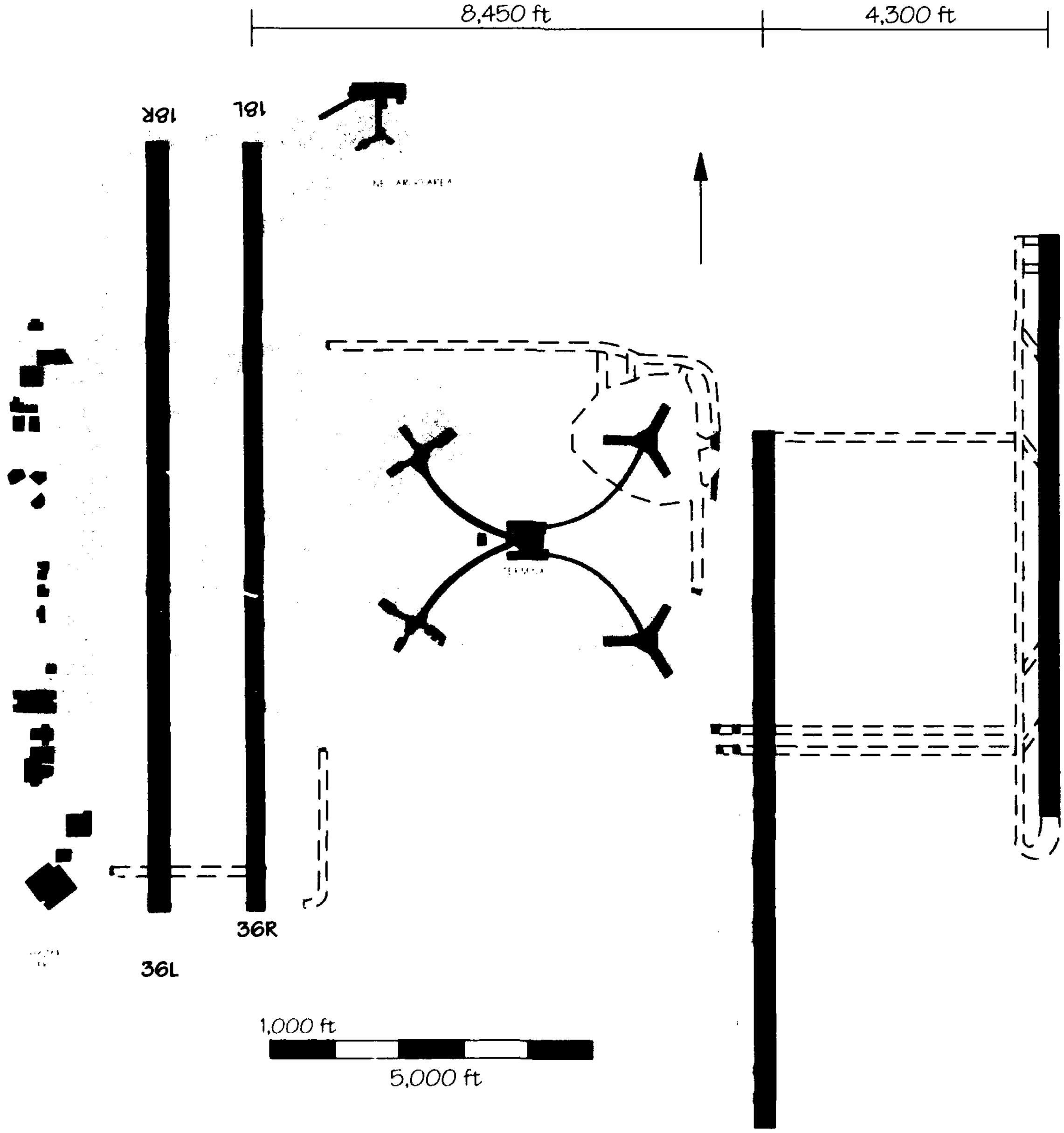
Oklahoma City (OKC)

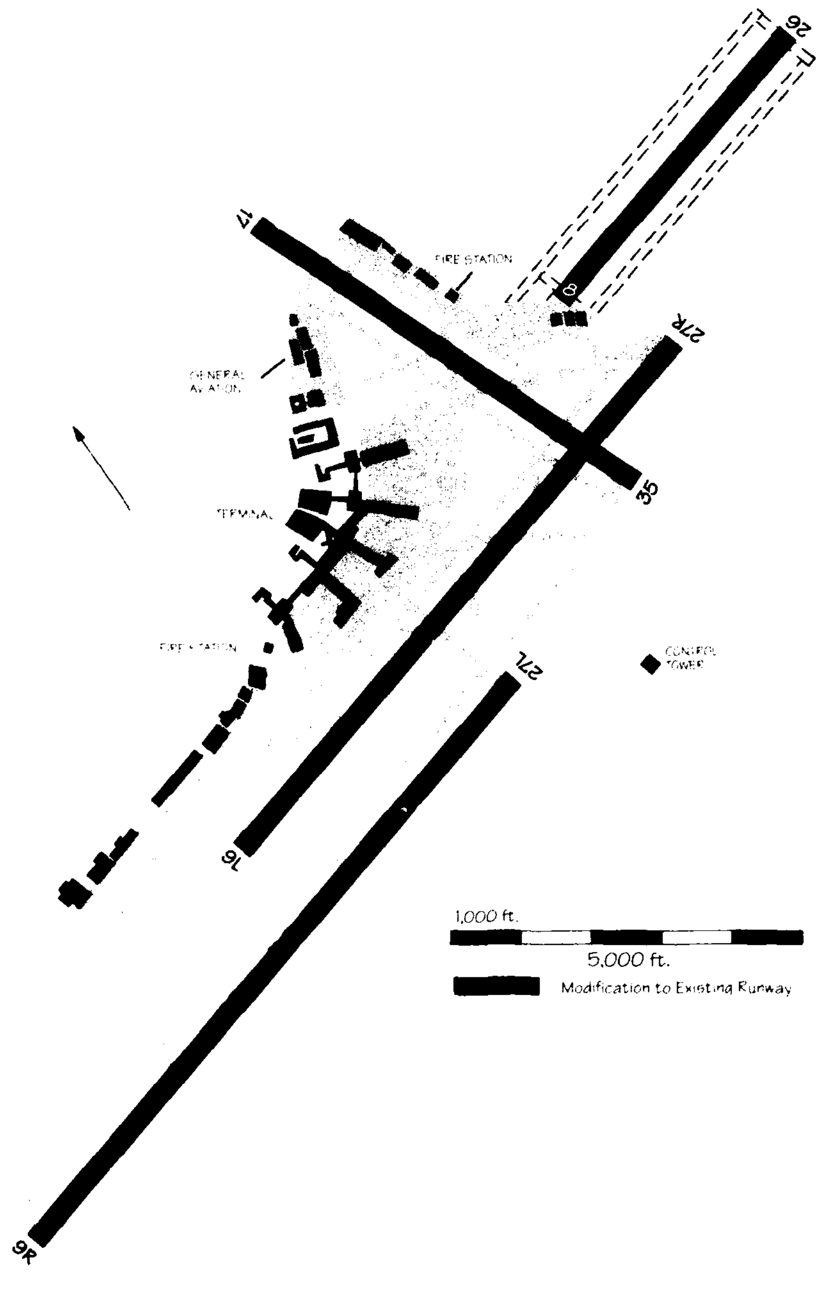


Extensions to both north-south runways to 12,500 feet are planned. It is anticipated that the extensions will be operational in 2001. The estimated cost of extending Runway 17R/35L is $20 million; the estimated cost of extending Runway 17L/35R is $24 million. Plans also exist for a 10,000 foot long parallel runway 1,600 feet west of Runway 17R/35L. The estimated cost of construction is $55 million and the estimated operational date is October 2001.

Orlando (MCO)

A fourth north-south runway, Runway 17L/35R, is expected to be operational in 1993. It will be located 4,300 feet east of the third runway, Runway 17R/35L. This may permit triple independent IFR operations. The estimated cost of construction of this runway is $80 million. A fifth runway, Runway 17C/35C, has been proposed but does not appear in the Master Plan.



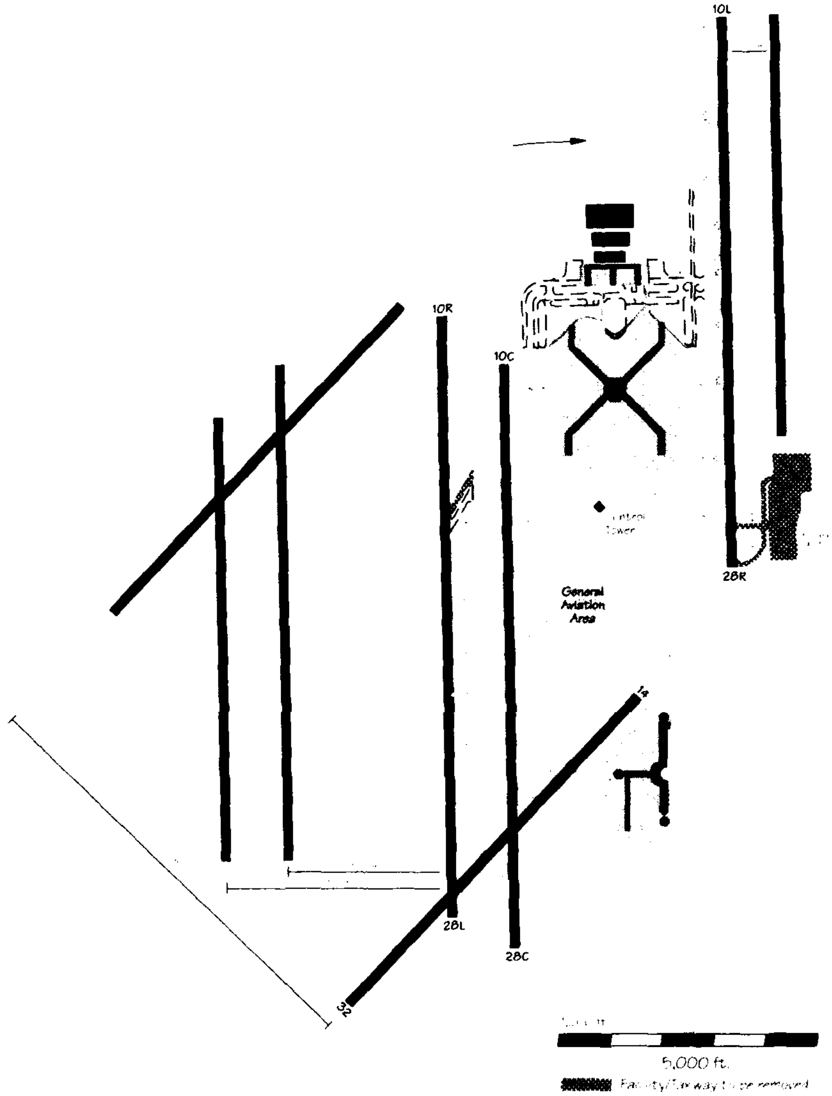


Philadelphia (PHL)

The inner parallel, Runway 9L/27R, will shift 600 feet south closer to Runway 9R/27L. The relocated Runway 9L/27R is expected to be operational in January 1997 at an estimated cost of $55 million. A new 5,000 foot parallel commuter runway, Runway 8/26, has been proposed to be located in the northeast quadrant. It could be spaced as wide as 4,300 feet from the relocated inner parallel. The location has not been established yet. This could potentially provide independent parallel IFR operations. The estimated cost of commuter Runway 8/26 is $169 million.

Phoenix (PHX)

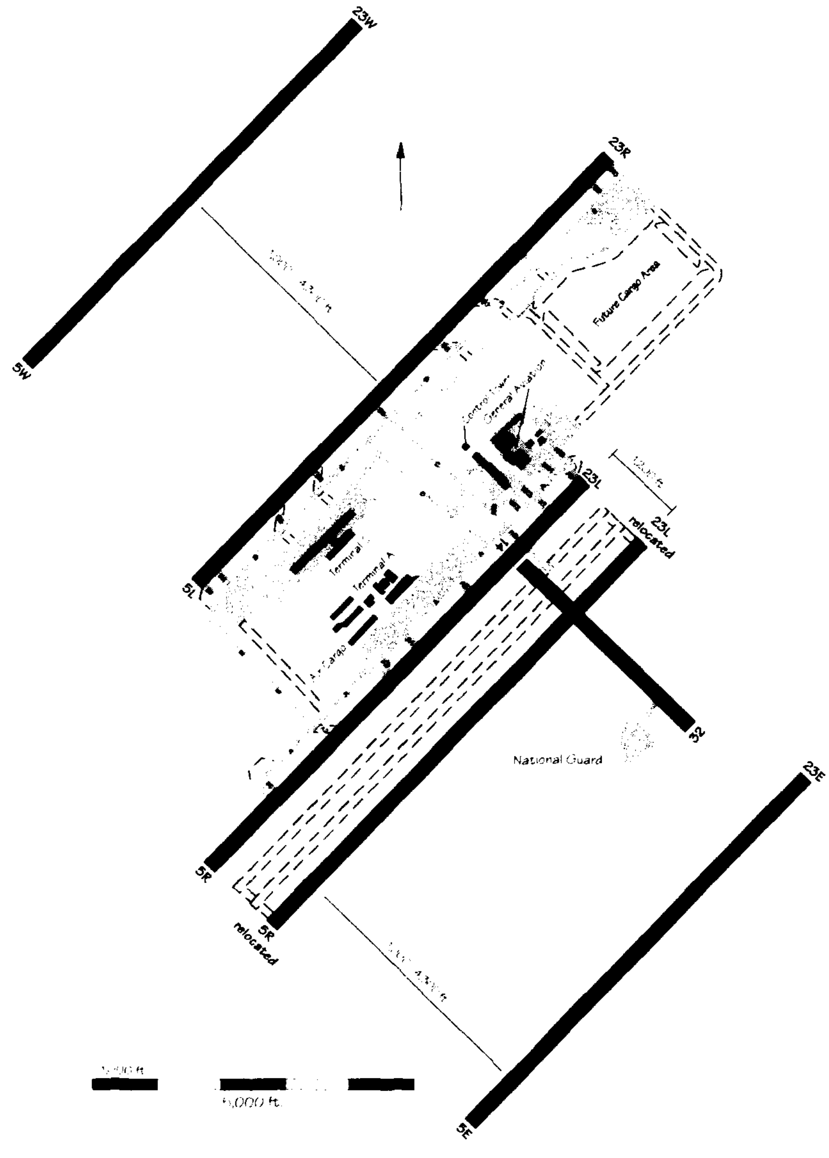
A 9,500-foot third parallel runway, Runway 8S/26S, is proposed 800 feet south of Runway 8R/26L. The cost of construction is estimated to be $88 million. An environmental assessment of this third runway is underway and was submitted during the second quarter of FY91. The estimated operational date is 1994.



Pittsburgh (PIT)

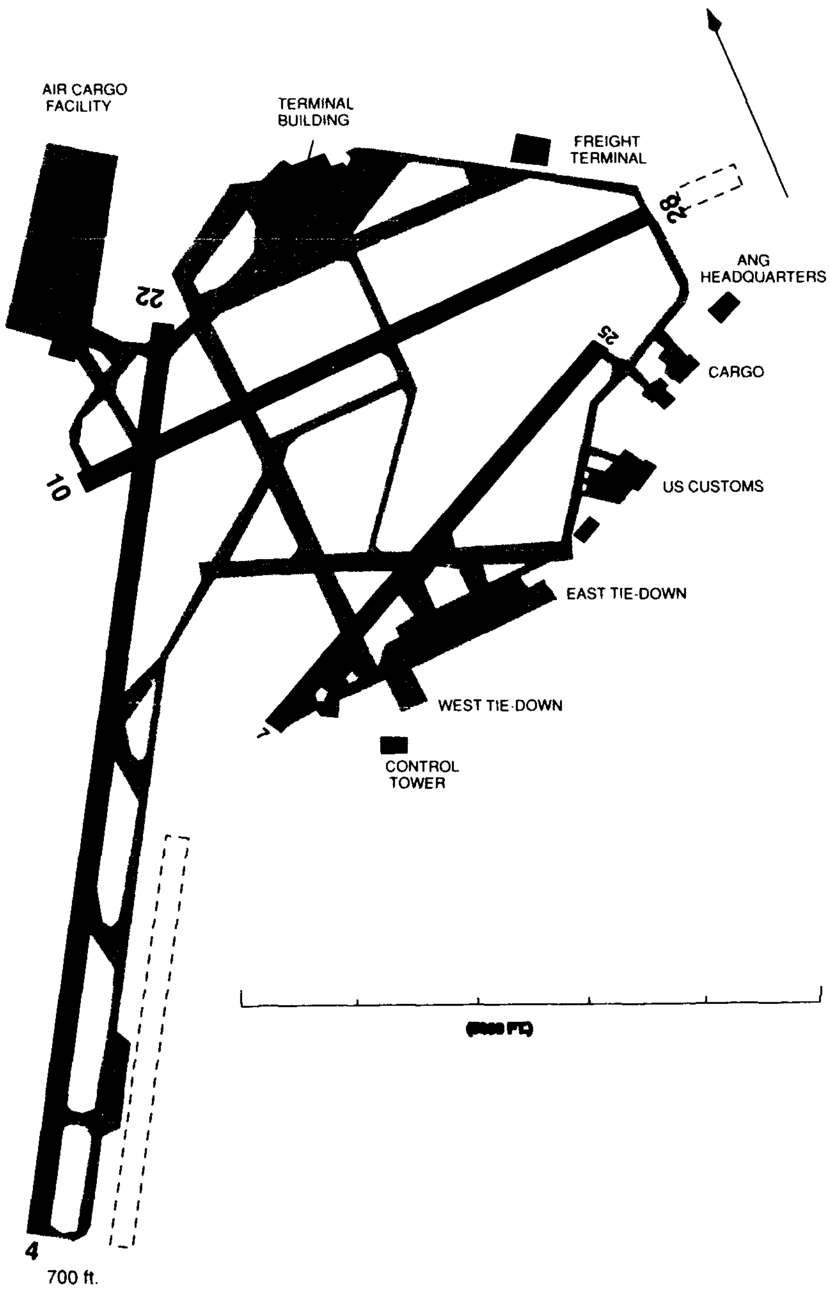
A new Master Plan was started in 1990. It recommended a choice between a new parallel crosswind runway and a fourth Runway 10/28 parallel. Construction of Runway 14R/32L, parallel to existing crosswind Runway 14/32, is tentatively scheduled to begin in June 1993 and be completed in 1995. It will be located more than 11,650 feet from the existing crosswind runway. Estimated cost is $100 million. The fourth Runway 10/28 parallel may take higher priority. It is also currently scheduled to begin in 1993, and be completed in 1995, also at an estimated cost of $100 million. Completion of the fourth parallel may permit triple independent IFR approaches.

Raleigh-Durham (RDU)



The relocation of Runway 5R/23L and associated taxiways is expected to begin in 1993. The new runway will be parallel to and approximately 1,200 feet southeast of existing Runway 5R/23L. It will be a 9,000-foot long air carrier runway and could permit independent IFR approaches. The estimated operational date is 1996 and the estimated cost is $45 million. Two other runways are proposed for eventual construction. One is a parallel commuter runway, southeast of the existing Runway 5R/23L. The other would be a parallel runway approximately 1,200 feet southwest of Runway 5L/23R.

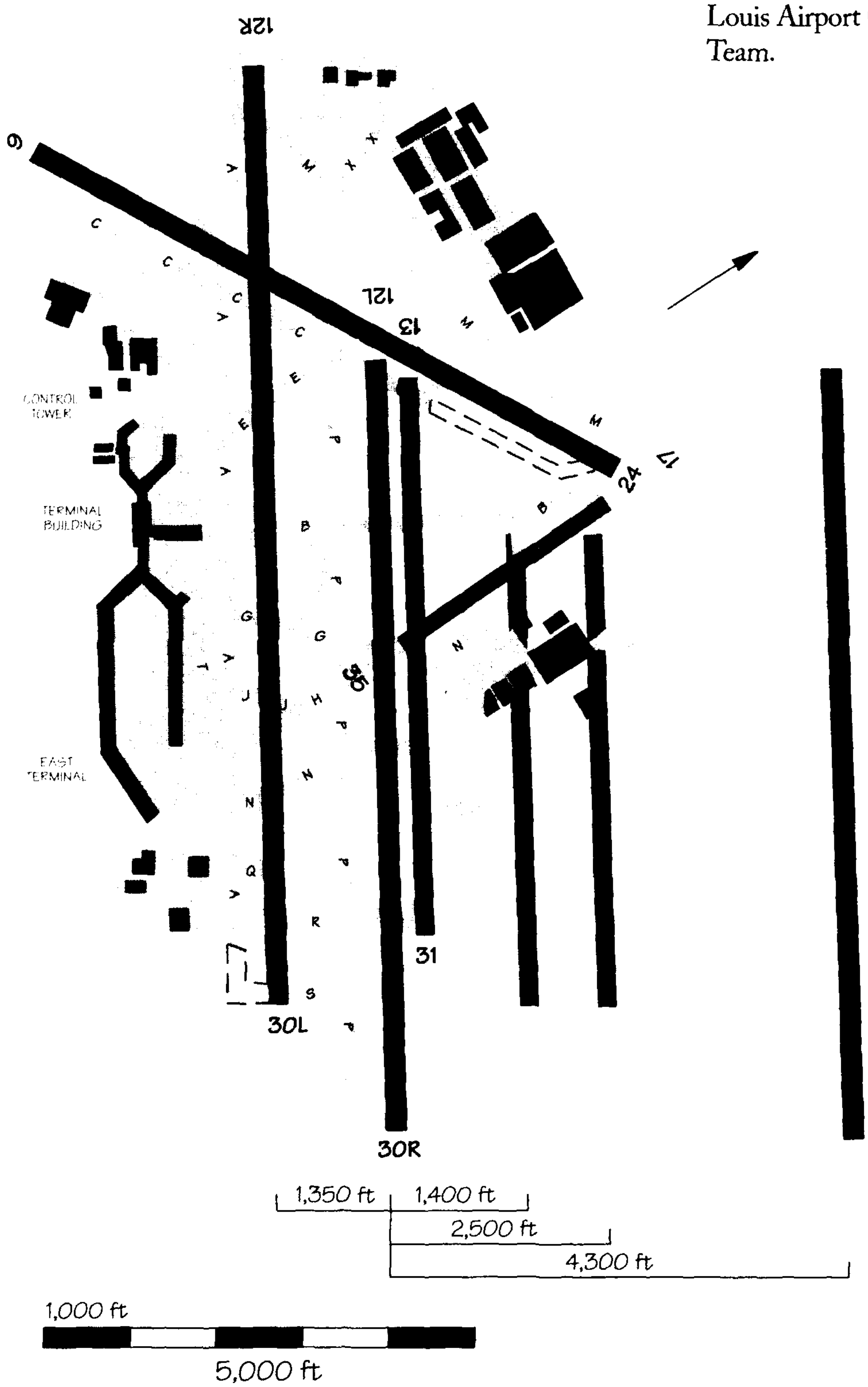
Rochester (ROC)



Construction is expected to begin in 1993 on an extension to Runway 10/28 to be completed in 1994. The estimated cost of construction is $2.3 million. An extension to Runway 4/22 is expected to cost $0.5 million. Construction will begin in 1995 and the extension should be operational in 1996. Parallel Runway 4R/22L is estimated to cost $4.7 million and should be operational in 2000. Environmental assessments have not yet been started for these projects.

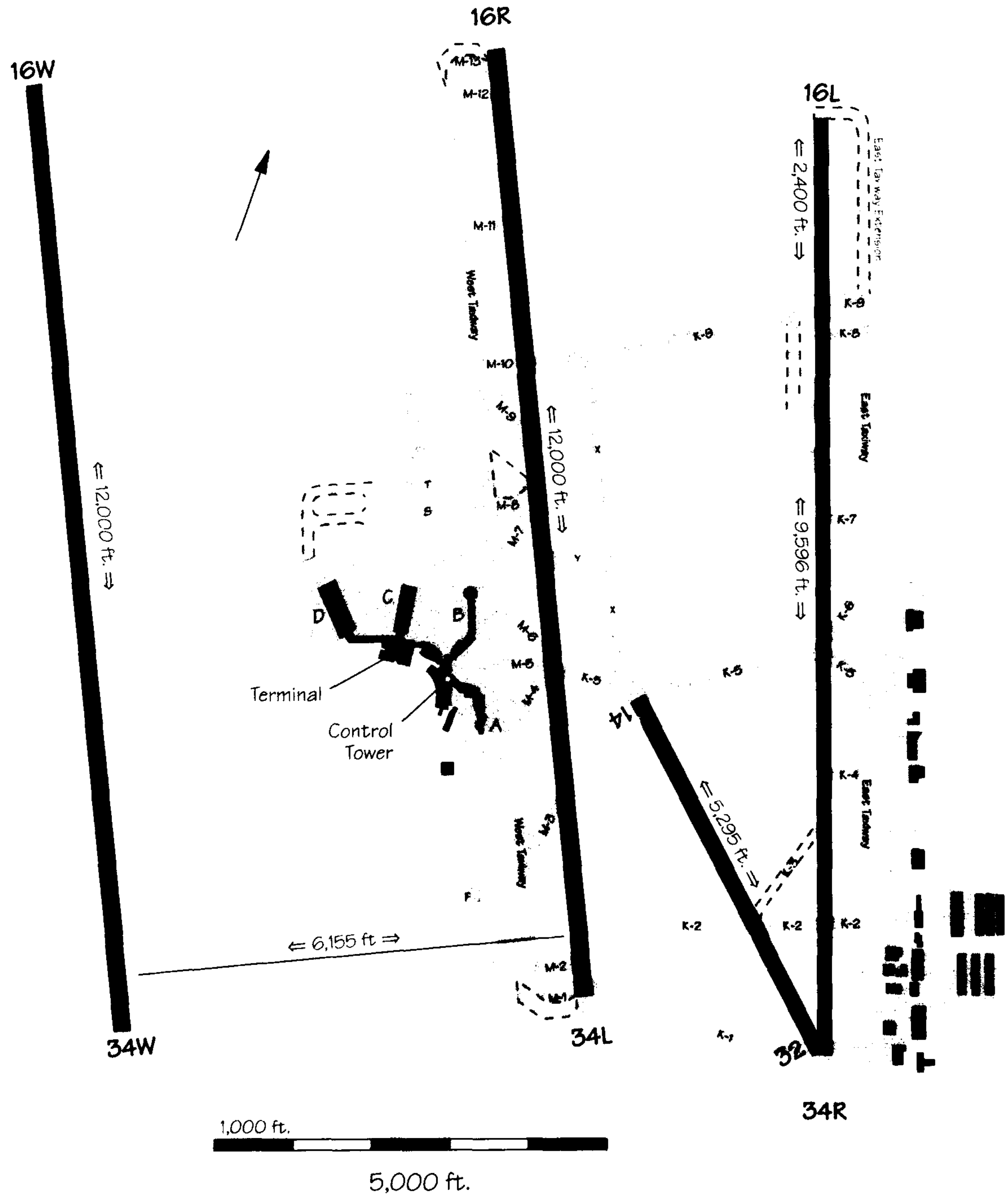
St. Louis (STL)

A new parallel Runway 12L/30R in several configurations has been recommended by the St. Louis Airport Capacity Design Team.



Salt Lake City (SLC)

A new 12,000 foot runway parallel to and 6,300 feet west of existing Runway 16R/34L is planned. Construction is scheduled to begin in September 1992 and should be completed in 1994. The estimated cost of construction is $95 million. This may permit triple IFR approach operations, if approved.

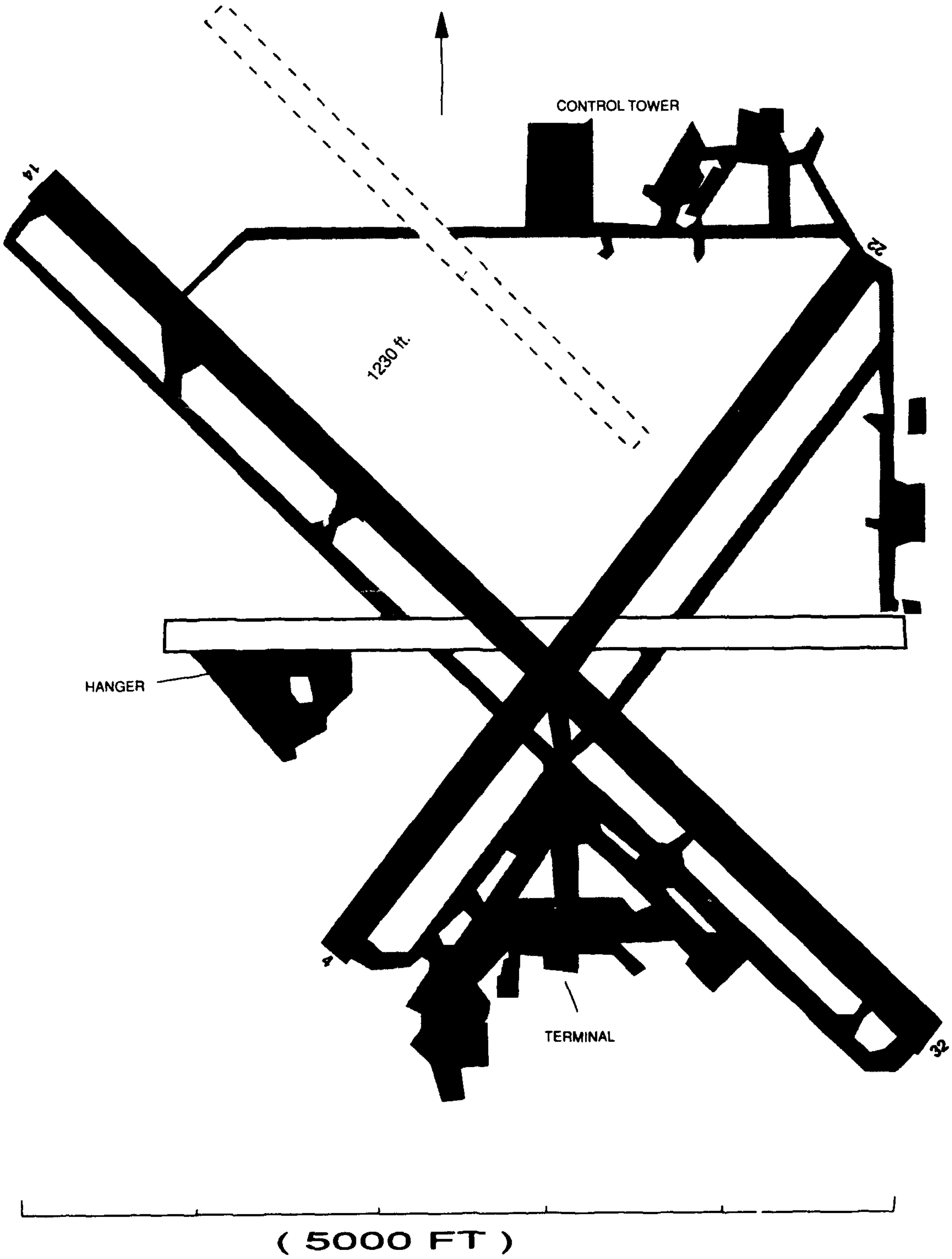


San Jose (SJC)

Consideration is being given to extend Runway 30R/12L for air carrier capability. The estimated cost of construction of the extension is $10 million.

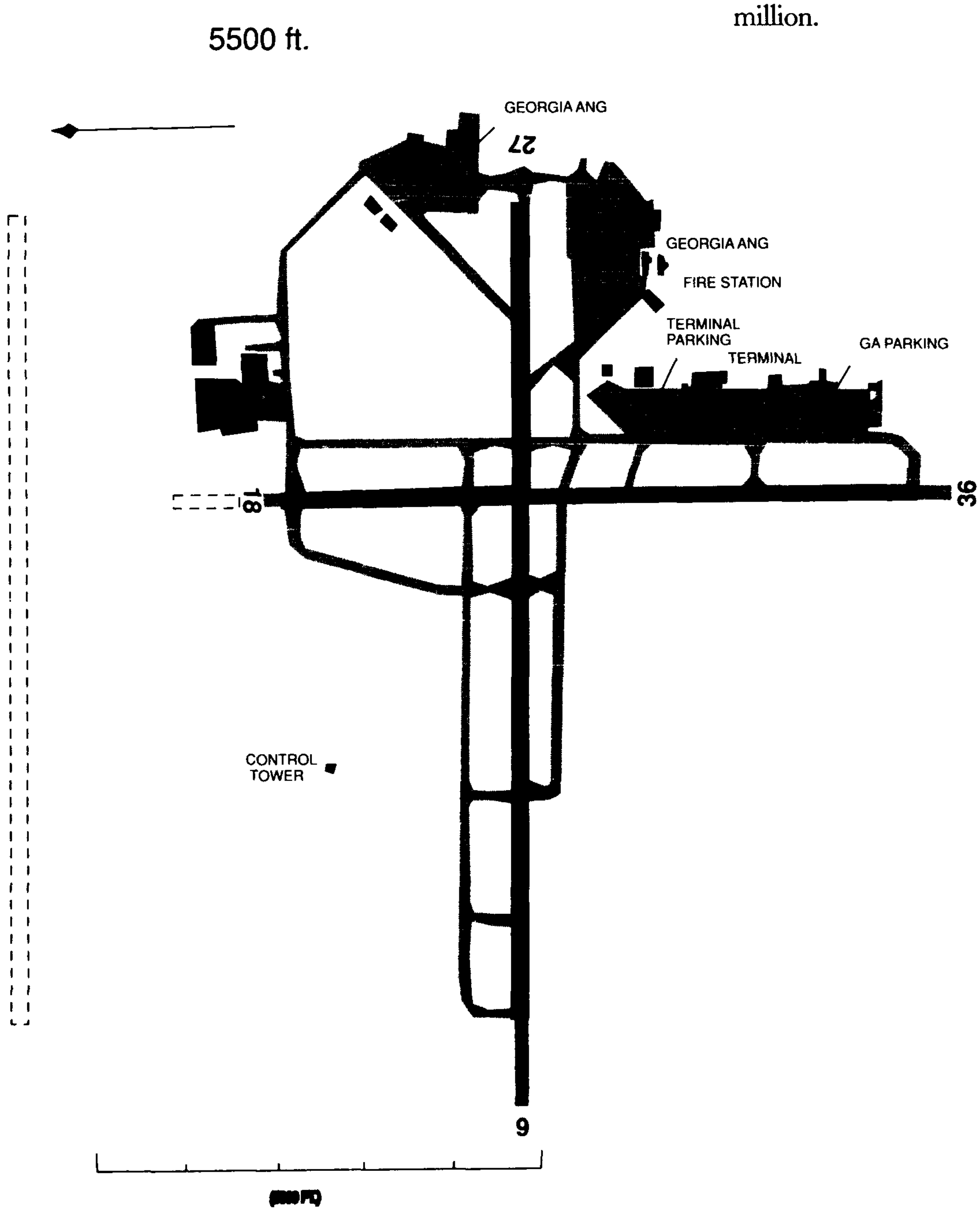
Sarasota (SRQ)

A new parallel Runway 14R/32L is being considered.



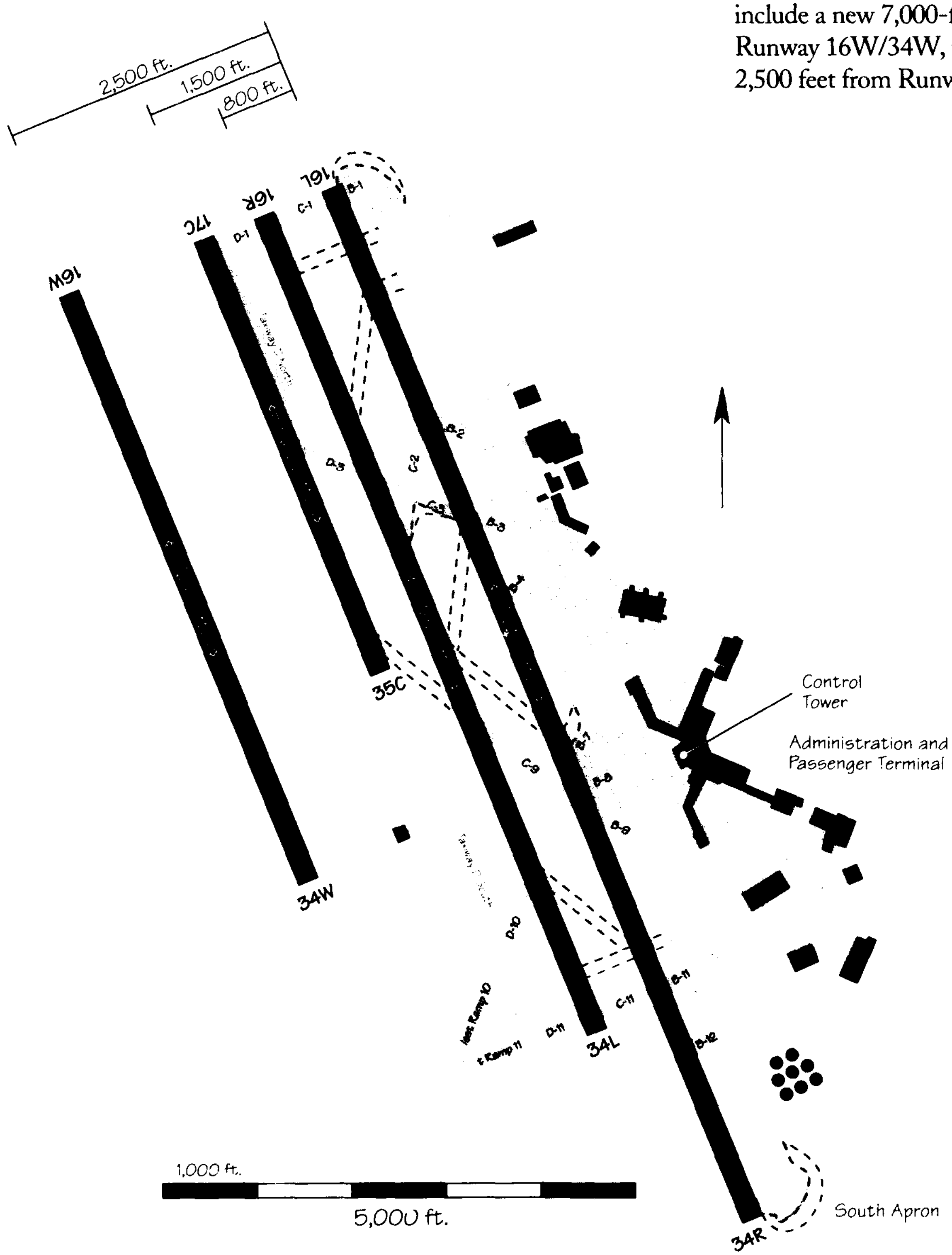
Savannah (SAV)

Two runway construction projects are being planned. A 1,000 foot extension to Runway 18/36 is expected to begin in 1994 and should be completed in 1995 at a cost of $3.9 million. A new 9,000 foot long parallel runway, Runway 9L/27R, is shown on an airport layout. Construction is expected to begin in 2009 and should be completed in 2010 at a cost of $20 million.



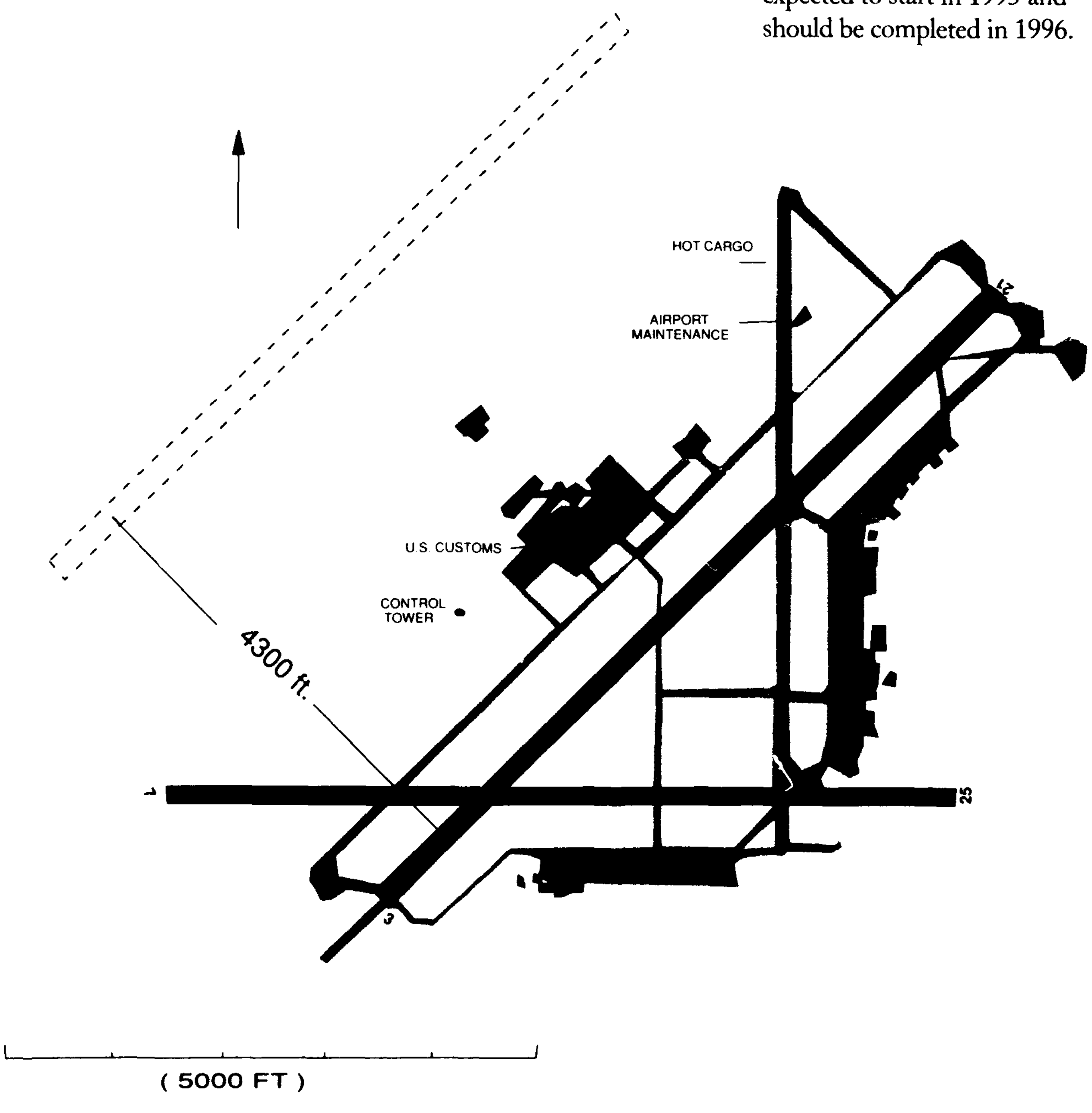
Seattle-Tacoma (SEA)

Potential airport improvements include a new 7,000-foot runway, Runway 16W/34W, to be located 2,500 feet from Runway 16L/34R.



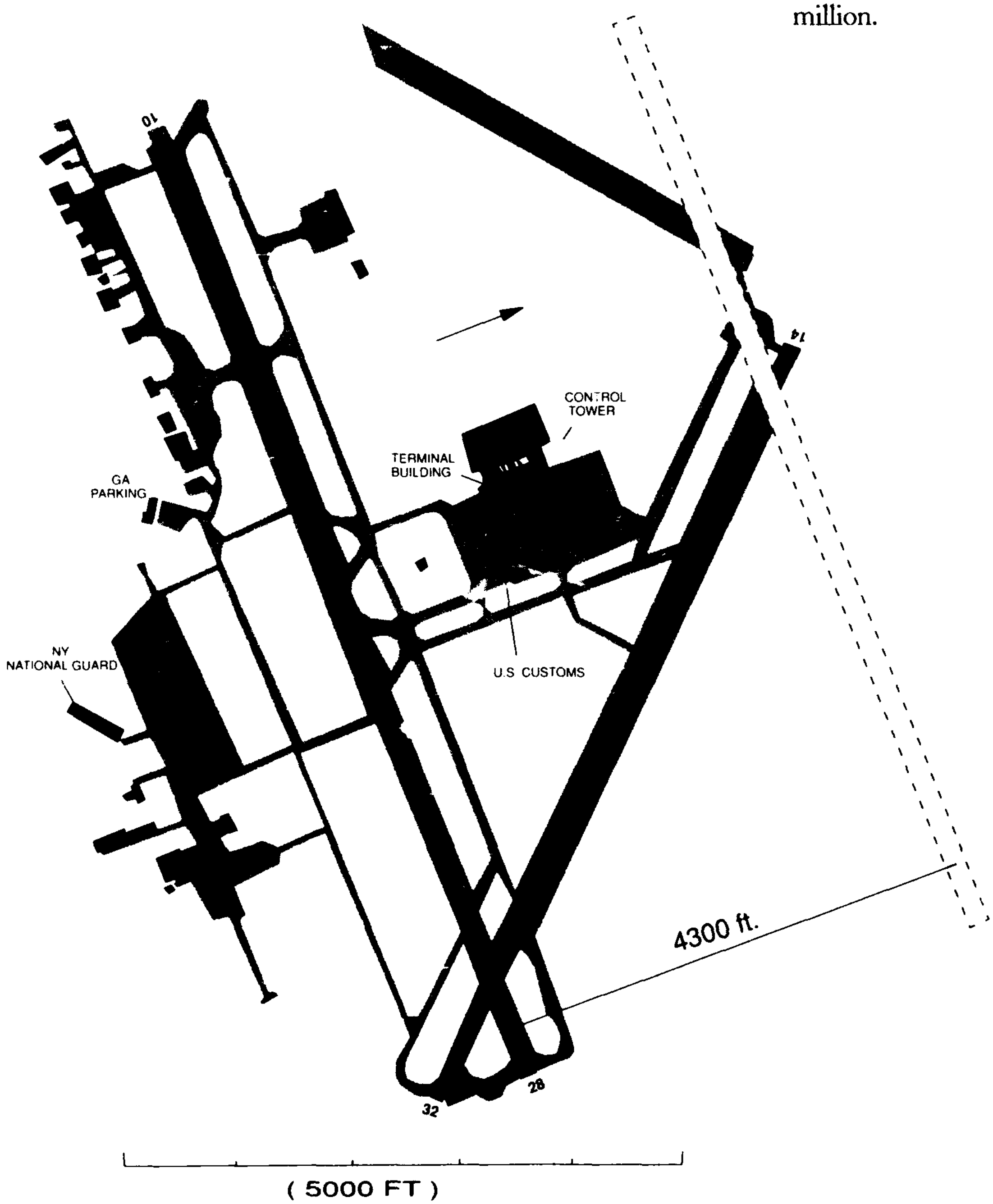
Spokane (GEG)

Future projects for capacity enhancement include the construction of a parallel runway, Runway 3L/21R. The new runway will be 8,800 feet by 150 feet, and will be separated from Runway 3R/21L by 4,300 feet. This would enable independent parallel operations, doubling hourly IFR arrival capacity. The estimated cost of construction of the new runway is approximately $11 million. Construction is expected to start in 1995 and should be completed in 1996.



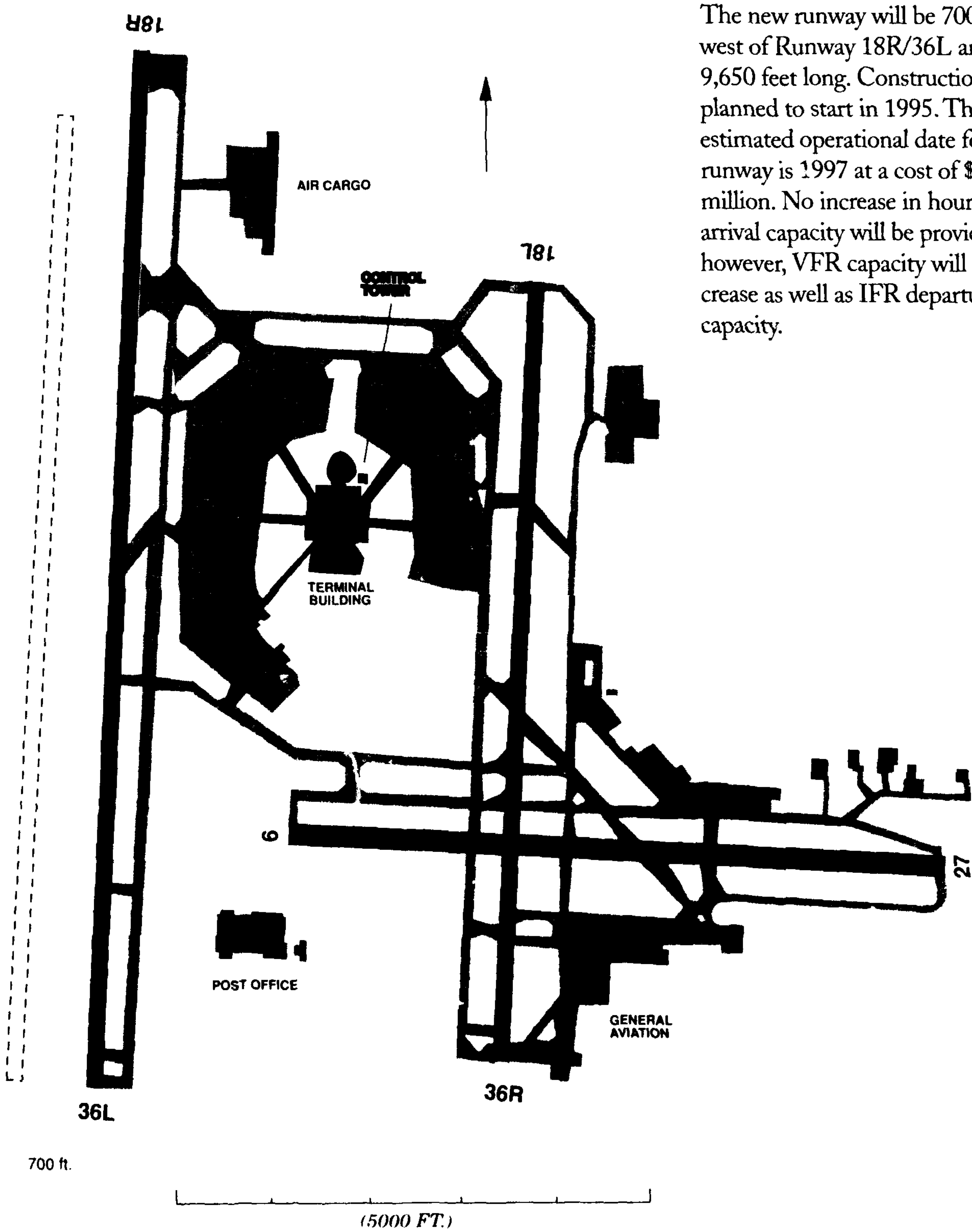
Syracuse (SYR)

There is potential for a parallel Runway 10L/28R, 9,000 feet long, and separated from the existing Runway 10/28 by 4,300 feet. This would provide independent parallel IFR operations, doubling hourly IFR arrival capacity. The expected operational date is sometime in 1997 if construction starts in 1996 as anticipated. The cost of construction is estimated to be $5 million.



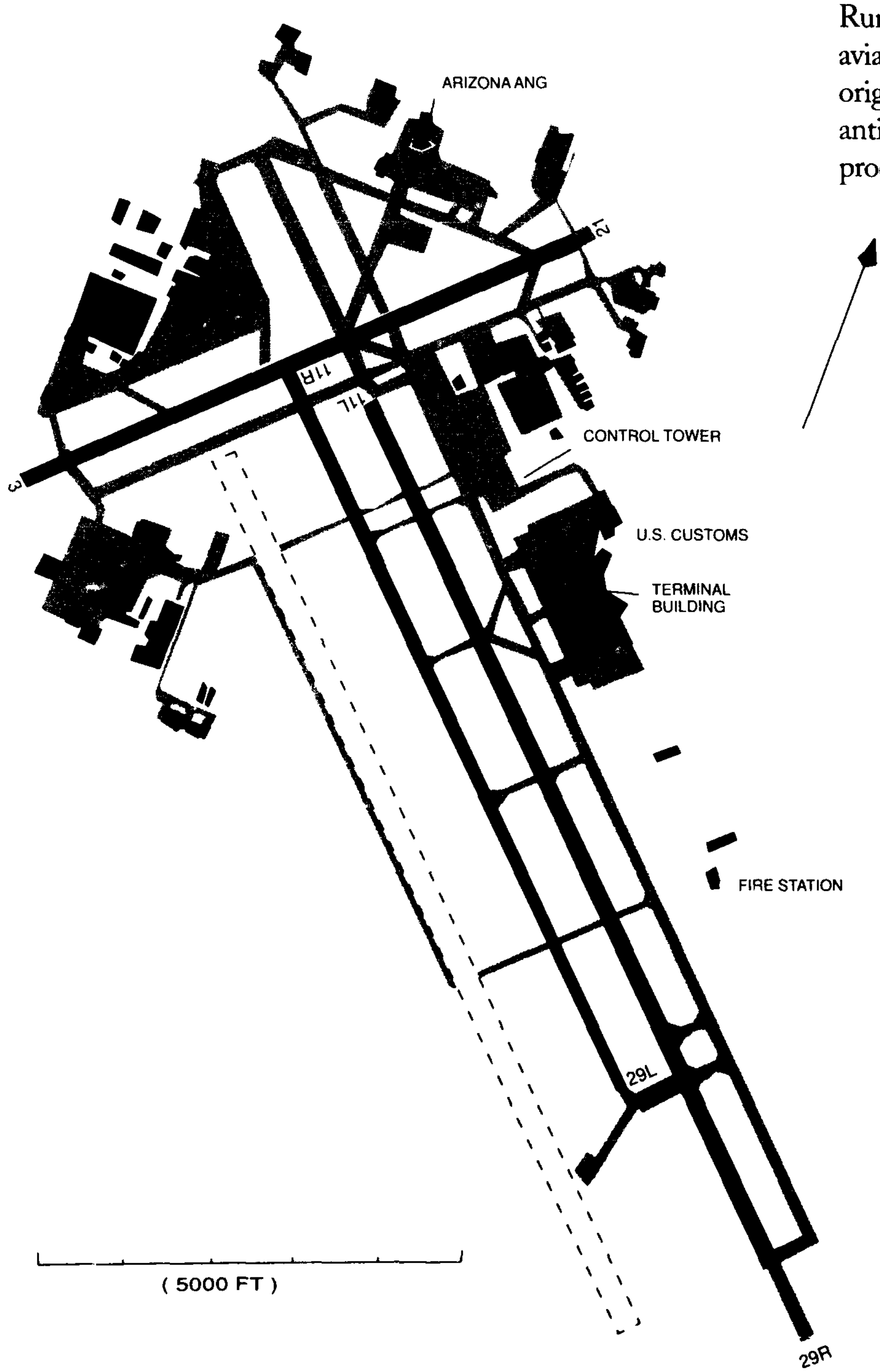
Tampa (TPA)

Plans have begun for a third parallel runway, Runway 18R/36L. The new runway will be 700 feet west of Runway 18R/36L and 9,650 feet long. Construction is planned to start in 1995. The estimated operational date for the runway is 1997 at a cost of $53 million. No increase in hourly IFR arrival capacity will be provided; however, VFR capacity will increase as well as IFR departure capacity.



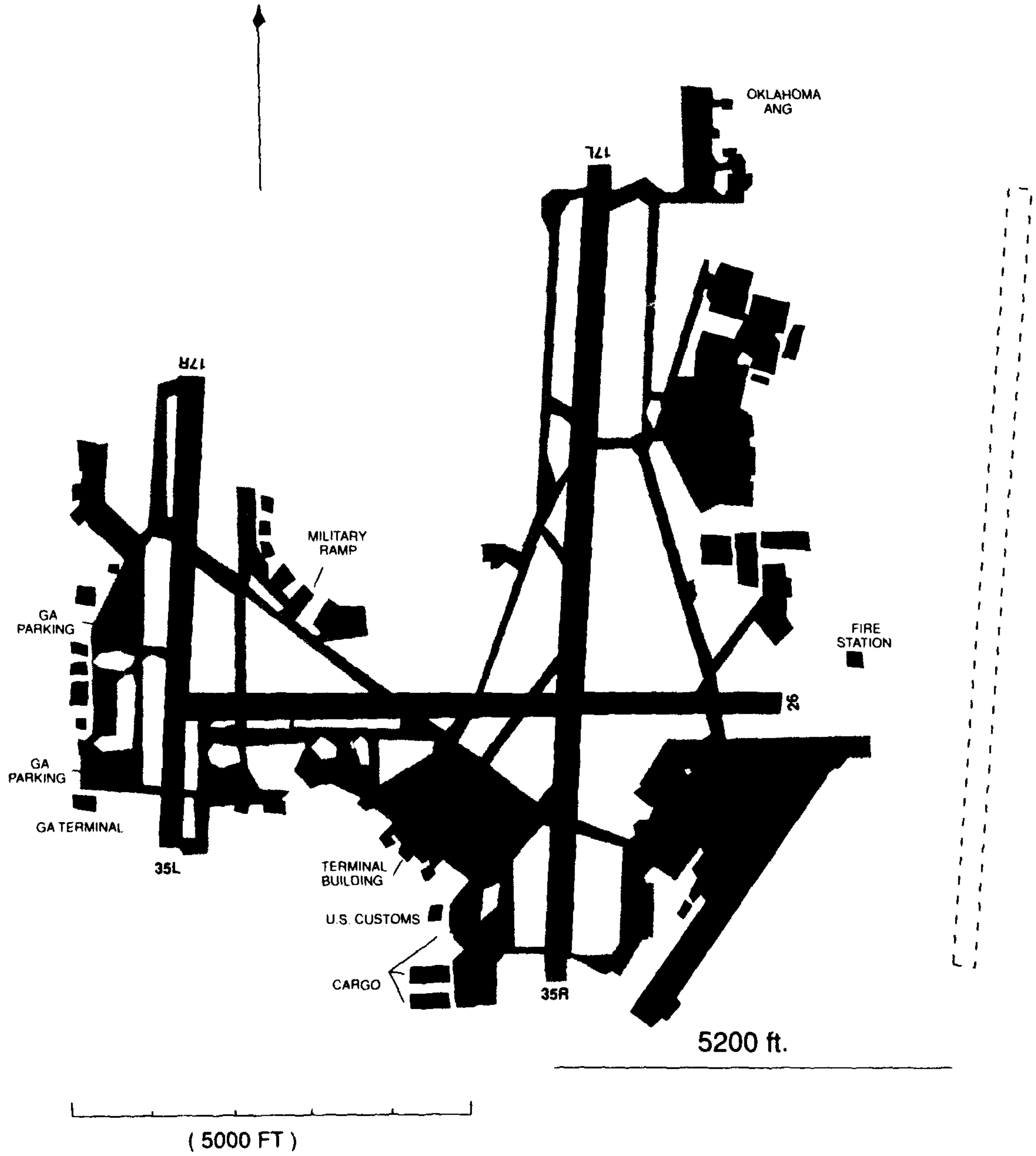
Tucson (TUS)

An additional parallel air carrier runway, Runway 11R/29L, has been proposed. Upon completion of the new runway, the current Runway 11R/29L, a general aviation runway, will revert to its original taxiway status. It is not anticipated that the sponsor will proceed before 1993-1995.



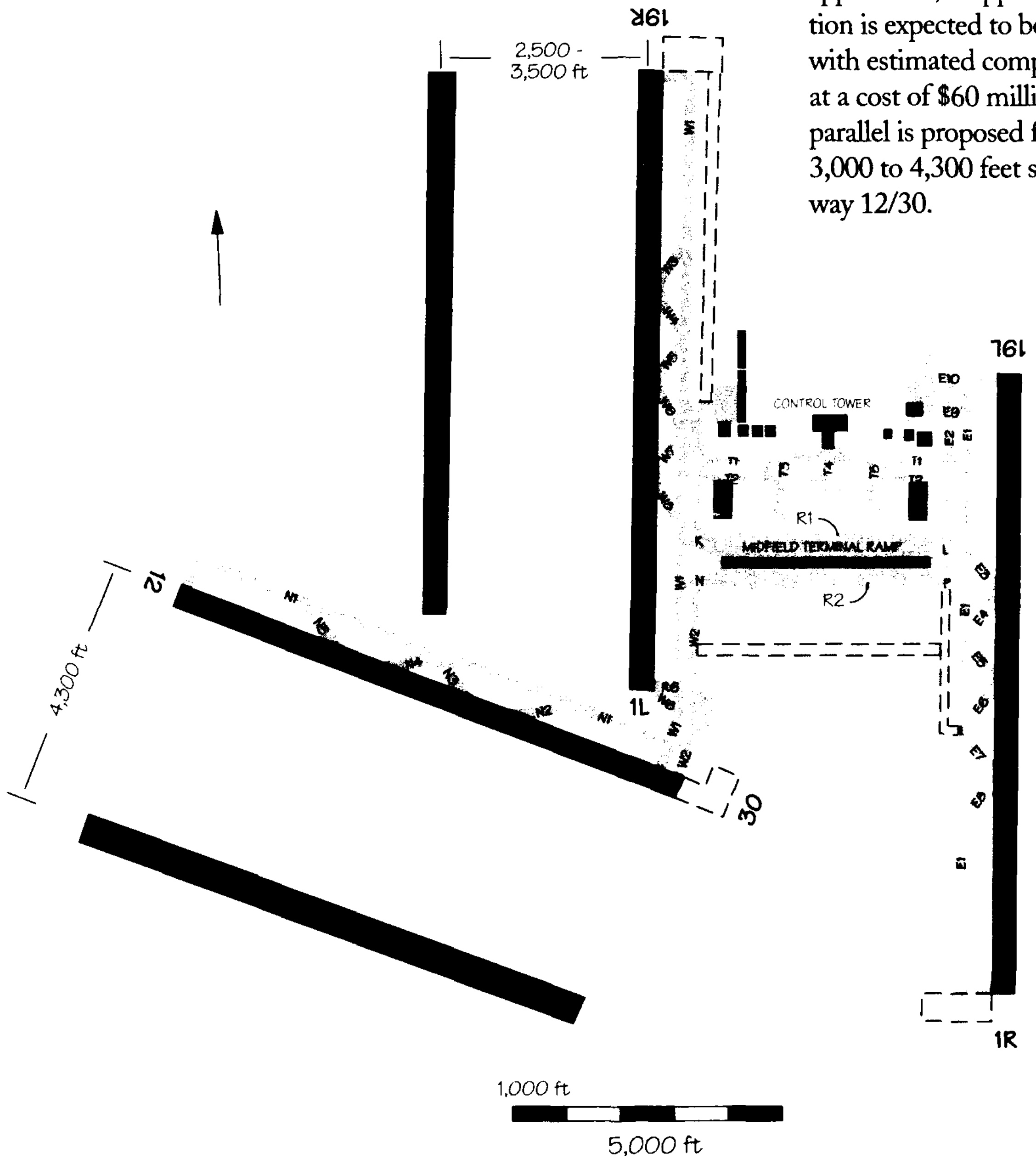
Tulsa (TUL)

A new parallel runway, Runway 17L/35R, is planned to be located 5,200 feet east of the present 17L/35R and will be 9,600 feet long. Construction is projected to start in January 1994 with an estimated operational date of July 1998. The cost of the new runway is estimated to be $100 million. The new runway could permit IFR triple independent approaches, if approved, to Runways 17L, 17C, and 17R.



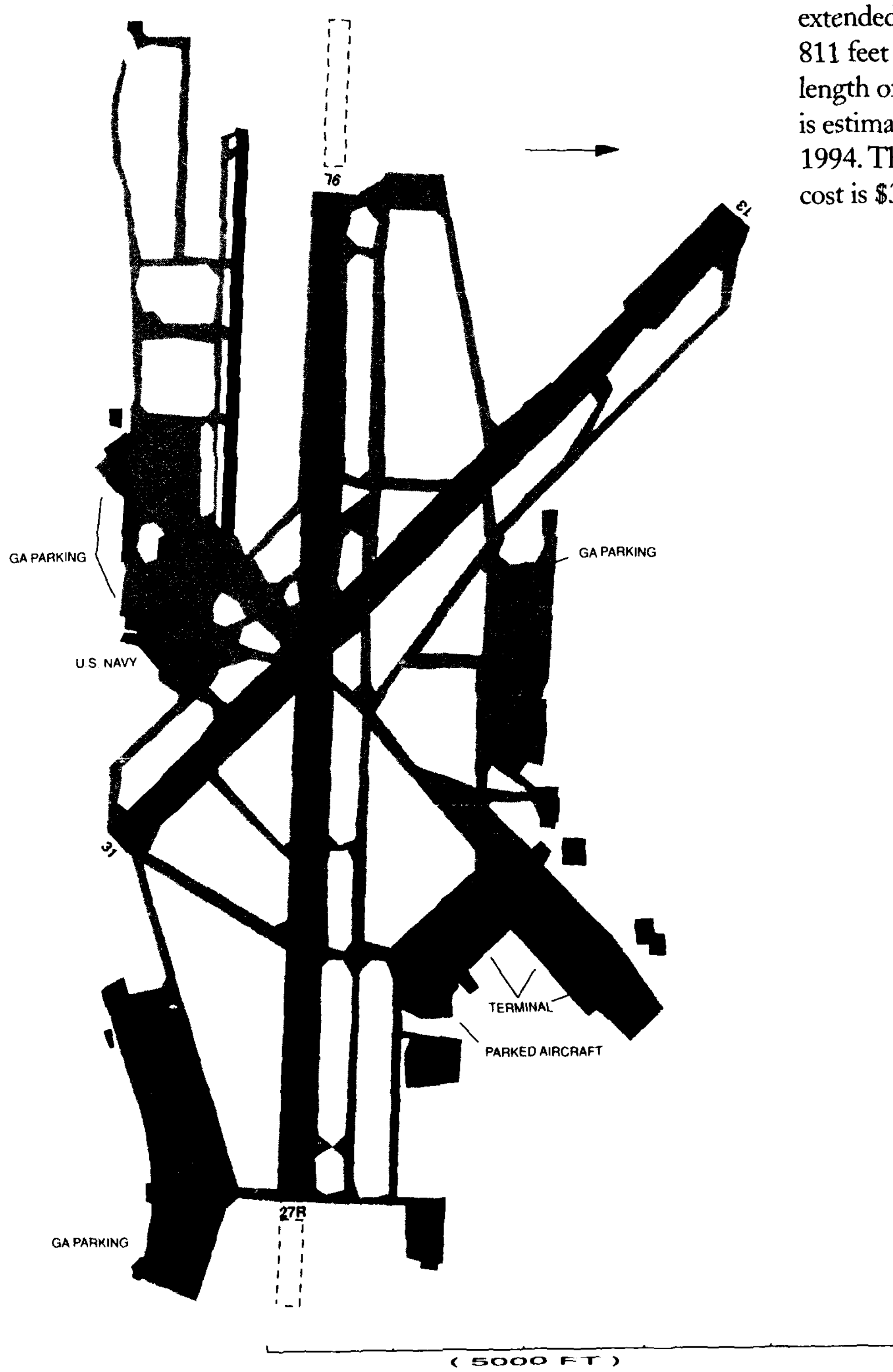
Washington (IAD)

Construction of an extension to Runway 12/30 began in January 1991 and should be completed in September 1992. The estimated cost of construction is $7.2 million. Two new parallel runways are under consideration. A north-south parallel, Runway 1W/19W, is planned to be located 3,500 feet west of the existing parallels and north of Runway 12/30. This could provide triple independent parallel approaches, if approved. Construction is expected to begin in 1999 with estimated completion in 2000 at a cost of $60 million. A second parallel is proposed for location 3,000 to 4,300 feet south of Runway 12/30.



West Palm Beach (PBI)

The environmental process to extend Runway 9L/27R on both ends will be completed in December 1991. The runway will be extended 1,200 feet to the west and 811 feet to the east, for a total length of 10,000 feet. Construction is estimated to be completed in 1994. The total estimated project cost is $3.5 million.

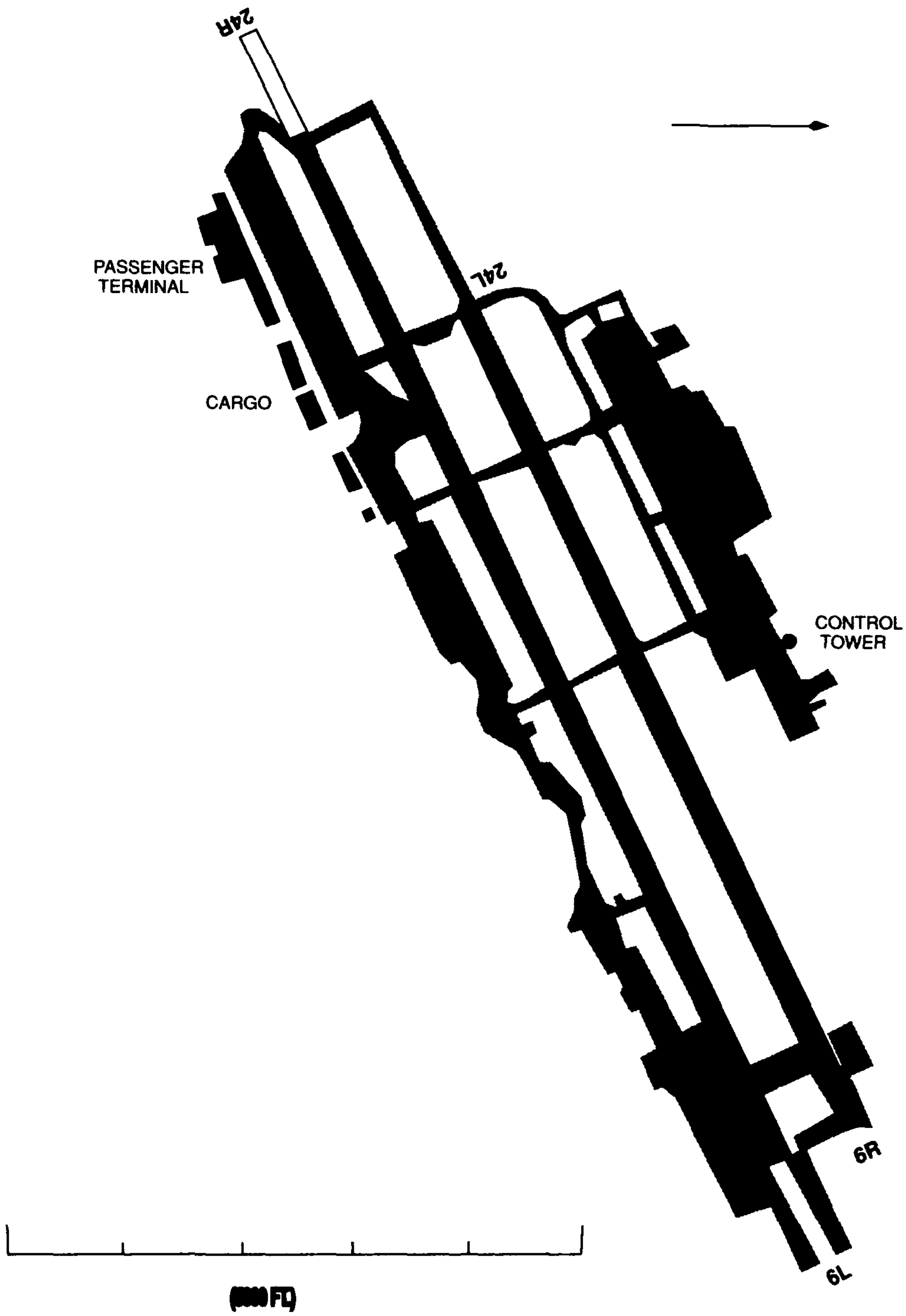


Appendix D

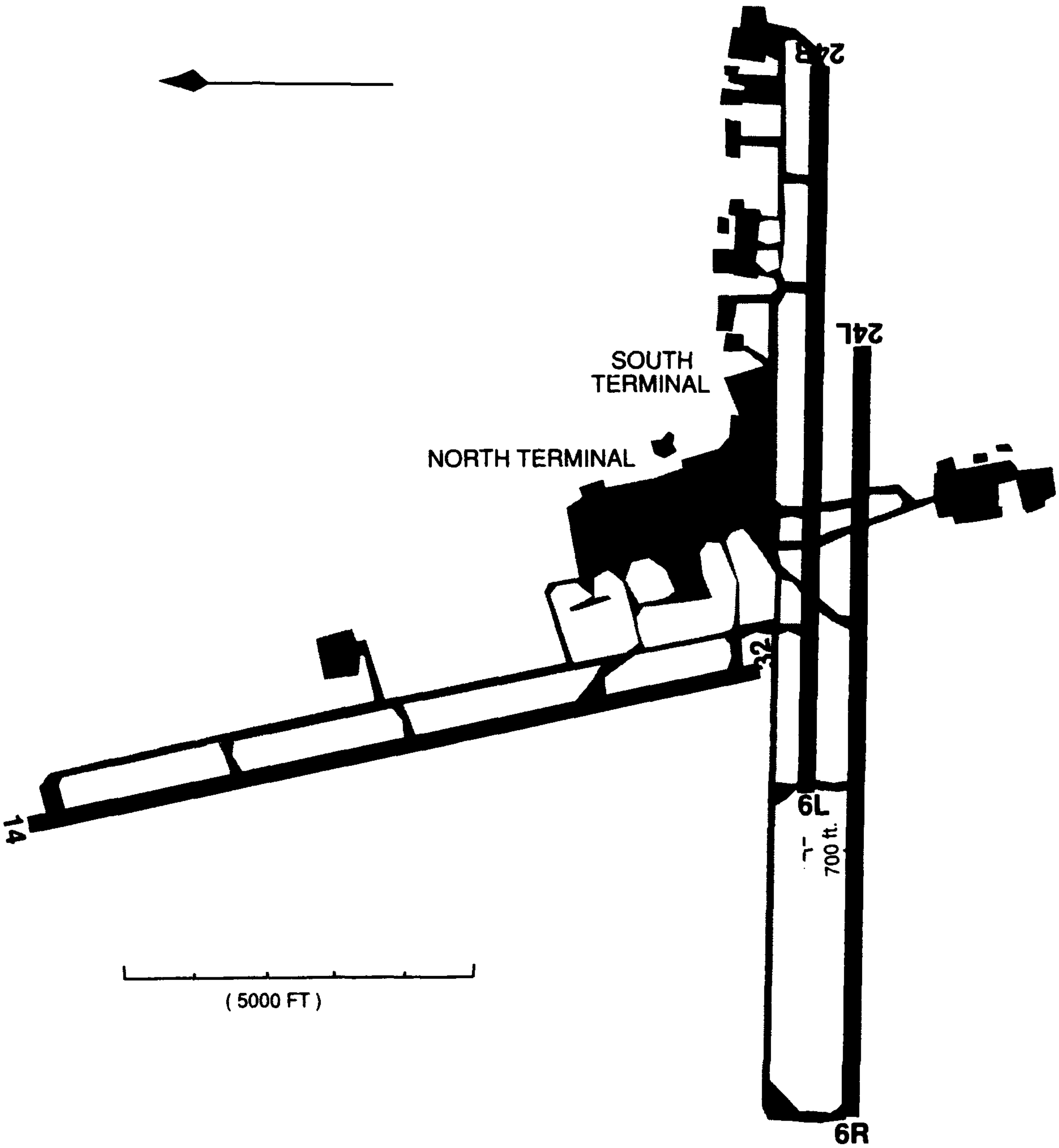
Layouts of the Remaining Top 100 Airports[1]

Agana Field, Guam D-2
Anchorage International Airport D-3
Boise Air Terminal Gowen Field D-4
Bradley International Airport D-5
Burbank-Glendale-Pasadena Airport D-6
Charleston (SC) AFB International Airport D-7
Columbia Metropolitan Airport D-8
Dallas-Love Field Airport D-9
Denver Stapleton International Airport D-10
Des Moines International Airport D-11
El Paso International Airport D-12
Eppley Field Airport (Omaha) D-13
General Lyman Field Airport (Hilo) D-14
Harrisburg International Airport D-15
Honolulu International Airport D-16
John Wayne, Orange County Airport (Santa Ana) D-17
Kahului Airport D-18
Keahole Airport (Kailua-Kona) D-19
New York La Guardia Airport D-20
Lihue Airport D-21
Long Beach Daugherty Field Airport D-22
Ontario International Airport D-23
Portland, OR International Airport D-24
Reno Cannon International Airport D-25
Richmond International Airport (Byrd Field) D-26
Robert Mueller Municipal Airport (Austin) D-27
Sacramento Metropolitan Airport D-28
San Antonio International Airport D-29
San Diego International-Lindbergh Field Airport D-30
Theodore Francis Green State Airport (Providence) D-31
Washington National Airport D-32
Wichita Mid-Continent Airport D-33

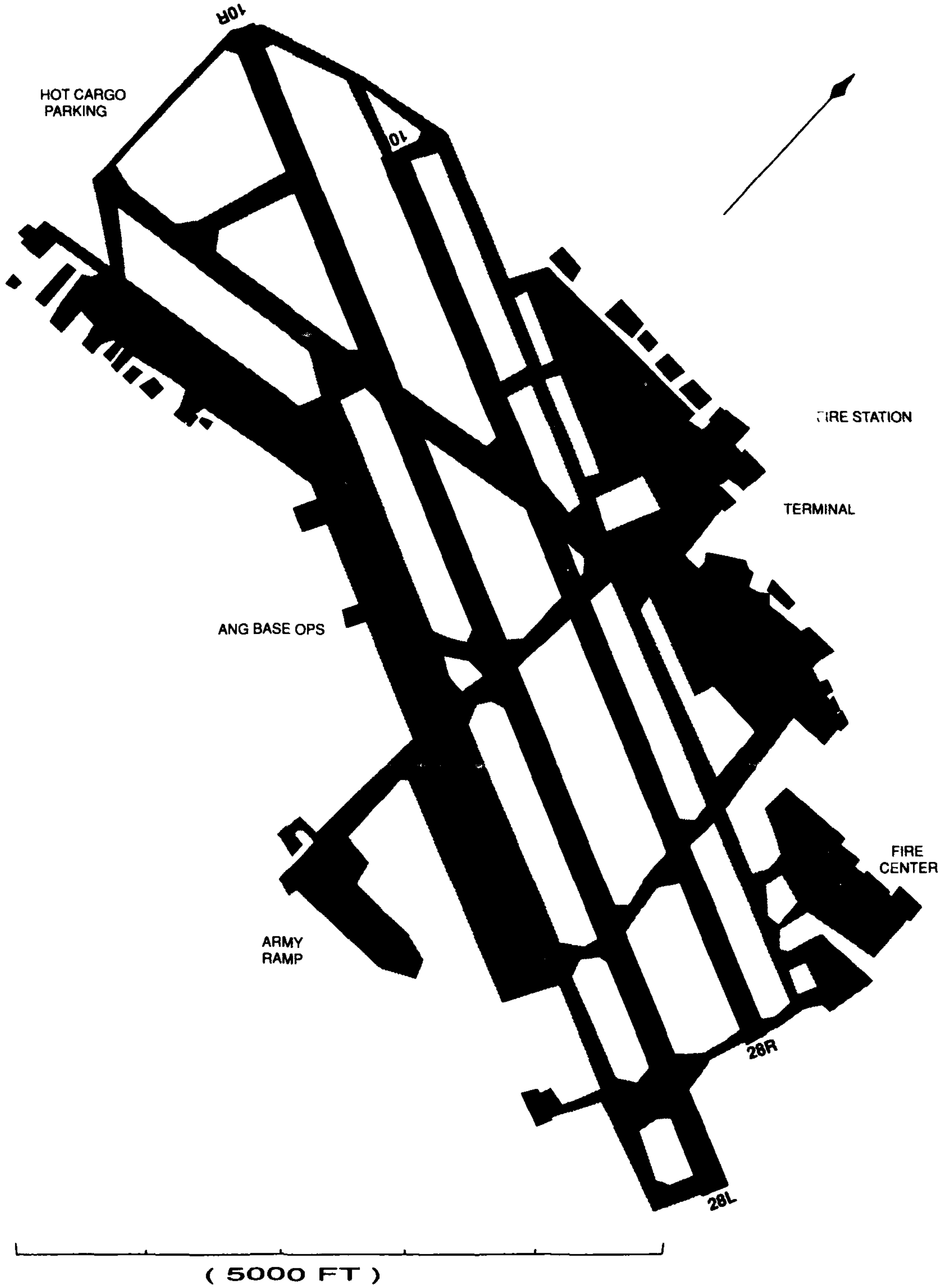
1. All 100 airports are pictured in either Appendix B, Appendix C, or Appendix D, with some duplication between appendicies.



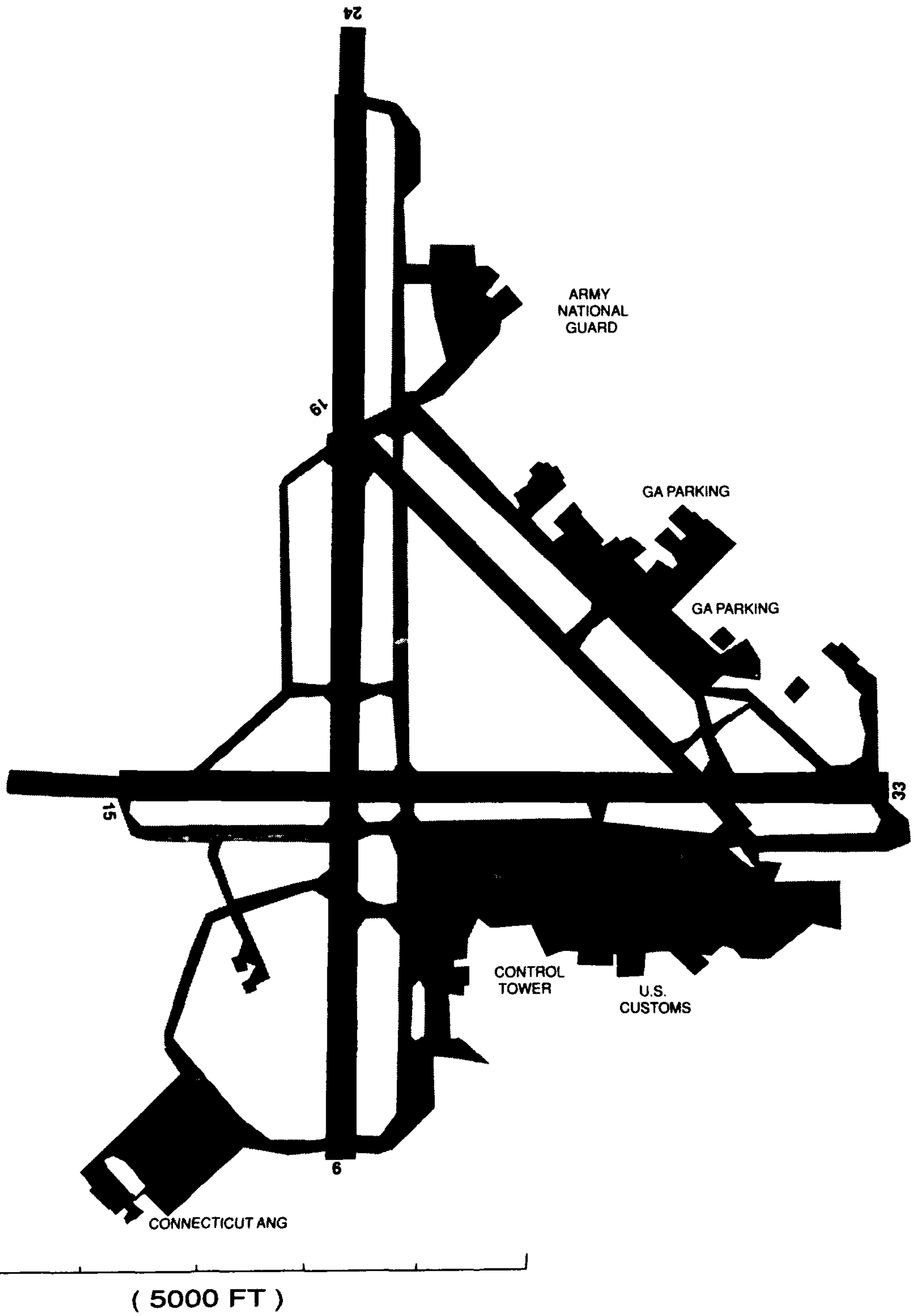
Agana Field, Guam



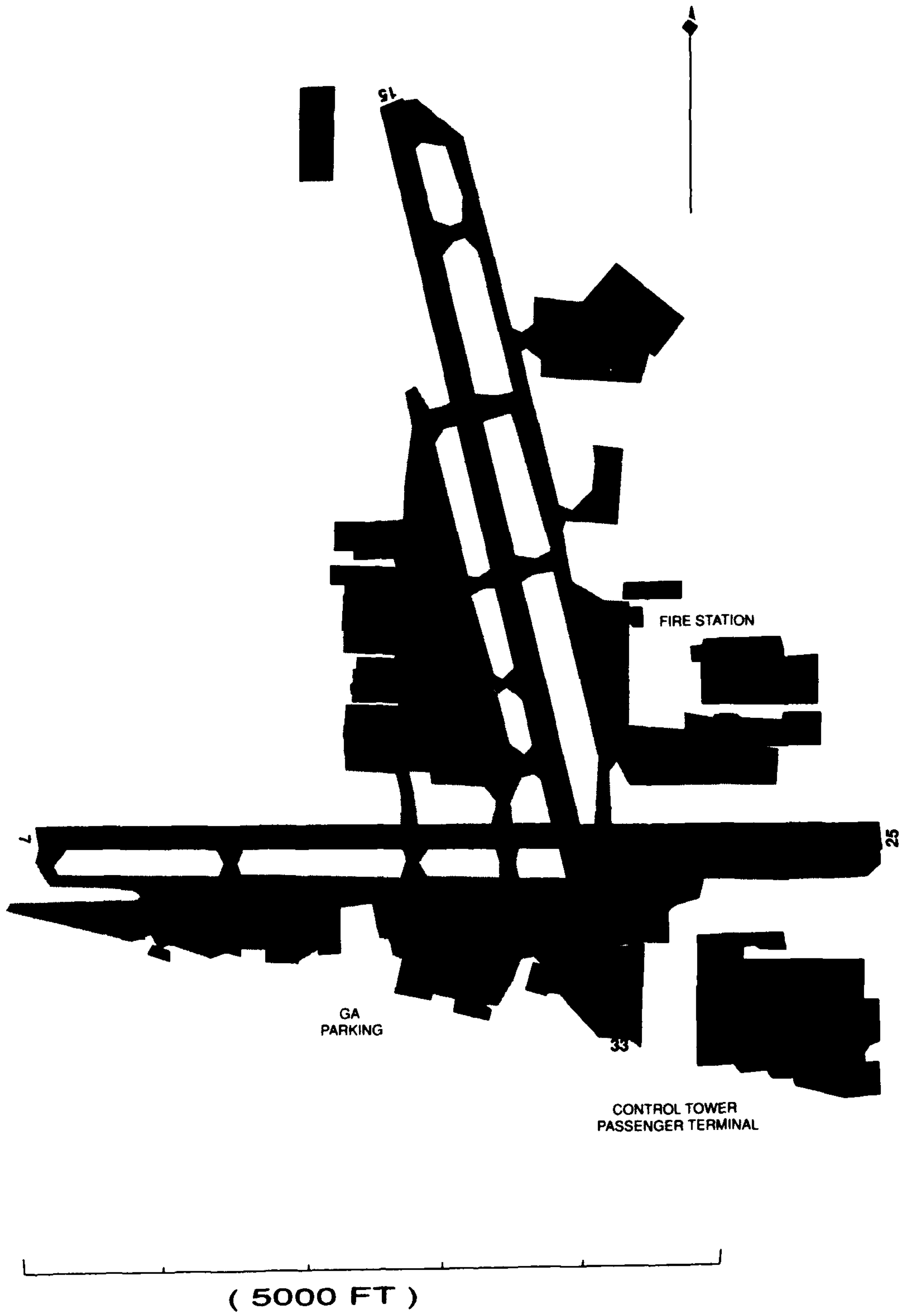
Anchorage International Airport



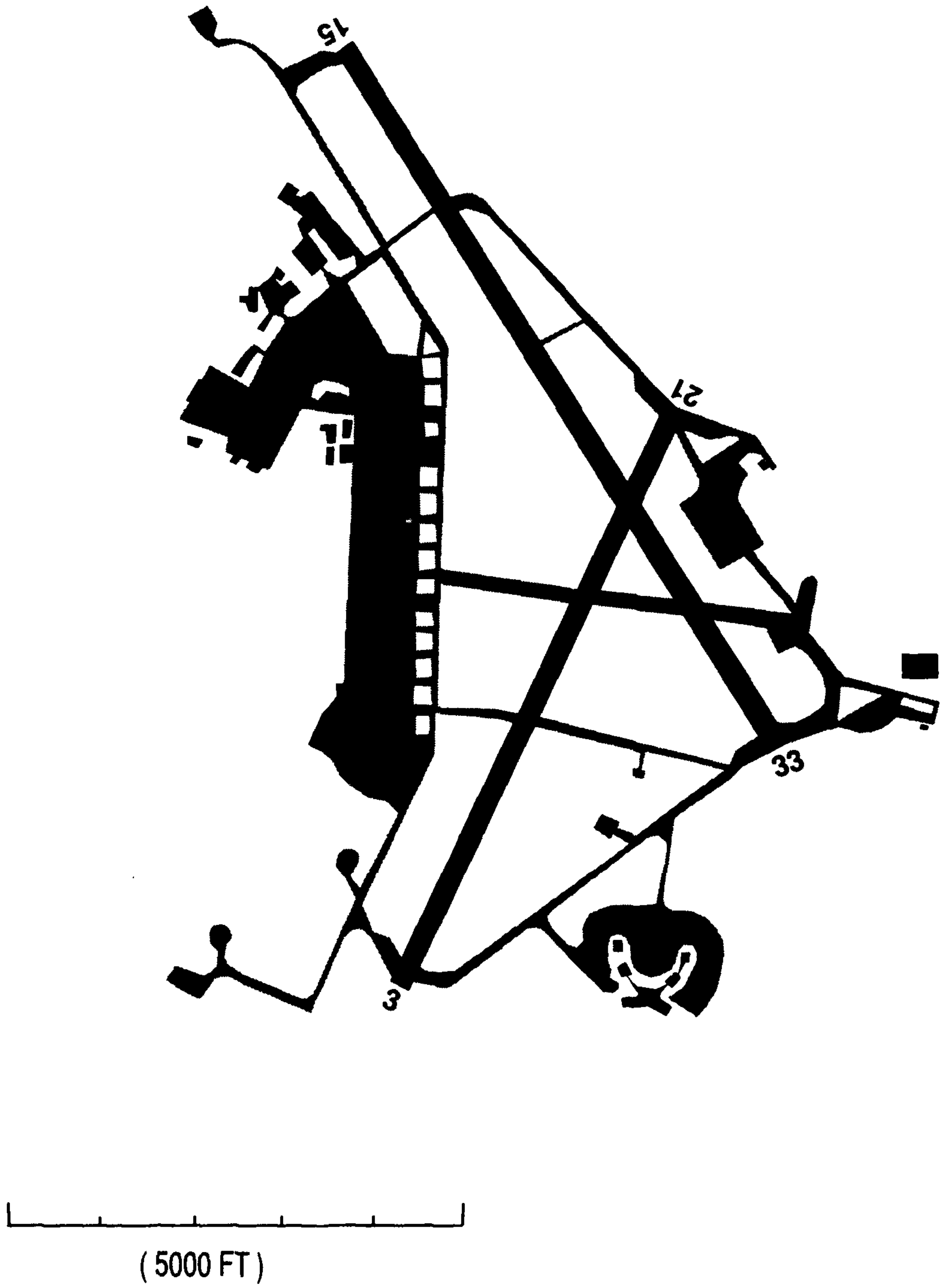
Boise Air Terminal Gowen Field



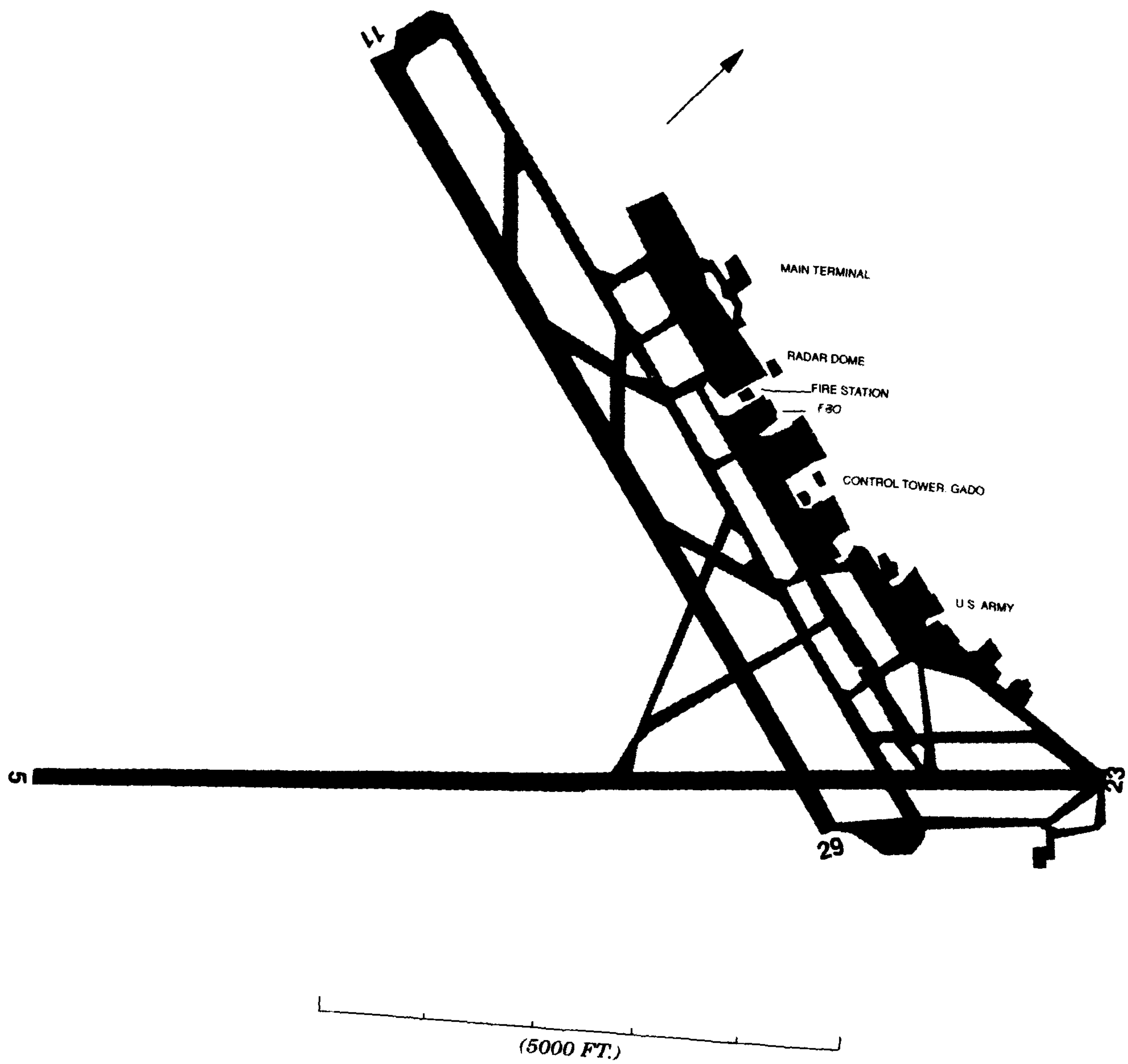
Bradley International Airport



Burbank-Glendale-Pasadena Airport

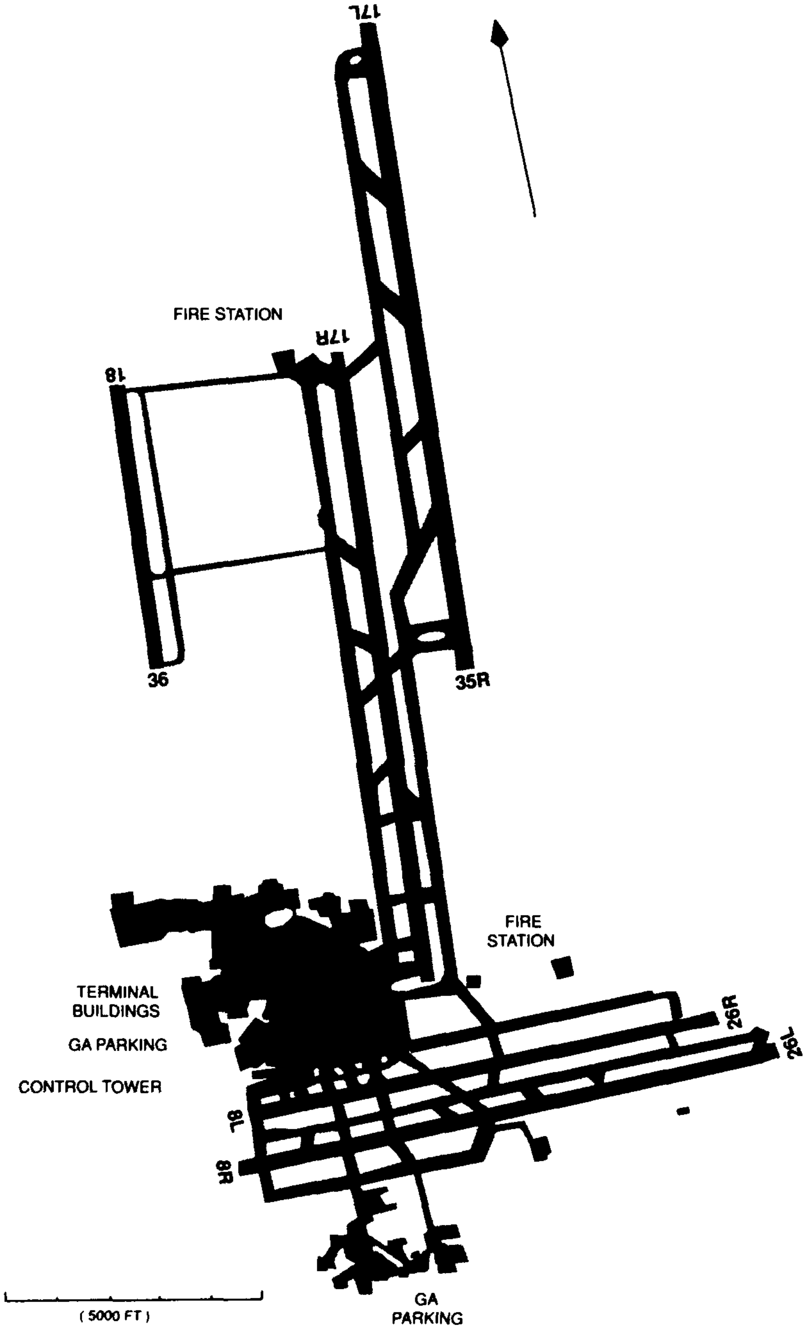


Charleston (SC) AFB International Airport

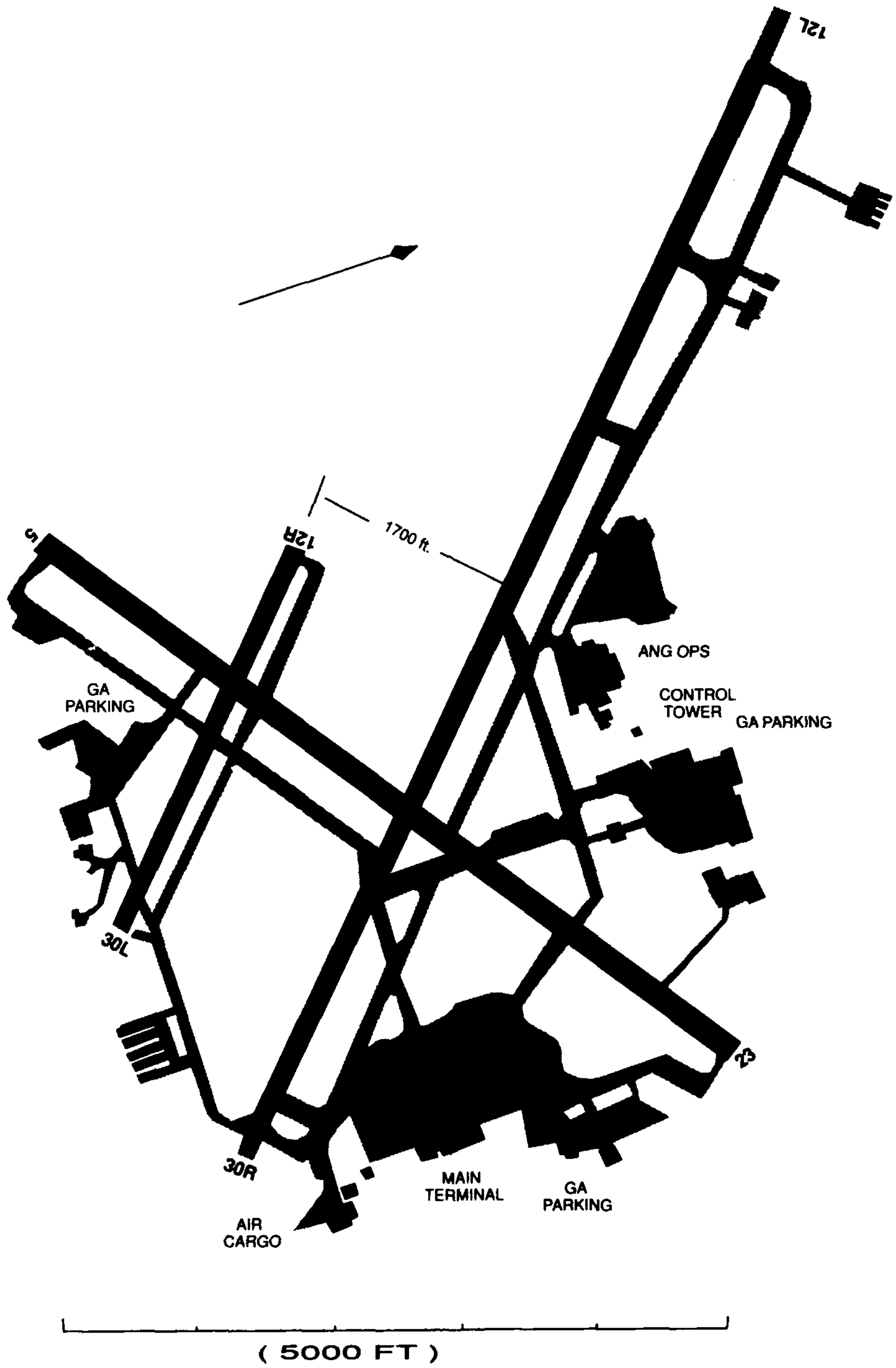


Columbia Metropolitan Airport

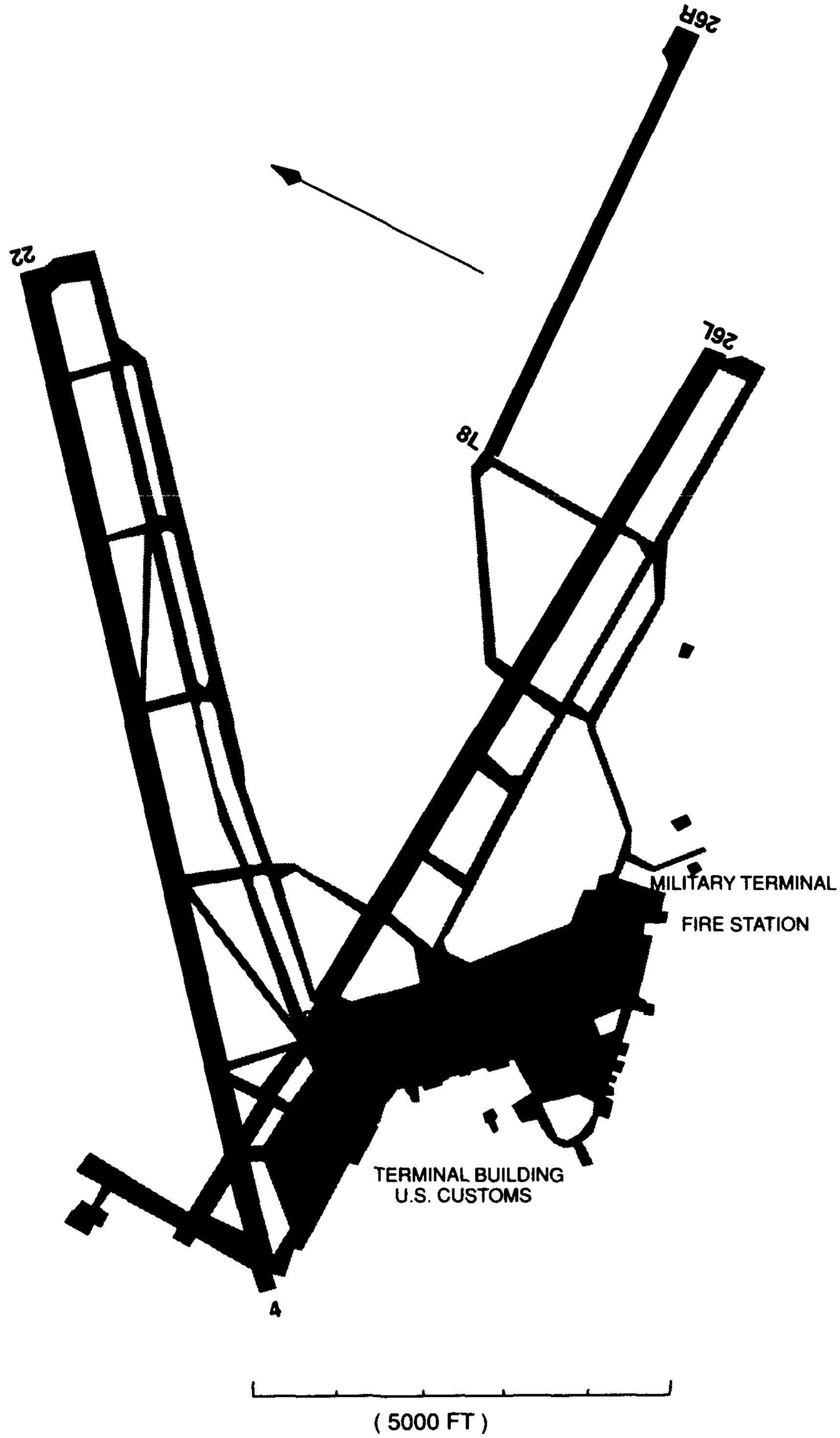
Dallas-Love Field Airport



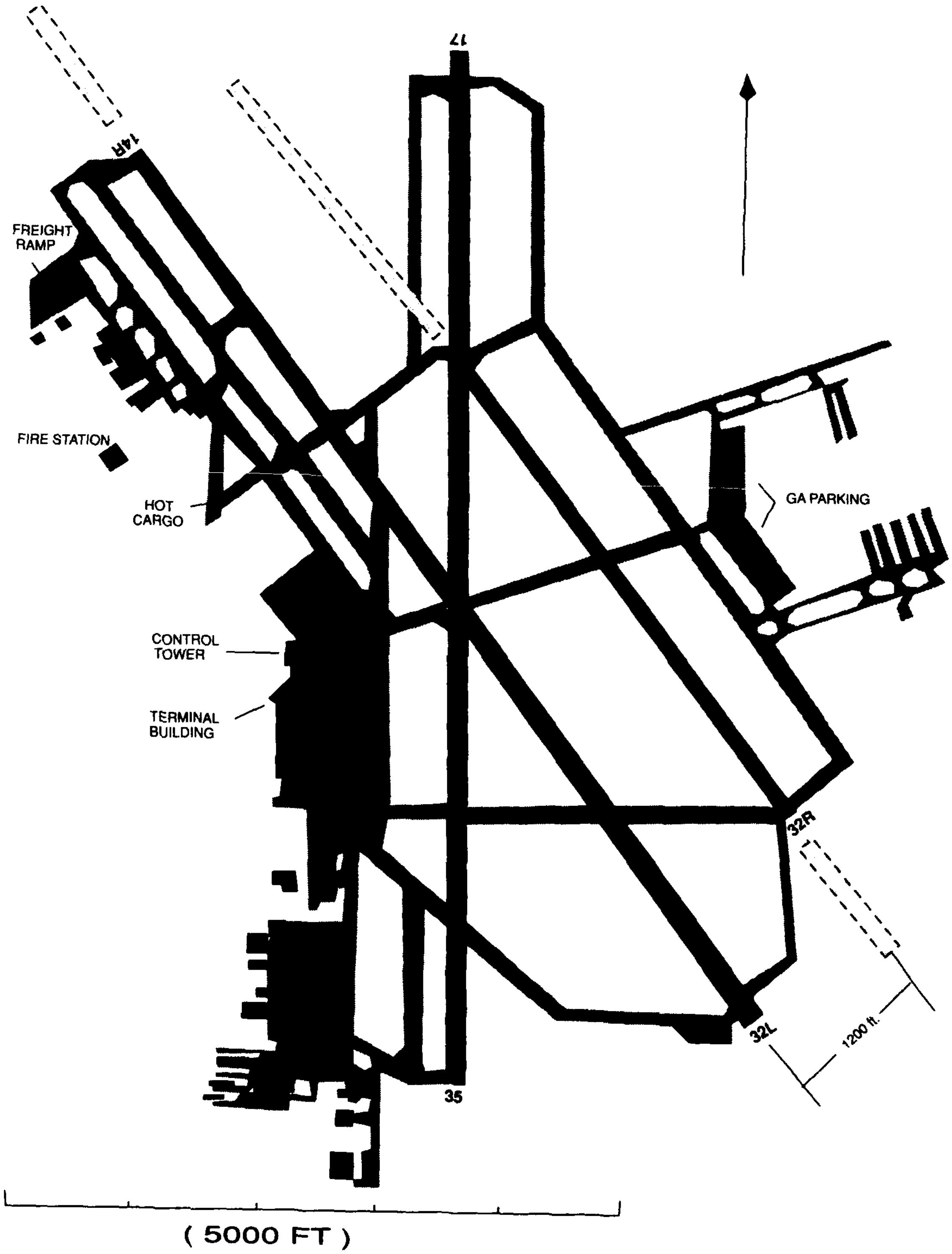
Denver Stapleton International Airport



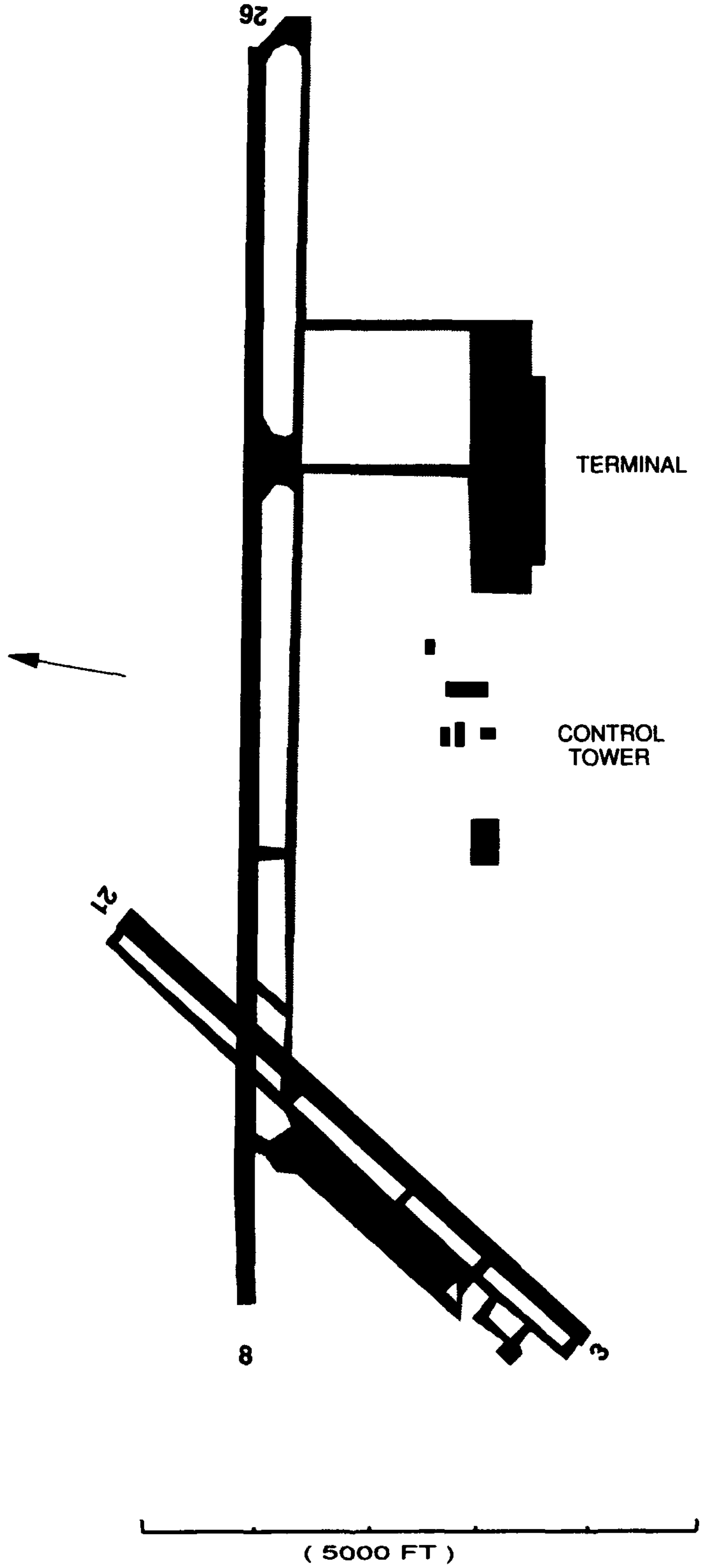
Des Moines International Airport



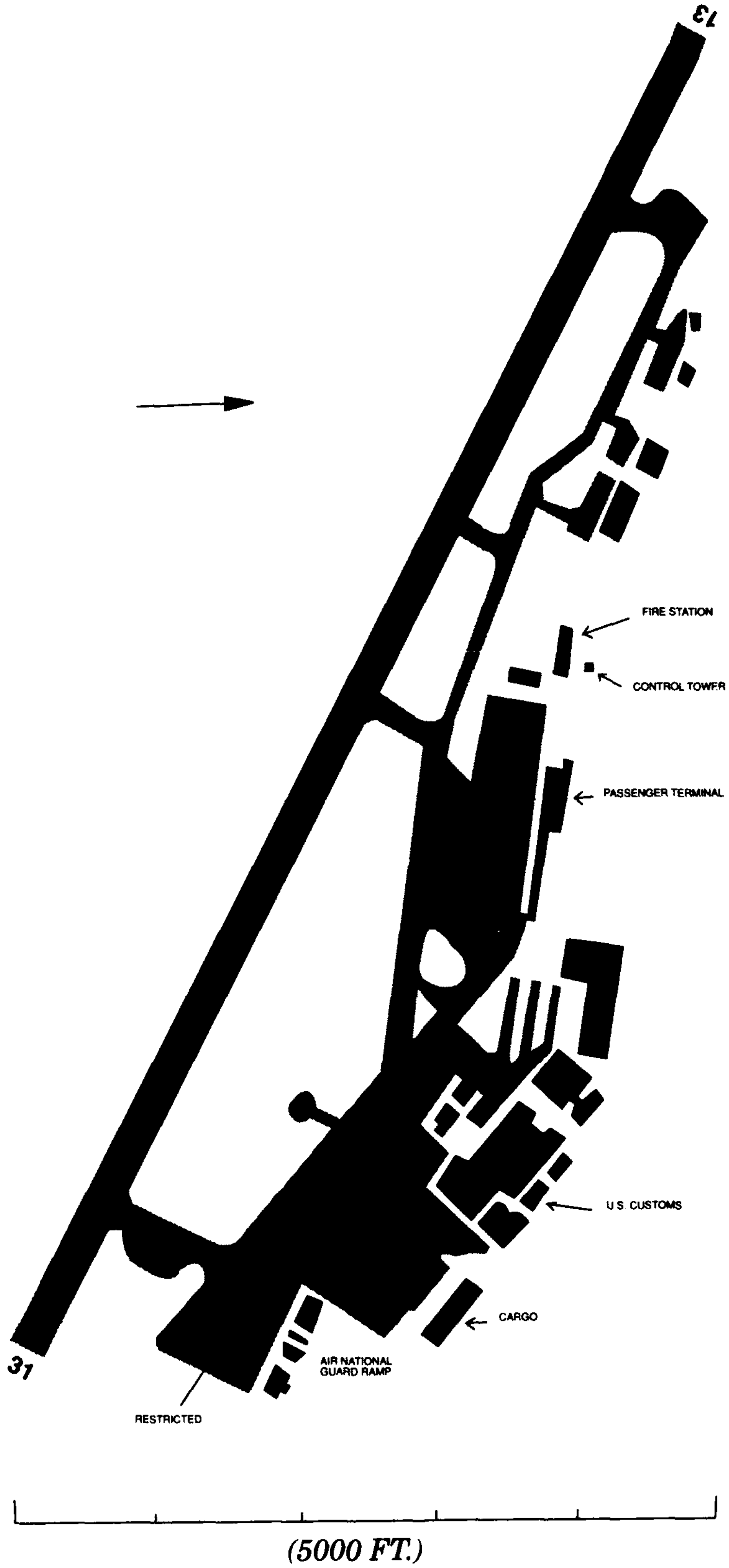
El Paso International Airport



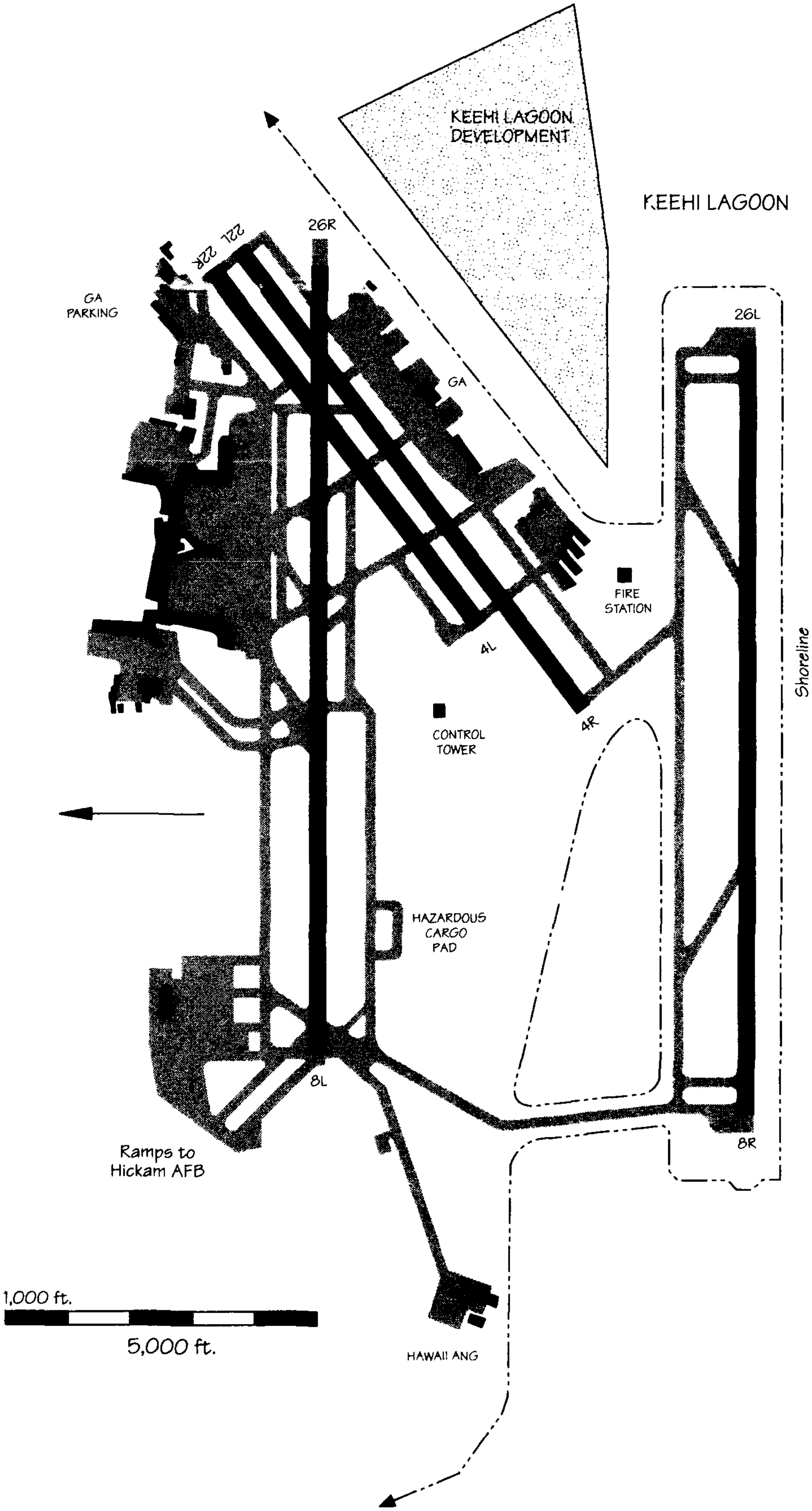
Eppley Field Airport (Omaha)



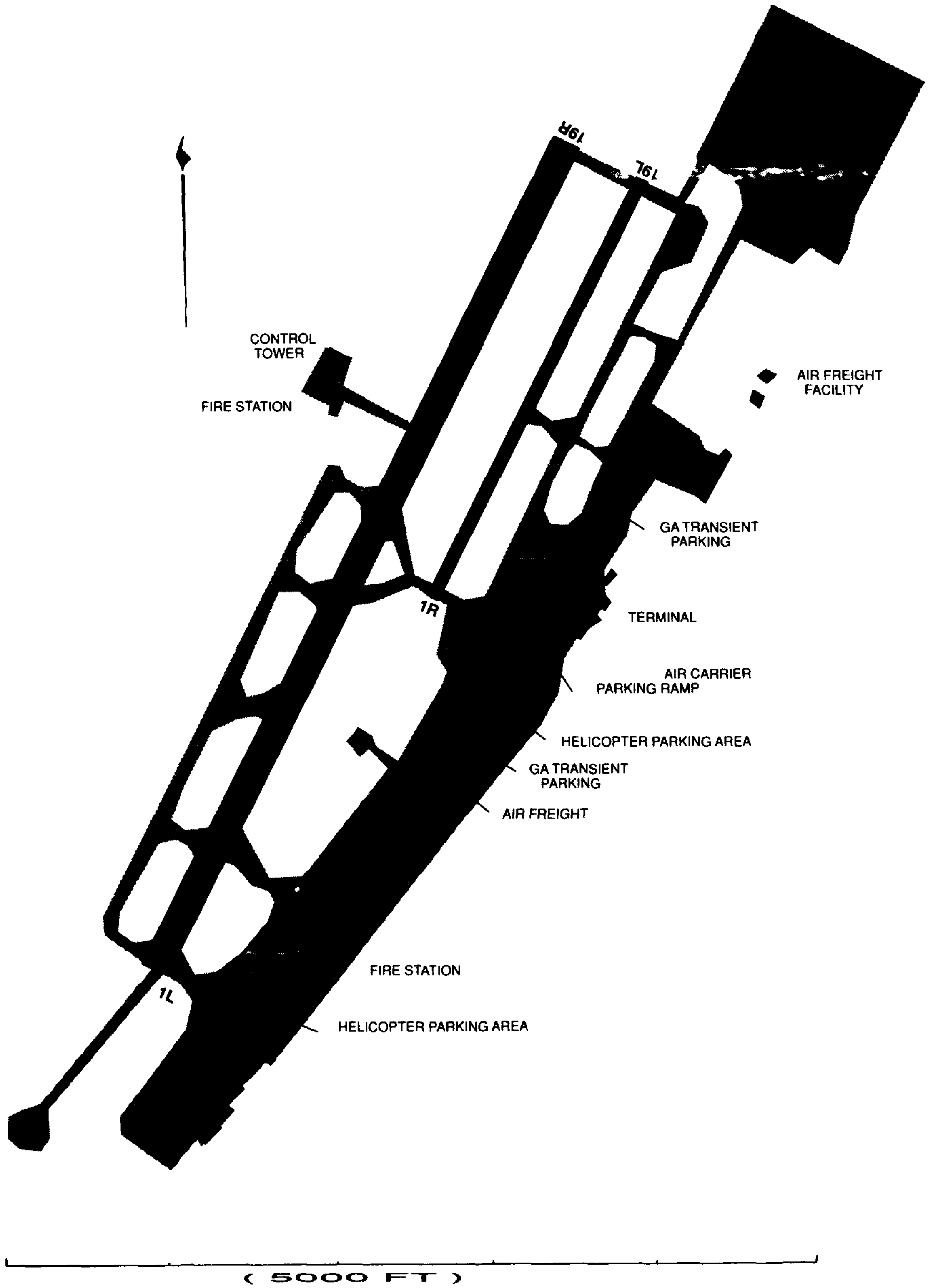
General Lyman Field Airport (Hilo)



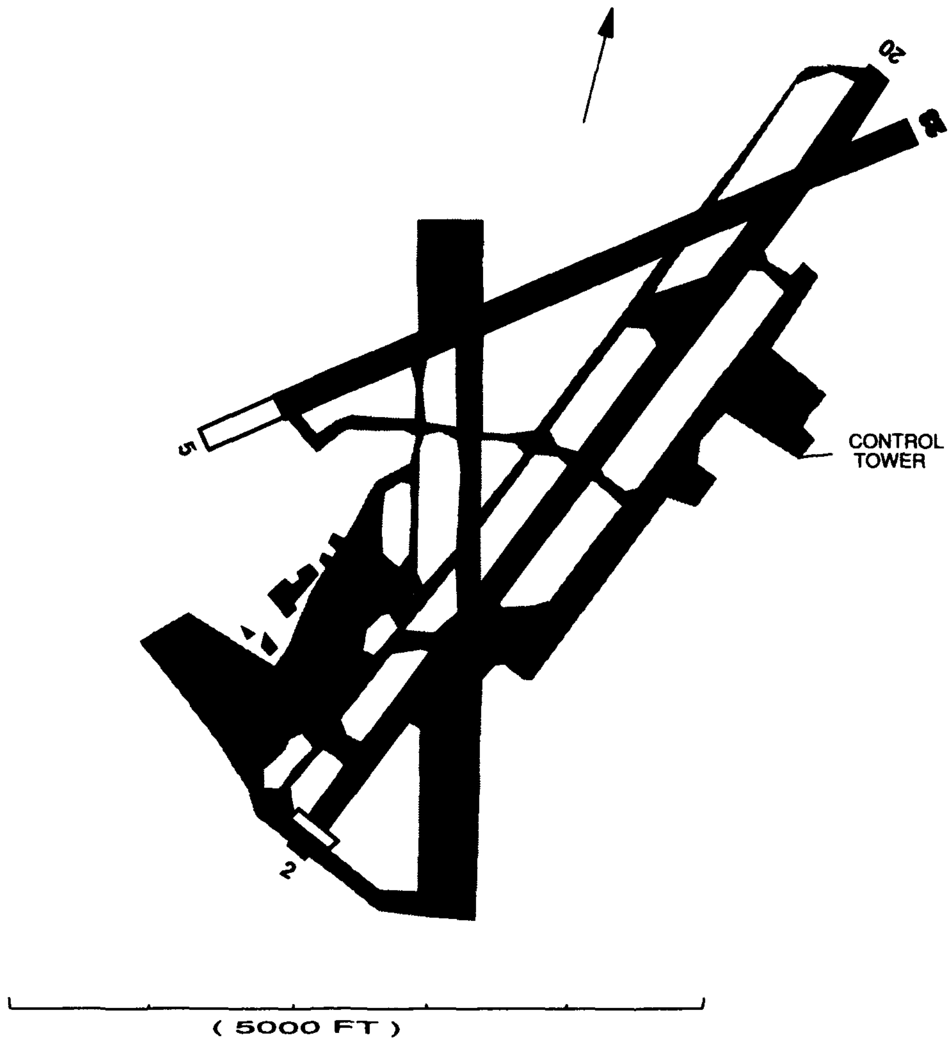
Harrisburg International Airport



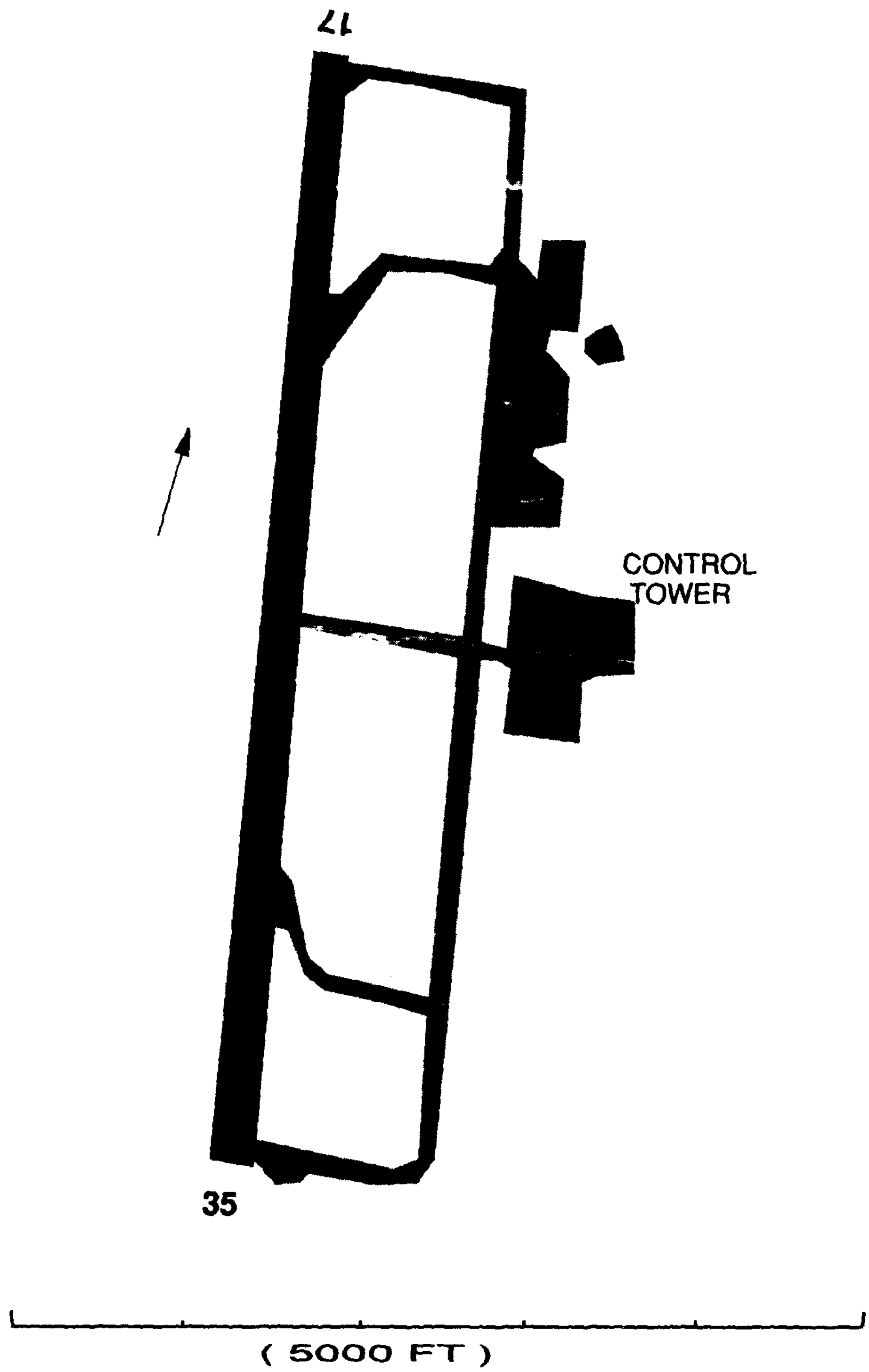
Honolulu International Airport



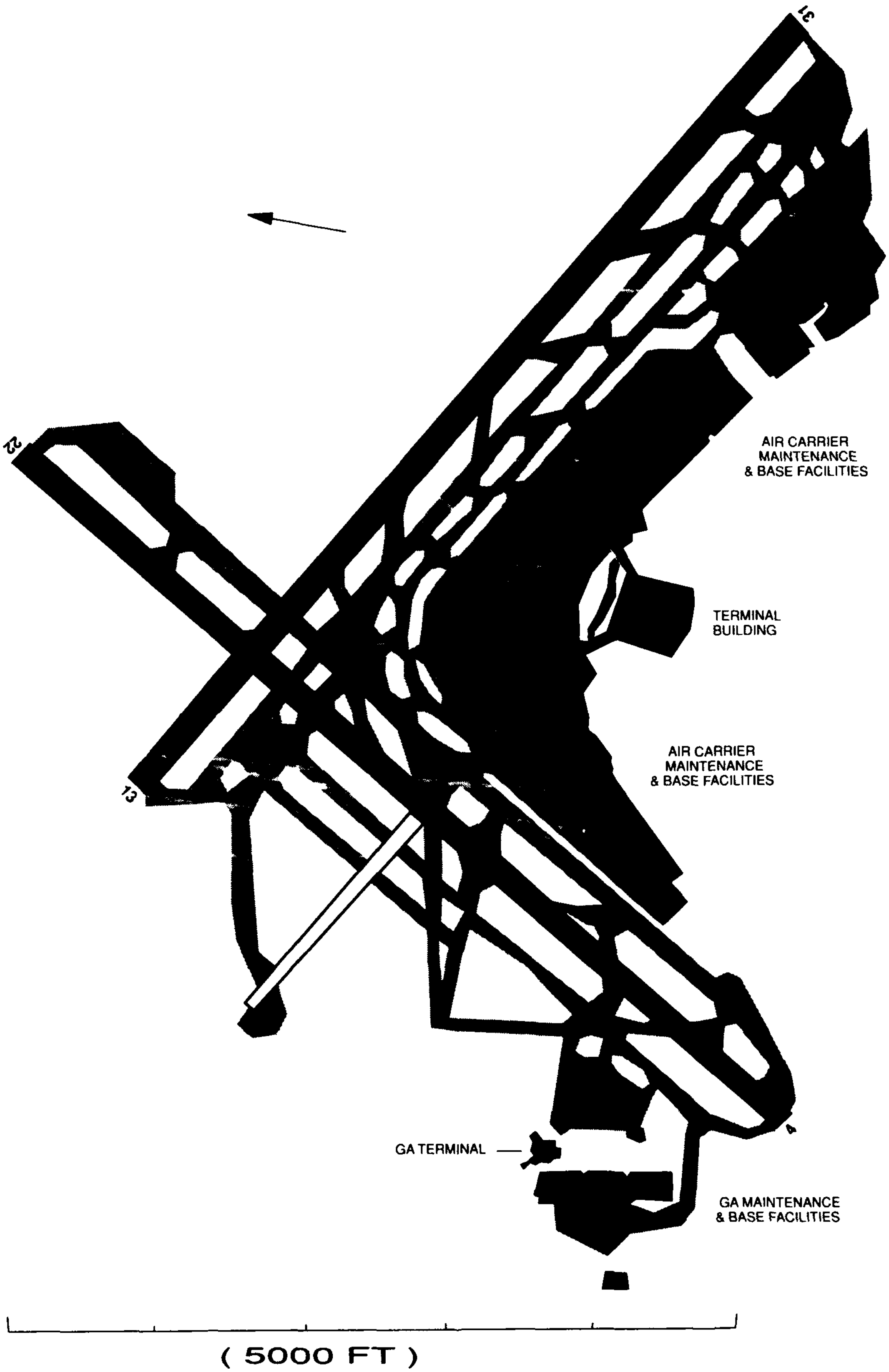
John Wayne, Orange County Airport (Santa Ana)



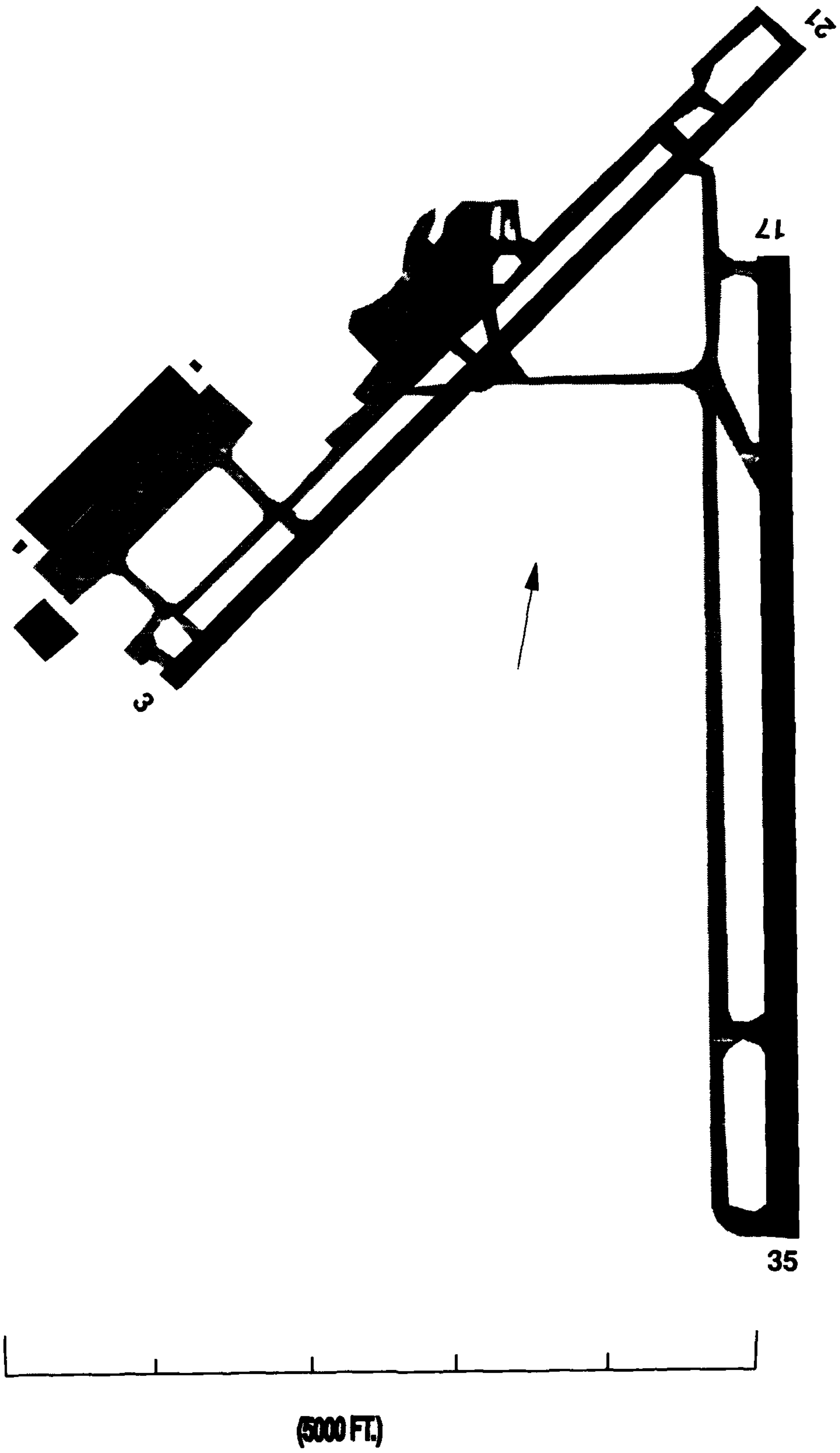
Kahului Airport



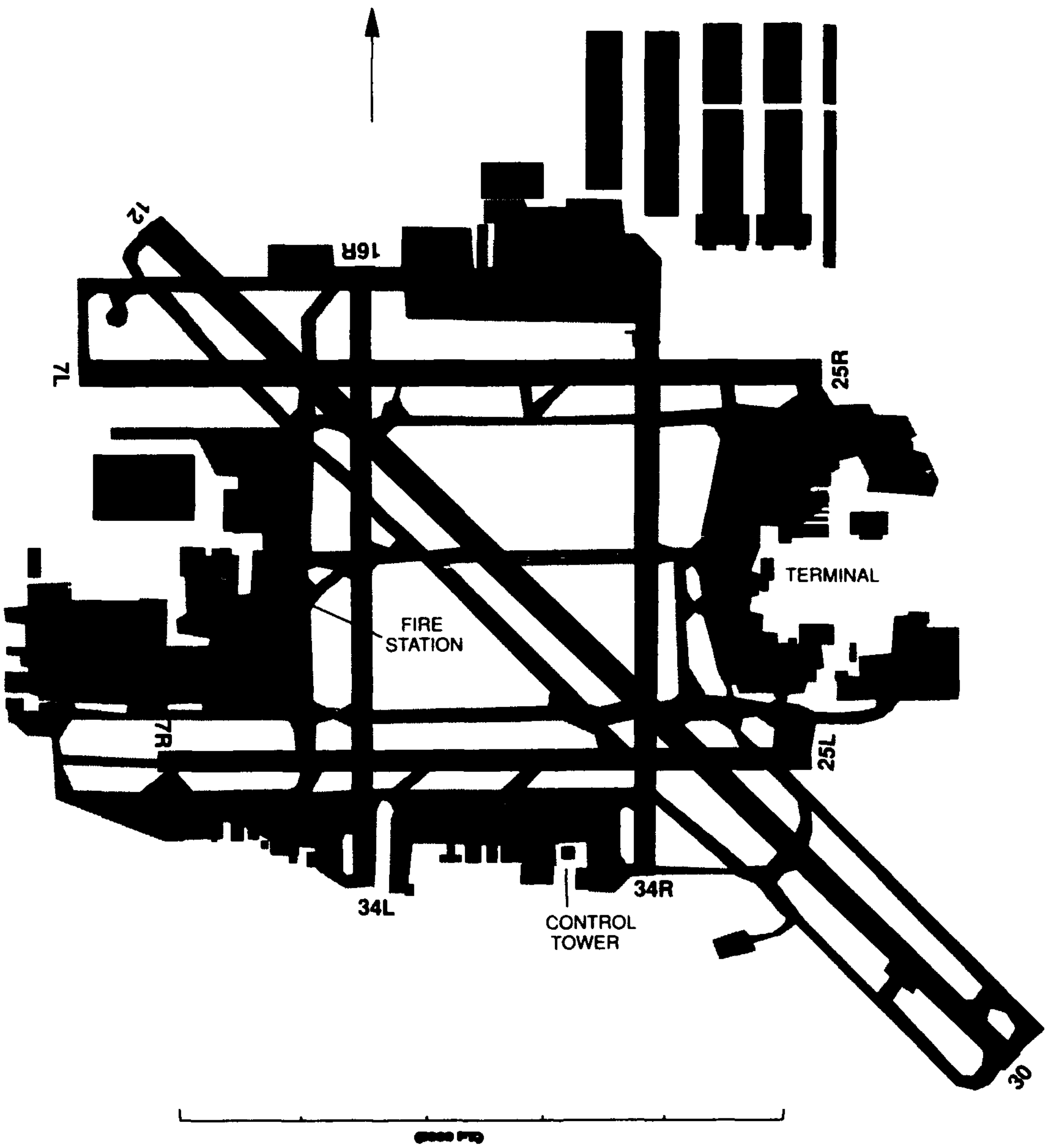
Keahole Airport (Kailua-Kona)



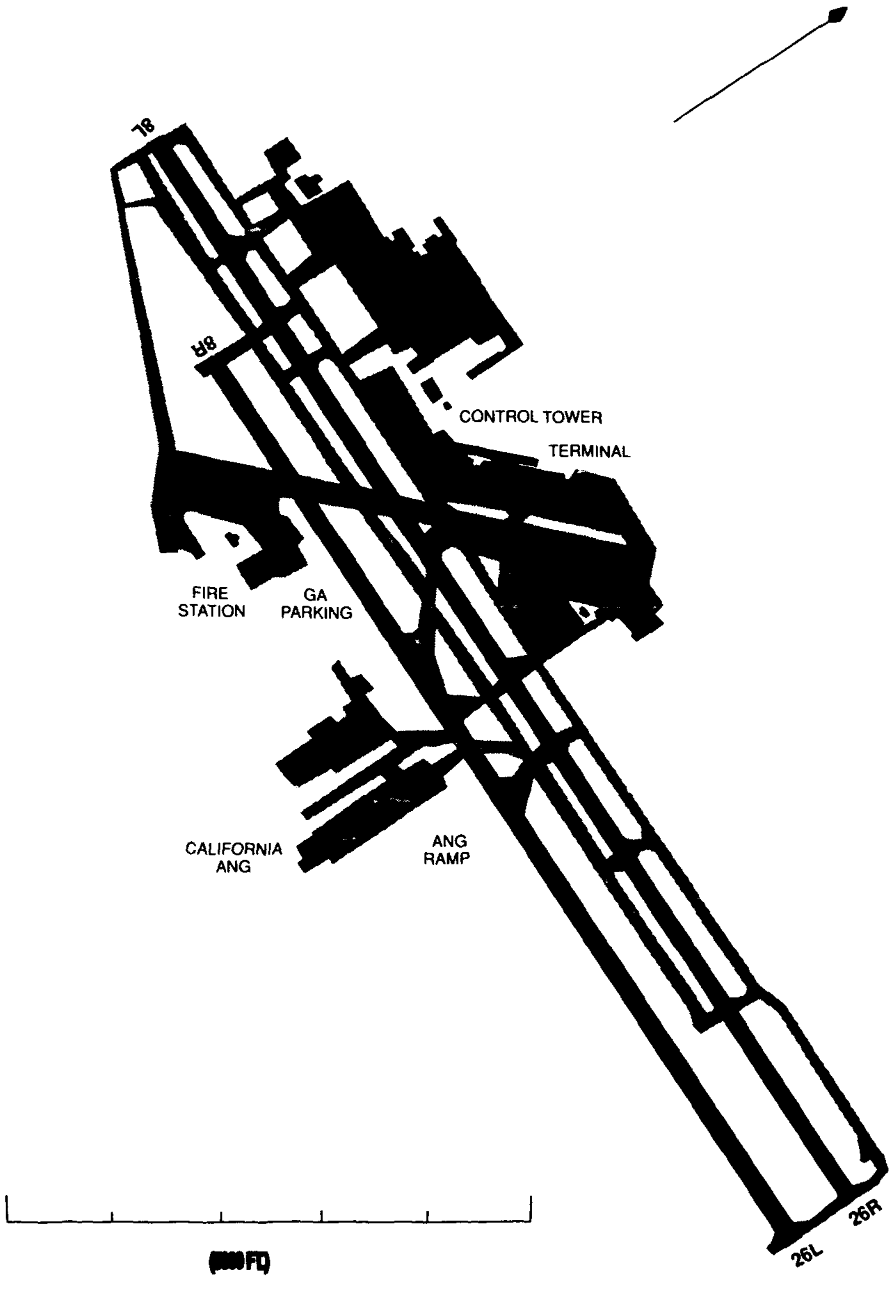
New York La Guardia Airport



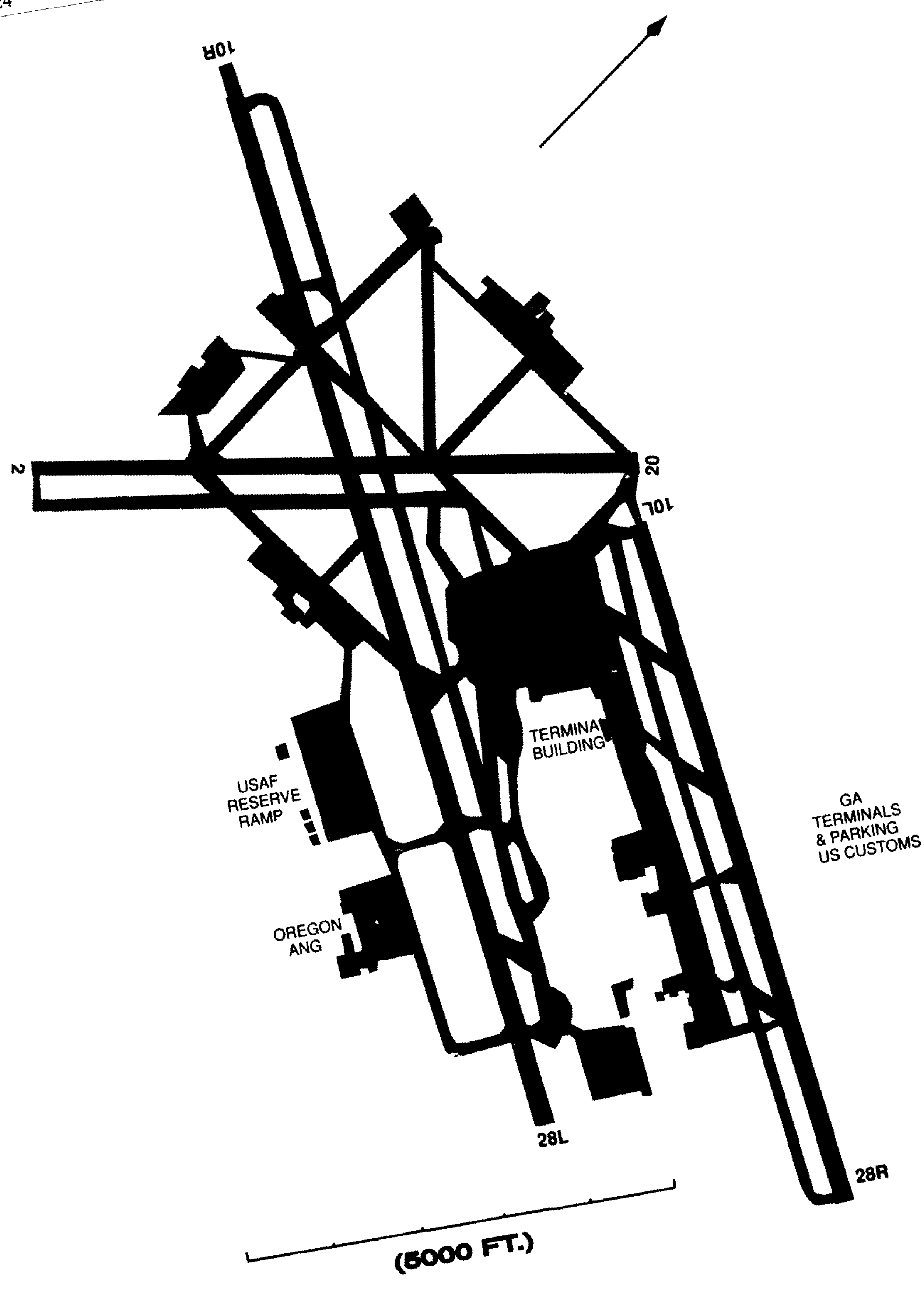
Lihue Airport



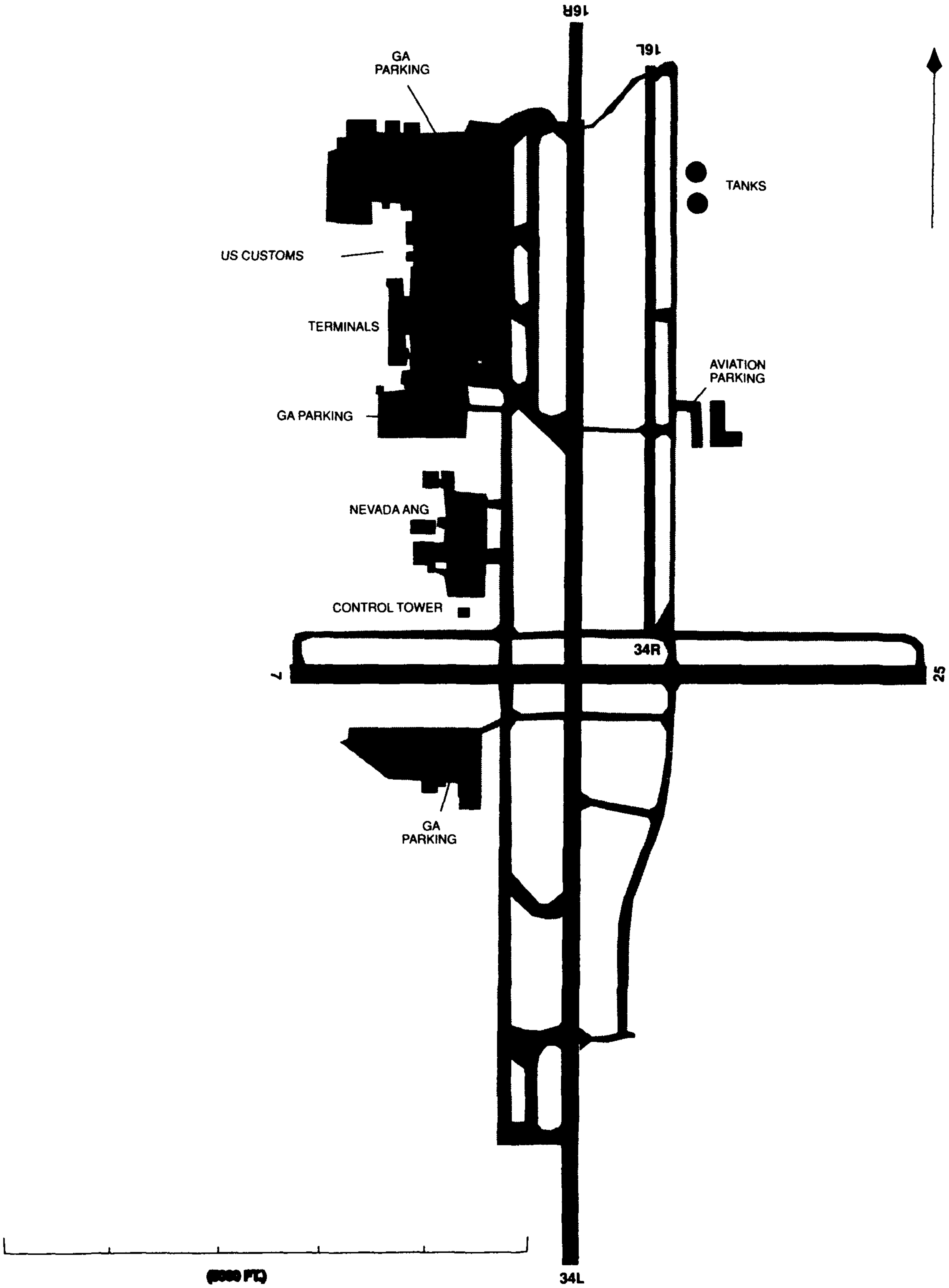
Long Beach Daugherty Field Airport



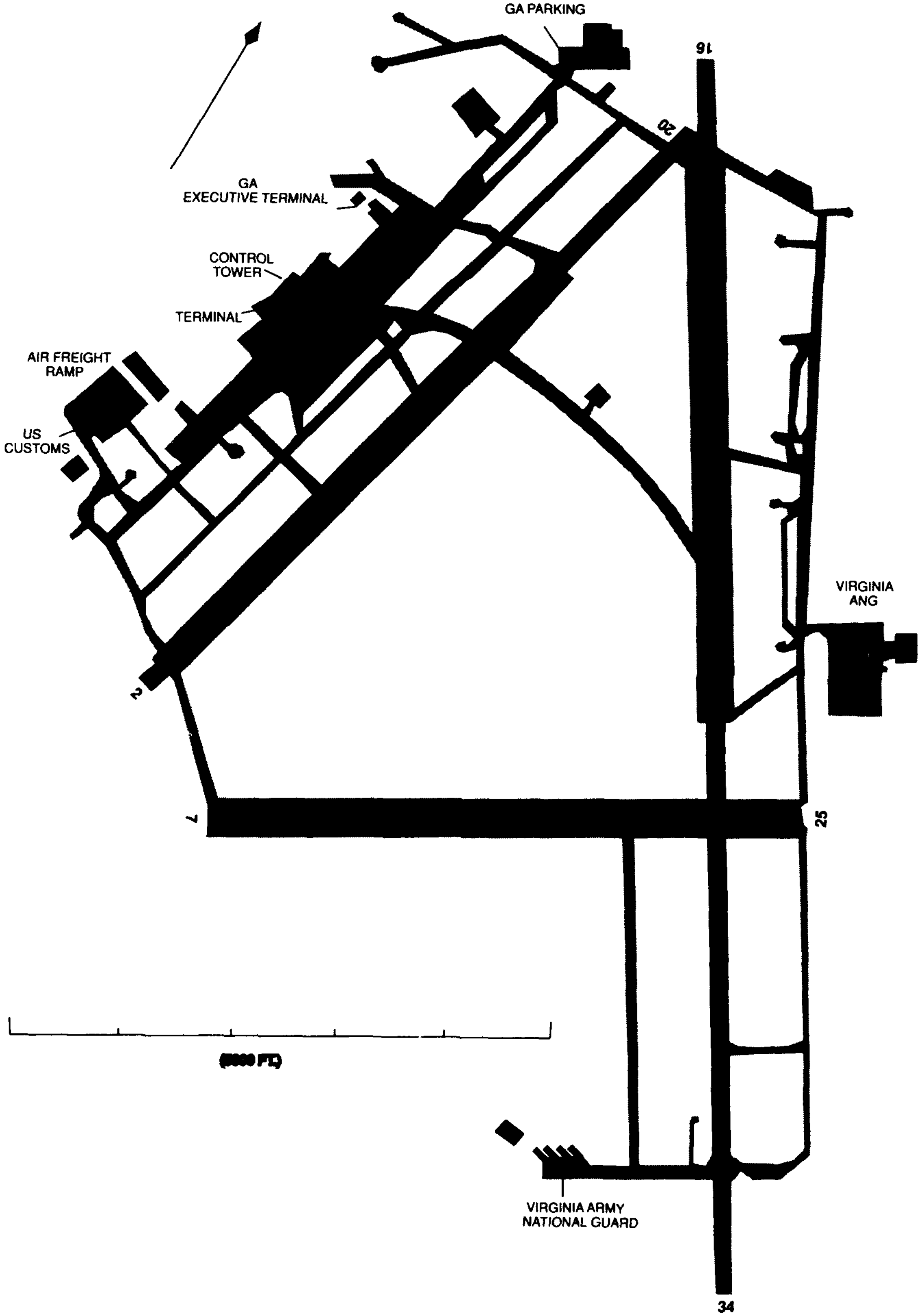
Ontario International Airport



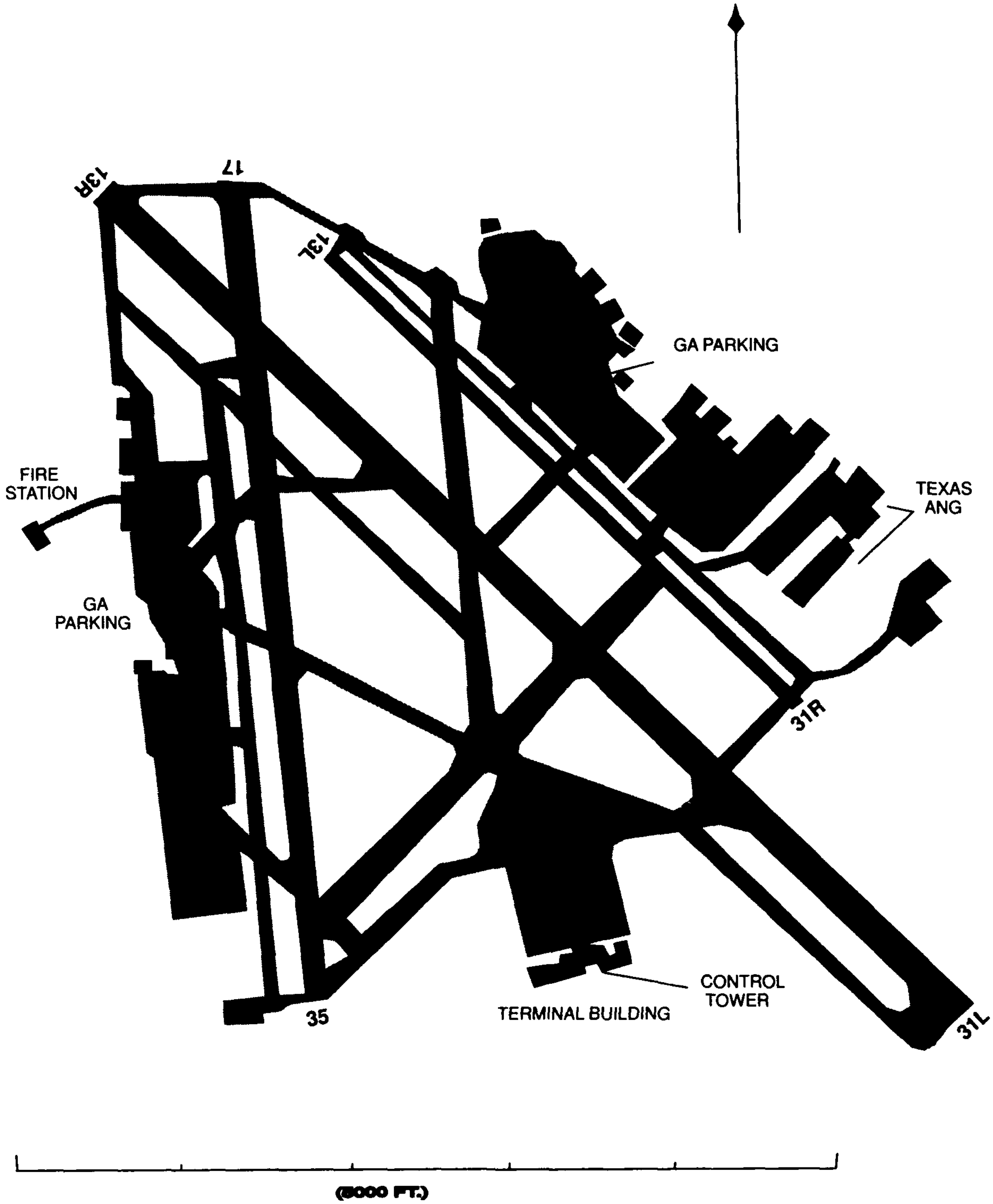
Portland, OR International Airport



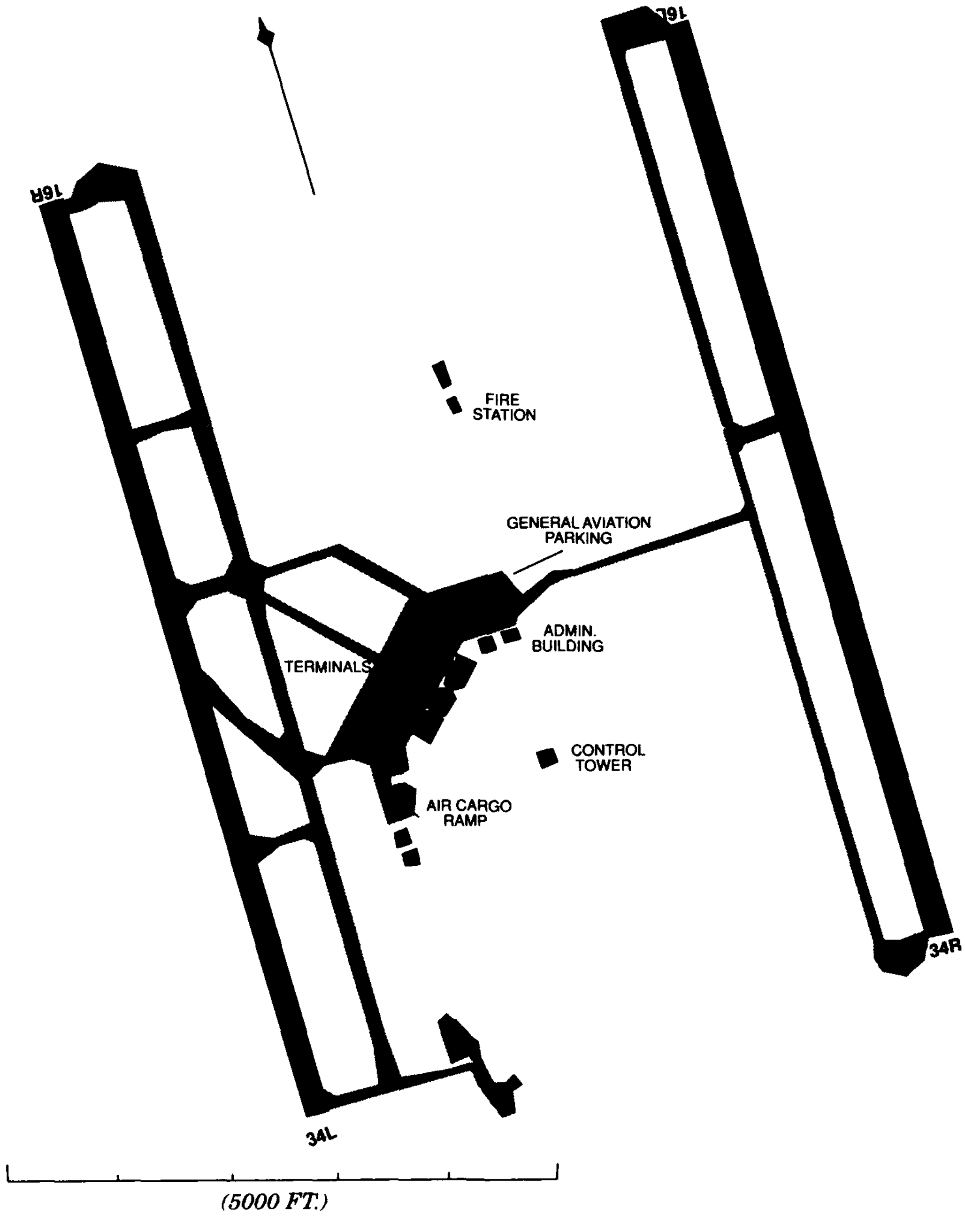
Reno Cannon International Airport



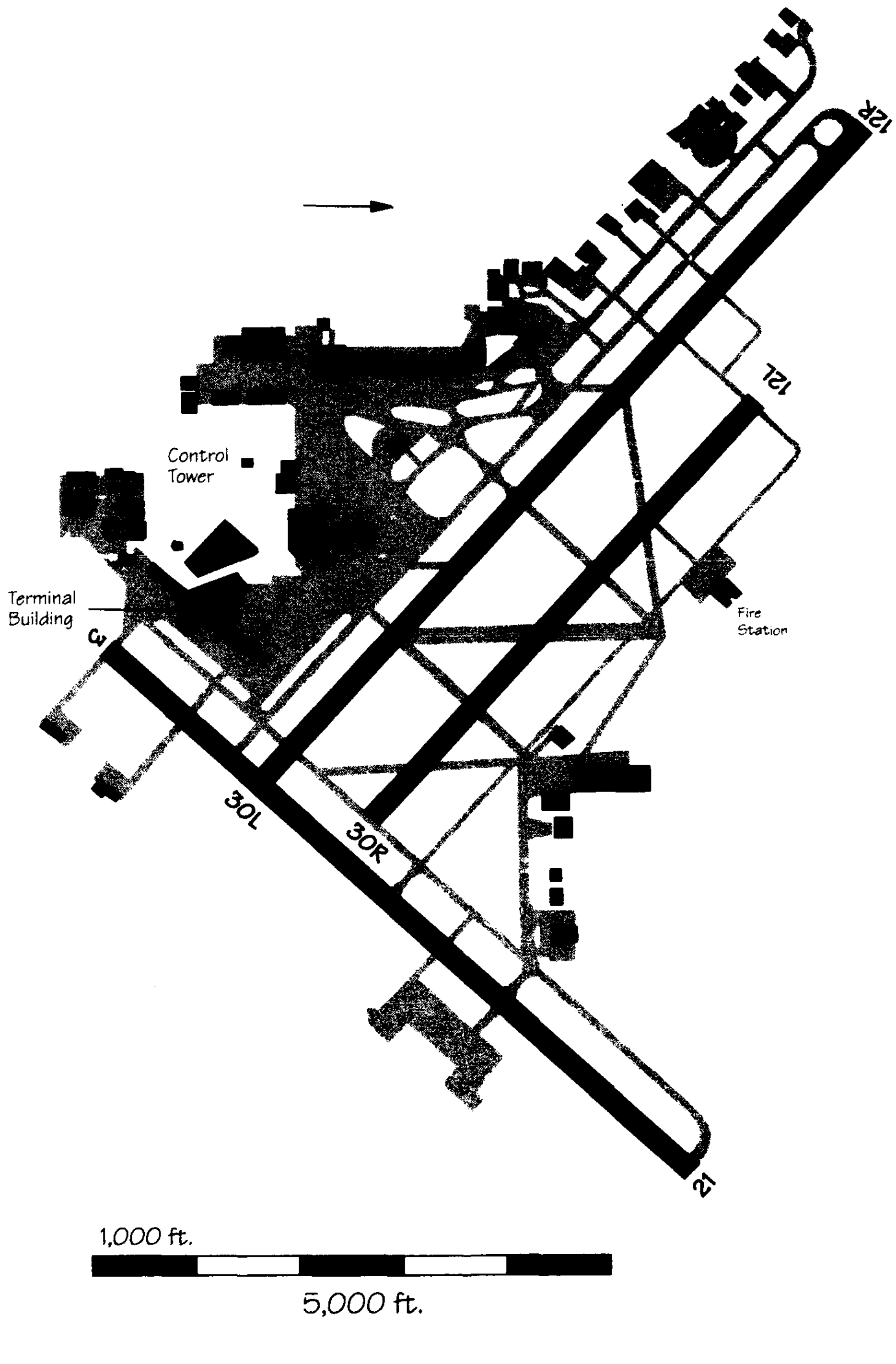
Richmond International Airport (Byrd Field)



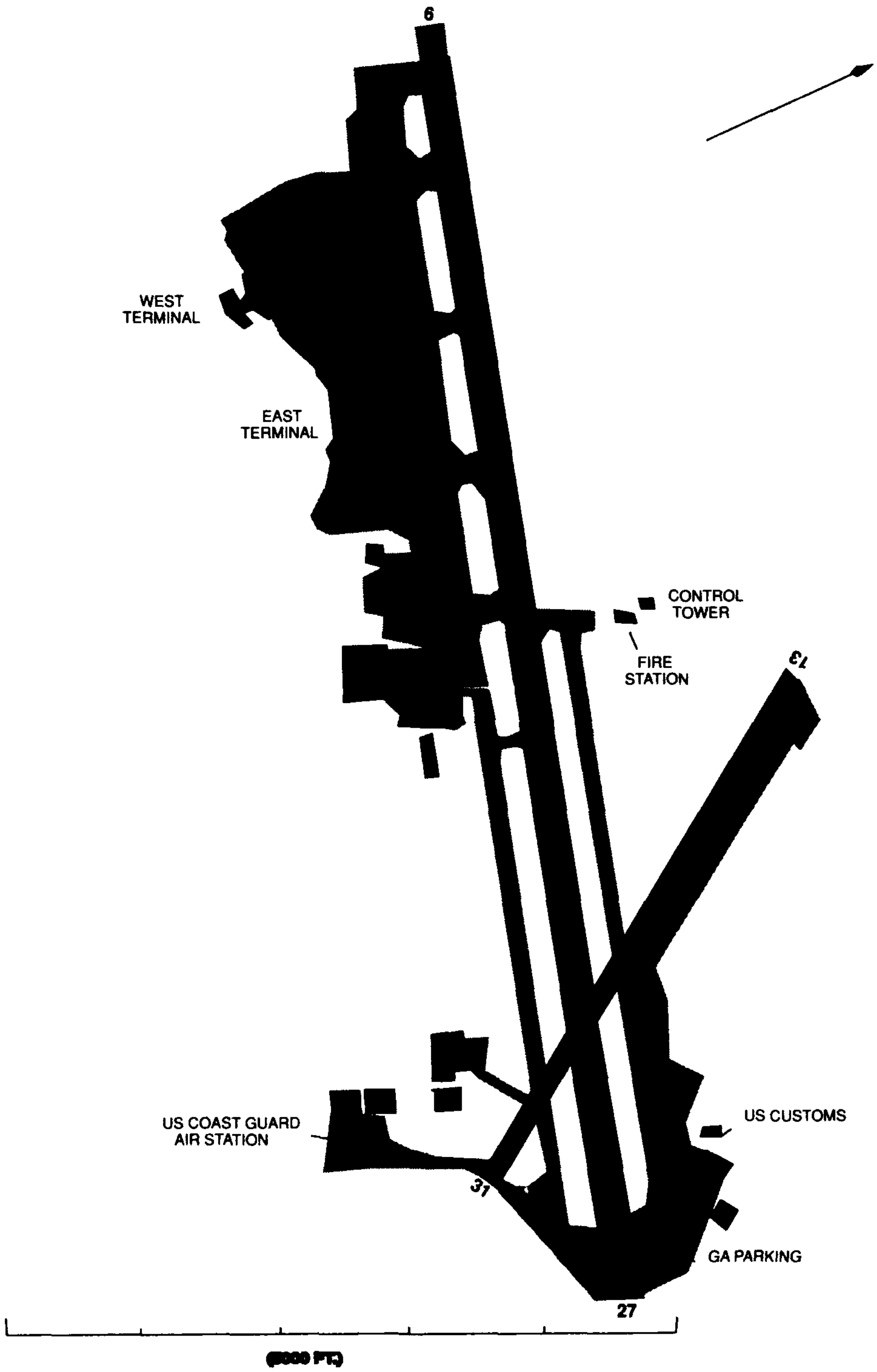
Robert Mueller Municipal Airport (Austin)



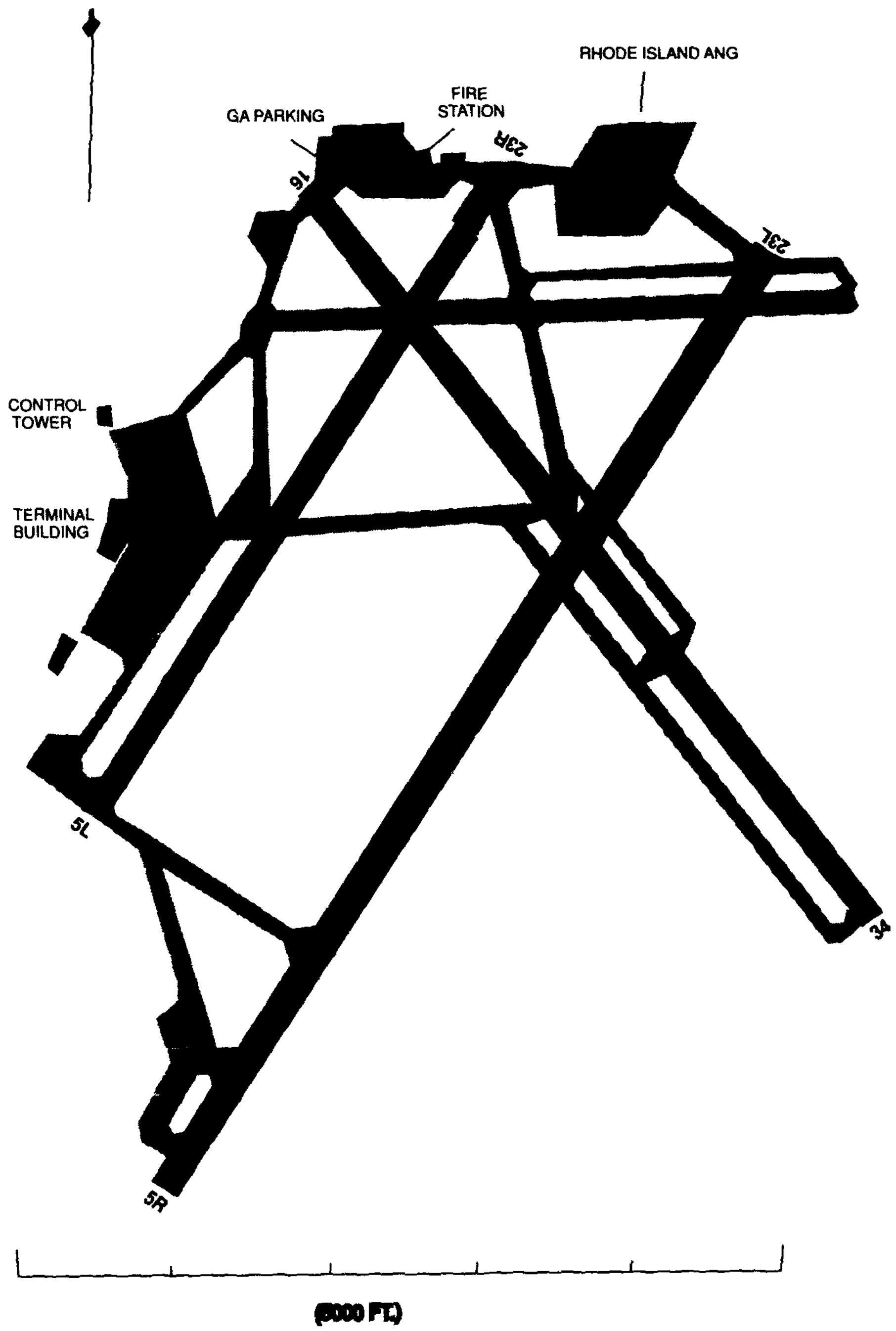
Sacramento Metropolitan Airport



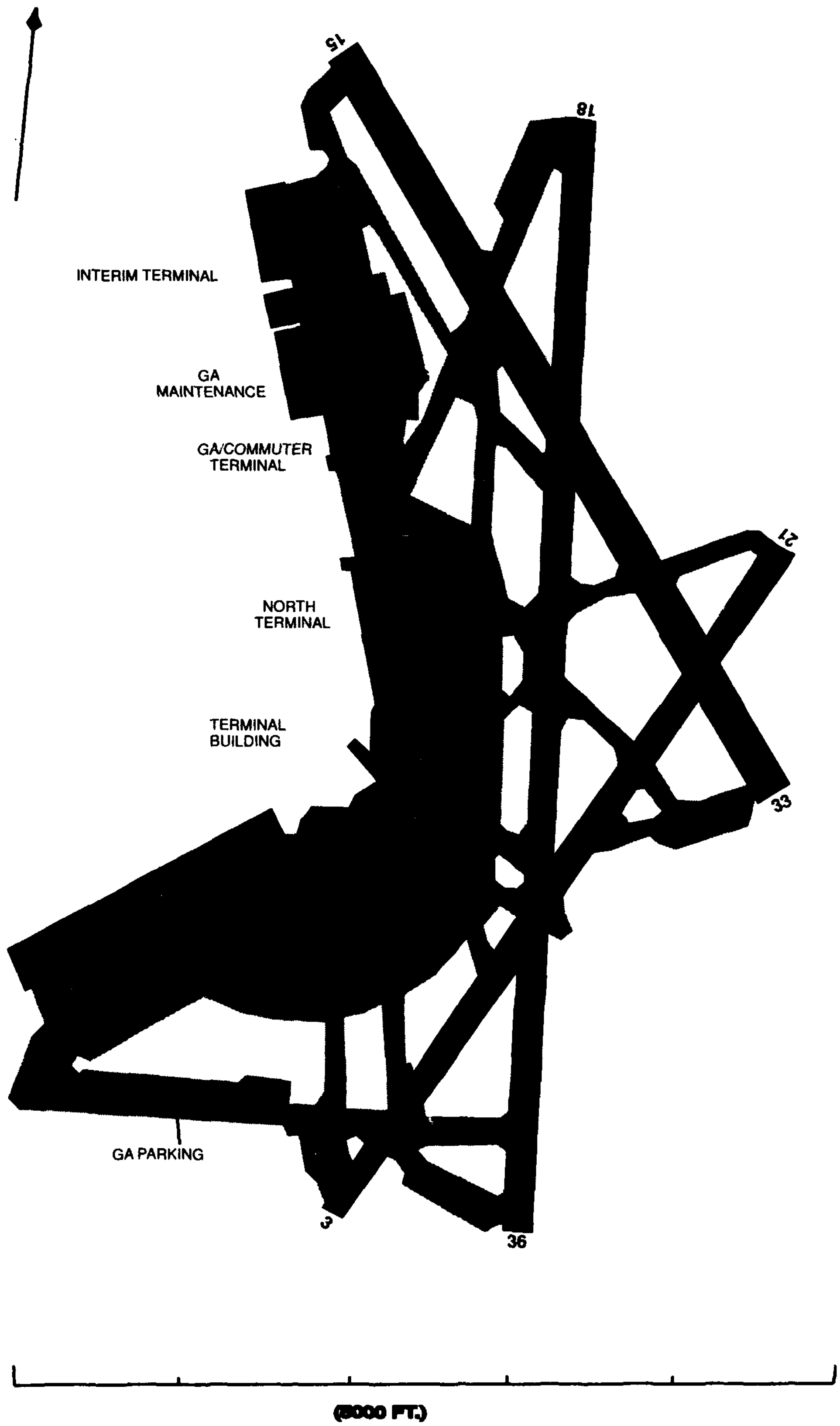
San Antonio International Airport



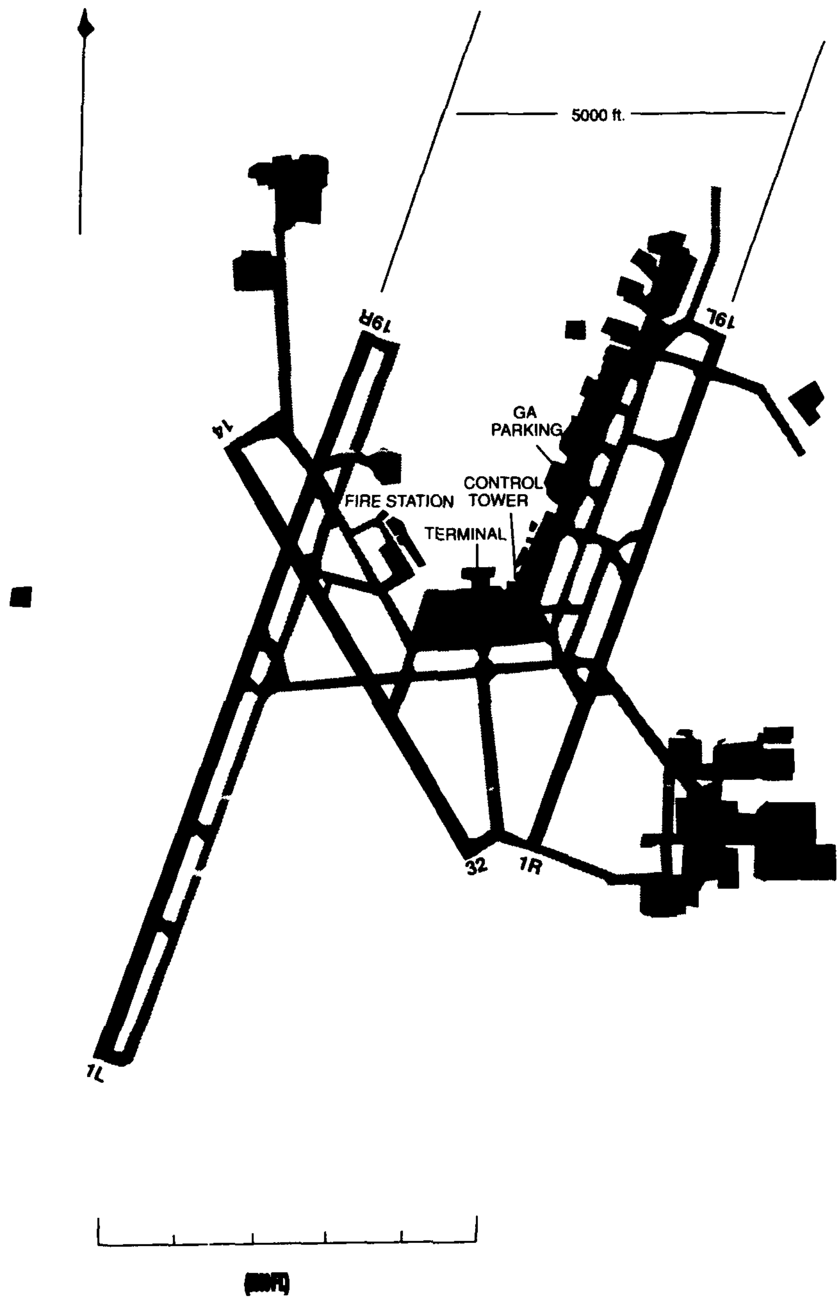
San Diego International-Lindbergh Field Airport



Theodore Francis Green State Airport (Providence)



Washington National Airport



Wichita Mid-Continent Airport

Appendix E

Airport Capacity Design Teams Potential Savings from Recommended Airfield Improvements

This appendix expands on the summary material in Table 2-1. Estimates of savings are in hours of delay and dollars for selected airfield improvements recommended by various Airport Capacity Design Teams. Estimates are given based upon demand at current (baseline) levels and future projections.

Atlanta-Hartsfield International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	750,000	Future 1	780,000	Future 2	796,500
Delay (aircraft hours/year): (without improvements)	Baseline	165,000	Future 1	200,400	Future 2	216,400

	Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1)	Fifth concourse		17.1 $25.7	12.3 $18.4	$60.0
(2)	Commuter/GA terminal and runway complex south of Runway 9R/27L		119.4 $179.1	134.7 $202.1	$100.0

Charlotte/Douglas International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	430,000	Future 1	520,000	Future 2	600,000
Delay (aircraft hours/year): (without improvements)	Baseline	19,100	Future 1	38,000	Future 2	71,400

	Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1)	Build a third parallel runway, Runway 18W/36W				
(1A)	Two IFR arrival streams	6.6 $9.3	12.4 $17.3	24.5 $34.3	
(1B)	Three IFR arrival streams (one dependent)	7.4 $10.3	14.7 $20.6	29.3 $41.0	
(1C)	Three independent IFR arrival streams	7.5 $10.5	15.1 $21.1	30.1 $42.2	
(2)	Build a fourth parallel runway, Runway 18E/36E	— —	— —	8.7 $12.2	

Detroit Metropolitan Wayne County Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	409,000	Future 1	500,000	Future 2	600,000
Delay (aircraft hours/year): without improvements)	Baseline	81,700	Future 1	178,400	Future 2	423,800

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) Construct independent crosswind Runway 9R/27L	54.99	104.93	201.90	
	$85.3	$173.1	$366.4	
(2) Construct independent fourth north/south runway	3.32	6.97	25.46	
	$5.1	$11.5	$46.5	

Kansas City International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	212,000	Future 1	260,000	Future 2	325,000	Future 3	450,000
Delay: (aircraft hours/year) (without improvements)	Baseline	5,000	Future 1	*	Future 2	*	Future 3	235,000

Recommended Improvement	Baseline	Future 1	Future 2	Future 3	Development Cost (000,000)
(1) New N/S 9500' independent runway (1R/19L)	2.7 $2.8	8.3 $8.6	28.2 $29.1	176 $181.8	$48.3
(2) New dependent 10,000' parallel Runway 9R/27L				3.6 $3.7	$40.9
(3) New independent 10,000' parallel Runway 18R/36L	— —	— —	.2 $ .2	4.9 $5.1	$46.3
(4) New dependent 10,000' parallel Runway 18L/36R					$40.9
(11) High speed exit for Runway 27R				1.3 $1.4	$.7

Memphis International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	382,000	Future 1	440,000	Future 2	510,000
Delay (aircraft hours/year): (without improvements)	Baseline	15,826	Future 1	28,380	Future 2	64,630

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) Construct Runway 18E/36E, dual departures		3.094 $5.1	6.255 $10.4	
(2) Construct Runway 18E/36E, triple departures in VFR-1		8.997 $14.9	19.988 $33.2	
(3) Construct Runway 18E/36E, triple departures in all weather conditions (waiver required)		10.356 17.2	23.359 $38.8	
(7) Extend Taxiway A from B to BB for existing runways		1.244 $2.1	1.261 $2.1	
(12) Angled exits on Runway 18R/36L (reduce occupancy times by 10%)	0.147 $0.3	.234 $.4	0.620 $1.0	

Miami International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	326,825	Future 1	390,700	Future 2	421,700	Future 3	532,700
Delay: (aircraft hours/year) (without improvements)	Baseline	7,300	Future 1	10,800	Future 2	17,260	Future 3	46,500

Recommended Improvement	Baseline	Future 1	Future 2	Future 3	Development Cost (000,000)
(1) Dual taxiway around Concourse H (remove 2 end gates)	$0.13			$5.00	$2.5
(2) Extend Taxiway L to end of Runway 9L	$0.09			$12.75	$.35
(3) Construct new partial dual Taxiway K	$1.50				$1.8
(4) Develop improved exits for Runway 9L/27R northside	$0.49			$21.30	$1.2
(4a) Strengthen/reconstruct Runway 9L/27R					$6.2
(5) Improve Exits M4 and M5 on Runway 9L/27R	$1.60			$1.90	$1.5

Orlando International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	294,000	Future 1	400,000	Future 2	600,000
Delay (aircraft hours/year): (without improvements)	Baseline	9,835	Future 1	24,076	Future 2	122,254

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) Extend Taxiway C to threshold of Runway 36R				$3.2
(3) North crossfield taxiway	$2.9	$3.9	$6.0	$26.0
(4a) New Taxiway B9 from Runway 36R to Runway 36L				
(4b) New Taxiway B9 from Taxiway A to threshold of Runway 36L				
(5) Staging areas at all runway ends	$.3	$.3	$6.3	$3.0
(6) Fourth Runway and associated taxiways		$1.4	$47.3	$100.0

Phoenix-Sky Harbor International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	465,000	Future 1	550,000	Future 2	650,000
Delay (aircraft hours/year): (without improvements)	Baseline	45,741	Future 1	108,518	Future 2	701,296

	Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1)	Construct new runway 800' south of Runway 8R/26L	25.03 $27.03	56.44 $60.95	370.36 $399.99	$28.0
(2)	Construct run-up pads at two runway ends				$2.3
(3)	Widen fillets at Taxiways C5 and C7 off Runway 8R/26L	0.58 $0.63	3.05 $3.30	21.63 $23.37	$0.5
(4)	Construct holding area southeast of Terminal 3				$0.5
(5)	Construct angled exit off of Runway 8R/26L between Taxiways C3 and C4 to Taxiway C	0.71 $0.76	3.46 $3.73	30.03 $32.44	$0.4
(6)	Construct angled exit off of Runway 8S/26S between Taxiways D3 and D5 to Taxiway D	0.05 $0.06	0.15 $0.16	0.24 $0.27	$0.4
(7)	Construct second midfield crossover Taxiway Y adjacent to Taxiway X	7.72 $8.34	24.02 $25.95	150.61 $162.66	$7.5
8)	Construct crossover Taxiway W at ends of Runways 26R and 26L	3.38 $3.65	11.00 $11.88	88.24 $95.30	$6.5
(9)	Construct crossover Taxiway Z west of Terminal 1 (from Exit B3 to Exit C3)	5.69 $6.15	12.77 $13.79	76.28 $82.38	$4.1
(10)	Construct Terminal 4 (77 gates) and remove Terminal 1	9.56 $10.31	30.79 $33.26	207.31 $223.89	$287.0
(11A)	Extend Taxiway A to end of Runway 26R				$1.2
(12)	Complete northside taxilane (parallel to Taxiway C) from end of Runway 8R to crossover Taxiway X				$4.9
(13)	Relocate ANG south of Runway 8R/26L				$60.0

St. Louis-Lambert International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	530,000	Future 1	585,000	Future 2	740,000
Delay (aircraft hours/year): (without improvements)	Baseline	158,000	Future 1	305,000	Future 2	875,000

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) New runway parallel to Runway 12L/30R				
(1A) Alternate 1: New independent commuter runway 2500' from Runway 12L/30R	94 $139	154 $228	617 $913	$8
(1B) Alternate 2: New dependent commuter runway 1400' from Runway 12L/30R	84 $124	137 $203	577 $853	$7.8
(1C) Alternate 3: New independent air carrier runway parallel to Runway 12L/30R	132 $195	203 $300	693 $1025	$30.0
(2) Convert Taxiway F to permanent VFR Runway 13/31	21 $30	37 $55	313 $463	$0.9
(3) Angled exits on Runway 12L/30R	1.7 $2.5	2.8 $4.1	27 $40	$2.5
(4) Taxiway extensions				
(4A) Extend Taxiway A south to end of Runway 30L	12 $18			$3.0
(4B) Extend Taxiway P from Taxiway C to Taxiway M	11 $16			$1.3
(4C) Extend Taxiway C from Taxiway F to end of Runway 24	14 $20	17 $26		$2.0
(6) Establish queuing areas at various runway ends				$7.5
(7) Relocate cargo area	3.0 $4.5			$2.0

Salt Lake City International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	269,600	Future 1	351,000	Future 2	418,000
Delay (aircraft hours/year): (without improvements)	Baseline	14,900	Future 1	51,350	Future 2	104,000

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) New independent air carrier runway to west with CAT III on both ends		28.84 $31.4	61.67 $67.19	$80.7
(4) Revised taxiway exit layout	.6 $.65	1.77 $1.93	4.11 $4.50	$2.4
(8) Rehab Taxiways X and Y	.18 $.19			$4.2

Seattle-Tacoma International Airport Capacity Design Team Project Summary

Demand Level: (annual operations)	Baseline	320,000	Future 1	390,000	Future 2	425,000
Delay (aircraft hours/year): (without improvements)	Baseline	48,000	Future 1	168,000	Future 2	241,000

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) Runway alternates:				
(a) Convert Taxiway D to 5000' commuter Runway 17C/35C with associated taxiway system	6.03 $8.69	43.65 $62.84	66.19 $95.31	$10.0
(b) Dependent air carrier 7000' Runway 16W/34W 2500' from Runway 16L/34R	32.86 $47.30	121.81 $175.41	167.39 $241.04	$250.0
(c) Independent air carrier 7000' runway 2500' from Runway 16L/34R	37.49 $53.98	141.93 $204.39	196.57 $283.06	$250.0
(2) Taxiway construction:				
(a) High speed exits and other taxiways	2.26 $3.25	4.34 $6.25	6.23 $8.97	$8.0

Washington Dulles International Airport Capacity Design Team Project Summary

Demand Level (annual operations)	Baseline	320,000	Future 1	400,000	Future 2	450,000
Delay (aircraft hours/year): (without improvements)	Baseline	7,541	Future 1	17,246	Future 2	28,731

Recommended Improvement	Baseline	Future 1	Future 2	Development Cost (000,000)
(1) Add Runway 1W/19W—3500' west of Runway 1L/19R, with full ILS	—	3.86 $5.3	6.23 $8.5	
(2) Add Runway 12R/30L—4300' south of Runway 12/30, with full ILS	—	3.60 $4.9	8.37 $11.4	

Appendix F

New Technology for Improving System Capacity

The major purpose of the Research, Engineering, and Development (R,E&D) program is to develop and exploit technologies in an effort to increase system capacity and fully utilize capacity resources, accommodate user-preferred flight trajectories, increase user involvement in air traffic management decision-making, and develop air traffic control and aircraft systems that enhance overall safety at the increased levels of operations forecasted for the 21st century.

Major FY1990-91 Accomplishments

During FY1990-91, the FAA's Capacity R,E&D program made the following advances:

- Successful demonstration of conducting independent IFR approaches to parallel runways spaced 3,400 ft. apart
- Approval of simultaneous IFR approaches to the proposed triple and *quadruple parallel runways at* Dallas/Ft. Worth International Airport
- The use of computer-based analytical models for airspace capacity and design studies for 13 airports
- Field evaluations of the Converging Runway Display Aid and laboratory evaluation of the Center-TRACON Automation System
- The installation and test of track generation programs and traffic management displays in New York, Oakland, and Anchorage ARTCC's for oceanic ATC
- Reduction in vertical separation standards from 2,000 ft. to 1,000 ft. above FL 290
- Airport capacity design team studies completed for 11 airports; 8 still underway, 5 new ones being considered for 1992, and new runways planned for 7 airports
- Installation of MLS's at New York (JFK) and Chicago (Midway) to evaluate capacity enhancements at runways on which an ILS cannot be installed

Current Program

Complete project details, including funding and implementation dates, where appropriate, are given in the following pages. The key elements of the R,E&D capacity program are:

- ATC Technology Program - To enhance the operational capabilities of the air traffic control system through the aggressive introduction of automation. Such projects include Advanced Traffic Management System, Oceanic Display and Planning System, Dynamic Ocean Tracking System, Automatic Dependent Surveillance, AERA, Terminal ATC Automation, Airport Surface Traffic Automation, Airport Movement Safety System, Airport Capacity Improvements, and Wake Vortex Avoidance/Advisory System.
- Aircraft Technology Program - To develop aircraft technologies to enhance ATC capacity and efficiency by enabling aircraft to safely assume some aspects of the air traffic controller's current responsibilities for ensuring aircraft separation and to develop operational procedures and certification criteria to exploit the capabilities of rotorcraft and tiltrotor aircraft. The projects in this program are Traffic Alert and Collision Avoidance System, Cockpit Display of Traffic Information, and Vertical Flight Operations and Certification.
- Future Systems Engineering Program - To develop and maintain the necessary steps required for successful integration of the new and proposed subsystems into the evolving ATC system. This program includes Future System Definition, Flight Operations and ATM Integration, Separation Standards, Integrated Traffic Flow Management, and NAS System Operational Concepts.
- Capacity Planning - To develop technological (other than ATC), procedural, and airport design alternatives which will increase the operational capacity of the system. These projects include airport design, airspace design, and approach procedures.
- Modeling and Simulation Program - To develop tools to plan and implement the Capacity and ATC Technology Program, to develop new facilities to realistically simulate the operation of future air traffic control systems, to develop new models and research techniques to analyze, assess impacts, and guide the long-term technological evolution of the National Airspace System, and to integrate the major pieces of the system so that they play in harmony with one another. The projects include the National Simulation Laboratory, Operational Traffic Flow Planning, Traffic Models and Evaluation Tools, and Airports and Airspace Impacts Assessments.

The projects described above are explained in detail in the following section. They are divided into four categories: Terminal Airspace Capacity Related Projects, Other Capacity Related Projects, En Route Capacity Related Projects, and Airport Capacity Related Projects.

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F.1 Terminal Airspace Capacity Related Projects

F.1.1 Terminal Radar (ASR) Replacement Program

Responsible Division: ANR-200
Contact Person: Gerald Taylor, 202/606-4574

Purpose

To provide economical radar service at airports with air traffic densities high enough to justify the service and upgrade the highest density airports with the latest state-of-the-art equipment.

ASR-4/5/6 radars need to be replaced because of the decreasing availability of spare parts and the high-maintenance workload. Furthermore, repair parts for the ASR-4/5/6 radars are in short supply. A total of 96 ASR-4/5/6 radars are being replaced. Of these, 40 ASR-4/5/6 sites are being upgraded to ASR-9's, 40 ASR-4/5/6's are being upgraded to ASR-8's, and 16 ASR-4/5/6's are being upgraded to ASR-7's, a procedure called "leapfrogging."

Program Milestones

The first ASR-9 Operational Readiness Demonstration (ORD) was in FY1989 and the first leapfrog ORD was in FY1990. The last leapfrog ORD is scheduled for FY1993 and the last ASR-9 ORD is planned for FY1994.

Products

- Replace 96 radars
- Leapfrog 56 radars

F.1.2 Los Angeles Basin Consolidation

Responsible Division: ANS-300
Contact Persons: Frank McArthur, 202/267-8680
Bill Henshaw, FTS/984-0220

Purpose

To consolidate five Los Angeles Basin Terminal Radar Approach Control Facilities (TRACONs) to be known as the Southern California TRACON. This new facility will enhance traffic management in Southern California and allow more efficient use of the airspace.

The Los Angeles Basin is created by the Pacific Ocean and the San Rafael, Sierra Madre, Techachapi, San Gabriel, San Bernardino, San Jacinto, and Santa Ana Mountain ranges. The basin area is approximately 75 miles wide and 100 miles long. The major portion of this airspace below 10,000 feet is currently controlled by TRACON facilities located at Los Angeles, Burbank, El Toro (coast), Ontario, and San Diego. These five TRACON facilities provide instrument flight rule services for 29 airports within their respective areas of jurisdiction. This includes eight major air carrier airports and five military air fields. Instrument operations in Southern California have increased 122 percent over the last two years to 2,700,000 instrument operations. Forecasts call for well over 3,000,000 operations by the year 2000.

Products

This consolidation will enhance safety, improve airspace utilization, and provide an IFR air traffic control system approach for the major hub and satellite reliever airports in Southern California.

- Start site adaptation 01/90
- Building contract award (completed) 09/91
- Building occupancy date 02/93
- Los Angeles TRACON consolidated 12/93
- Coast TRACON consolidated 05/94
- Burbank TRACON consolidated 10/94
- Ontario TRACON consolidated 04/95
- San Diego TRACON consolidated 09/95
- Project completed 02/96

F.1.3 Simulation Model Development (SIMMOD)

Responsible Division: AOR-200
Contact Person: Jake Plante, 202/267-3539

Purpose

To provide an accurate, comprehensive, and cost-effective analytical tool for evaluating proposed improvements to the national airspace system.

This capability will provide quantitative analyses to determine the impact of proposed changes to airports, airspace, and aircraft traffic. The FAA Airport and Airspace Simulation Model (SIMMOD) will play a significant role in future development of the national airspace system by reliably identifying the most appropriate airport and airspace design and procedural alternatives.

SIMMOD will be enhanced with logic improvements that will increase realism in simulating the actual behavior of the air traffic control system and air operations. The cost of extensive data preparation will be reduced by developing automated data-acquisition hardware and software. Visual replay of scenarios will continue to be developed as an effective quality-control technique and for specific site calibration. Full documentation of the model's algorithms has been provided, as well as training manuals and courses, so that the model may be widely used by the FAA and others to improve designs and procedures in the airspace system.

Program Milestones

Version 1.0 of SIMMOD was validated in FY1988 and publicly released in FY1989. Through FY1990, SIMMOD has been applied to numerous airspace design tasks at Los Angeles, Boston, Dallas-Ft. Worth, Denver, Chicago, Kansas City, Houston-Austin, New York (Phase I), and Miami. Studies that focused on airport design and ground operations during this period include San Diego, Salt Lake City, Portland, Milwaukee-Mitchell, and Minneapolis-St. Paul. SIMMOD was used outside the United States for airport and airspace capacity studies at Madrid, Majorca, Quebec, Toronto, Ottawa, Hong Kong, Sydney and Melbourne.

In FY1991, SIMMOD continued to be used for major airspace capacity and design studies at Cleveland, Washington, New York (Phase II), Oakland, Jacksonville, and Atlanta. The model has been purchased by 145 organizations, many of which are applying the model in numerous locations for airline, airport, and government agencies.

For FY1992, applications work will continue for both airport and airspace environments. In addition, Version 2.0 of SIMMOD will be completed. This version, available for workstations, will be significantly faster than that for microcomputers. This version will include better graphical output displays and automated data-acquisition capability. For example, SIMMOD will generate output data that can be used directly by other FAA models, including the Integrated Noise Model used for environmental studies.

Products

- Complete computer program for workstations and microcomputers
- An organization of users throughout the FAA and industry
- Training sessions, manuals, and technical documentation for users

F.1.4 Terminal ATC Automation (TATCA)

Responsible Division: ARD-40
Contact Person: Peter Challan, 202/267-7335

Purpose

To develop automation aids to assist air traffic controllers and supervisors in overcoming the limitations of the terminal area air traffic management process, and to facilitate the early implementation of these aids at busy airports.

The TATCA program consists of two projects: the Converging Runway Display Aid (CRDA), and the Center-TRACON Automation System (CTAS). CRDA provides geometric spacing aids for aircraft by means of software changes within existing ARTS terminal radar processors. The CRDA project is in a field evaluation phase.

The CTAS project is now in laboratory development. CTAS uses auxiliary workstation processors interfaced to existing ATC processors to project the future location of aircraft, develop a coordinated and fuel efficient arrival traffic plan, and provide ATC advisories to help controllers meet the plan. The earliest CTAS products are a Traffic Management Advisor (TMA) and Descent Advisor (DA) for the Air Route Traffic Control Center and a Final Approach Spacing Tool (FAST) for the TRACON.

TMA is a scheduling tool while DA is a tool for providing fuel-efficient descent profiles to meet the arrival plan specified by the TMA. These are automation aids for sequencing and spacing aircraft from the top of the descent point to the terminal area. FAST is a final approach sequencing and spacing tool.

Longer term TATCA activities focus on fully developed terminal automation techniques integrated with other ATC and cockpit automation capabilities of the Advanced Automation System (AAS).

Program Milestones

CRDA is currently being evaluated at Lambert-St. Louis International Airport. When the field development is complete, national implementation will proceed for up to 30 airports with converging or intersecting runways.

CTAS laboratory evaluations and demonstrations have been completed. A preliminary plan and design was completed for the important task of implementing interfaces to the ARTS IIIA and IIIE for FAST.

Products

- Major CRDA milestones include:
  - Complete evaluation at St. Louis 11/91
  - Begin national implementation 07/92
  - Complete national implementation 03/93
- Major TMA milestones include:
  - Test field prototype at FAA Tech Center 09/91
  - Develop TMA prototype at ARTCC 05/92
  - Evaluation of TMA at FAA Tech Center 11/92
  - Site testing of TMA 05/93
  - Implementation at first site 10/93
- FAST milestones include:
  - Complete laboratory development of FAST 03/92
  - Test FAST concept at FAA Tech Center 06/92
  - Field development for system specs 03/93
  - Evaluation of FAST at FAA Tech Center 10/93
  - Site testing of FAST 09/94
  - Implementation of FAST at first site 06/95
- The major TATCA/AAS milestone is:
  - Modification to the System Level Specification for the AAS 04/94

F.1.5 Airport Surface Traffic Automation (ASTA)

Responsible Division: ARD-50
Contact Person: Mike Harrison, 202/267-8556

Purpose

To develop airport surface surveillance, communications, and automation techniques that will provide an effective runway incursion prevention capability.

To provide departure traffic management to sequence aircraft to the departure end of the runway according to schedules designed to expedite traffic flow and increase the capacity of the airport surface in all weather conditions.

To provide a linkage of information between terminal air traffic control automation tools.

ASTA improvements will be developed in three phases. ASTA-1 will focus on the prevention of runway incursion based on use of radar surveillance (ASDE-3 data), runway/taxiway signal lighting, and an interface for the tower controller, providing appropriate advisories and alerts regarding aircraft movements. These will serve as enhancements to the Airport Movement Area Safety System (AMASS).

ASTA-2 will include surveillance and automation features that will monitor aircraft movements and coordinate traffic planning and sequencing. Initial elements for the departure traffic management capability will be introduced in Phase 2.

ASTA-3 will add a data-link communications capability.

Program Milestones

The ASTA project was started in FY1989 to reduce the risk of runway incursions and improve airport capacity through better departure traffic management and increased efficiency of aircraft surface movements. In FY1990, alternative capabilities for reducing runway incursions were identified. In addition, a preliminary system was defined. Planned work includes the following:

- Field validation and testing 08/92
- System design contract award 10/92
- AMASS production contract award 11/92
- Demonstration of ASTA-1 (Boston) 12/92
- Functional specifications for ASTA-2 .... 02/92
- Prototype competition ASTA-2 .... 06/94
- Production award ASTA-2 .... 10/94
- Delivery of first AMASS system 11/94
- ASTA-3 data link added 08/95

Products

- 29 AMASS hardware and software enhancements for each of the ASDE-3 locations
- ASTA-1 at 29 ASDE-3 locations
- ASTA-2 at 100 to 150 airports

F.1.6 Low Cost Surface Detection Alternatives

Responsible Division: ARD-50
Contact Person: Mike Harrison, 202/267-8556

Purpose

To review technologies other than ASDE-3 for the detection and alerting of runway incursions at towered airports not equipped with ASDE-3.

Program Milestones

Other alternatives to ASDE-3 have been identified. For FY1991 the capabilities of these systems will be analyzed, with respect to accuracy, and candidate systems with the potential for rapid procurement will be identified. A broad agency announcement soliciting alternative technologies was issued in July 1991. Contract awards demonstrating these alternatives are scheduled for FY1992. Those that are promising will be expanded to full-scale airport demonstrations.

Products

Product examples include:

- Demonstration of GPS for ground navigation
- Surface pressure sensor for controlling lights
- Specifications for surface surveillance system using aircraft beacon codes

F.1.7 TCAS II Applications to Improve Capacity

Responsible Division: ARD-300
Contact Person: Tom Williamson, 202/267-8465

Purpose

To identify and evaluate potential applications of the Cockpit Display of Traffic Information (CDTI) provided by TCAS for improving the efficiency, capacity, and safety of aircraft operations.

To determine which applications are worthwhile and develop the standards and procedures required for their operational implementation.

CDTI has the capability of increasing the efficiency and capacity of the National Airspace System (NAS), reducing controller workload and, at the same time, increasing the level of safety. With the advent of TCAS, pilots will have an electronic display of nearby traffic in the cockpit.

A user group consisting of air carrier pilots, general aviation pilots, and air traffic controllers will be convened to identify and prioritize potential CDTI applications. The most promising of these applications will be evaluated by a combination of analysis, fast-time and real-time person-in the-loop simulations, and flight tests. Consideration will be given both to applications which can use the TCAS display "as is" and ones that require additional information and enhanced display capability. For each studied application, the impact on flight safety will be assessed, procedures will be developed, and any special data and/or display requirements will be defined.

Program Milestones and Products

- Identification of near-term CDTI applications 12/92
- Safety assessment of near-term applications 12/93
- Display requirements for CDTI 12/93
- Implementation of CDTI use 07/94
- Identification of long-term CDTI applications 07/94
- Safety assessment of long-term CDTI applications 01/95
- Implementation of long-term CDTI applications 01/97

F.2 Other Capacity Related Projects

F.2.1 FAA National Simulation Laboratory (NSL)

Responsible Division: AOR-20
Contact Person: Randall J. Stevens, 202/267-7056

Purpose

To establish the NSL to assess proposed future subsystems, aviation procedures, airspace organization, and human factors in an integrated fashion to determine the definition of the 21st century NAS.

The NSL will provide a means of analyzing and experimenting with alternative concepts for potential NAS development, as well as a capability for hands-on development of prototype configurations for future NAS integration. This will enable improved assessment of new concepts and high-level system design, new technologies, system requirements, potential problems, and issues. Resulting requirements specifications for procuring NAS equipment will be more accurate, complete and achievable. The initial effort has been to establish the Integration and Interaction Laboratory (I-Lab) as a proof-of-concept.

The NSL will feature rapid prototyping, configuration, modularity, flexibility, and expandibility to address research, engineering, and development ATC issues and provide feedback to interacting programs. Initial NSL capabilities will be derived from the I-Lab. This base will be expanded through FY1992 to support the conduct of human-in-the-loop simulations of the future En route, Terminal, and Traffic Flow Automation. The functionality will be extended in FY1993 to incorporate human-in-the-loop interoperability simulations adding oceanic and an interface with applicable weather dissemination subsystems. Applicable TCAS enhancements, such as using TCAS for flight-following, will also be incorporated. Results will provide tangible support for operational suitability and the efficacy of proposed future enhancements within the NAS.

Program Milestones

In FY1990, the FAA initiated the I-Lab Project. Initial development included facility preparation, commercial equipment and software procurement, and software infrastructure development. FY1990 activities culminated in an illustration of technical feasibility by creating an integrated, interactive simulation encompassing six existing prototypes. The illustration supported arrival and departure control within the New York Metroplex.

During FY1991, the I-Lab completed the integration of initial hardware (common console and cockpit mockups) and commercial off-the-shelf software procurements. Development activities included addition of prototypes and simulations of AERA services (en route automation) and components of the Center TRACON Automation System (CTAS). Initial NSL technical planning will be completed and preliminary steps will be taken to establish the NSL.

In FY1992, the I-Lab will complete establishment of its initial experimentation capability including central simulation control. This will extend the concepts illustrated in the proof-of-concept and provide the capability to conduct experimentation with operational personnel. The initial experiments will assess alternatives for interaction between traffic flow management and controller automation aids in the en route and terminal airspace. Detailed NSL planning will continue.

The NSL is expected to begin operation in FY1993 by porting I-Lab simulations and prototypes to the more capable processors expected to be available. I-Lab experimentation will continue in parallel.

Products

- Operational I-Lab/NSL experimentation capability to support assessments of interaction and interoperability among ATC (including aircraft) automation elements and human-in-the-loop performance
- Simulation results from alternative configurations of proposed future systems

F.2.2 Dynamic Special-Use Airspace Management

Responsible Division: ARD-100
Contact Person: Stephen Alvania, 202/267-3078

Purpose

To develop automation capabilities and operational requirements for enhancing the ability of FAA and DoD to dynamically coordinate the use of military Special Use Airspace (SUA).

The current manual methods for coordinating the use of military SUA between FAA and DoD operational entities do not allow for the timely exchange of information, thereby limiting the ability of the FAA to efficiently manage the NAS airspace or to incorporate that coordination information into real-time ATC flow management decision-making. New ATC procedures and the operational requirements for the associated technologies will be developed to enable the dynamic coordination of military SUA.

Program Milestones

Interagency procedures were examined in FY1989 to identify and document the current methods for the FAA/DoD coordination of military SUA. During FY1990, additional discussions between FAA and DoD were conducted to determine the general development direction the agencies should pursue to enhance that coordination process. In FY1991, an effort was initiated to develop an "end-state" concept of a Dynamic Special Use Airspace system that would interface with the DoD SUA scheduling organizations to satisfy the requirements of the FAA's ATC mission. Those ATC requirements are: the timely exchange of military SUA scheduling information and a direct interface with the FAA Traffic Management System.

Products

- DSUA "end-state" concept document
- Evolutionary stages of DSUA automation functionality
- Interactive TMS/DSUA functionality

F.2.3 National Airspace System Performance Analysis Capability (NASPAC)

Responsible Division: AOR-100
Contact Person: Arturo Politano, 202/267-7016

Purpose

To maintain a long-term analysis capability through the application of modern tools of operations research and computer modeling to develop, design, and manage the nation's airspace on a system-wide level.

This capability allows analysts to identify limiting factors in national airspace system performance and provides quantitative analyses to determine the impacts of proposed changes on the overall aviation system, while offering useful information to decision makers and strategic planners.

The principal tool used in the project is a simulation model of the entire national airspace system. The model simulates the movement of individual aircraft through the nationwide network of airports, navigation fixes, routes, and sectors. The model incorporates the general structure of the national airspace system as a system of airports, (58 of which are modeled in detail), 106 arrival and departure fixes, and all en route sectors. It also considers en route flow restrictions, the effects of instrument meteorological conditions at airports, and additional details.

Program Milestones

In FY1990, several analyses were conducted using NASPAC to assess the implications of NAS performance. These analyses included studies of the impacts of a new airline hub, the potential failure of an Area Control Facility, the addition of a new runway to a major airport, and the restructuring of airspace at several Air Route Traffic Control Centers. In addition, enhancements, such as improved airspace routing, aircraft pushback delays, and additional flow restrictions, were made to the model.

Also in FY1990, an initial version of a user-friendly interface to the NASPAC simulation, called "Mini-NASPAC," was completed. This interface will be supplanted in FY1991 by NASPAC Release 1, which incorporates a more complete interface to the NASPAC simulation modeling system.

NASPAC will continue to be improved in FY1991 with the addition of flight cancellations and arrival slot swapping, improved sector loading and aircraft routing algorithms, enhancements to the Future Demand Generator, improvements to the modeling of en route sector capacity and sector delays, and further enhancements to the user interface. A set of standalone tools for simplifying the preparation of model inputs, and a capability to estimate annual delays as well as the cost of delays, will also be developed in FY1991.

Analyses to be performed in FY1991 include an analysis of the nationwide effects of the Precision Runway Monitor and a study of the impacts of Civil Tiltrotor service in the northeast corridor.

In FY1992, the NASPAC simulation modeling system will be enhanced and used to study proposed improvements to the National Airspace System. Improvements will be made to the user interface to make the model easier to use, and improvements will also be made to improve the fidelity of the model and to make it more usable for a broader range of possible applications. The model will be applied to study a broad range of proposed improvements and to study in detail selected proposed system changes.

Products

- Model documentation and validation
- NASPAC simulation model enhancement
- System impacts of airline hubbing and proposed new airports
- Identification of future congested airspace and airports
- Desktop version of NASPAC
- Weather annualization
- Southern California airspace analysis

F.2.4 Vertical Flight Operations and Certification

Responsible Division: ARD-30
Contact Person: Steve Fisher, 202/267-8535

Purpose

To define aircraft certification standards and explore alternative ATC procedures that will enable the National Airspace System to realize the full potential of vertical flight aircraft.

Program Milestones

Economic studies and procedural requirements analysis are needed to determine the most effective integration and expansion by these type aircraft in air taxi, commercial, and air carrier operations. Terminal Instrument Procedures (TERPS) criteria, ATC procedures, and IFR operational standards and aircraft certification requirements tailored to the needs of these aircraft are needed to realize their full potential. In addition, noise prediction and control techniques are needed to ensure their acceptance by the public. A three-phase program has been devised to address these issues.

Phase I includes the analysis of economic, operational, and environmental impacts of advanced rotorcraft and vertical flight aircraft. It also includes the initiation of a comprehensive noise control program.

Phase II includes the assemblage of data needed for TERPS development based upon simulation of tiltrotor aircraft and actual flight data. Noise control efforts will be continued by applying the results obtained in Phase I to real-world applications.

Phase III includes a demonstration phase where the data and criteria developed from the previous phases are applied to various real world scenarios. During this phase, the FAA will be validating the results and findings of earlier efforts. ATC route standards and TERPS criteria will be developed from the data and results obtained.

Products

- Aircraft training and certification requirements for vertical flight aircraft in air carrier operations category (Part 121)
- Airborne systems definitions for tiltrotor operations; navigation and avionics requirements for tiltrotor TERPS, en route, and transition requirements
- MLS area navigation TERPS for rotorcraft operations; terminal procedures for rotorcraft utilizing MLS approaches
- Revised TERPS for rotorcraft operations using flight directors and coupled approaches
- Proposed ATC procedures for the most effective integration of tiltrotor and helicopter IFR flights into the NAS
- Improved rotorcraft and tiltrotor noise prediction models
- Vertical flight noise abatement and control procedures
- An automated planning tool to allow the FAA and local/urban planners to design the quietest and most effective terminal area operations

Schedule

- CTR Economics Study 02/90
- CTR Flight Simulator Study 06/90
- Pre-TERPS Development Kick-off 12/90
- CTR Missions and Applications 01/91
- CTR Flight Simulator Study (HUD/Autopilot) 04/91
- Rotorcraft Decelerating Approaches 09/91
- Tiltrotor Noise Control Plan 10/91
- Heavy-Lift Helicopter Approaches Study 06/92
- Tiltrotor (V-22/XV-15) Noise Evaluation Test 12/92
- CTR Flight Simulator Performance Analysis 12/92
- Preliminary TERPS Criteria for Tiltrotor IFR Approaches 12/93
- Draft Rotorcraft IFR Terminal Area ATC Procedures 12/94
- Draft Tiltrotor IFR Transition to Terminal Area ATC Procedures 12/95

F.3 En Route Capacity Related Projects

F.3.1 Airspace System Models: Sector Design Analysis Tool (SDAT)

Responsible Division: AOR-100
Contact Person: Ken Geisinger, 202/267-7568

Purpose

To develop analytic models, including computer simulations, for evaluating current and future impacts of proposed new National Airspace System (NAS) equipment, air traffic control (ATC) procedural changes, and revised airspace configurations.

The models will provide quantitative measurements of system performance in terms of safety, capacity, efficiency, and controller workload. This program supports provisions of the Aviation Safety Research Act of 1988, which requires development of models of the ATC system to predict safety and capacity problems. Models developed will emulate the airspace system with a high level of detail and flexibility.

The models will share common elements, but will be tailored for specific ATC needs and users. For example, the first product will be a tool for use by en route airspace designers to evaluate the impact of alternative designs on controller workload. The new product will address terminal airspace. These models will allow analyses of proposed changes in procedures, traffic flow, and airspace design in terms of safety, efficiency, and controller workload. Later products will address the impacts of proposed new NAS equipment and automation on the ATC environment.

Program Milestones

A prototype sector design analysis tool has been developed. This tool analyzes given traffic flow data and estimates separation assurance workload. Validation and demonstration of the concept was achieved in FY1991. This tool will be expanded to include other controller workload elements in FY1992. This computer-based tool will be implemented at field facilities in FY1993.

Products

- A computer-based sector design analysis tool capable of being used on ARTCC existing automation equipment by air traffic personnel to assist in resectorization
- Terminal airspace evaluation tool
- ATC automation model
- NAS equipment evaluation model
- Tools for processing, storing, retrieving, and displaying data

F.3.2 Airspace and Traffic Optimization: Dynamic Ocean Tracking System (DOTS)

Responsible Division: ARD-100
Contact Person: David Ford, 202/267-3534

Purpose

To minimize fuel consumption, facilitate aircraft operations for users and the ATC system, and improve ATC designs and procedures.

To develop a tool to optimize flight track design and track utilization.

Computer-efficient algorithms have been developed which determine an aircraft's projected time and fuel consumption over the ocean. Optimization techniques use these algorithms, together with an automatic dynamic weather database and varying ATC separation criteria, to design flexible fuel-efficient tracks for oceanic traffic. A similar process is used to advise individual scheduled flights of the optimal track based on their oceanic entry time and other aircraft traffic they will encounter.

Tests have shown that aircraft flying on a typical trans-Pacific route fly six or eight thousand feet lower than their most efficient altitude. This is due to large separation requirements and the fact that airlines are not able to determine airspace availability. Rough estimates indicate that a DOTS capability will save between 5% and 7% on fuel. Other benefits include reduced controller workload associated with controlling aircraft on structured rather than random track systems designed to flex with changing wind conditions.

With the addition of ADS functionality, the DOTS dynamic wind and temperature data base and track advisory capability will be greatly enhanced. Traffic planners will be able to take advantage of wind and temperature changes to identify fuel-efficient alternative tracks in near real time.

Program Milestones

In FY1991, track generation programs and traffic management displays were installed in New York, Oakland, and Anchorage ARTCCs. The tests showed that there was a cost benefit to having aircraft fly the generated flight tracks. In addition, DOTS was installed in the Air Traffic System Command Center (Central Flow). The functional application of DOTS in the CONUS will be investigated.

In FY1992, ADS position reporting will be implemented in DOTS, a track advisory system will be installed in New York, Oakland, and Anchorage ARTCCs, and a prototype system will be developed by AOR to demonstrate the functionality of DOTS in CONUS airspace.

Products

- Algorithms for minimal fuel path generation for any set of position, altitude, velocity, wind, weather, and time constraints
- Prototype hardware and software
- Algorithms and operational guidelines for minimum fuel computations within the oceanic ATC system
- Dynamic simulation model
- Applications

F.3.3 Oceanic Display and Planning System (ODAPS)

Responsible Division: AAP-310
Contact Person: Richard Simon, 202/267-8341

Purpose

To provide an automation infrastructure for oceanic airspace that includes automatic receipt and processing of aircraft position reports, a dynamic flight plan database, an aircraft situation display, and a conflict probe. The system will allow controllers to more effectively utilize oceanic airspace without revising separation standards.

Oceanic controllers in facilities on the east and west coasts of the United States are confronted with an increasing need for random and direct routes and are not able to visualize these routes from data presented on current flight progress strips or plotting boards. The Oceanic Display and Planning System (ODAPS) will reduce this problem by providing controllers with adequate information to apply separation standards in a timely manner. Requirements validation and design have been completed. Systems have been delivered to both sites, Site Acceptance Tests have been conducted, and ODAPS is operational in Oakland.

Program Milestones

The contractor has resolved all high and critical priority software problems identified to date. Fifteen NAS Change Proposals (NCPs) have been approved. These NCPs are enhancements to the basic system and are deemed necessary to fully implement ODAPS. The schedule was re-baselined to reflect the impact of these NCPs. Following demonstration of the 15 NCPs, five additional NCPs were identified for full implementation. These five are expected to be implemented by mid-1993.

The ODAPS contract options have been exercised for the New York ARTCC and the FAATC test bed.

Products

Oceanic display and flight data automation for two ARTCCs

- ZOA S/W handoff to ATR-400 .... 07/91
- SYS delivery to last operational site (ZNY) (Package I, II, III & IV) 07/93
- Last integration test complete (IOC) (ZNY) 09/93
- Last ORD complete (ZNY) 10/93

F.3.4 Traffic Management System (TMS)

Responsible Division: ANA-300
Contact Person: Harry B. Kane, 202/267-8336

Purpose

To upgrade the present flow control system into an integrated Traffic Management System (TMS) which operates at the national level through the Air Traffic Control System Command Center (ATCSCC) and the local level through traffic management units (TMUs).

The upgrading of the traffic management system is designed to improve air traffic system efficiency, minimize delays, expand services, and be more responsive to user requirements. The TMS functions include Central Altitude Reservation Function (CARF); Airport Reservation Function (ARF); Emergency Operations Facility (EOF); Central Flow Weather Service Unit (CFWSU); various flow management programs with integrated metering functions such as the Departure Sequencing Program (DSP), En route Spacing Program (ESP), and the Arrival Sequencing Program (ASP); and Enhanced TMS (ETMS) functions including the Aircraft Situation Display (ASD) and Monitor Alert (MA).

Program Milestones

Phase I of the TMS program has been completed. It replaced outdated computer systems, implemented a data communications system to interface users and ARTCC computers in a two-way data mode interfacility flow control network (IFCN), and relocated CARF and the automation staff to FAA headquarters.

Phase II has provided the Enhanced Traffic Management System, which is a computer network that implements the aircraft situation display (ASD) and monitor alert (MA) functions developed by the Advanced Traffic Management System (ATMS) research and development program, for the Air Traffic Control System Command Center (ATCSCC), all Air Route Traffic Control Centers (ARTCCs), and several Terminal Radar Approach Control Centers (TRACONs). New computer systems with color graphics workstations have also been provided to the ATCSCC, TMUs, and the FAA Technical Center, which interface with the Traffic Management Computer Complex (TMCC), the host computers, and the ETMS computers to provide enhanced information displays and near real-time flight data. The Arrival Sequencing Program (ASP) and En Route Spacing Program (ESP) Package 1 metering enhancements to the host computers have also been provided.

Continuing Phase II activities are focused on replacing the TMCC, completing implementation of ASD and MA functions in all en route centers, implementing ASP and ESP Package 2 on the Host computer, and providing standalone monitors in the ATCSCC and the TMUs to display weather products.

Follow-on activities to Phase II will include providing automation equipment to non-en route facilities, relocating the ETMS computers from the development location to an FAA facility, providing an enhanced high data rate interface between the Host and ETMS computers, integrating DSP into the TMS and providing meter list display devices for the ARTCCs. Other activities will include implementing ATMS functions on the ETMS, providing TMS hardware and software in the Advanced Automation System time frame until the next generation TMS becomes operational, and improving traffic management performance analysis capabilities by developing standards, procedures, and tools to facilitate the accurate reporting, collection, and analysis of NAS data.

Products

- One Air Traffic Control Command Center, comprised of a CFCF, CARF, ARF, CFWSU and a central altitude reservations function. The TMS computer complex is located at the FAATC. ETMS computers are currently located at Transportation Systems Center, Cambridge, Mass.
- One computer program suitable for adaptation and use at 20 domestic ARTCCs and selected TRACONs.

F.3.5 LORAN-C Systems

Responsible Division: AND-30
Contact Person: Richard Arnold, 202/267-8709

Purpose

To conduct necessary procurement and implementation projects to meet FAA responsibilities for the use of LORAN-C in the NAS.

LORAN-C is the government's navigation aid for coastal areas of the United States, including southwestern Alaska and Hawaii. Signal coverage was increased in 1991 over the mid-continent area and now all 48 contiguous states have LORAN-C service. Low-cost avionics have made LORAN-C an attractive area navigation aid for general aviation; it has been approved for en route and non-precision approach use under instrument conditions. One goal remains: to bring LORAN-C into maximum use in the NAS as a supplemental aid by completion of the installation of signal monitors to support non-precision approaches throughout the NAS. The signal monitors will provide the seasonal time difference correction information required to accurately perform a non-precision approach.

Program Milestones

Two new LORAN-C chains of stations were completed in the U.S. mid-continent in April 1991. LORAN-C monitor units consist of two parts: monitors and interface electronics to VOR equipment. Signal monitors were installed at 196 sites. Installation will be completed in 1992 when interface electronics are placed in the host facilities.

Products

- LORAN-C Signal Monitor System
- LORAN-C mid-continent transmitters

F.3.6 Automatic Dependent Surveillance

Responsible Division: ARD-100
Contact Person: Peter Massoglia, 202/267-9845

Purpose

To support the development and implementation of an automatic dependent surveillance (ADS) function to improve safety and provide economic benefits to users of oceanic airspace, as well as to aid oceanic controllers in effectively controlling oceanic airspace, with evolutionary applications to domestic airspace.

The ADS function will provide for improvement in tactical and strategic control of aircraft. Automated processing and analysis of frequent position reports will result in nearly real-time monitoring of aircraft movement. The capability of ADS to provide timely and high-integrity aircraft position data via a satellite air/ground data link will permit possible reduction in separation standards, as well as increased accommodation of user-preferred routes and trajectories.

The program will be developed in incremental steps, with the first step being the ADS capability. The second step will add two-way digital data communications for air traffic command and control. Follow-on steps will add additional features, including digital voice, all leading to safer and more efficient use of the airspace.

Program Milestones

Implementation of ADS will be at the Oakland and New York Centers only. Step 1 is scheduled for 1993 and Step 2 for 1995.

Products

- ADS Step 1 mod operational on Oceanic Development Facility (ODF)
- Perform Pre-Operational Trials
- Complete Step 2 Requirements Definition
- ADS Step 1 installed at Oakland and New York
- Complete Step 2 Operational Concepts and System Specification
- ADS Step 2 mod operational on ODF
- Complete display enhancements to ADS
- Complete integration and validation of Step 2 mod on ODF
- Complete avionics development support
- ADS Step 2 installed at Oakland and New York
- Complete advanced satellite tests
- Commence ADS integration into AAS
- Complete Laboratory and Flight Test

F.3.7 En Route Separation Standards

Responsible Division: ASE-300
Contact Person: Jerry W. Bradley, 202/646-4824

Purpose

To provide quantitative guidance for domestic and international decision-making concerning adequate minimum safe horizontal and vertical separation standards.

Quantitative guidance based on statistical analysis is provided to support decision-making to reduce vertical and horizontal (lateral and longitudinal) separation requirements. This activity consists of model development, data collection, data reduction, and analysis. It also includes: (1) the investigation of the effect on separation standards of imposing tighter required navigational performance specifications, (2) determinations of the effect of tolerating mixtures in the total aircraft population of both old and new specifications, and (3) investigations of the potential for the safe improvement of separation requirements in a system with advanced future navigation systems. These analyses include considerations of the role of pilot and controller and their feedback loop process in evaluating navigational performance within the framework of collision risk methodology. This program also provides support in developing and establishing methods and procedures for monitoring standards compliance and safety.

This effort will also help establish separation requirements based on Automatic Dependent Surveillance (ADS), Area Navigation (RNAV), and other developing technologies for supporting reduced permissible separation minima.

The oceanic horizontal separation standards program will analyze separation standards in the North Atlantic, West Atlantic, Central East Pacific, and North Pacific route systems. It will examine the impact of various system improvements on safe minimal horizontal and longitudinal spacings for oceanic traffic. As oceanic control becomes increasingly flexible through automation, this program will establish appropriate separation standards to facilitate maximum traffic efficiency and safety.

Onboard, time-based navigation capabilities and associated ATC capabilities will be analyzed in an effort to study the feasibility of time-based separation standards.

The vertical separation program will determine the practical feasibility of reducing the vertical separation minimum between FL 290 and FL 410 from 2,000 to 1,000 feet, thus adding six additional flight levels in this altitude range. This change would provide the ATC system with enhanced flexibility to accommodate user-preferred flight profiles and would lead to substantial savings in user fuel costs.

Program Milestones

In FY1990, the development of a data package to support rulemaking on the vertical separation standards change in U.S. domestic airspace from 2,000 to 1,000 feet above FL290 was completed. In addition, ICAO guidance material was finalized. The investigation of system performance monitoring techniques was begun in FY1991 and is continuing through FY1992.

In FY1990, material for worldwide RNAV procedures was completed and submitted to ICAO. This information was combined with that from other countries and integrated with the Required Navigation Performance Capability (RNPC) concept for review during FY1995 and 1996. This effort supported the ICAO Review of General Concepts of Separation Panel (RGCSP), North Atlantic Special Planning Group (NATSPG), and other special groups. This support will continue in FY1991 and 1992.

In FY1989, an effort was initiated to develop revised oceanic separation standards based on ADS. In FY1990, a data collection plan was developed and coordinated with the airline community. As aircraft are equipped with ADS, data will be collected.

Products

Horizontal Separation Standards

- Reports on the feasibility of reduced horizontal separation in oceanic airspace
- Reports on simulation and test results for reduced horizontal oceanic separations
- Data packages for international coordination of horizontal oceanic separation standards

Vertical Separation Standards

- Data analysis and operational tests and evaluation of reduced vertical separation
- Recommendations for rulemaking on vertical separation standards
- Input to ICAO documents
- NASP Group to implement 1,000 ft. vertical separation standards in 1997. This will be the first time it will be used in flight levels above 290.

F.3.8 Advanced Traffic Management System (ATMS)

Responsible Division: ARD-100
Contact Person: Stephen M. Alvania, 202/267-3078

Purpose

To reduce delays and enhance operating efficiencies through a highly automated traffic management system.

The ATMS program is the FAA research and development effort in direct support of the operational Enhanced Traffic Management System (ETMS). The ATMS is used to investigate automation and technology applications that will enhance the operational capabilities of the FAA Traffic Management System. The ATMS program is structured as the development of a sequence of evolutionary flow management capabilities which, once determined to be operationally beneficial, migrate to the operational ETMS system through a common development/testbed facility. The ATMS evolutionary stages currently defined are: Aircraft Situation Display (ASD) to monitor the NAS in "near real time;" Monitor Alert (MA) to automatically alert flow managers to projected congestion and delay conditions; Automated Demand Resolution (ADR) to generate alternative flow management strategies that deal with the projected conditions; Strategy Evaluation (SE) to provide real-time analytical support to the flow management decision-making process; and Automated Execution (AEX) to automatically distribute facility-specific flow management directives that will implement the selected strategy.

Program Milestones

The Aircraft Situation Display (ASD) and Monitor Alert (MA) functions are currently being deployed as part of the operational ETMS at the Air Traffic Control System Command Center (ATCSCC), all ARTCCs, and selected TRACONs.

Prototype Automated Demand Resolution (ADR) algorithms are being designed and incorporated into the ATMS testbed for evaluation. During FY1991 and FY1992, these algorithms will be tested and refined. Migration to the ETMS is expected in FY1993.

The development of the Strategy Evaluation (SE) function will begin in FY1993 with migration to the ETMS anticipated in FY1994.

The Automated Execution (AEX) function will be significantly more sophisticated than the previous stages. Development of this function is expected to commence in FY1994, with migration to the ETMS currently scheduled for FY1998.

Products

- Prototype Aircraft Situation Display (ASD) functionality
- Prototype Monitor Alert (MA) functionality
- Prototype Automated Demand Resolution (ADR) functionality
- Prototype Strategy Evaluation (SE) functionality
- Prototype Automated Execution (AEX) functionality

F.3.9 Automated En Route ATC

Responsible Division: ARD-100
Contact Person: Vern Edwards, 202/267-9851

Purpose

To provide evolving improvements in capacity and safety in the en route and/or positive control airspace (PCA) through the integration and enhanced automation of various air traffic functions.

To improve capacity by better accommodating individual user objectives through direct user involvement inflight planning and the integration of onboard flight management systems (FMS) with ATC computers.

To improve capacity by improving airspace efficiency/ throughput by use of more airspace and facilitate the use of direct routing.

To improve safety through the reduction of operational errors.

Automated En Route Air Traffic Control (AERA) is a continuing program that involves the evolution of the en route system to higher levels of automation and sophistication. The program is structured in two parts — implementation (AERA Services) and research and development (Advanced AERA Concepts). The implementation part of AERA introduces an introductory set of automation capabilities in the form of automation aids that will support air traffic personnel in the detection and resolution of problems along an aircraft's flight path, and in the planning of traffic flows. AERA Services combine what was initially known as AERA 1 and AERA 2 and may involve some of the functionality currently undergoing research and development by the time it becomes operational. These introductory AERA Services also set the stage for evolution to higher levels of automation which is currently under investigation in Advanced AERA Concepts (AAC).

Currently, AAC is involved in research and development activities related to functionality envisioned for the most highly automated phase of the AERA program to date. The essence of the AAC activities is to develop, evaluate, and validate operationally and technically the capability and suitability of automating the aircraft separation assurance function and much of the local flow management functions into a more highly automated and integrated system. The human will maintain a presence, albeit at a different level, where he becomes a supervisor of the automation rather than reactive to the automation. The air traffic control system of today will become the air traffic management system of tomorrow.

Program Milestones

Laboratory facilities for AERA Services were established in 1987. This laboratory has been used for prototyping and analyses of AERA Services' functionality to refine and/or revise operational and specification requirements, as well as associated supporting technical documentation. These algorithmic and performance specifications and candidate ATC procedures were completed in 1991.

In the next phase of AERA Services portion of AERA, that software will be developed and undergo an operational evaluation at the FAA Technical Center. This software and the ATC procedures will be updated as a result of the operational evaluation. This operational evaluation phase has already begun and is scheduled to continue through 1997.

AAC functionality is scheduled to be completed in five (5) Builds in a research and development prototype environment called the "ProtoCenter." In 1989, Build 1.0 of preliminary components Advanced AERA Services functionality was completed at the ProtoCenter. Build 1.0 integrated several standalone R&D prototype functions and successfully separated aircraft, using actual behind-the-panel algorithms in lieu of simulation, in realistic simulation scenarios consisting of over 100 aircraft.

In 1990, work continued on the integration, refinement, and problem corrections arising from Build 1.0 demonstration/evaluation. Additionally, functionality was incorporated into the ProtoCenter in preparation for Build 2.0. A metering function was included so that functionality would not only keep aircraft separated but would also develop time schedules and general schedules to ensure that aircraft meet assigned time constraints (e.g., metering into terminal areas).

In 1991, the Build 2.0 demonstration/evaluation was completed with positive results. Build 2.0 functionality was run against data from the Denver ARTCC at today's traffic levels. The ProtoCenter was augmented with a set of functions to cope with data uncertainties, in a deterministic manner, resulting from imperfect knowledge of winds aloft and aircraft speed. Work also continued in a parallel effort to develop the revised human role in a more highly automated system and determine how the data should be presented for human comprehension. These human computer interface requirements will be incorporated into the ProtoCenter over the next several years.

CONTINUED ⇒

Products

- AERA Services:

  Specification and perfomance requirement being incorporated into the AAS. Operational availability of functionality scheduled around 1998.

  Enhancement package to functionality resulting from FAA Technical Center operational evaluation or enhancement packages from Advanced AERA Concepts.

- Advanced AERA Concepts:

  Technical Data Package (TDP) defining functionality for implementation. This will include specifications, changes required to baseline NAS documents, performance and interface requirements, and other supporting documentation.

  Spin-offs for early implementation. For example, early implementation (1994) of Airspace Manager function as part of TMU in centers as a standalone system.

  Supporting analyses and technical documentation.

F.3.10 Operational Traffic Flow Planning

Responsible Division: AOR-200
Contact Person: Robert Rovinsky, 202/267-9952

Purpose

To provide dynamic, fast-time automated traffic planning and decision support tools which (1) plan daily air traffic flow based on user schedules, aircraft performance, weather, and other operational situations; (2) develop traffic plans for joint FAA/user planning and decision-making; (3) predict traffic problems and probable delay locations; and (4) generate routes and corresponding traffic flow strategies that minimize fuel and time for scheduled traffic.

A coordinated system of interactive computer models and decision support tools are being developed through rapid prototyping. The development program capitalizes upon proven technology such as the Dynamic Ocean Tracking System (DOTS) and will extend this technology to the domestic U.S. airspace. Other prototyping efforts will be based on previously developed optimization and simulation technology.

Program Milestones

In FY1991, the High Altitude Route System (HARS) program will complete development and evaluation of a test-bed prototype. In FY1992, the prototype will be used as the "core" of the initial operational HARS planning model for field implementation at the ATCSCC and TMUs. The HARS initial prototype will provide functional software for optimized track generation and traffic flow planning for major U.S. city pairs. HARS will also include an alternate flow generation function (FLOWALTS) that provides rapid analysis of alternate route and flow strategies. HARS field prototype development and demonstration will begin in FY1993, and will provide both follow-on enhancements enabling full track generation and traffic optimization for high altitude traffic anywhere in the U.S. and integration with oceanic traffic management systems.

In FY1991, work on a fast-time simulation model for traffic flow planning (FLOWSIM) will help the FAA plan daily air traffic flow based on user schedules, aircraft performance, weather, and other operational situations; predict traffic problems and probable delay locations; and facilitate joint FAA/user planning and decision-making. Development of a consolidated U.S. airspace data model will also begin in FY1992 and will demonstrate and test an initial prototype in FY1993. Finally, the development of a National Airspace System model, which will provide the capability for detailed prediction and simulation of daily traffic and flow strategies, will also begin in late FY1992. It will utilize and integrate many of the technologies and tools developed in the preceding projects (e.g., HARS, FLOWSIM, FLOWALTS, DOTS, etc.).

Products

- Algorithms and models for optimized, fuel-efficient high altitude routes
- Algorithms and models for developing optimum departure and arrival sequencing plans
- Fast-time simulation of traffic flow plans
- Algorithms to generate alternate traffic flow strategies by computer ranking fuel and time impacts
- An integrated U.S. airspace data model for detailed national simulation
- Detailed prediction and simulation of daily traffic

F.3.11 ATC Automation Bridge Development: TRACON Re-code, Display Channel Re-host, and Full Digital ARTS Displays

Responsible Division: ARD-20
Contact Person: Royce Wilkerson, 202/267-7547

Purpose

To develop a TRACON replacement system and an en route display channel replacement system.

Advanced Automation System (AAS) end-state equipment will be used in this system where technically feasible. The minimum functional capability of this new system will be equivalent to the current system. Capacity and display capabilities will be increased to allow for future growth.

Program Milestones

Alternative design approaches will be identified in FY1991. Detailed designs will be completed in FY1992. Risk mitigation demonstrations will be conducted in FY1993.

Products

- Design alternatives for TRACON systems and en route display channel systems

F.3.12 Ground Delay Substitution Analysis

Responsible Division: AOR-200
Contact Person: Robert Rovinsky, 202/267-9952

Purpose

To provide FAA's Air Traffic Management Service with a set of strategies to follow to improve the ground delay substitution process.

Program Milestones and Products

A report on the ground delay substitution system to help air traffic management establish policies and operational options is planned for the beginning of FY1992.

F.3.13 Meteorologist Weather Processor (MWP)

Responsible Division: ANW-300
Contact Person: Donald Stadtler, 202/267-5857

Purpose

To implement a system that provides for the processing of alphanumeric and graphic weather products received from the National Weather Service (NWS) and radar and satellite imagery.

The MWP will support the delivery of improved services by the Center Weather Service Units (CWSUs) at Air Route Traffic Control Centers (ARTCCs) and the Central Flow Weather Service Unit (CFWSU) at the Air Traffic Control System Command Center (ATCSCC).

Program Milestones

The MWP system has been delivered to the first operational site, the Atlanta ARTCC. The current deployment schedule will have MWP delivered to all ARTCCs by the end of November 1991.

Products

- MWP systems, including an interactive workstation for the CWSU/CFWSU and briefing terminals for air traffic personnel to display alphanumeric, graphic, radar, and satellite weather products.

F.3.14 Aviation Weather System

Responsible Division: ARD-220
Contact Person: Arthur Hansen, 202/267-9743

Purpose

To improve the analysis and forecasting of weather that affects the safety, capacity, and efficiency of the National Airspace.

To develop sensors for the collection and analysis of meteorological data from both airborne and ground operations.

To develop training programs to improve aviation weather services.

To develop and demonstrate, in an operational environment, airborne detection and warning technology leading to reduced risks associated with severe windshear conditions.

To provide weather services that will reduce the weather information handling workload of air traffic controllers.

Program Milestones

High resolution upper wind and temperature analyses and forecasts will be provided operationally every 3 hours beginning in 1992.

In FY1991, the development of the flight crew and ground-system flight procedures will be developed to support the flight test activities in FY1992. The first flight tests of combined radar, lidar, infrared, and windshear data communications will take place in the summer of FY1992 and be completed in FY1993.

Products

- Sensors to measure humidity, visibility, and temperature icing aboard air carriers
- Mesoscale numerical prediction models, data assimilation, nowcasting methods, and model evaluation for analysis and forecasting of aviation weather parameters
- Experimental forecast center for testing and evaluating new products and methods
- Enhanced terminal weather products (e.g., hazardous storm cell detection)
- New local area nowcasts and short-range forecasting techniques using statistical techniques and expert systems
- Algorithms to quantify the hazard from windshear data communications
- Modules for computer-aided training in aviation weather
- Advanced airborne windshear sensors for integration into the flight deck

F.3.15 Aeronautical Data Link

Responsible Division: ARD-300
Contact Person: Ron Jones, 202/267-8655

Purpose

To develop aeronautical data link communications standards to support use requirements for satellites, Mode S, and VHF.

To develop and implement ATC and non-ATC data link applications.

Program Milestones

A draft advisory circular has been published and distributed to industry for comment. Planned for FY1991 is the operational deployment of pre-departure clearance at 30 airports. A Data Link Processor (DLP) was delivered to the first operational site in FY1991. The first operational use of DLP will be a DLP weather database available via Mode S, scheduled for early FY1993. A prototype digital ATIS service using a tower data link system will be evaluated in FY1991 with deployment of the operational ATIS service in FY1995. Development of DLP Build-2 enhancements to support added communications functionality and additional data link services began in FY1991 with operational deployment planned for FY1996. Initial en route and terminal ATC services are being developed with implementation planned in the FY1996-1998 timeframe.

Products

- Communications standards (RTCA, ICAO, AEEC, etc.)
- Data Link Processor that supports a weather database for pilot access (Build-1 and support for the Aeronautical Telecommunications Network Build-2)
- Tower datalink system to support Pre-Departure Clearance delivery and other tower applications
- Specifications for ATC and non-ATC data link applications (e.g., Automated Terminal Information System, wind shear alerts, hazardous weather information, traffic information, and en route and terminal automation)
- FAA Advisory Circular for airworthiness approval of data link systems

F.3.16 Satellite Navigation

Responsible Division: ARD-300
Contact Person: Joe Dorfler, 202/267-8463

Purpose

To develop augmentation(s) and verify the use of satellite navigation systems such as the Global Positioning System (GPS) for civil aviation in order to obtain the capacity and flexibility benefits of a space-based navigation system that will be available for use in NAS for en route, terminal, departure, non-precision and precision approaches, and airport surface guidance everywhere.

Program Milestones

In FY1991, Minimum Operational Performance Standards (MOPS) for GPS avionics will be developed to support GPS use as a navigation supplement. This will enable a Technical Standards Order (TSO) to be developed for certification of avionics and will enable Flight Standards to develop an FAA Advisory Circular authorizing operational use of GPS. In FY1992, requirements for augmentation to GPS to support its use as a sole-means navigation source will be developed. MOPS for use of GPS and GPS hybrids for use as a sole-means navigation source will be developed starting in FY1993. In FY1995, MOPS for integrated GPS/GLONASS will also be developed to support their use for en route navigation. Starting in FY1994, modifications to MOPS for avionics to support non-precision instrument approaches will be developed. A study and verification of the feasibility of the use of GPS for precision approaches will then proceed and is planned for completion in FY1997.

Products

- Performance standards for aircraft avionics
- GPS system performance specifications
- Requirements for augmenting GPS for use as sole-means navigation, non-precision, and (potentially) precision approaches

F.4 Airport Capacity Related Projects

F.4.1 Airport Capacity Design Team Studies

Responsible Division: ASC-100
Contact Person: James McMahon, 202/267-7425

Purpose

To establish a forum, sponsored and supported by the FAA, in which airport management, the local FAA, airlines, commuters, industry groups, and airport planning consultants work together to develop technically feasible alternatives for improving airport capacity and reducing delay.

Design team studies have been established at airports where the need for capacity improvement is identified. The studies typically investigate application of new air traffic control procedures, navigation aids, system installations, airport development, and other prospective capacity improvements. Alternatives are then evaluated using state-of-the-art simulations. The simulations provide a measure of benefit in terms of hours of delay reduction and allow the FAA to refine modeling techniques while gaining operational benefits through assistance to the design team studies.

Program Milestones

During FY1991, design team efforts were successfully completed in Salt Lake City, Washington-Dulles, Seattle, Orlando, Chicago, Nashville, Raleigh-Durham, Charlotte, and Los Angeles. Design team studies still underway include Pittsburgh, Philadelphia, San Juan, San Antonio, New Orleans, Honolulu, Ft. Lauderdale, Houston, Cincinnati, and Cleveland. Among the airports being considered for design team studies in 1992 are Port Columbus, Indianapolis, Bradley, Dayton, and Las Vegas. New runways are being planned at Atlanta, Detroit, Kansas City, Orlando, Phoenix, St. Louis, and Washington-Dulles as a direct result of airport capacity design team efforts.

Completed design team studies resulted in over 270 recommendations in FY1990-91, 76 of which have already been implemented. Another 76 recommendations are either in the planning phase or the environmental assessment phase. Over 500 proposals for enhancing capacity have been developed for analysis by the design teams since the program began in 1985.

Products

- Action plans incorporating the projects and programs that produce capacity improvements and delay reductions at airports under study
- Analysis of airport capacity

F.4.2 Aviation System Capacity Planning

Responsible Division: ASC-100
Contact Person: James McMahon, 202/267-7425

Purpose

To develop a capacity plan that meets forecasted increases in aircraft operations and allows aircraft to move safely through the airport and airspace environment.

Aviation System Capacity Planning is made up of airport design, airspace design, and approach procedures. Airport capacity design teams, currently on-site at 12 airports, are made up of airport operators, the FAA, airlines, and other users. The team starts with a simulation of the current airport and adjacent airspace environment using actual operating data to establish a baseline. The team then develops a list of potential improvements to increase capacity and, using a variety of simulation and queuing models, tests their effect in the specific airport environment. Among the improvements investigated are airfield improvements, such as new runways and runway extensions; improved approach procedures, such as reduced longitudinal separations; new facilities and equipment, such as the Microwave Landing System (MLS); and user improvements, such as relocating a portion of the general aviation traffic to a nearby reliever airport. Those improvements found to produce the greatest capacity increases, together with the estimated delay reduction and cost-saving benefits of each, are integrated in the final report. Residual delay, after all enhancements are implemented, creates requirements for additional research and development into new capacity-enhancing approaches.

To provide for the projected increases in traffic and the implementation of the airport capacity design team recommendations, the airspace structure is redesigned and the traffic flows are modified to accommodate more aircraft and ease the burden on control facilities. Airspace redesign begins with the simulation of the airway environment of the air traffic control center. Actual operational data is used to establish a baseline. The airspace design team then develops alternatives such as more direct routing, segregating jet, turboprop, and prop traffic, and relocating cornerpost navigational aids to allow for more arrival and departure routes. These alternatives are simulated to determine their effect on delay, travel time, sector loading, and aircraft operating cost. The most successful alternatives are incorporated into a plan to redesign the airspace for increased capacity and efficiency. Ultimately, all 20 centers, encompassing the whole U.S. airspace system, will be included in the baseline run, making it possible to accurately evaluate the effect of a specific airspace redesign project on the entire system.

Terminal approach procedures are designed to increase the number of arrivals in poor weather. In most cases these are multiple approach procedures aimed at allowing the simultaneous, or near-simultaneous use of more than one arrival runway. Implementation of many of these procedures is dependent on the use of new technology such as the Precision Runway Monitor (PRM) and the Converging Runway Display Aid (CRDA).

Program Milestones

In CY1991, the 1991-92 Aviation System Capacity Plan will be produced, analyzing the benefits of new airport development, airspace changes, progress on implementing improved airspace procedures, and new technology to support airport, airspace, and procedures improvements. In addition, final reports of the airport capacity design teams at Chicago/O'Hare, Seattle, Charlotte, Salt Lake, Pittsburgh, Raleigh-Durham, Nashville, Los Angeles, Philadelphia, and San Juan will be issued. Airspace design teams are scheduled to complete reports for the Washington and Cleveland centers and to begin work on New York (Phase II), Oakland, and Miami/San Juan.

Products

- Aviation System Capacity Plans
- Airport Capacity Design Team Reports
- Airspace Analysis Technical Reports
- Approach Procedure Improvement Reports

F.4.3 Terminal/Landside Traffic Modeling

Responsible Division: APP-400
Contact Person: Larry Kiernan, 202/267-3451

Purpose

To develop a microcomputer-based process for designing airport terminal buildings for functional efficiency and to alleviate congestion.

There is a significant need to improve and enhance the capacity of airports on the airside, ground side, and in terminal areas, as well as the combined capacity of all these components. Some airports have efficient airside designs and poor terminal designs, while others have better terminal designs than airside. For any airport to operate efficiently, these elements need to be planned and constructed in combination, as an integral design solution. The FAA is developing standard computer simulations which can be used to evaluate airport terminal design. These standardized, readily accessible programs will be useful tools for architects, engineers, and planners involved in terminal design and expansion. Simulations also will aid airport operators in evaluating terminal improvement options and planning for expansion.

This program will develop a series of models for use in planning airport passenger terminals and ground access. These models will analyze pedestrian flow through terminals and related areas as an aid in estimating space and access requirements. Commercial software will be evaluated to determine whether it meets agency requirements. Modifications or new software may then be developed.

Program Milestones

During FY1989 and 1990, several existing terminal models were reviewed and analyzed. Based on the results of the review, an expert group was convened to establish operating characteristics of a standard terminal design model.

Research is underway on the means by which passengers arrive at the airport and the ability of the ground access system to handle that demand. In addition, there is ongoing research on the interface between mass transit and air/ground transportation.

An advisory circular containing computer-aided design tools will be developed to guide architects, engineers, and planners in airport terminal and ground access design.

Products

- Public-domain microcomputer software
- User manuals
- Advisory circular on Computer-Aided Design

F.4.4 Supplemental Landing System (ILS)

Responsible Division: ANN-200
Contact Person: Gary Skillicorn, 202/267-6675

Purpose

To establish new, partial, and full ILSs, and upgrade existing ILS facilities.

Runways qualifying for new ILSs in all categories will result from new airport construction and the need for increased landing capacity at existing airports. These new systems will provide precision approach guidance for new installations until the transition to MLS. Some of the older systems have been in service for nearly two decades. These systems are experiencing severe logistics support problems because spare parts are not readily available and maintenance costs are up sharply. The systems being replaced are AN/GRN-27 ILS, Wilcox CAT II/III ILS, and Mark 1A, 1B, and 1C ILS.

Production of AN/GRN-27 equipment ceased in 1976. As such, parts are no longer available. Maintenance costs are up because parts must be custom manufactured or refurbished to restore failed systems and subassemblies.

Wilcox CAT II/III ILS systems will be replaced to prevent severe logistics support problems and to maintain the integrity and reliability of these facilities.

Mark 1A, 1B, and 1C ILS systems are nearing the end of their life cycles and must be replaced.

Products

- Replacement of equipment will incorporate remote maintenance monitoring capabilities and require only minimal manual intervention. Work is ongoing to install 79 CAT I ILSs at identified locations. An additional 200 CAT I ILSs will be installed over the next 10 years. Over the next ten years, 50 partial ILSs will be installed.
- 120 existing localizer-only facilities will be upgraded to full ILS status through the acquisition of glide slopes and middle marker beacons. Approximately 50 existing CAT I ILSs will be upgraded to CAT II or CAT III ILSs to meet the needs of expanding airports.
- 25 CAT II/III ILS systems through Wilcox CAT II/III ILS replacement
- 75 AN/GRN-27 ILS replacement systems
- 180 CAT I Mark 1A, 1B, 1C replacement systems

F.4.5 New Denver Airport

Responsible Division: ANS-300
Contact Person: Jerry Champion, 202/267-7333

Purpose

To build a major new international airport to replace Stapleton.

This project provides for the establishment of new and the modernization/relocation of existing systems, facilities, and equipment to support the operation of the new airport. The new airport will allow for increased capacity and efficiency of aircraft operations to support the growing needs of the air transportation system.

Denver currently ranks seventh in the nation in volume (enplanements and operations) of aircraft. Based upon forecasted growth over the next 10 years, the airport will reach saturation, and delays will be unacceptable during the peak traffic periods. During adverse weather conditions, the acceptable operations rate at Stapleton is reduced to approximately one-half the rates attainable during visual procedures. Completion of the new Denver airport will increase arrival capacity from 38 to more than 90 arrivals per hour in adverse weather conditions. This will reduce delays at Denver and throughout the NAS.

Program Milestones

The new Denver airport is scheduled to open with five 12,000 ft. runways and a commuter runway in the fall of 1993, with an additional jet transport runway completed by the end of the next construction season (fall of 1994). The new airport has the largest land area (34,000 acres) of any airport in the United States. The runways are far enough apart to conduct triple simultaneous independent approaches in IFR weather. In addition, the design of the airfield is such that aircraft will be able to taxi to and from the terminals without crossing an active runway. This will reduce the possibility of runway incursions. The airfield has been designed to allow flow-through dual taxiways between each concourse. The airport has been built on such a large area that aircraft are unobstructed by push-back conflicts and no noise restrictions are in place.

The reliever airport for the new Denver airport is Front Range Airport, located three miles away. This airport is more attractive to business jets and general aviation. The runways at Front Range all line up in the same direction with those at Denver so they do not interfere with Denver traffic. In addition, there will be a satellite tower for Denver located at Front Range.

Products

- FAA facilities and equipment to meet the navigation and operation requirements of the new Denver International Airport.

F.4.6 Low-Level Wind Shear Alert System (LLWAS)

Responsible Division: ANW-400
Contact Person: Steve Hodges, 202/267-7849

Purpose

To monitor winds in the terminal area and alert the pilot, through the air traffic controller, when hazardous windshear conditions are detected. Windshear conditions occurring at low altitude in the terminal area are hazardous to aircraft encountering them during takeoff or final approach.

Program Milestones

The LLWAS program was initiated in early 1975. Among the sensors evaluated were pressure jump detectors, pulsed and CW Lasers, acoustic Doppler systems, pulsed Doppler radar and arrays of anemometers. The last technique was selected as the most cost-effective approach. Doppler radar promised the best capability at the time, but the technology was not sufficiently mature and the cost and technical risks were high. Full-scale development began in 1976, resulting in the evaluation of LLWAS at six airports. Production was initiated in 1978 and, of the 110 airports that were designated to receive the system, to date, 110 LLWAS units are now operating.

The program to upgrade the systems began in 1985 and contracts were awarded in 1987. The upgrade provided new processors and significantly improved the algorithm which increased the probability of detection and reduced the false alarm rate. This program was completed in the spring of 1991.

The LLWAS Expanded Network upgrade will provide additional sensors for microburst detection and identification. It will provide new displays for controllers and provide runway oriented wind shear information. The new upgrade has been tested at Denver and New Orleans and has been highly praised by pilots and controllers. The system saved a passenger aircraft in 1989. The competitive RFP to completely retrofit all 110 systems will be issued in 1992. The new system will have tall poles, new hardware and software, ice-free sensors and will interface with Terminal Weather Doppler Radar (TWDR) and will be equipped with a high reliability integrated sensor package.

Products

- One hundred and ten production systems, including spares, training, and documentation.

F.4.7 VORTAC Program

Responsible Division: ANN-130
Contact Person: Don Shaklee, 202/267-6661

Purpose

To form a modern cost-effective national navigation network which provides required coverage through the replacement, relocation, conversion, and establishment of VORTAC, VOR/DME, and VHF Omnidirectional Range Test (VOT).

Very High Frequency Omnidirectional Ranges (VOR) with Distance Measuring Equipment (DME) or Tactical Air Navigation (TACAN) are en route air navigational and approach aids used by pilots to conduct safe and efficient flights and landings.

From FY1982 through FY1989, the FAA replaced 950 vacuum tube-type VOR and VORTAC systems with modern solid-state equipment. New Remote Maintenance Monitoring compatible DME systems will replace existing DME systems at 40 VOR/DME sites. The units removed from these sites will be redeployed to ILS sites. 77 tube-type VOTs will be replaced with solid-state equipment, and 35 new VOT systems will be established. VOR/DME facilities are being relocated to accommodate route structure changes, real estate considerations, and site suitability. Conventional VORs are being converted to Doppler VORs to solve siting problems and to obtain required signal coverage. Operational requirements that arise in various geographic areas require the establishment of VHF navigational aid services. Provisions have been made to establish 70 VOR/DME sites including new VOR/DME equipment at non-Federal takeover locations. DME systems will be added at 47 sites equipped with VOR only.

Program Milestones

All vacuum tube-type VOR and VORTAC equipment has been replaced with solid-state equipment which has embedded remote monitoring and control capabilities. DME service will be provided at all VOR facilities. A network plan has been developed to redistribute VORs to meet operational requirements. Tube-type VOT equipment will be replaced with solid-state equipment. VOR/DME and VOT sites will be established to meet operational requirements.

In FY1990, the VOR/DME contract was awarded, the VOR/DME system design review was completed, and the design qualification test for VOT was completed.

Products

- To date, 725 VORTACs, 145 VOR/DMEs, and 80 VOR's have been replaced, 15 VORs have been converted to Double Sideband (DSB) DVOR, 50 DVORs have been retrofitted with RMM and DSB, 35 VOTs have been established, and 77 VOTs have been replaced.
- In the next ten years, the FAA plans to establish 70 VOR/DMEs, establish 40 DMEs at VORs, replace 47 DMEs at VORs, reinstall 47 DMEs at ILSs, and convert 94 VORs to DSB DVOR.

F.4.8 Microwave Landing System (MLS)

Responsible Division: AND-30
Contact Person: Richard Arnold, 202/267-8709

Purpose

To develop and implement a new common civil/military precision approach and landing system that will meet the full range of user operational requirements well into the future.

This system will be the international standard replacement for the current Instrument Landing System (ILS).

The approach to accomplish the program objectives concentrates as much on the user issues as on the technical issues. The international requirements for this system are on a firm foundation and there are vendors in several countries that manufacture at least the Category I version of the MLS. There are also several manufacturers of the basic avionics sets. Some users at this time are questioning the benefits of equipping with MLS, given possible alternatives of improvements in the ILS, and the potential use of satellite-based systems for precision approaches. Other users are willing to equip with MLS to use its inherent advantages over ILS. In December 1988, OST approved a new MLS implementation strategy and a nine-point demonstration program to ascertain the economic and operational benefits of MLS.

Program Milestones

All nine evaluation activities within the demonstration program are scheduled for completion in FY1991. An interim report was given to Congress in May. The program to compare the frequency congestion potential of MLS and ILS has issued its report showing the limited number of ILS frequency allocations available in several major metropolitan areas. Advanced approach procedures in wide body aircraft have received favorable ratings from the airline crews flying very short final curved segments in a 747 simulator. Simulation of advanced procedures in a multi-airport environment determined the benefits of MLS approaches to airports in the New York, Chicago, and San Francisco areas. To evaluate the general aviation/commuter capacity enhancements, MLSs have been installed at JFK and Chicago Midway. Work has been underway on technical comparisons of ILS/MLS. Activities foc[illegible] on minima reductions are underway, including assessments of decision height and other MLS Terminal Instrument Procedures (TERPS) standards. A contract has been awarded to design a low-cost Precision Distance Measuring Equipment (DME/P) interrogator which will be used as part of the evaluation program, and then be made available to other manufacturers. MLS avionics costs have been analyzed for all categories of aircraft. Activity is underway to work with a major aircraft manufacturer to certify an entire class of aircraft for MLS Category III operations.

The 1984 contract with Hazeltine to produce and install 178 Category I MLSs was terminated in August 1989. This contract represented less than 14 percent of the FAAs requirement for 1,250 MLSs to replace the ILSs. A second procurement of 1,250 Category II/III systems will occur at the successful conclusion of the demonstration program. A request for proposal was issued in 1990 and two vendors will be chosen in 1991 to design and produce prototype Category II/III ground systems.

To meet the demand for MLSs for the operational and economic evaluations of MLS benefits, up to 28 FAR Part 171 Category I MLSs will be procured. A contract has been awarded for the first two units, and they have been installed. The second procurement for up to 26 units was awarded in June 1991. The units will be installed starting in June 1992.

The FAA's transition plan will provide an MLS at every commissioned ILS location until parity is reached, at which time the MLS will become the primary system in the United States. Following a reasonable time period to allow the air carriers to equip, ILS systems will be decommissioned in a structured, and coordinated fashion.

Products

- Up to 28 FAR Part 171 Category I MLSs
- A DME/P interrogator design
- Demonstrations of the MLSs operational and economic benefits from the nine-point evaluation program
- Approximately 400 Category II/III MLSs will be delivered from 1995 to 1999 with our international commitments met by January 1998, and an additional 850 will be delivered after 1999
- Modifications to TERPS and approach procedures to effectively integrate MLS into the ATC system

F.4.9 Runway Visual Range (RVR) Systems

Responsible Division: ANN-200
Contact Person: John Saledas, 202/267-6529

Purpose

To establish and modernize existing Runway Visual Range (RVR) systems on qualifying Category I, II, III a/b ILS and MLS runways. RVRs support precision approach landing operations.

RVR equipment provides real-time measurement of visual range along the runway. The RVRs in the NAS utilize old technology and cannot be economically upgraded to satisfy the requirements of the NAS in the 1990s and beyond. A new generation RVR has been conceived to economically satisfy all future NAS operating and maintenance requirements.

Program Milestones

A contract has been awarded to procure 528 RVR systems. The RVR systems have completed all factory required testing. Production systems are scheduled for delivery in FY1992 - 93.

Products

- 528 RVR systems with proper documentation

F.4.10 Airport Planning and Design

Responsible Division: ACD-100
Contact Person: Thomas J. O'Brien, 609/484-4129

Purpose

To improve airport designs to reduce runway occupancy and taxiing time and enhance aircraft ground operations.

Program Milestones

Studies will be conducted to improve airport design and configuration to decrease runway occupancy time and taxiing time from runways to gates and back to runways; an increase in airport capacity is expected to result from these studies. In addition, current and improved airport designs and configurations will be evaluated for compatibility with new aircraft.

Simulator evaluation of the exit design was initiated in FY1989. An exit design was completed for demonstration at a specific airport in FY1990. In FY1991, simulator evaluation of exit designs will continue and acceptable designs will be provided for demonstration at additional airports.

In FY1991, analyses of current airport designs for compatibility with new aircraft will be initiated and will be completed in FY1992. Requirements for clearances, fillets, curves, and aprons are considered in this work. Results will be used to recommend improvements in airport designs.

In FY1991, analyses of multiple exit/taxiway/crossover designs will be initiated to determine the increase of aircraft flow rates afforded by the multiple systems over the current single lane system. The multiple systems are expected to handle more aircraft per unit time from runways to gates to runways, relieve gate congestion, and increase airport capacity.

Products

- Technical reports
- Computer programs and users guides
- Design criteria and guidelines for airports
- Test methods and procedures
- Analysis methods

F.4.11 Visual NAVAID

Responsible Division: ANN-300
Contact Person: Charles Ochoa, 202/267-6601

Purpose

To provide enhanced safety-related visual NAVAID at airports.

The facilities to be provided are medium intensity approach lighting system with runway alignment indicator lights (MALSR), runway end identification lights (REIL), precision approach path indicator (PAPI), and omnidirectional airport lighting system (ODALS).

This program also includes the retrofitting of remote radio controls for visual aids to meet the operational requirements of air traffic controllers. The new system will permit single-button control of each visual aid function.

The establishment of visual NAVAID projects are based on each region submitting qualified candidates. In addition, the President's Task Force on aircrew complement recommended the installation of vertical guidance capability at all air carrier runways, and those locations not equipped with vertical guidance devices will receive priority consideration.

Products

- Current Capital Investment Plan (CIP) planning envisions the installation of 200 additional MALSRs, 300 REILs, 400 PAPIs, and 200 ODALs in the FY1993 and beyond time frame.

F.4.12 Precision Runway Monitor (PRM) for Closely Spaced Runways

Responsible Division:	ARD-300 (R&D), ANR-300 (implementation of F&E systems)
Contact Persons:	Ken Byram (R&D), 202/267-3081
	Pike Reynolds (F&E), 202/267-7632

Purpose

To assess and demonstrate the feasibility of applying Precision Runway Monitor (PRM) to increase the aircraft arrival rate at airports with closely spaced runways and develop the necessary equipment.

An airport's capacity to handle arriving aircraft is limited by the number of runways that are usable at any one time. In instrument meteorological conditions (IMC), the number of usable runways depends on the spacing between the runways. Without PRM — an enhanced radar and an associated controller display — simultaneous dependent and independent approaches are only allowed if runways are spaced at least 4,300 ft apart. With PRM, the spacing required between closely spaced runways is reduced to 3,400 ft. This change would allow more airports to conduct simultaneous and independent approaches during inclement weather.

This project demonstrates the increases in an airport's arrival capacity that are possible with enhanced radar and controller displays. It will also produce a series of measurements on the effect of navigational accuracy, effect of the distance between the parallel runways, and response times of controllers, pilots, and aircraft. These measurements will also be useful in other similar applications such as triple and quadruple parallel runways.

Program Milestones

Two engineering models of secondary beacon radars were tested. An electronically scanned (E-scan) beacon radar capable of a 0.5 second update interval (compared with a 4.8 second update interval available from today's radars), and a system that uses Mode S monopulse processing on back-to-back beacon antennas mounted on a conventionally rotating ASR system, capable of a 2.4 second update interval. The demonstrations of both E-scan and Mode S, begun January 1990, used improved 20 by 20 inch displays that were acquired in 1989.

In FY1990-91, engineering models were successfully demonstrated in conducting independent IFR approaches to parallel runways spaced 3,400 ft. apart. As a result, simultaneous IFR approaches to the proposed triple and quadruple parallel runways at Dallas/Ft. Worth Airport have been approved. Simulations of independent parallel IFR approaches to runways spaced 3,000 ft. apart using 1 mrad, 1 second update rate were conducted in FY1991. Further research and development will be required before simultaneous IFR approaches at spacings below 3,400 ft. can be approved.

Specifications, both for the modifications to the Mode S system and for the production E-scan systems were prepared. Implementation of the E-scan system is at a greater cost than implementation of the Mode S, but provides a faster update rate. Information on which update rate is suitable at which airports is an expected outcome of the demonstration.

Products

- Operational requirements definition
- Automatic blunder-detection algorithms
- Validated runway separation model
- Measured performance of displays, blunder-detection algorithms, and E-scan and Mode S sensors
- Evaluation and procurement specification for production sensors or sensor modifications
- Operational procedures and guidelines

F.4.13 Airport Capacity Improvements

Responsible Division: ARD-300
Contact Person: Gene Wong, 202/267-3475

Purpose

To develop ATC concepts and procedures to reduce airport delays by more fully utilizing the capacity of multiple runway configurations during Instrument Meteorological Conditions (IMC).

Air traffic procedures and flight standards criteria for simultaneous triple and quadruple Instrument Flight Rules (IFR) parallel approaches will be developed and validated. Requirements and techniques for improved surveillance and navigation capabilities will be developed to support these procedures.

Studies sponsored by the FAA and the aviation industry have identified operational concepts with the potential to reduce airport arrival delays by better utilizing multiple runway configurations in IMC. These concepts include simultaneous and independent IFR parallel approaches to triple and quadruple parallel runways. ATC procedures and associated navigation and surveillance techniques for implementing the triple and quadruple IFR parallel approaches will be developed. Promising concepts will be validated through ATC simulations and, in some cases, full-scale demonstrations at airports.

Initially, multiple IFR parallel approach procedures for Dallas-Ft. Worth Airport, which has planned the addition of third and fourth parallel runways, were developed in order to gain technical and operational insights, as well as to help expedite the implementation of such procedures. This is being followed by the development of national standards for triple and quadruple IFR parallel approaches based on the current Airport Surveillance Radar (ASR) capabilities. The final phase of the multiple IFR parallel approach procedure development will focus on national standards based on Precision Runway Monitor (PRM) demonstrations being tested at Memphis and Raleigh-Durham Airports.

Program Milestones

In FY1990, simulation evaluation of simultaneous IFR approaches to the proposed triple and quadruple parallel runways at Dallas-Ft. Worth Airport with controller participation were completed. The Nation's first triple and quadruple parallel IFR approach procedure was approved early in FY1991 for the proposed runways at Dallas.

In FY1991, simulation evaluation of simultaneous IFR approaches to parallel runways spaced 5,000 ft. apart, using existing ASR and displays, was completed. Recommended standards for use of this equipment were developed. Also, simulations of dual and triple runways spaced 3,000 ft. apart, using the PRM and displays, were conducted. Additional research in this area is planned in FY1993.

Simulations of triple parallel IFR approaches to runways spaced 3,400 feet apart using PRM with 2.4 second update rate and simulations of triple parallel IFR approaches to runways spaced 4,300 feet apart using ASR-9 and new controller displays with automated alert features are planned. These simulations will begin in late FY1991 and continue through FY1992. Analysis and simulations of quadruple parallel IFR approaches will also begin in FY1992.

Products

- Simulation analysis of ATC procedures
- Flight procedures and system requirements for simultaneous IFR approaches to triple and quadruple parallel runways

F.4.14 Airport Surface Visual Control (Lighting)

Responsible Division: ACD-100
Contact Person: Thomas J. O'Brien, 609/484-4129

Purpose

To provide concepts and criteria for improved lighting, marking, and signing devices. These concepts and criteria will improve airport safety by providing better guidance in low-visibility conditions.

Program Milestones

The efforts in this program will be accomplished by developing and testing improved lighting, marking, and signing devices for the ground guidance of aircraft at very low visibility conditions. New concepts for lighting and its energy sources, as well as self-contained systems requiring little or no maintenance, will be investigated. Tests of promising systems and concepts will be initially conducted at the FAA Technical Center. When necessary, improved systems will be validated by field tests at operational airports. Recommendations will be developed for incorporation of the improved lights, markings, and signs in the Advisory Circular.

In FY1991, an effort was initiated to determine specifications for a lighting simulator and to further develop recommendations (in the form of a research report) for design criteria for the following visual guidance systems:

- Stop-bar system test at JFK
- Markings for holding aircraft in low-visibility conditions (Sea-Tac)
- Hold-short lighting system for Boston
- Improved taxiway exit identifier
- Improved circling guidance from runway lights

Products

- Research reports and design criteria
- Lighting standards for airports

F.4.15 Development of "Land and Hold Short" Runway Warning Lights

Responsible Division: ACD-110
Contact Person: Paul H. Jones, 609/484-6713

Purpose

To develop and test a visual guidance system intended to indicate to the pilot the point at which he must stop his aircraft on rollout after landing on a runway which intersects with another active runway, thus ensuring safety and increasing capacity on airports having intersecting runways.

Program Milestones

During FY1991, testing of a prototype system at Boston Logan Airport was completed. A draft report on the prototype system will be completed by FY1992.

Products

- Specifications for a pulsing, white, in-pavement lighting system arranged as a "bar" across the landing runway.

F.4.16 Development of ATC-Controlled Stop-Bar Lighting System

Responsible Division: ACD-110
Contact Person: Paul H. Jones, 609/484-6713

Purpose

To develop, test, and evaluate prototype ICAO-modified-standard stop-bars installed at the intersections of taxiways with runways.

To obtain operational, maintenance, controller workload, and human factors experience in use of stop-bars to prevent runway incursions in all visibility conditions.

Program Milestones

Operational testing of stop-bars at JFK was begun in FY1991 and will be completed in FY1992. A final report on the use of stop bars that will provide airport operators with information on maintenance requirements and air traffic personnel with operating procedures for the use of stop-bars will be issued.

Products

- Report on maintenance requirements and operating procedures for control of runway access using stop-bars.

F.4.17 Evaluation of Airfield "Smart Power"

Responsible Division: ACD-110
Contact Person: Paul H. Jones, 609/484-6713

Purpose

To test the prototype system components of a Swedish/CAA-developed system for controlling lighting devices on airfields.

This system superimposes a coded control signal on existing power cables, providing a capability to turn individual lights on and off. Such a system could, through selective control of circuits, light only those lights needed to guide pilots along preferred routes or even sequence the lights to progressively guide pilots.

Program Milestones

The acquisition and installation of the components of a "smart power" system is planned for FY1991. This will enable testing of the system which will continue through FY1992. The completion of a final report that will provide data to the FAA Office of Airport Standards for use in developing standards for the use of "smart power" is planned for FY1993.

Products

- Draft report identifying potential U.S. applications of Airfield "Smart Power," evaluating the effectiveness of the applications, and evaluating the compatibility of such a system with existing and proposed U.S. equipment.

F.4.18 Development of Cockpit Airfield Surface Maps for Ground Navigation

Responsible Division: ARD-50
Contact Person: Mike Harrison, 202/267-8556

Purpose

To develop an onboard position-tracking avionics capability, initially based on LORAN or GPS navigation systems, that uses airport maps stored in memory.

To evaluate the suitability of providing pilots with guidance in the cockpit to assist in navigation on the airfield surface in low visibility conditions as a way to reduce the likelihood of runway incursions.

Program Milestones

Research is underway to identify the capabilities and accuracy requirements of a prototype system. A draft report completed in FY1991 will be used to develop the system requirements in FY1992. Demonstrations of LORAN/GPS/INS-based prototypes and glass cockpit demonstrations are planned for FY1993.

Products

- One week devoted to GPS at FAA Technical Center in FY1991
- System requirements for position-tracking aircraft avionics
- Prototype demonstration

F.4.19 Pavement Strength Durability and Repair

Responsible Division: ARD-200
Contact Person: Aston McLaughlin, 202/267-8694

Purpose

To provide support, through research and development, for the rulemaking and advisory mission of the FAA in setting minimum acceptable standards for airport pavements.

This program involves material quality, design, evaluation, construction, and maintenance that will assure airport pavement integrity and longevity.

The FAA sponsors research on methods to arrest premature deterioration of pavements and to develop new or improved criteria for materials at the request of airport owners, operators, and industry groups. Surveys, studies, and tests are conducted to determine improved pavement performance and longevity. Where necessary, laboratory investigations are performed or prototype test pavements constructed to verify findings before making recommendations for new or improved criteria.

The FAA provides guidelines on new cost-effective approaches, design and construction techniques, and methods for enhancing the strength and durability of geotechnical materials suitable for use in airport pavements. These materials must be strong enough to sustain repeated wheel loading, must be insensitive to changes in temperature and moisture, and must be free from susceptibility to frost damage and thaw weakening. Certain polymers and resins have also been used on an experimental basis and on a limited scale. Acceptance criteria and pavement adjustment factors being developed will be field validated. This project also will investigate the use of reinforced aggregate and marginal materials for airport pavements.

In parallel with the development of better pavement materials, improved analytical techniques for pavement design and evaluation will be formulated. These techniques will provide an accurate assessment of pavement response to different aircraft wheel loadings, and will model the effects of variations in temperature and moisture on new pavement joint configurations. These analytical techniques will be programmed for computation on personal computers, and the programs will be streamlined and improved as much as possible to decrease computation time. Test methods will be developed to provide material-property parameters required by the improved analytical techniques for pavement design.

Finally, this project will develop improved methods of nondestructive structural testing, evaluation, and rehabilitation. Runway smoothness criteria that limit aircraft vertical accelerations will be established and analytical methods will be developed to determine the deterioration of runway smoothness.

Program Milestones

In FY1989, a methodology was completed to provide guidance on the use of lime, cement, fly ash, and coal-tar seal coatings for airport pavements; efforts continued on quality control and acceptance criteria. Work was initiated to develop a unified methodology for the design and evaluation of pavement strength to devise guidelines for the application of novel construction technology.

In FY1990, studies were conducted on the use of marginal materials and polypropylene fibers to reduce pavement wear. Those studies are still in progress and are expected to be completed in FY1994. Work will continue on the evaluation of a new drainage system in FY1991 (plastic core and wrap). New quality control acceptance criteria will be completed and made available to appropriate airport officials. Also to be completed in FY1991 is a study on nondestructive testing methodology and layered elastic design.

In FY1991, new polymer fibers were evaluated for their ability to reduce cracking, decrease maintenance costs, and provide greater strength and durability to pavement components. These binders must be cost effective when produced in quantity, environmentally acceptable for use in construction, and energy efficient in production and use.

Efforts to develop a unified design and evaluation methodology are in progress and will be summarized in a report. The theoretical portion is to be completed in FY1993. The laboratory validation is expected to be completed in FY1996. A product of the project will be computer software that can be used by airport pavement designers. Users guides will be issued and the relevant advisory circulars will be updated or portions replaced.

Products

- Technical reports and procedures manuals
- Design and analysis software and users guides
- Test methods and nondestructive testing methodology
- Guidelines and criteria for pavement design, construction, and maintenance

F.4.20 Wake Vortex Research

Responsible Division: ARD-50
Contact Person: Mike Harrison, 202/267-8556

Purpose

To establish an acceptable strength threshold for wake vortex encounters leading to development of flight simulator scenarios to measure pilot performance.

To evaluate the feasibility and benefits of reclassification of aircraft from three to four categories.

To develop a set of new, reduced wake vortex separation standards for use by ATC, starting with heavy-behind-heavy separations.

To characterize wake vortex transport and decay close to the ground and between closely-spaced parallel and intersecting runways as a function of meteorological conditions.

To determine the time interval for a safe departure on the same and on intersecting runways.

Program Milestones

In FY1991, wake vortex signatures of B757 and B767 aircraft were collected and data was collected to measure the decay and transport of wake vortices under varying meteorological conditions at Dallas-Ft. Worth International Airport.

Products

- Wake vortex encounter characteristics and creation of flight simulator scenarios to evaluate pilot performance and for use inpilot training
- New aircraft wake vortex separation criteria
- Runway spacing criteria, starting with heavy-behind-heavy
- Specifications for a VFR vortex warning device
- Time-based separation criteria for departures to support terminal air traffic control automation

F.4.21 Visual Guidance System Simulation Capability

Responsible Division: ACD-110
Contact Person: Paul H. Jones, 609/484-6713

Purpose

To develop a visual simulation capability for use in visual guidance research and development to improve the ability to assess pilot acceptance of visual guidance changes.

Program Milestones

The contract for a requirements study will be awarded in FY1991 and the system specifications for the facility will be developed in FY1992. The project design cost/benefit analysis is also expected to be completed in FY1992.

Products

- Definition of requirements for hardware and software development for a visual flight simulator

F.4.22 Synthetic Vision Technology Demonstration (Joint FAA/DoD/Industry)

Responsible Division: ARD-200
Contact Person: Malcolm Burgess, 804/864-1905

Purpose

To demonstrate and document the performance of a low-visibility, visual imaging aircraft landing system based on millimeter-wave sensor technology that will complement existing and evolving landing guidance capabilities.

Program Milestones

The Synthetic Vision Technology Demonstration Program is divided into three concurrent activities. Activity I consists of Development and Test of Sensors. Activity II consists of Sensor Integration/Technology Demonstration, and Activity III is concerned with Certification Issues.

Design studies of alternative sensors were completed. Based on these studies, one sensor was selected for development, test, and evaluation. Delivery of a sensor for testing is scheduled for FY1991 and tower and flight tests will be conducted.

Simulation studies of human factors and other design parameters will be conducted in FY1992 to resolve design issues for the demonstration system. Evaluation and demonstration flights of the functional prototype system on a Gulfstream II aircraft are planned for FY1992. These flights will document and demonstrate system performance in measured weather conditions (fog, rain, and snow) using a cross-section of pilots in takeoff, approach, landing, and taxi phases of operation.

A draft Advisory Circular has been developed that identifies certification issues and processes to be used by FAA and industry. The final version of the Advisory Circular on Synthetic Vision is planned for completion in FY1993.

Products

- Functional prototype of a weather-penetrating synthetic vision sensor
- Report identifying certification issues and outlining potential certification methodology
- Sensor and system performance documentation
- Flight demonstrations

Appendix G

Glossary

AAC .... Advanced AERA Concepts
AAP .... Advanced Automation, FAA
AAS .... Advanced Automation System
ACCC .... Area Control Computer Complex
ACD .... Engineering, Research and Development Service, FAA
ACF .... Area Control Facility
ADR .... Automated Demand Resolution
ADS .... Automatic Dependent Surveillance
ADSIM .... Airport Delay Simulation Model
AEEC ....
AERA .... Automated En Route Air Traffic Control
AEX .... Automated Execution
AIP .... Airport Improvement Plan
AIRNET .... Airport Network Simulation Model
ALP .... Airport Layout Plan
ALS .... Approach Lighting System
AMASS .... Airport Movement Area Safety System
ANA .... Program Director for Automation, FAA
AND .... Associate Administrator for NAS Development, FAA
ANN .... Program Director for Navigation and landing, FAA
ANR .... Program Director for Surveillance, FAA
ANS .... NAS Transition Implementation Service, FAA
ANW .... Program Director for Weather and Flight Service Stations, FAA
AOR .... Operations Research Service, FAA
APO .... Office of Aviation Policy and Plans, FAA
APP .... Office of Airport Planning and Programming, FAA
ARD .... Research and Development Service, FAA
ARF .... Airport Reservation Function
ARTCC .... Air Route Traffic Control Center
ARTS .... Automated Radar Terminal System
ASC .... Office of System Capacity and Requirements, FAA
ASD .... Aircraft Situation Display
ASDE .... Airport Surface Detection Equipment
ASE .... NAS System Engineering Service, FAA
ASP .... Arrival Sequencing Program
ASQP .... Airline Service Quality Performance
ASR .... Airport Surveillance Radar
ASTA .... Airport Surface Traffic Automation
ATC .... Air Traffic Control
ATCSCC .... Air Traffic Control System Command Center
ATIS .... Automated Terminal Information Service
ATN .... Aeronautical Telecommunications Network
ATMS .... Advanced Traffic Management System
ATO .... Air Traffic Operations Service, FAA
ATOMS .... Air Traffic Operations Management System
CAA .... Civil Aviation Authority
CAEG .... Computer Aided Engineering Graphics
CARF .... Central Altitude Reservation Function
CAT .... Category
CDTI .... Cockpit Display of Traffic Information
CFWSU .... Central Flow Weather Service Unit
CIP .... Capital Investment Plan
CONUS .... Continental United States
CRDA .... Converging Runway Display Aid
CRS .... Computer Reservation System
CTAS .... Center–TRACON Automation System
CTR .... Civil Tilt Rotor
CW .... Continous Wave
CWSU .... Center Weather Service Unit
CY .... Calendar Year
DA .... Descent Advisor
DLP .... Data Link Processor
DME .... Distance Measuring Equipment
DME/P .... Precision Distance Measuring Equipment
DOD .... Department of Defense
DOTS .... Dynamic Ocean Tracking System
DSB .... Double Sideband

DSP .... Departure Sequencing Program
DSUA .... Dynamic Special-Use Airspace
DVOR .... Doppler VOR
ECVFP .... Expanded Charted Visual Flight Procedures
EIS .... Environmental Impact Statement
EOF .... Emergency Operations Facility
ESP .... En Route Spacing Program
ETMS .... Enhanced Traffic Management System
EVAS .... Enhanced Vortex Advisory System
F & E .... Facilities and Equipment
FAA .... Federal Aviation Administration
FAATC .... Federal Aviation Administration Technical Center
FAST .... Final Approach Spacing Tool
FBO .... Fixed Base Operator
FDAD .... Full Digital ARTS Display
FL .... Flight Level
FLOWALTS ...... Flow Generation Function
FLOWSIM .... Traffic Flow Planning Simulation
FMS .... Flight Management System
FT .... Feet
FY .... Fiscal Year
GA .... General Aviation
GAO .... General Accounting Office
GLONASS .... Global Orbiting Navigational Satellite System
GPS .... Global Positioning System
HARS .... High Altitude Route System
HUD .... Heads Up Display
HF .... High Frequency
ICAO .... International Civil Aviation Organization
IFCN .... Inter-Facility Flow Control Network
IFR .... Instrument Flight Rules
I-Lab .... Integration and Interaction Laboratory
ILS .... Instrument Landing System
IMC .... Instrument Meteorological Conditions
ITWS .... Integrated Terminal Weather System
LDA .... Localizer Directional Aid
LLWAS .... Low Level Wind Shear Alert System
LORAN .... Long Range Navigation
MA .... Monitor Alert
MALSR .... Medium Intensity Approach Lighting System with RAIL
MAP .... Military Airport Plan
MCF .... Metroplex Control Facility
MLS .... Microwave Landing System
MOA .... Military Operations Area
MOPS .... Minimum Operations Performance Standards
MRAD .... Milli-Radian
MWP .... Meteorologist Weather Processor
NAS .... National Airspace System
NASP .... National Airspace System Plan
NASPAC .... National Airspace System Performance Analysis Capability
NATSPG .... North Atlantic Special Planning Group
NAVAID .... Navigational Aid
NCF .... National Control Facility
NCP .... NAS Change Proposal
NFDC .... National Flight Data Center
NMC .... National Meteorological Center
NMCC .... National Maintenance Coordination Complex
NMI .... Nautical Mile
NSL .... National Simulation Laboratory
NWS .... National Weather Service
OAG .... *Official Airline Guide*
ODALS .... Omni-Directional Approach Lighting System
ODAPS .... Oceanic Display and Planning System
ODF .... Oceanic Development Facility
ORD .... Operational Readiness Demonstration
OST .... Office of the Secretary of Transportation
PAPI .... Precision Approach Path Indicator
PCA .... Positive Control Airspace
PDC .... Pre-Departure Clearance
PRM .... Precision Runway Monitor
R & D .... Research and Development
R, E & D .... Research, Engineering and Development
RAIL .... Runway Alignment Indicator Lights
RDSIM .... Runway Delay Simulation Model
REIL .... Runway End Identifier Lights
RFP .... Request for Proposal
RGCSP .... Review of General Concepts of Separation Panel
RMM .... Remote Maintenance Monitoring
RNAV .... (Remote) Area Navigation
RNPC .... Required Navigation Performance Capability

ROT .... Runway Occupancy Time
RTCA .... Radio Technical Commission for Aeronautics
RVR .... Runway Visual Range
SDAT .... Sector Design Analysis Tool
SDRS .... Standardized Delay Reporting System
SE .... Strategy Evaluation
SIMMOD .... Airport and Airspace Simulation Model
SOIR .... Simultaneous Operations on Intersecting Runways
SOIWR .... Simultaneous Operations on Intersecting Wet Runways
TACAN .... Tactical Air Navigation — UHF omnidirectional course and distance information
TATCA .... Terminal ATC Automation
TAVT .... Terminal Airspace Visualization Tool
TCAS .... Traffic Alert and Collision Avoidance System
TDP .... Technical Data Package
TERPS .... Terminal Instrument Procedures
TMA .... Traffic Management Advisor
TMCC .... Traffic Mangement Computer Complex
TMS .... Traffic Management System
TMU .... Traffic Management Unit
TRACON .... Terminal Radar Approach Control
TSC .... Transportation Systems Center
TSO .... Technical Standards Order
TWDR .... Terminal Weather Doppler Radar
VFR .... Visual Flight Rules
VHF .... Very High Frequency
VMC .... Visual Meteorological Conditions
VOR .... VHF Omnidirectional Range — course information only
VORTAC .... Combined VOR and TACAN navigational facility
VOT .... VOR Test