1993 Aviation System Capacity Plan

U.S. Department
of Transportation

**Federal Aviation
Administration**

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Denver International Airport (DIA) under construction

Prepared by:
Federal Aviation Administration
Office of System Capacity and Requirements
Washington, DC 20591

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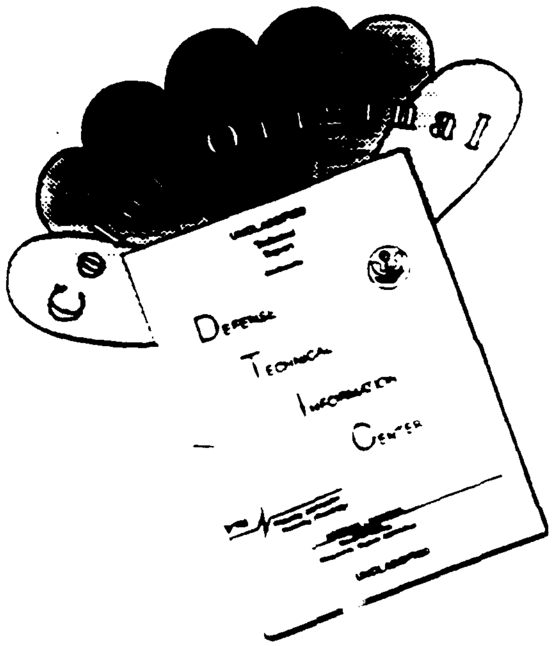

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U.S. Department of Transportation
Federal Aviation Administration

Office of the Administrator

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Aircraft delays cost the airlines and their passengers many millions of dollars each year. The same 23 airports experienced over 20,000 hours of annual aircraft delays in 1992 as in 1991 in spite of the overall decline in air travel that resulted from the Persian Gulf War, a slower recovery than expected from the economic recession, and a more moderate level of growth in air traffic as the economy struggled to recover. The latest aviation activity forecasts (February 1993) project increasing growth in passenger emplanements and air carrier aircraft operations as the U.S. economic recovery gathers strength. As the number of aircraft operations increases, the level of delay will increase unless improvements are made to aviation system capacity.

The Federal Aviation Administration (FAA) is committed to increasing the capacity of the National Airspace System to reduce delays. The FAA's efforts are directed at an integrated approach that develops capacity-producing improvements throughout the aviation system, while at the same time maintains or improves the current level of safety. Included in these efforts are airport development, new air traffic control procedures, terminal and en route airspace improvements, and the application of new technologies.

The *Aviation System Capacity Plan* serves to quantify the magnitude of delay for the top 100 airports in the United States and to catalogue and summarize programs that have the potential to enhance capacity and reduce delay. The 1993 version of the plan features the following new material:

* A summary of major airports under consideration in planning studies by State and local government organizations.
* An expanded discussion of airspace capacity studies that have been completed to date.
* National standards that have been published in the past year incorporating new capacity-enhancing instrument approach procedures.

The need for capacity improvements and innovative solutions to delay problems must continue to be emphasized so that projects will continue to be planned, funded, and built to keep pace with the projected increases in demand.

David Hinson

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Administrator

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16. Abstract

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
4) Marketplace Solutions

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Chapter 1

Introduction

1.1 The Need for Aviation System Capacity Improvement

In 1991, 23 airports each exceeded 20,000 hours of annual aircraft flight delays. With an average airline operating cost of about $1,600 per hour of delay,[1] this means that each of these 23 airports incurred a minimum of $32 million dollars of delay. By 2002, the number of airports that will exceed 20,000 hours of annual delay is projected to grow from 23 to 33, unless capacity improvements are made.

In 1991, 23 airports each exceeded 20,000 hours of annual aircraft flight delays.

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:

By 2002, the number of airports that will exceed 20,000 hours of annual delay is projected to grow from 23 to 33, unless capacity improvements are made.

- Airport Development
- New Air Traffic Control Procedures
- Airspace Development
- New Technology
- Marketplace Solutions

Flights exceeding 15 minutes of delay decreased 24 percent in 1991 compared to 1990. The forecast for 33 airports exceeding 20,000 hours of annual aircraft flight delays in 2002 is seven less than the 40 airports predicted in last year's forecast. These and other delay statistics for 1991 show a reduction in almost every category of delay over 1990. This reduction reflects the overall decline in air travel that resulted from the Persian Gulf War, a slower recovery than expected from the economic recession, and a more moderate level of growth in air traffic as the economy struggled to recover.

1. This average figure equates approximately to the cost for large air carrier aircraft (<300,000 lbs.) and small jets ($1,607 per hour). Heavy aircraft (>300,000 lbs) cost approximately $4,575 per hour of delay. Single-engine and twin-engine aircraft under 12,500 lbs. cost $42 and $124 per hour of delay respectively.

Yet, even with overall demand throughout the system temporarily reduced, demand at the most congested airports remained high. The same 23 airports experienced over 20,000 hours of annual aircraft flight delays in 1991 as in 1990. As the economy recovers, the demand for air travel will grow. As the number of aircraft operations increases to meet that demand, the level of delay will increase concurrently unless improvements are made to system capacity.

Resolving the problem of delay will require an integrated approach that develops capacity improvements throughout the aviation system, while at the same time maintaining or improving the current level of aviation safety. These capacity improvements will include not only airport development itself, but also development of new air traffic control procedures, improvements in terminal and en route airspace planning, and implementation of new technologies. Each of these topics will be discussed in turn in subsequent chapters.

Resolving the problem of delay will require an integrated approach that develops capacity improvements throughout the aviation system, while at the same time maintaining or improving the current level of aviation safety.

Although the current forecasts continue to project serious delays in the absence of capacity improvements, the message contained in the following pages is positive. For example, much is currently being done to improve capacity and reduce delays through new construction projects at airports and recent enhancements in Air Traffic Control (ATC) procedures. Airspace capacity design projects are being undertaken to study the terminal airspace associated with delay-impacted airports across the country. In addition, there are many emerging technologies in the areas of surveillance, communications, and navigation that will further improve the efficiency of new and existing runways and of terminal and en route airspace.

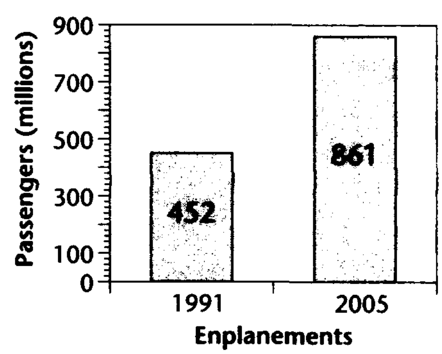
1.2 Aviation System Capacity Plan

The *Aviation System Capacity Plan* (ASCP) is an important part of Federal Aviation Administration (FAA) and Department of Transportation efforts to improve the Nation's transportation system. The Secretary of Transportation's *National Transportation Policy* (NTP) describes the enormity of the Nation's transportation infrastructure needs and sets as a major theme the need to maintain and expand the national transportation system. The *Federal Aviation Administration Strategic Plan*, based on the NTP, provides the long-term goals and objectives that the FAA is working towards. The ASCP supports the key strategic issue of improving capacity and access.

The *Aviation System Capacity Plan* is also linked to other FAA plans. In particular, the ASCP addresses requirements for research, for facilities and equipment, and for airport improvements that can be funded from the FAA's *Airport Improvement Program* (AIP). Each of these areas is addressed in a major FAA plan, and the ASCP generates projects for each of those plans. *The Research, Engineering, and Development (*RE&D*) Plan* is used to determine which systems and technologies the FAA should use to accomplish agency goals and objectives. The RE&D Plan includes the research needed to validate the new instrument approach procedures detailed in Chapter 3. The *Capital Investment Plan* (CIP) provides a framework for investment in the facilities and equipment needed to improve the National Airspace System (NAS). The CIP funds the technological improvements described in Chapter 5. The *National Plan of Integrated Airport Systems* (NPIAS) presents airport improvement projects nationwide that are eligible for AIP funding. Among these are projects, detailed in Chapter 2, to build new airports and to improve existing airports to increase capacity and safety.

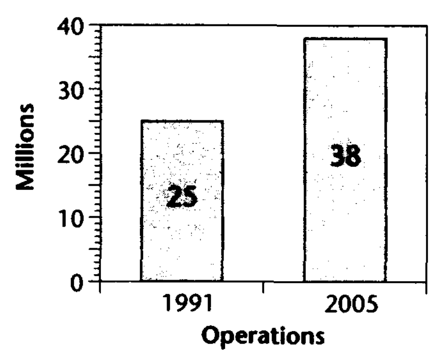
The *Aviation System Capacity Plan* identifies the causes of delay and quantifies its magnitude for the top 100 airports in the U.S. The purpose of the plan is to catalogue and summarize programs that have the potential to enhance capacity and reduce delay. Within the plan, these programs have been organized into broadly related categories which, in turn, parallel chapter development: Airport Development, New Air Traffic Control Procedures, Airspace Development, New Technology, and Marketplace Solutions.

The top 100 airports accounted for 90 percent of the 452 million domestic passengers who enplaned nationally in 1991.



1.3 Level of Aviation Activity

This plan concentrates on the top 100 airports in the U.S., shown in Figure 1-1, as measured by 1991 passenger enplanements. The top 100 airports[2] accounted for 90 percent of the 452 million domestic passengers who enplaned nationally in 1991.



In 2005, 861 million domestic and international passengers are forecast to enplane at these airports.[3] This represents a projected growth in enplanements of 90 percent over the 15 year period of the forecast, for an average annual growth of about 6 percent.

2. The top 100 airports were chosen based on CY91 passenger enplanements as listed in preliminary data intended for the annual report, *Airport Activity Statistics of Certificated Route Air Carriers*. 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 FY1992–2005*, FAA-APO-92-5, July 1992. FY90 enplanement data, a 15 year forecast, and percentage growth that the forecast represents are shown in Table A-2 (Appendix A).

In 1991, approximately 25 million aircraft operations occurred at the top 100 airports. By 2005, operations are forecast to grow to nearly 38 million at these same airports; a projected growth in operations of 52 percent.[4]

1.3.1 Activity Statistics at Top 100 Airports

Aircraft operations increased from FY90 to FY91 at 26 of the top 100 airports.

For the top 100 airports, enplanements increased at only 36 airports from Calendar Year (CY)90 to CY91 and decreased at the remaining 64.[5] Aircraft operations increased from Fiscal Year (FY)90 to FY91 at only 26 of the top 100 airports.[6]

1.3.2 Traffic Volumes in Air Route Traffic Control Centers (ARTCCs)

IFR operations decreased slightly at all 20 of the CONUS ARTCCs over 1990.

Air traffic volume statistics for 1991 showed that instrument flight rules (IFR) operations decreased slightly at all 20 of the Continental United States (CONUS) Air Route Traffic Control Centers (ARTCCs) over 1990.[7] This downturn in operations throughout the aviation system reflects the significant decline in air travel in 1991 that resulted from the Persian Gulf War and the U.S. economic recession.

4. Table A-3 (Appendix A), based on FAA's *Terminal Area Forecast FY1992–2005*, FAA-APO-92-5, July 1992, shows FY90 aircraft operations, a 15 year forecast, and percentage growth 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.
7. Figure 1-2 provides a map of the 20 CONUS ARTCCs. Figure 1-3 provides a comparison of the number of operations during FY90 versus the number of operations in FY91 at each of the 20 ARTCCs in CONUS. Figure 1-4 shows FY91 operations and a forecast for 2005.

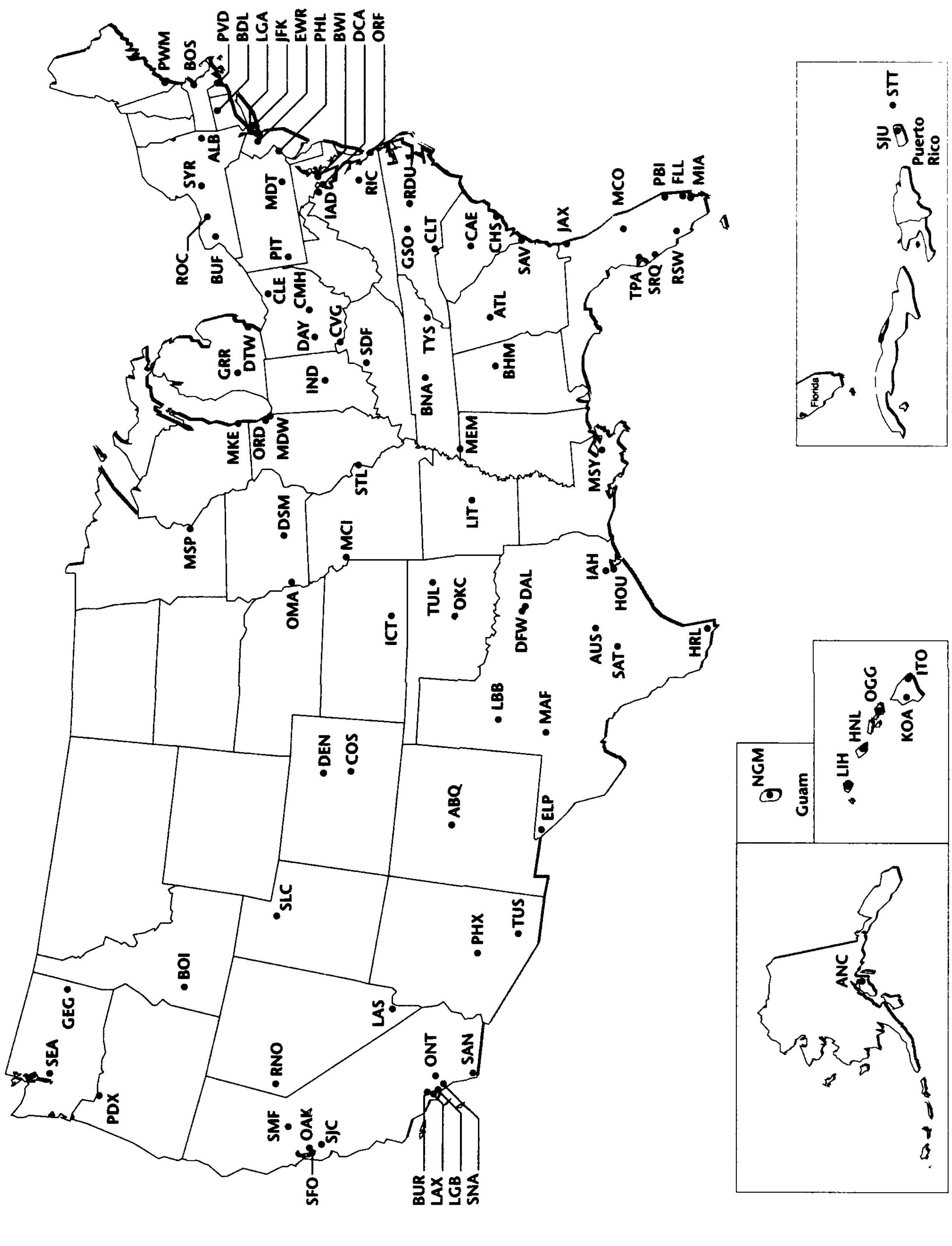


Figure 1-1. The Top 100 Airports by 1991 Enplanements

Source: Airport Activity Statistics of Certificated Air Route Carriers, 1990

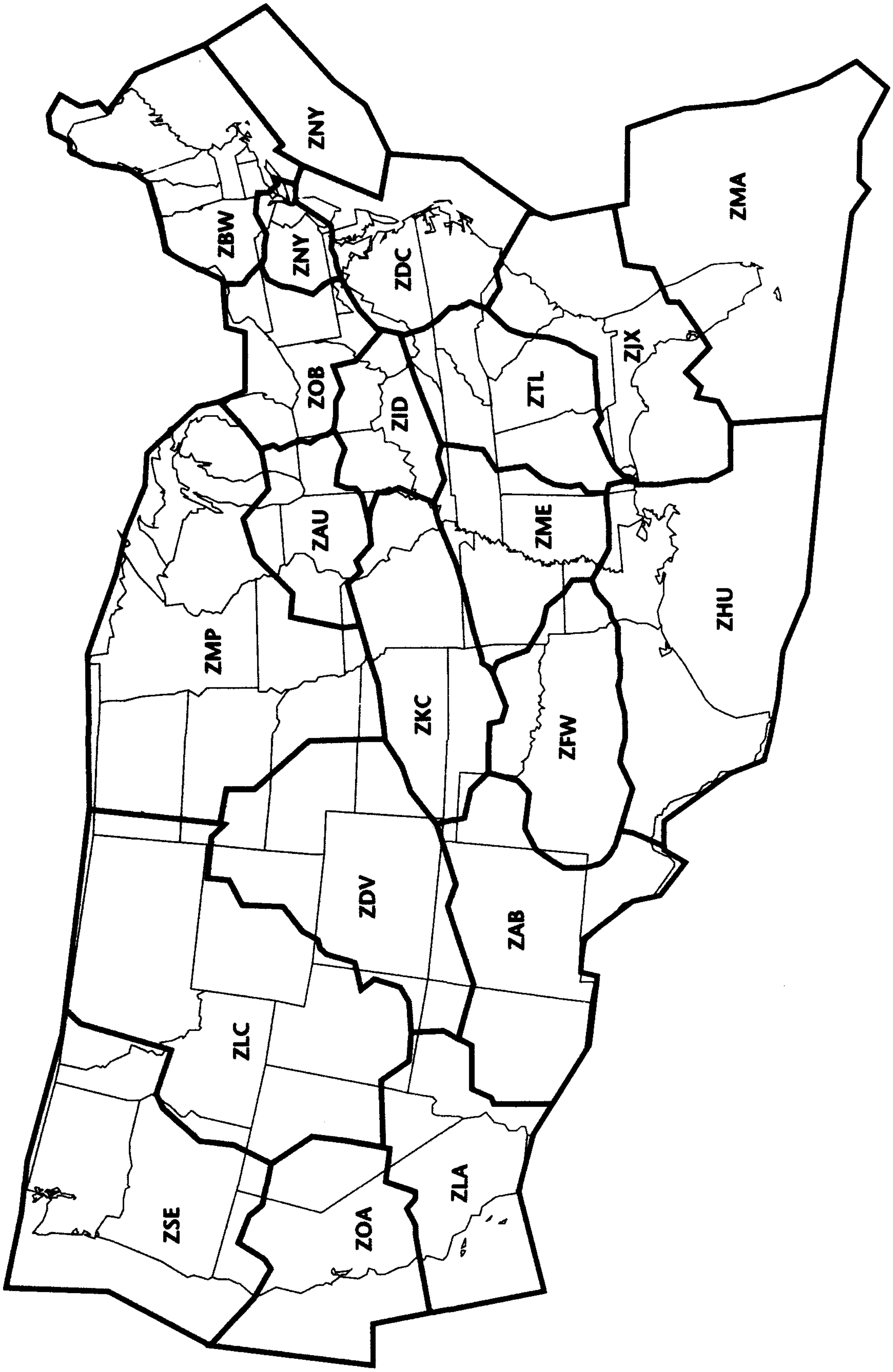


Figure 1-2. The 20 Continental U.S. Air Route Traffic Control Centers

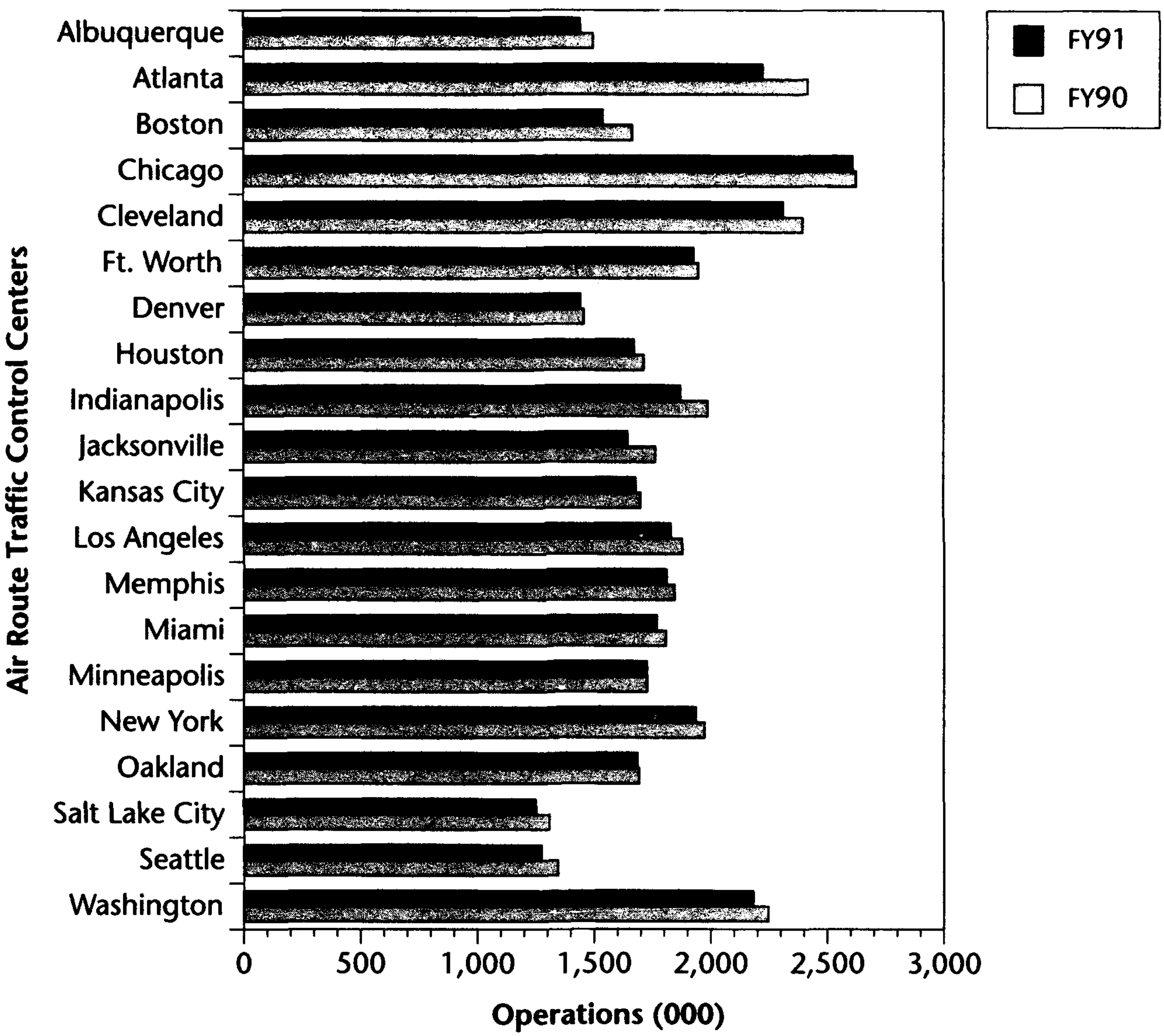


Figure 1-3. Operations at Air Route Traffic Control Centers

Source: APO Forecast of IFR Aircraft Handled by ARTCC, FY92-FY05, June 1992

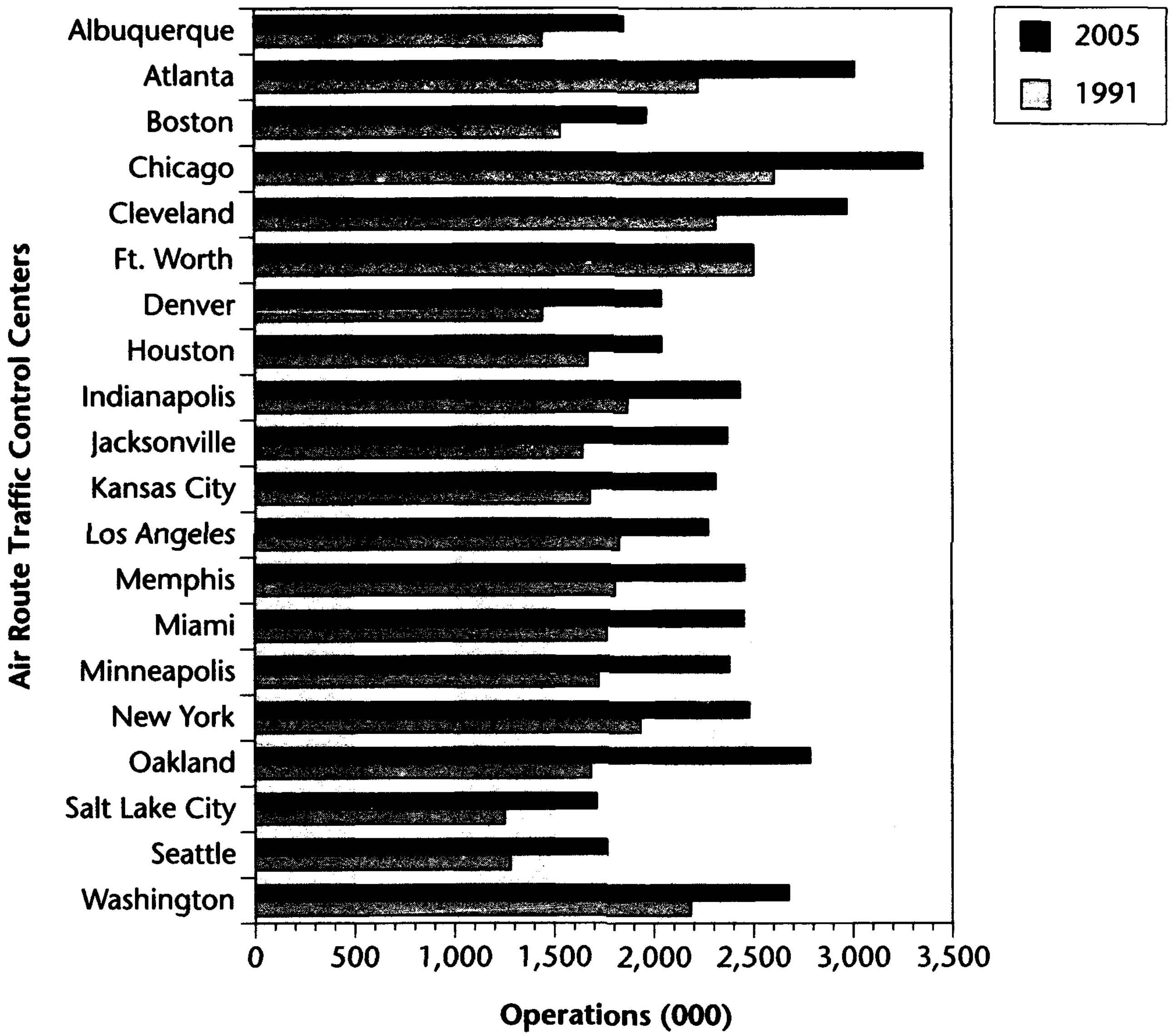


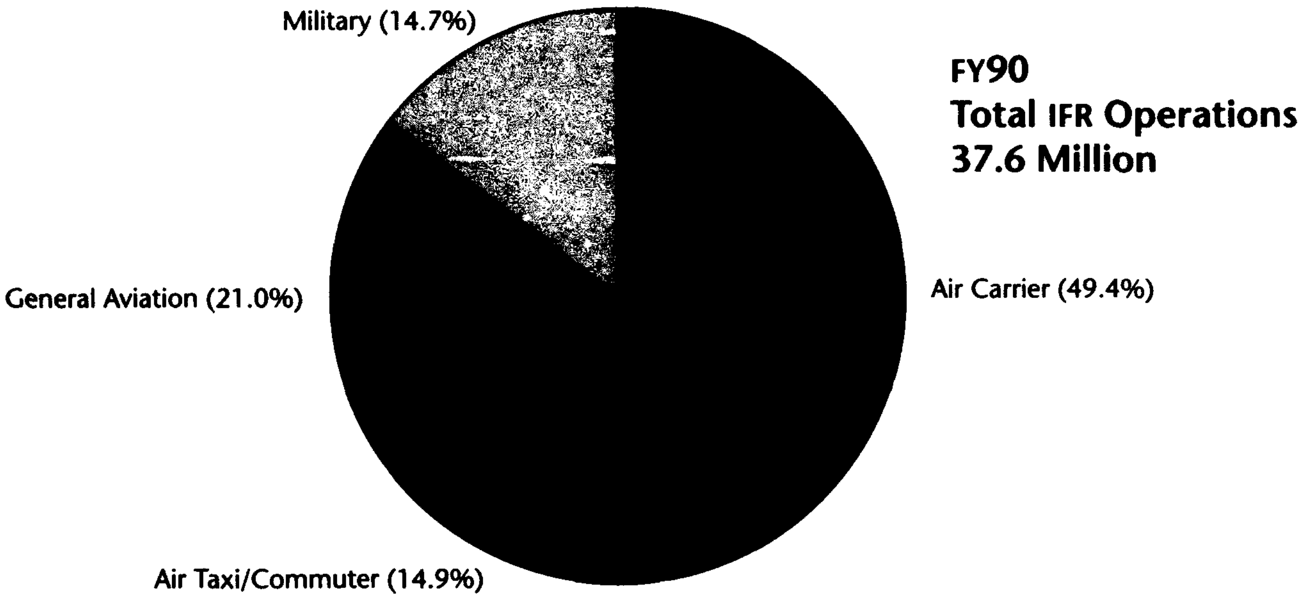
Figure 1-4. Air Route Traffic Control Center Forecasts
Source: APO Forecast of IFR Aircraft Handled by ARTCC, FY92-FY05, June 1992

In 1991, the number of aircraft flying under instrument flight rules handled by ARTCCs decreased by 3.2 percent compared to 1990, from 37.6 down to 36.4 million operations. Commercial aircraft handled at the centers decreased by 1.4 percent, compared with a decline of 6.3 percent in non-commercial aircraft handled. Table 1-1 shows the rate of decline for each user group from 1990 to 1991. Figure 1-5 compares a breakdown by user group of the traffic handled by the centers in 1990 and 1991.

In 1991, the number of aircraft flying under instrument flight rules handled by ARTCCs decreased by 3.2 percent compared to 1990, down to 36.4 million operations.

Table1-1. Rate of Decline by User Group in Traffic Handled by Air Route Traffic Control Centers FY90 to FY91

User Group	Rate of Decline FY90 to FY91
Air Carrier	1.4%
Air Taxi/Commuter	1.2%
General Aviation	6.8%
Military	5.5%



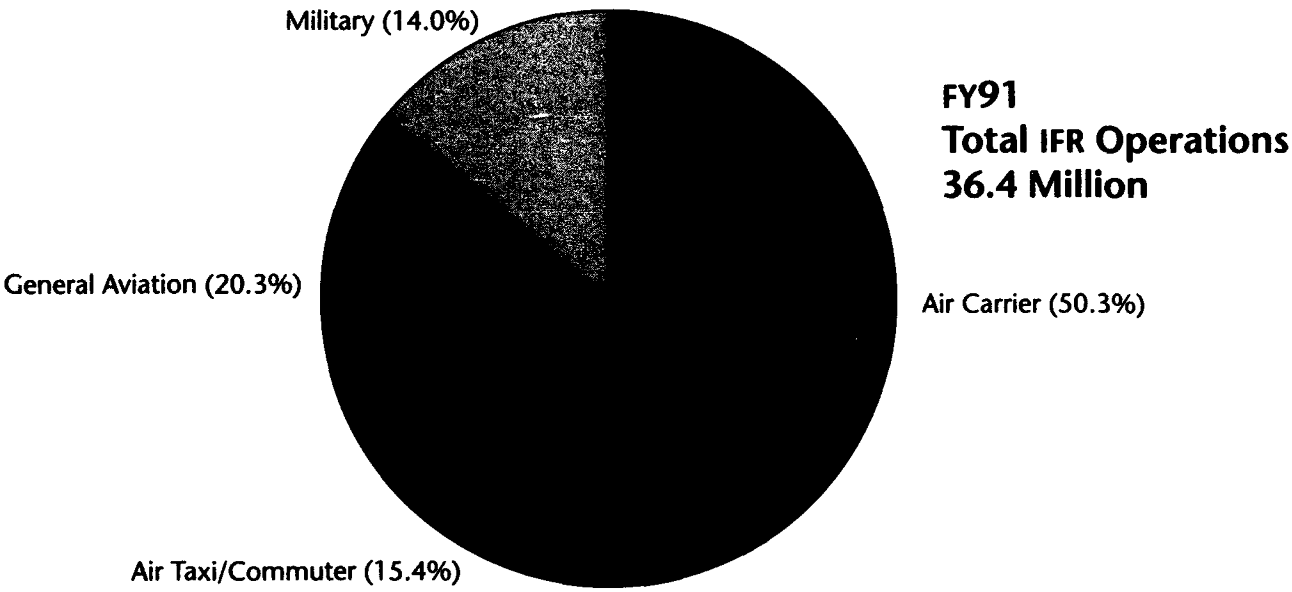


Figure 1-5. Traffic Handled by ARTCCs, FY90 and FY91

Aircraft operations at the centers are expected to grow at an average rate of 2.3 percent a year between 1991 and 2005. In absolute numbers, center operations are forecast to increase from 36.4 million aircraft handled in 1991 to 48.2 million in 2005. Table 1-2 shows the projected annual growth rates for each user group over the forecast period. In 1991, 50.3 percent of the traffic handled at centers were air carrier flights. This proportion is expected to increase only slightly to about 51.3 percent in 2005. Figure 1-6 compares a breakdown by user group of the traffic handled by the centers in 1991 and projected for 2005.

Center operations are forecast to increase from 36.4 million aircraft handled in 1991 to 48.2 million in 2005.

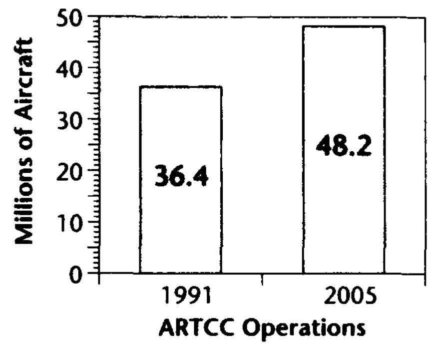
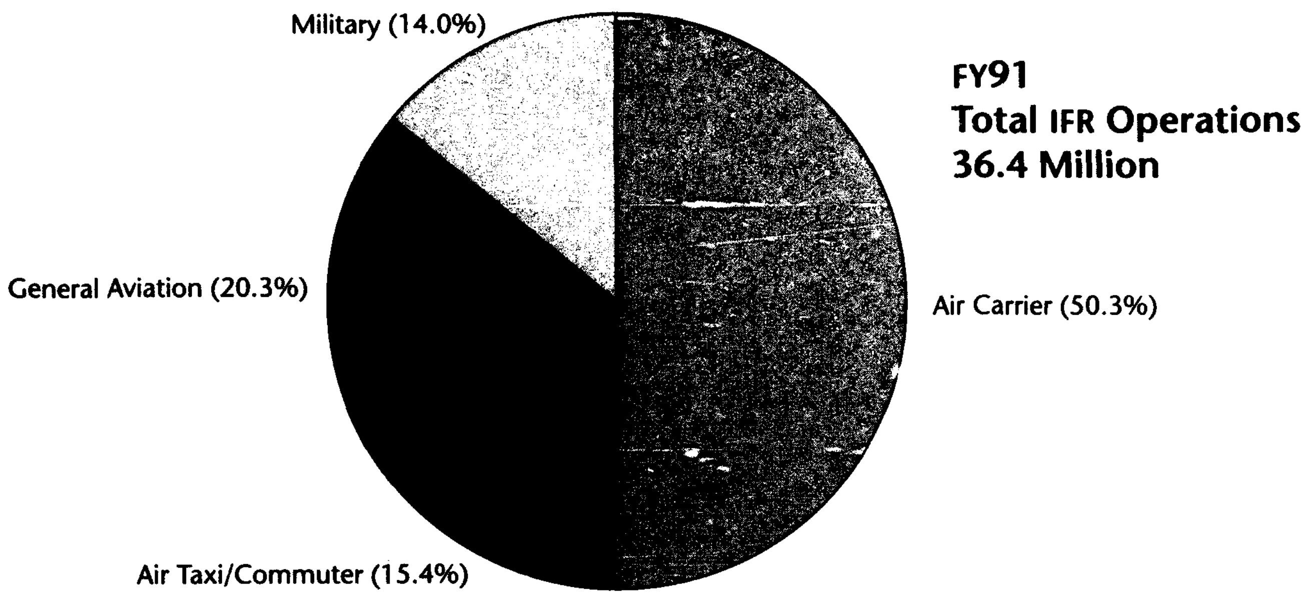


Table1-2. Projected Annual Growth Rate by User Group in Traffic Handled by Air Route Traffic Control Centers FY90 to FY05

User Group	Rate of Growth FY91 to FY05
Air Carrier	2.5%
Air Taxi/Commuter	3.8%
General Aviation	1.9%
Military	>1%



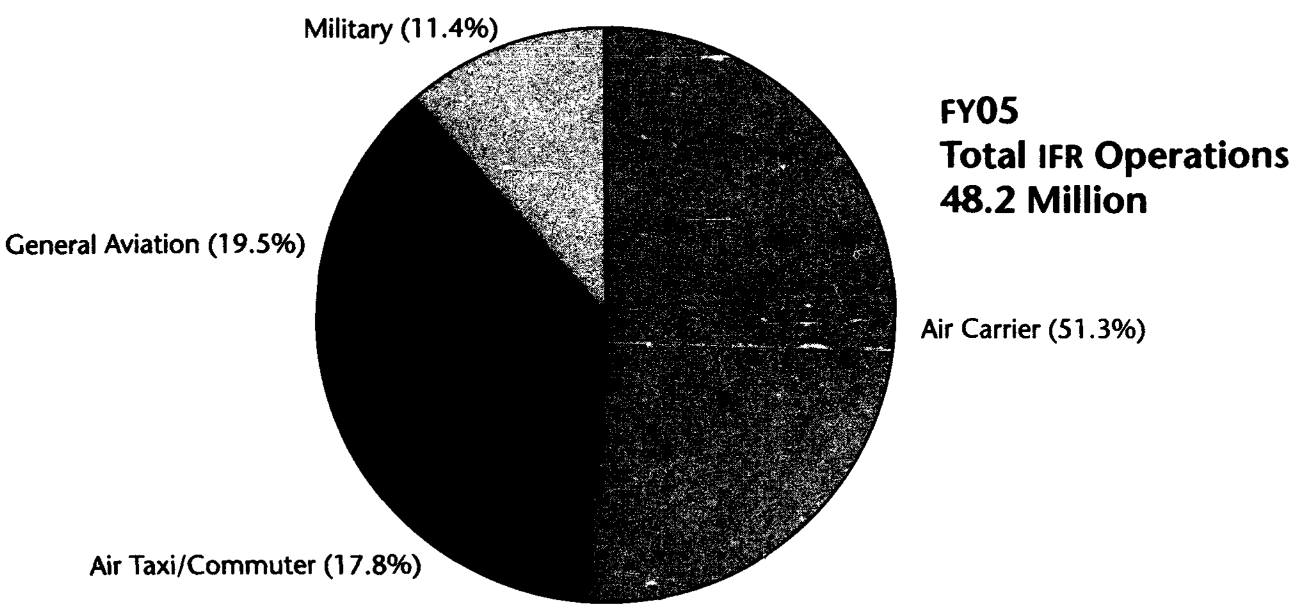
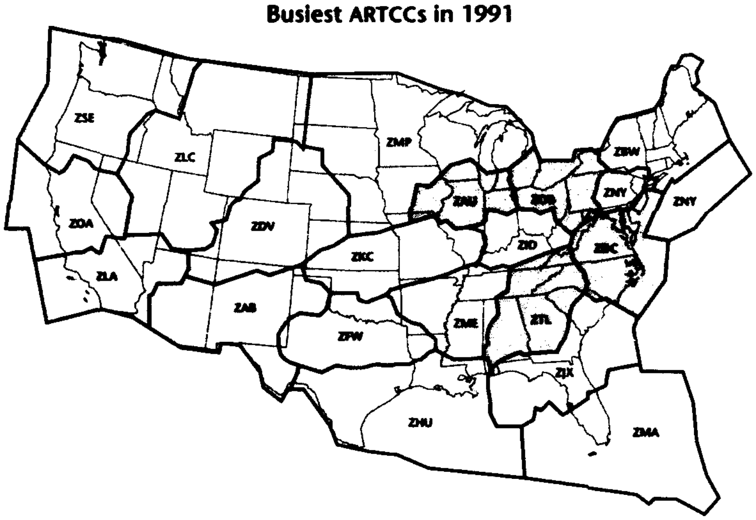


Figure 1-6. Traffic Handled by ARTCCs, FY91 and Forecast FY05

The busiest Federal Aviation Administration (FAA) ARTCCs in 1991 were: Chicago, Cleveland, Atlanta, and Washington. Forecasts for 2005 indicate a change in ranking of the busiest ARTCCs to: Chicago, Atlanta, Cleveland, and Oakland.

Chicago Center, the busiest FAA ARTCC in 1991, handling 2.6 million aircraft, is projected to handle 3.4 million aircraft by the year 2005. The centers with the highest average annual growth rates are Oakland and Jacksonville, which are projected to grow by 4.1 and 2.8 percent respectively. The relatively high growth at these two centers reflects the projected high growth of domestic traffic demand in the West and South. Oakland Center is forecast to experience the largest absolute growth, from 1.7 million aircraft operations in 1991 to 2.8 million in the year 2005. This reflects the continuing development and strong projected growth on trans-Pacific routes.

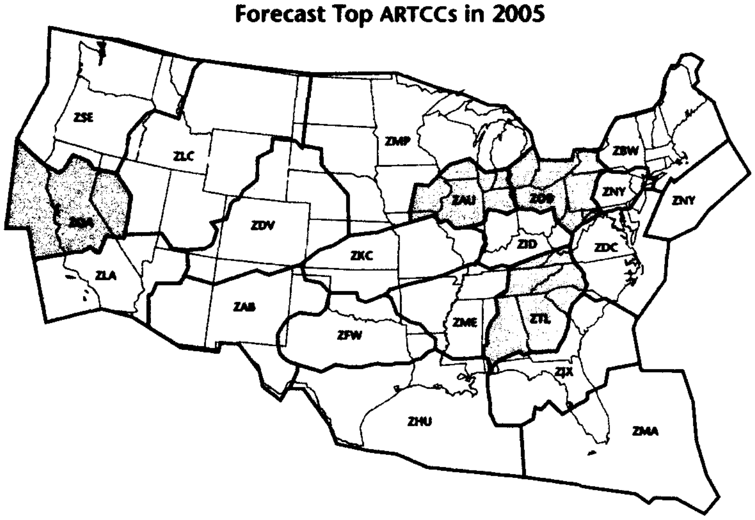
Busiest ARTCCs in 1991



The busiest FAA ARTCCs in 1991 were:
Chicago,
Cleveland,
Atlanta, and
Washington.

Forecasts for 2005 indicate a change in ranking of the busiest ARTCCs to:
Chicago,
Atlanta,
Cleveland, and
Oakland.

Forecast Top ARTCCs in 2005



1.4 Delay [8]

1.4.1 Sources of Delay Data

Delay can be thought of as another system performance parameter, as an indicator that capacity is perhaps being reached and even exceeded. Currently, the FAA gathers delay data from two different sources. The first is through the Air Traffic Operations Management System (ATOMS), in which FAA personnel record aircraft that are delayed more than 15 minutes by cause, (weather, terminal volume, center volume, closed runways or taxiways, and NAS equipment interruptions). Aircraft that are delayed by less than 15 minutes are not recorded.

The second source of delay data is through the Airline Service Quality Performance (ASQP) data, which is collected, in general, from airlines with one percent or more of the total domestic scheduled service passenger revenue[9] and represents delay by phase of flight (gate-hold, taxi-out, airborne, or taxi-in delays).[10] Actual departure time, flight duration, and arrival time 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). ASQP delays range from 0 minutes to greater than 15 minutes. In the discussion that follows, "delay by cause" refers to ATOMS data, and "delay by phase of flight" refers to ASQP data.

1.4.2 Delay by Cause

Flight delays exceeding 15 minutes, as recorded by ATOMS, were experienced on 297,758 flights in 1991, a decrease of 24.2 percent over 1990. Weather was attributed as the primary cause of 66 percent of operations delayed by 15 minutes or more in 1991, up from 53 percent in 1990. Terminal air traffic volume accounted for 27 percent of delays greater than 15 minutes, down from 36 percent in 1990. Table 1-3 provides a history of this breakdown of delays greater than 15 minutes by primary cause, and Figure 1-7

Flight delays exceeding 15 minutes, as recorded by ATOMS, were experienced on 297,758 flights in 1991, a decrease of 24.2 percent over 1990.

8. 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. Airlines reporting Airline Service Quality Performance (ASQP) data as of July 1, 1991 include: Air West, Alaska, American, Continental, Delta, Midway, Northwest, Pan American, Southwest, TWA, United, and USAir.
10. See footnote on page 1-18.

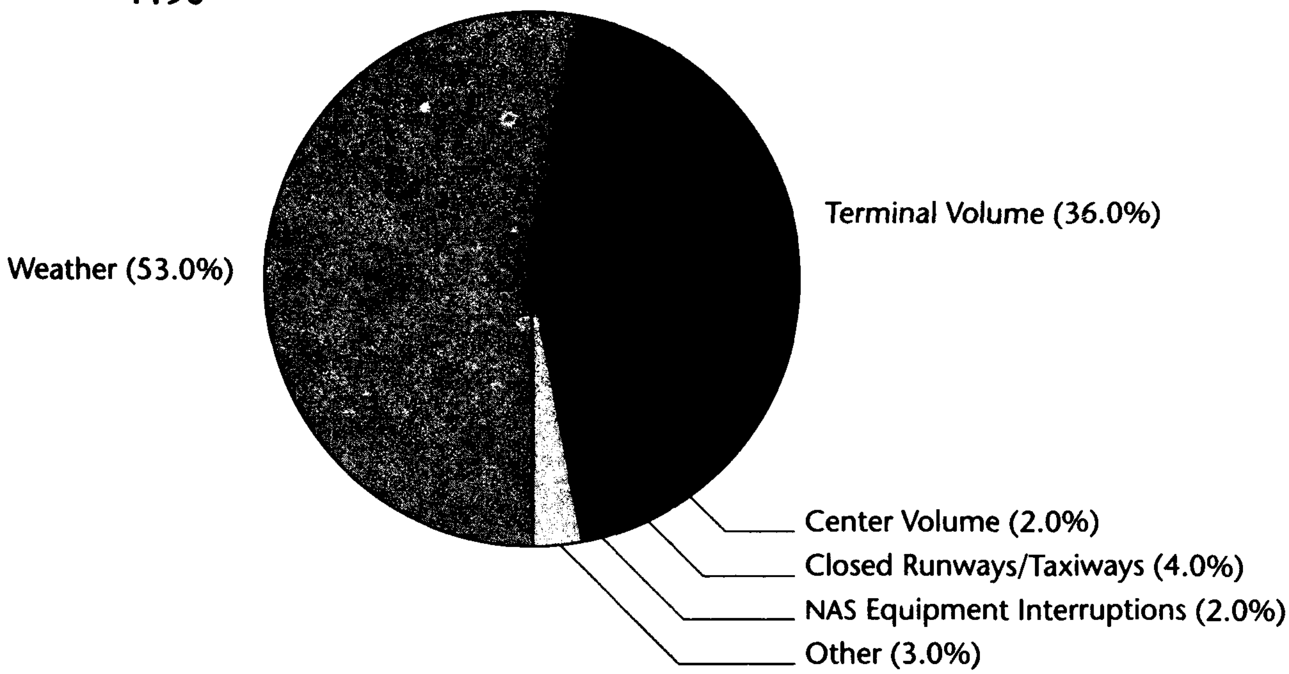
compares the primary causes of this delay for FY90 and FY91. With the exception of the split between terminal and center volume delays, the basic distribution of delay by cause has remained fairly consistent over the past seven years.

More than half of all delays are attributed to adverse weather conditions. These delays are largely the result of instrument approach procedures that are much more restrictive than the visual procedures in effect during better weather conditions. The FAA continues to install new and upgrade existing Instrument Landing Systems (ILSs) to support continued operations during conditions of reduced visibility. During the past few years, the FAA has developed new, capacity-enhancing approach procedures that take advantage of improving technology while maintaining the current level of safety. These new procedures, and the estimated increase in the number of operations per hour, are discussed in Chapter 3.

Table 1-3. Distribution of Delay Greater than 15 Minutes by Cause

Distribution of Delay Greater than 15 Minutes by Cause						
Cause	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Weather	67%	67%	70%	57%	53%	66%
Terminal Volume	16%	11%	9%	29%	36%	27%
Center Volume	**10%**	**13%**	**12%**	**8%**	**2%**	**0%**
Closed Runways/Taxiways	**3%**	**4%**	**5%**	**3%**	**4%**	**3%**
NAS Equipment	3%	4%	3%	2%	2%	2%
Other	1%	1%	1%	1%	3%	2%
Total Operations Delayed (000s)	**418**	**356**	**338**	**394**	**393**	**298**
Percent Change from Previous Year	+25%	-15%	-5%	+17%	0%	-24%

FY90



FY91

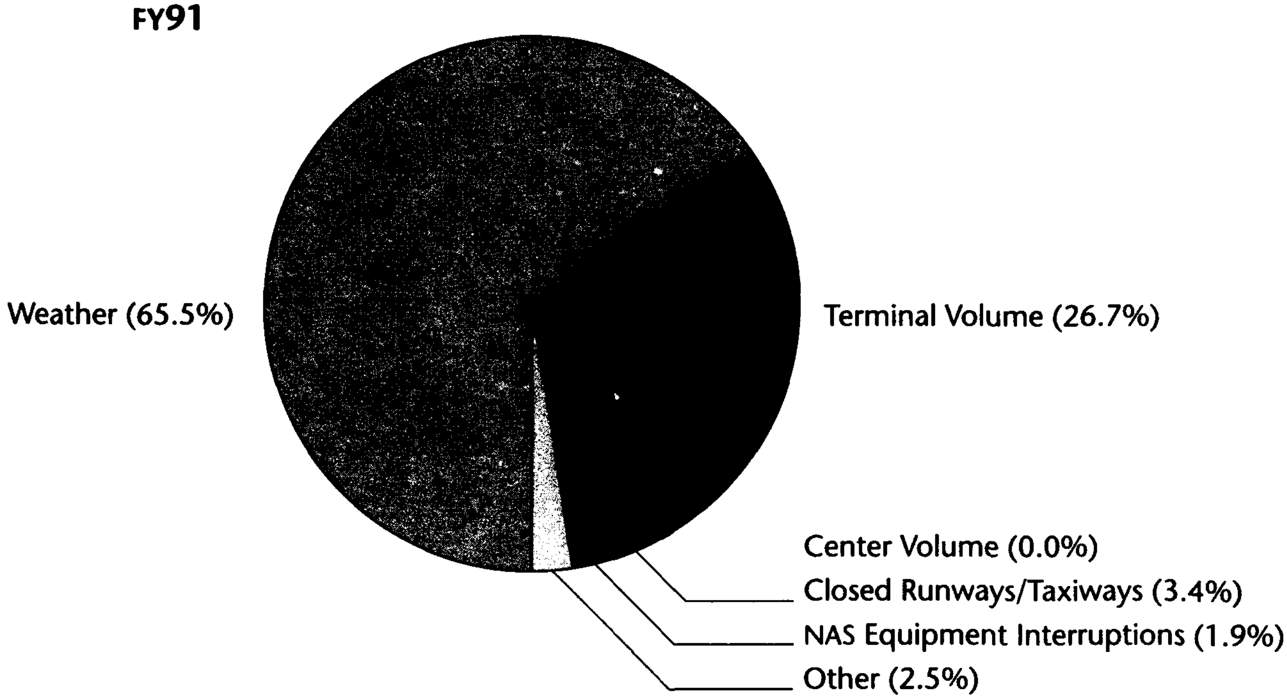


Figure 1-7. Primary Cause of Delay of 15 Minutes or More in FY90 and FY91

Source: Air Traffic Operations Management System (ATOMS) Data

1.4.3 Delay by Phase of Flight

As recorded by ASQP data, nearly 80 percent of all flights are delayed 1 to 14 minutes in taxi-in or taxi-out phases of flight, and only 5 percent of all flights have any gate-hold delay. To put this in perspective, there were approximately 6,456,000 operations in 1991. With an average airborne delay of 4.1 minutes per aircraft, this means that there was a total of over 441,000 hours of airborne delay that year, which, at an estimated $1,600 per hour, cost the airlines $706 million.

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

Based on ASQP data, Table 1-4 presents the percentage of operations delayed 15 minutes or more, and Table 1-5, the average delay in minutes by phase of flight. As shown in the table, more delays occur during the taxi-out phase than any other phase.

Table 1-4. Percent of Operations Delayed

Percent of Operations Delayed 15 Minutes or More (Total ASQP System)				
Year	1988	1989	1990	1991
Percent Delayed	8.6	9.7	10.3	9.0

Table 1-5. Average Delay by Phase of Flight

Average Delay by Phase of Flight (minutes per flight)[11]				
Phase	**1988**	**1989**	**1990**	**1991**
Gate-hold	1.0	1.0	1.0	1.1
Taxi-out	6.8	7.0	7.2	6.9
Airborne	4.0	4.3	4.3	4.1
Taxi-in	2.1	2.2	2.3	2.2
Total	14.0	14.6	14.9	14.3
Mins./Op.	7.0	7.3	7.5	7.1

11. 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 gate-hold.

    Mins/op: Average delay in minutes per operation.

1.4.4 Identification of Delay-Problem Airports

In CY91, the number of airline flight delays in excess of 15 minutes decreased compared to 1990 at 36 of 55 major airports at which the FAA collects air traffic delay statistics. Table 1-6 lists the percentage of operations delayed 15 minutes or more over the last six years at 22 of these airports. These delays ranged from 0.2 percent of flight operations at Cleveland and Fort Lauderdale to 6.7 percent at Newark. Figure 1-8 compares the number of delays in excess of 15 minutes per 1,000 operations for 1990 and 1991 at these same 22 airports. Three of the top five airports in delays exceeding 15 minutes were in the New York area.

In CY91, the number of airline flight delays in excess of 15 minutes decreased compared to 1990 at 36 of 55 major airports. The percentage of operations delayed at these airports ranged from 0.2 percent of flight operations at Cleveland and Fort Lauderdale to 6.7 percent at Newark.

1.4.5 Identification of Forecast Delay-Problem Airports

Forecasts indicate that, in the absence of capacity improvements, delays in the system will continue to grow.[12] In 1991, 23 airports each exceeded 20,000 hours of annual aircraft flight delays. Assuming no improvements in airport capacity are made, 33 airports are forecast to each exceed 20,000 hours of annual aircraft flight delays by the year 2002.[13] The current forecast for 36 delay-problem airports in 2002 is seven less than the 40 airports predicted in last year's forecast. This reflects the overall decline in air travel in 1991 as a result of the Persian Gulf War and the economic recession.

Figure 1-9 shows the airports exceeding 20,000 hours of annual aircraft delay in 1991, while Figure 1-10 shows the airports forecast to exceed 20,000 hours of annual aircraft delay in 2002, assuming there are no capacity improvements.

12. Figure 1-8. Delays Per 1,000 Operations.
13. Table 1-7. 1991 Actual and 2002 Forecast Air Carrier Delay Hours.

Table 1-6. Percentage of Operations Delayed 15 Minutes or More[14]

Airports	Percentage of Operations Delayed 15 Minutes or More						
	1985	1986	1987	1988	1989	1990	1991
New York La Guardia	9.2	8.9	6.5	5.2	9.6	8.7	6.2
Newark Int'l.	9.2	13.8	6.5	6.7	10.6	8.5	6.7
New York Kennedy	6.1	7.0	6.5	5.	6.1	6.8	4.2
Chicago O'Hare Int'l.	4.1	5.6	4.6	5.5	10.3	6.5	4.8
San Francisco Int'l.	3.4	5.3	6.2	6.3	7.1	4.6	5.8
Atlanta Hartsfield Int'l.	6.2	6.5	6.2	3.5	2.5	4.4	2.2
Philadelphia Int'l.	0.9	2.0	3.7	2.6	2.2	3.5	1.7
Boston Logan Int'l.	6.1	7.3	4.8	3.7	2.9	3.2	3.3
Minneapolis Int'l.	2.2	3.9	0.7	1.4	0.8	3.2	0.8
St. Louis-Lambert Int'l.	4.6	4.4	1.6	2.7	2.9	2.5	3.0
Denver Stapleton Int'l.	4.6	3.2	3.7	3.7	2.7	2.9	2.9
Dallas-Ft. Worth Int'l.	1.7	2.6	2.0	1.4	2.4	3.2	3.5
Detroit Metropolitan	2.1	1.3	1.5	1.5	1.6	2.0	0.9
Houston Intercontinental	0.3	0.2	0.5	0.7	0.6	1.3	1.3
Washington National	2.0	3.2	2.3	1.5	1.0	1.0	0.5
Pittsburgh Int'l.	1.7	0.6	0.7	0.7	0.8	0.9	0.5
Los Angeles Int'l.	0.8	1.1	3.3	1.7	1.1	0.7	1.5
Miami Int'l.	0.3	0.7	0.4	0.3	0.2	0.9	2.4
Cleveland Hopkins Int'l.	0.1	0.3	0.1	0.5	0.3	0.5	0.2
Kansas City Int'l.	0.3	1.0	0.5	0.2	0.3	0.2	0.3
Ft. Lauderdale Int'l.	0.1	0.3	0.2	0.2	0.3	0.3	0.2
Las Vegas McCarran Int'l.	0.0	0.0	0.1	0.1	0.2	0.1	0.0

14. Numbers included in the table can change because of updates made to the database after publication.

Table 1-7. 1991 Actual and 2002 Forecast Air Carrier Delay Hours

Annual Aircraft Delay in Excess of 20,000 Hours					
1991		2002			
Chicago O'Hare	ORD	Chicago O'Hare	ORD	Washington National	DCA
Atlanta Hartsfield	ATL	Dallas-Ft. Worth	DFW	San Diego	SAN
Dallas-Ft. Worth	DFW	Atlanta Hartsfield	ATL	Charlotte-Douglas	CLT
Los Angeles	LAX	San Francisco	SFO	Cincinnati	CVG
Newark	EWR	Washington Dulles	IAD	Honolulu	HNL
San Francisco	SFO	Newark	EWR	Houston	IAH
Boston	BOS	St. Louis	STL	Las Vegas	LAS
New York John F. Kennedy	JFK	Los Angeles	LAX	Windsor Locks	BDL
St. Louis	STL	Phoenix	PHX	Memphis	MEM
Phoenix	PHX	New York John F. Kennedy	JFK	Baltimore Washington	BWI
Miami	MIA	Miami	MIA	Ontario	ONT
Philadelphia	PHL	Philadelphia	PHL	Nashville	BNA
Washington National	DCA	Boston	BOS	Raleigh-Durham	RDU
Pittsburgh	PIT	Detroit	DTW	Seattle-Tacoma	SEA
Detroit	DTW	Pittsburgh	PIT	Salt Lake City	SLC
Orlando	MCO	New York La Guardia	LGA		
Minneapolis	MSP	Orlando	MCO		
Charlotte	CLT	Minneapolis	MSP		
Denver Stapleton †	DEN				
Honolulu	HNL				
Houston	IAH				
Seattle-Tacoma	SEA				
New York La Guardia	LGA				

† No projection for DEN can be made under this assumption since the increased level of activity projected for Denver in 2002 cannot be handled at the existing Denver Stapelton Airport.

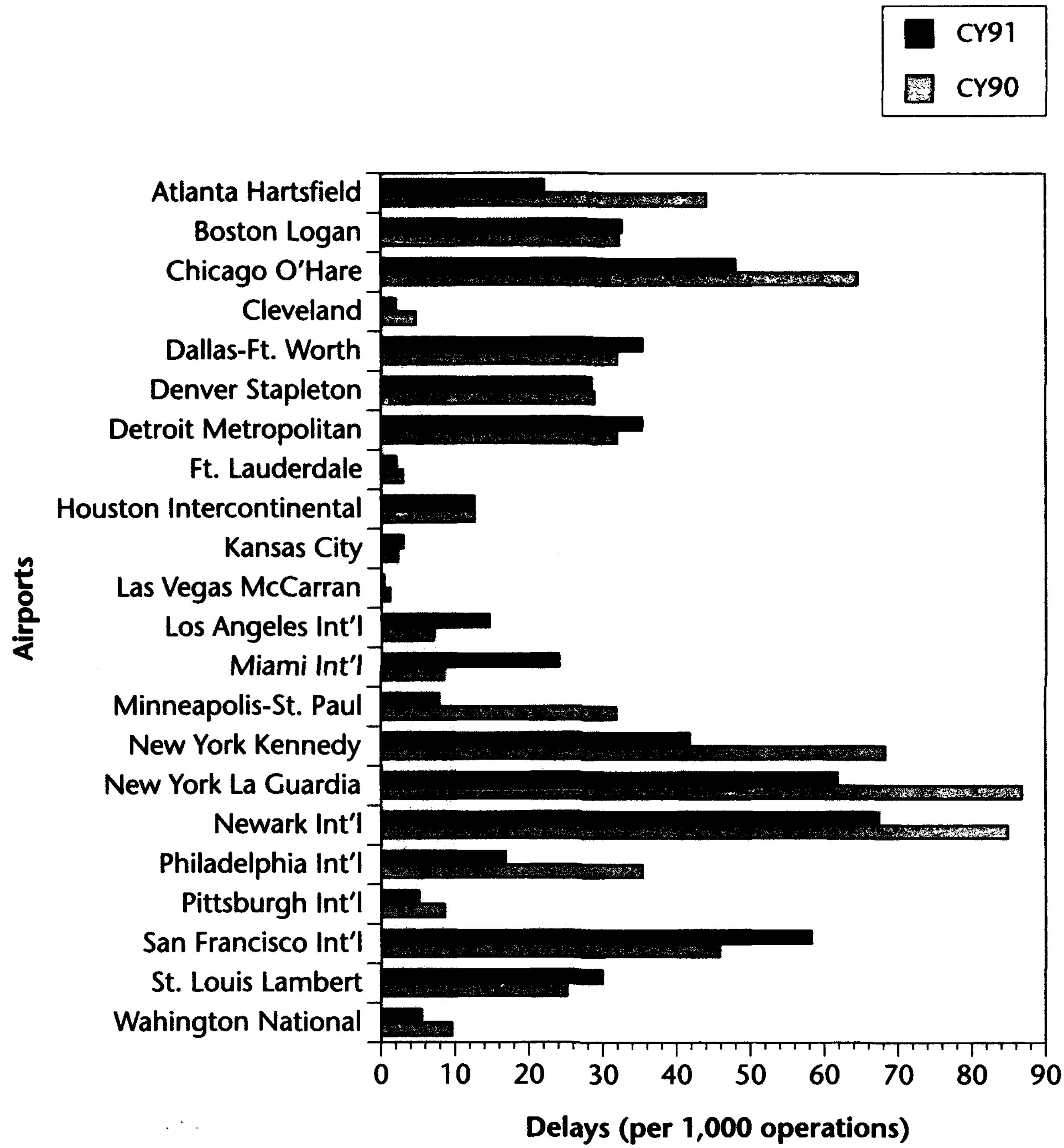


Figure 1-8. Delays Per 1,000 Operations
Source: ATOMS Data

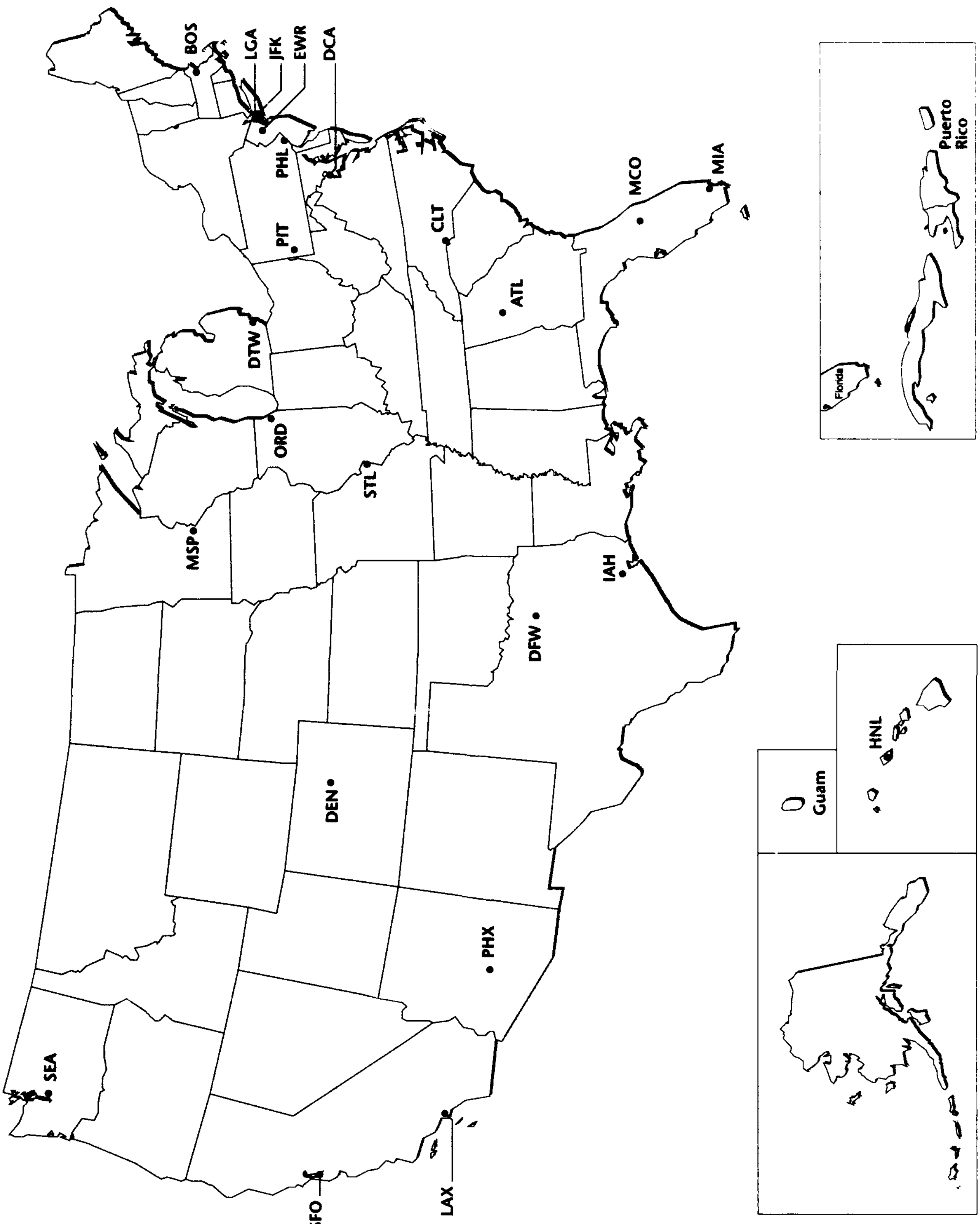


Figure 1-9. Airports Exceeding 20,000 Hours of Annual Delay in 1991

Source: FAA Office of Policy and Plans

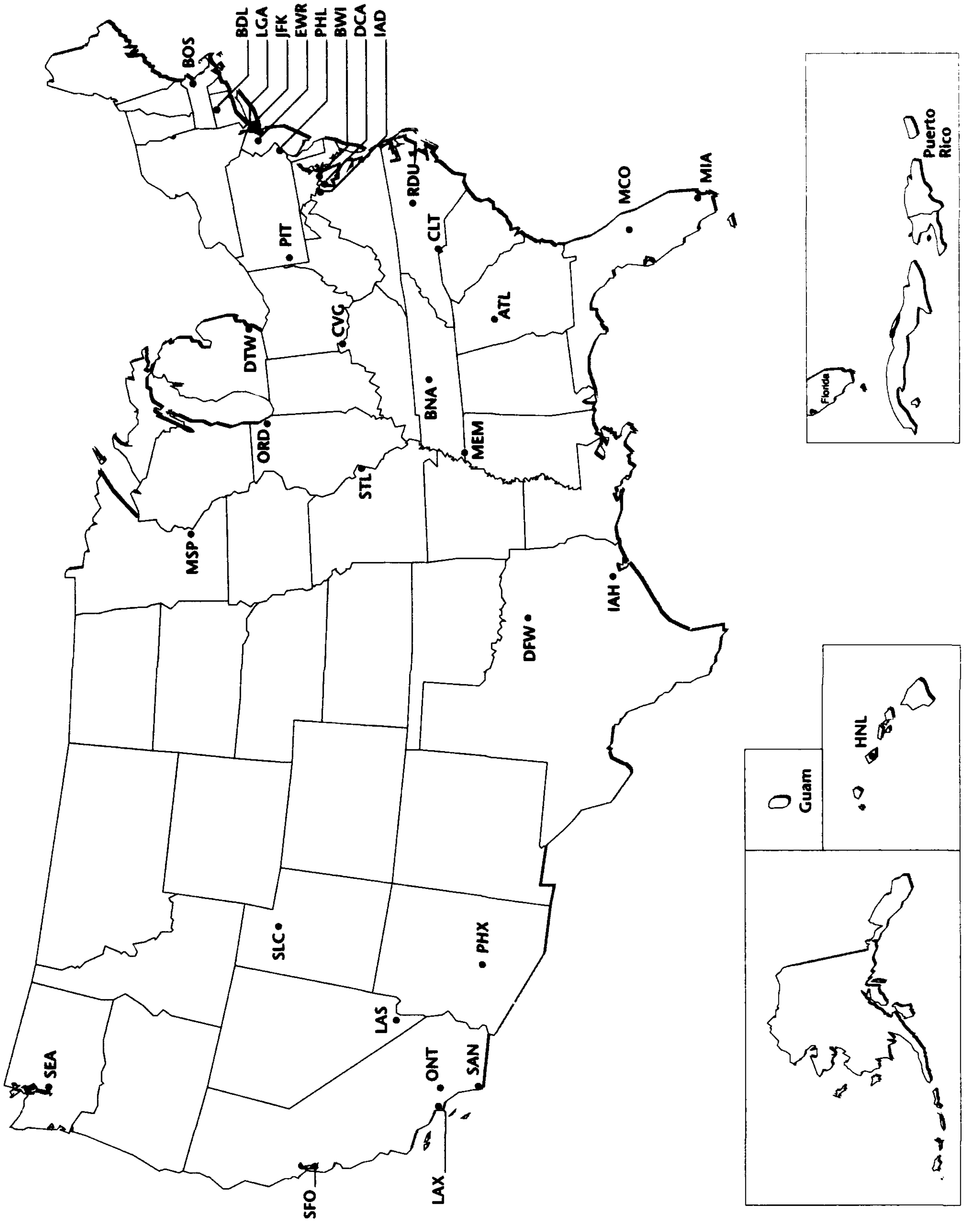


Figure 1-10. Airports Forecast to Exceed 20,000 Hours of Annual Aircraft Delay in 2002, Assuming No Capacity Improvements

Source: FAA Office of Policy and Plans

Chapter 2

Airport Development

2.1 Delay and the Need for Airport Development

Delay decreased a significant amount in 1991 over the previous year. As a result of the war in the Persian Gulf and the overall weakness of the economy, total aircraft operations declined, and the drop in flight operations resulted in fewer delays. However, air transportation has become a vital part of the U.S. economy. As the economy recovers, the demand for air travel will grow, and the number of aircraft operations will increase to meet that demand. Current forecasts indicate that, with the recovery of the economy and absent any capacity improvements, delays will increase substantially over the next decade, though at a somewhat slower pace than in the 1980s.

Delay decreased a significant amount in 1991 over the previous year as a result of the war in the Persian Gulf and the overall weakness of the economy. With the recovery of the economy and absent any capacity improvements, delays will increase substantially over the next decade.

Preliminary results of a survey conducted by the FAA's Office of Airport Planning and Programming, National Planning Division, indicate that, with the new improvements planned, capacity at the majority of the 29 "large hub" commercial service airports in the U.S. will be adequate to meet the forecast growth in demand. The few problem airports, which are predicted to continue to experience significant delays despite planned improvements, are primarily the large metropolitan area airports on the east and west coasts, principally in the Northeast and in California. At these problem airports, planned improvements are not adequate, to meet the projected growth in demand, for a variety of reasons.

The positive message contained in the preliminary results of this survey is that the capacity needed to meet future demand will be available at most of the Nation's busiest airports, if the improvements planned for these airports continue to be funded and built. It is, therefore, essential that the aviation community, in both the public and private sectors, continues to work together to ensure that these improvement projects are completed in time to meet the growth in demand.

However, this survey also points out that, even though capacity improvements are planned at the few delay-problem airports, they will not be enough to meet forecast demand at these airports. Delays there will most likely increase as demand increases. If the demand for air transportation in these large metropolitan areas cannot be met by the existing major airports in these areas, then other airports must be developed within the region to avoid severe constraints on air traffic growth.

From this perspective then, airport capacity improvements take on a two-tiered scheme of priorities. For most of the airports in the country, the need for capacity improvement must continue to be emphasized so that projects will continue to be planned, funded, and built to keep pace with the projected increases in demand. This has been the work of the Airport Capacity Design Teams, which is described in more detail in this chapter.

For most of the airports in the country, the need for capacity improvement must continue to be emphasized so that projects will continue to be planned, funded, and built to keep pace with the projected increases in demand.

For the few delay-problem airports in the Northeast, in California, and elsewhere, renewed emphasis must be given to finding innovative solutions beyond the airports themselves. New airports, expanded use of existing commercial-service airports, civilian development of former military bases, and joint civilian and military use of existing military facilities will be discussed in this and subsequent chapters. These options and more must be explored systematically with a view toward developing a multiple airport system within the local region to serve the expanding air transportation needs of these large metropolitan areas.

For the few delay-problem airports, renewed emphasis must be given to finding innovative solutions beyond the airports themselves.

2.2 New Airport Development

The largest aviation system capacity gains result from the construction of new airports. The new Denver airport, for example, not only will increase capacity and reduce delays in the Denver area but also will reduce delays throughout the aviation system. However, at a cost of over $2.9 billion for a new airport like Denver, it will remain a challenge to finance and build others. In addition, the development of new airports faces environmental and other constraints. Table 2-1 summarizes major new airports that are under construction or are under consideration in various planning studies by state and local government organizations. New Denver is the only major new airport currently under construction.

The largest aviation system capacity gains result from the construction of new airports.

Table 2-1. Major New Airports — Under Construction and Planning Studies

Airport	Purpose	Status
New Denver	Replacement airport for Denver Stapleton (DEN), which will close.	Under construction. Scheduled to be operational late 1993.
Dallas-Ft. Worth	Supplemental airport.	Phase 2 satellite study by North Central Texas Council of Governments.
Minneapolis-St. Paul	Replacement airport for MSP. Proposal is to close existing airport.	Dual track. Feasibility study for new airport. Capacity enhancement study for existing airport.
New Orleans	Replacement airport for MSY. Existing airport will remain in operation.	Phase 2 site selection study, investigating airspace at four possible sites.
Chicago	Supplemental airport.	Under study. No Regional Airport Commission legislation.
Seattle-Tacoma	Supplemental airport.	Satellite study by Port of Seattle and Puget Sound Regional Council recommended a multiple airport system for region.
Boston	Supplemental airport.	Satellite study by Massport and Council of Governments.
Atlanta	Supplemental airport.	Satellite study by Atlanta Regional Commission of non-ranked sites. Feasibility study by State of Georgia.
Northwest Arkansas	Replacement airport for Fayetteville (FYV), which will remain in operation.	Site selection/AMP/EIS underway. Feasibility study completed.
Birmingham, Alabama	Replacement airport. Proposal is to close existing airport.	Site selection completed. Ranked sites and preferred sites identified by State of Alabama.
North Carolina	All-cargo airport.	Sites ranked by State of North Carolina.
Eastern Virginia	Supplemental airport.	Regional study by three Councils of Governments.
Louisiana	Intermodal facility. Replacement airport for MSY and Baton Rouge (BTR). Existing airports will remain in operation.	New airport feasibility study by State of Louisiana. Regional Airport Commission appointed by State of Louisiana.
Austin	Replace Robert Mueller Airport.	Conversion of Bergstrom AFB to civil use.
Phoenix	Regional airport.	Feasibility study underway for Phoenix/Tucson regional airport.
San Diego	Supplemental airport.	Feasibility study underway for joint US/Mexican airport in Otay Mesa area.

2.3 Development of Existing Airports — Airport Capacity Design Teams

As environmental, financial, and other constraints continue to restrict the development of new airport facilities in the U.S., an increased emphasis has been placed on the redevelopment and expansion of existing airport facilities. Since 1985, the FAA has co-sponsored Airport Capacity Design Teams at airports across the country affected by delay. Airport operators, airlines, and other aviation industry representatives work together with FAA representatives to identify and analyze capacity problems at each individual airport and recommend improvements that have the potential for reducing or eliminating delay.

Aircraft flight delays are generally attributable to one or more 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 causes of delay were identified and resources applied to develop the necessary improvements to remove or reduce the deficiency.

Since the start of the program, 26 Airport Capacity Design Team studies have been completed. Currently, eight Capacity Team studies are in progress. Table 2-2 provides the status of the program at the airports with Airport Capacity Design Teams, and Figure 2-1 shows the location of each of these airports.

Figure 2-2 is a three-year plan for the Airport Capacity Design Team program. For FY93, Design Teams have been proposed for El Paso, Las Vegas, Milwaukee, Tampa, Tulsa, San Diego, and West Palm Beach. A second, follow-on study is planned for Detroit.

Table 2-2. Status of Airport Capacity Design Teams[1]

Airport Capacity Design Team Status			
Completed		**Ongoing**	**Planned**
Atlanta	Orlando	Albuquerque	El Paso
Boston	Philadelphia	Cleveland	Las Vegas
Charlotte	Phoenix	Eastern Virginia *	Milwaukee
Chicago	Pittsburgh	Ft. Lauderdale	San Diego
Detroit **	Raleigh-Durham	Houston Intercont.	Tampa
Honolulu	Salt Lake City	Indianapolis	Tulsa
Kansas City	San Antonio	Minneapolis *	West Palm Beach
Los Angeles	San Francisco	Port Columbus	
Memphis	San Jose		
Miami	San Juan, P.R.		
Nashville	Seattle-Tacoma		
New Orleans	St. Louis		
Oakland	Washington-Dulles		

* Projects recently initiated
** Follow-on study planned

1. Airport Capacity Design Status as of 2-1-93.

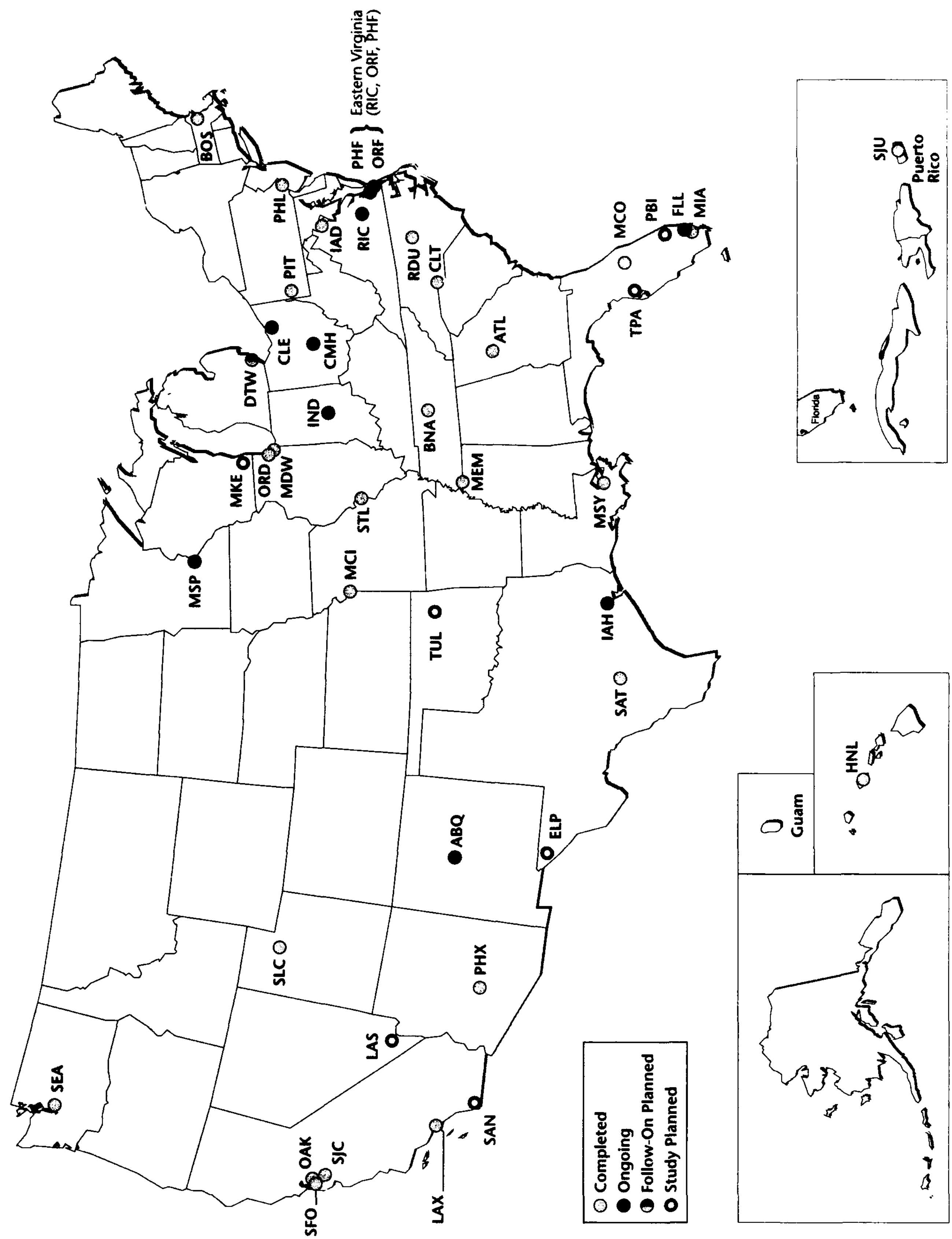


Figure 2-1. Airport Capacity Design Teams in the U.S.

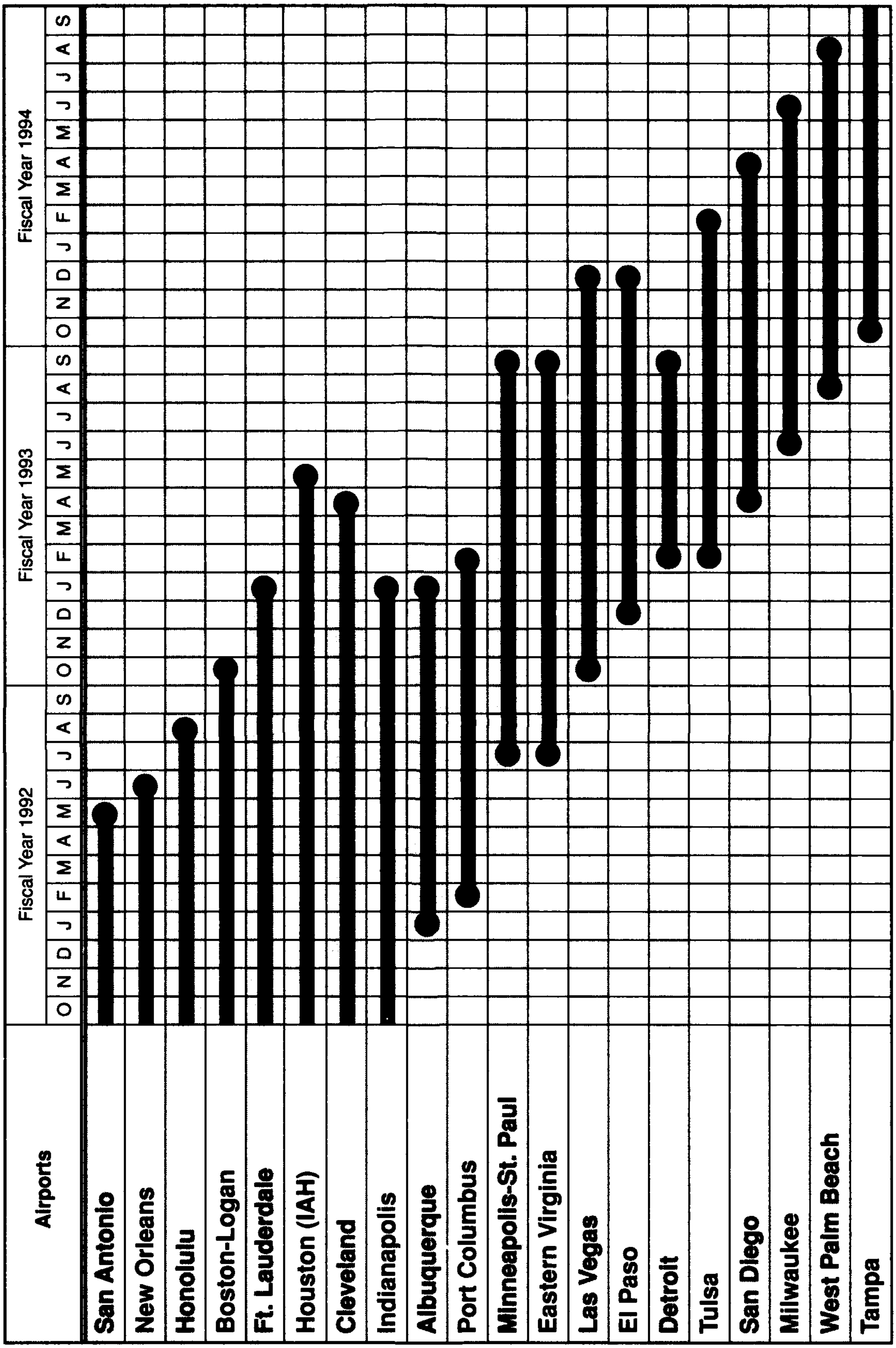


Figure 2-2. Airport Capacity Design Team — Three Year Plan

Source: FAA Office of System Capacity and Requirements

2.3.1 Airport Capacity Design Teams — Recommended Improvements

The Airport Capacity Design Teams identify and assess various corrective actions which, if implemented, will increase 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 examine each alternative 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 simulations provided by the FAA Technical Center at Atlantic City, New Jersey. In their final report, the capacity team recommends certain projects for implementation.

Airport Capacity Design Teams identify and assess various corrective actions which, if implemented, will increase capacity, improve operational efficiency and reduce delay at the airports under study.

Improvements recommended by the 26 completed studies can be divided into three categories: airfield, facilities and equipment, and operational improvements. Table 2-3 summarizes these recommendations according to generalized categories of improvements. The Airport Capacity Design Teams have developed more than 500 projects to increase airport capacity.

The Airport Capacity Design Teams have developed more than 500 projects to increase airport capacity.

Six airports are proposing to build a third or a fourth parallel runway, three are proposing to build both a third and a fourth parallel runway, five are proposing to build a new runway and a new taxiway, seven are proposing to build a new taxiway only, and one airport is proposing to build a new taxiway and new third and fourth parallel runways. Over half the design team reports have recommended runway extensions, taxiway extensions, angled/improved exits, or holding pads/improved staging areas.

The only facilities and equipment improvement that was recommended in more than half of the airport studies was the installation or upgrade of Instrument Landing Systems (ILSs) at one or more runways or runway ends, thus improving runway capacity during IFR operations.

Capacity Team recommendations demonstrate the FAA's efforts to increase aviation system capacity by making the most use of current airports.

The operational improvements that were recommended in half or more of the studies include improved IFR approach procedures and reduced separation standards for arrivals. Approximately one-third of the studies recommended an airspace analysis or restructuring of the airspace. Greater use of reliever airports was recommended at almost half of the airports.

In general, the Capacity Team recommendations demonstrate the FAA's efforts to increase aviation system capacity by making the most use of current airports. In the view of the Airport Capacity Design Teams, the "choke point" most often is found in the runway/taxiway system. Where possible, the construction of a third and even a fourth parallel runway has been proposed. Runway and taxiway extensions, new taxiways, and improved exits and staging areas have been recommended to reduce runway occupancy times and increase the efficiency of the existing runways. In addition to maximizing use of airport land, airports are making the best use of facilities, equipment, and procedures to increase arrival capacity during IFR operations. Equipment is being installed to accommodate arrivals under lower ceiling and visibility minima, including ILSs, RVRs, and improved radar, not to mention new and improved arrival procedures and reduced separation standards, both in-trail and laterally, for arrivals. Finally, in an effort to segregate larger jets from small/slow aircraft, the FAA is recommending improved use of reliever airports for general aviation and commuter traffic.

Table 2-3. Summary of Capacity Design Team Recommendations

Recommended Improvements / Airports	Atlanta	Boston	Charlotte-Douglas	Chicago Midway	Chicago O'Hare	Honolulu	Kansas City	Los Angeles	Memphis	Miami	Nashville	New Orleans	Oakland	Orlando	Philadelphia	Phoenix	Pittsburgh	Raleigh-Durham	St. Louis	Salt Lake City	San Antonio	San Fransisco	San Jose	San Juan, Puerto Rico	Seattle-Tacoma	Washington-Dulles
Construct third parallel runway			√			√	√		√						√	√		√	√	√	√	√			√	√
Construct fourth parallel runway							√				√			√			√	√				√			√	
Relocate runway					√						√				√			√								
Construct new taxiway	√	√		√	√			√	√	√	√	√	√	√		√		√			√			√		√
Runway extension		√	√	√	√	√		√	√		√				√		√				√	√	√			√
Taxiway extension		√	√				√	√	√	√	√			√		√			√	√	√	√		√		√
Angled exits/improved exits	√	√	√		√	√	√		√	√			√			√		√	√	√		√	√	√	√	
Holding pads/improved staging areas	√	√	√	√	√	√	√	√		√	√		√	√		√		√	√	√	√	√	√	√		√
Terminal expansion	√					√	√	√								√	√			√				√		√
Install/upgrade ILSs	√	√	√		√	√	√	√	√	√	√			√		√	√	√	√	√	√				√	
Install/upgrade RVRs	√						√			√								√		√	√					√
Install/upgrade lighting system	√		√							√						√			√	√	√			√		√
Install/upgrade VOR												√		√		√								√		
Upgrade terminal approach radar	√																									
Install ASDE	√		√				√			√				√				√	√	√						
Install PRM			√											√	√		√			√	√					
New air traffic control tower								√				√												√		
Wake vortex advisory system	√	√									√							√	√		√			√	√	
Airspace restructure/analysis								√			√	√		√	√		√	√			√					
Improve IFR approach procedures		√		√	√		√		√	√	√	√		√	√	√		√	√	√	√				√	√
Improve departure sequencing															√	√						√	√			
Reduced separations between arrivals	√			√			√		√			√				√		√	√	√	√			√	√	√
Intersecting operations with wet runways		√	√		√																					
Expand TRACON/Establish TCA			√								√							√								
Segregate traffic														√		√										
De-peak airline schedules	√					√	√		√		√					√			√			√			√	√
Improve use of reliever airports			√			√				√	√	√		√		√				√	√	√		√		√

2.3.2 Airport Capacity Design Teams — Potential Savings Benefits

As can be seen from the summary of recommendations in Table 2-3 and the detailed listing of recommendations in Appendix C, the typical design team will make 20 to 30 recommendations for improvements to reduce delay at each airport. Because of the large number of specific improvements, it is virtually impossible to summarize the expected benefits of each of these recommendations for all of the airports 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.

Table 2-4 summarizes the potential delay savings benefits from the airfield improvements recommended by the Airport Capacity Design Teams. These savings benefits were drawn from the final reports of various Capacity Teams. 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 F of this report.

Table 2-4. Potential Savings from Airfield Improvements Recommended by Airport Capacity Design Teams [2]

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

2. 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.

2.4 Construction of New and Extended Runways

The construction of new runways and extension of existing runways are the most direct and significant actions that can be taken to improve the capacity at existing airports. Large capacity increases, under both visual flight rules (VFR) and instrument flight rules (IFR), 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 percent to 100 percent (depending on whether the baseline airport has 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]

Seventeen of the 23 airports exceeding 20,000 hours of air carrier flight delay in 1991[4] are in the process of constructing or planning the construction of new runways or extensions of existing runways.

Of the 33 airports that are forecast to exceed 20,000 hours of annual air carrier delay in 2002, if no further improvements are made, 25 propose to build new runways or runway extensions.[5]

The total anticipated cost of completing these new runways and runway extensions exceeds $7.7 billion. The proposed projects are in various stages of development. Of the 114 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 1991. All runway extensions at Baltimore-Washington 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 forecast to exceed 20,000 hours of annual delay in 2002 are planning new runways. Table 2-5 shows new and extended runways that are planned or proposed.

The "generic" hourly IFR capacities included in Table 2–5 have been developed only to provide a common basis for comparing one airport configuration to another. They serve to illustrate the size of the capacity increases provided. These generic estimates should not be taken as the exact capacity of a particular airport.

The construction of new runways and extension of existing runways are the most direct and significant actions that can be taken to improve the capacity at existing airports. The resulting increase in capacity is from 33 percent to 100 percent.

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

Seventeen of the 23 airports exceeding 20,000 hours of air carrier flight delay in 1991 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 2-5, with the projected IFR capacity benefit, the estimated project cost (to the nearest million), and an estimated operational date. The single figure of IFR capacity benefit does not reflect all of the many significant capacity benefits resulting from this new construction, but it does provide a common benchmark for comparison.
4. At a cost of $1,600 in airline operating expenses per hour of airport delay, 20,000 hours of flight delay translates into over $32 million per year.
5. As reflected in Figure 2-4.
6. As reflected in Table 2-5 and Appendix D.

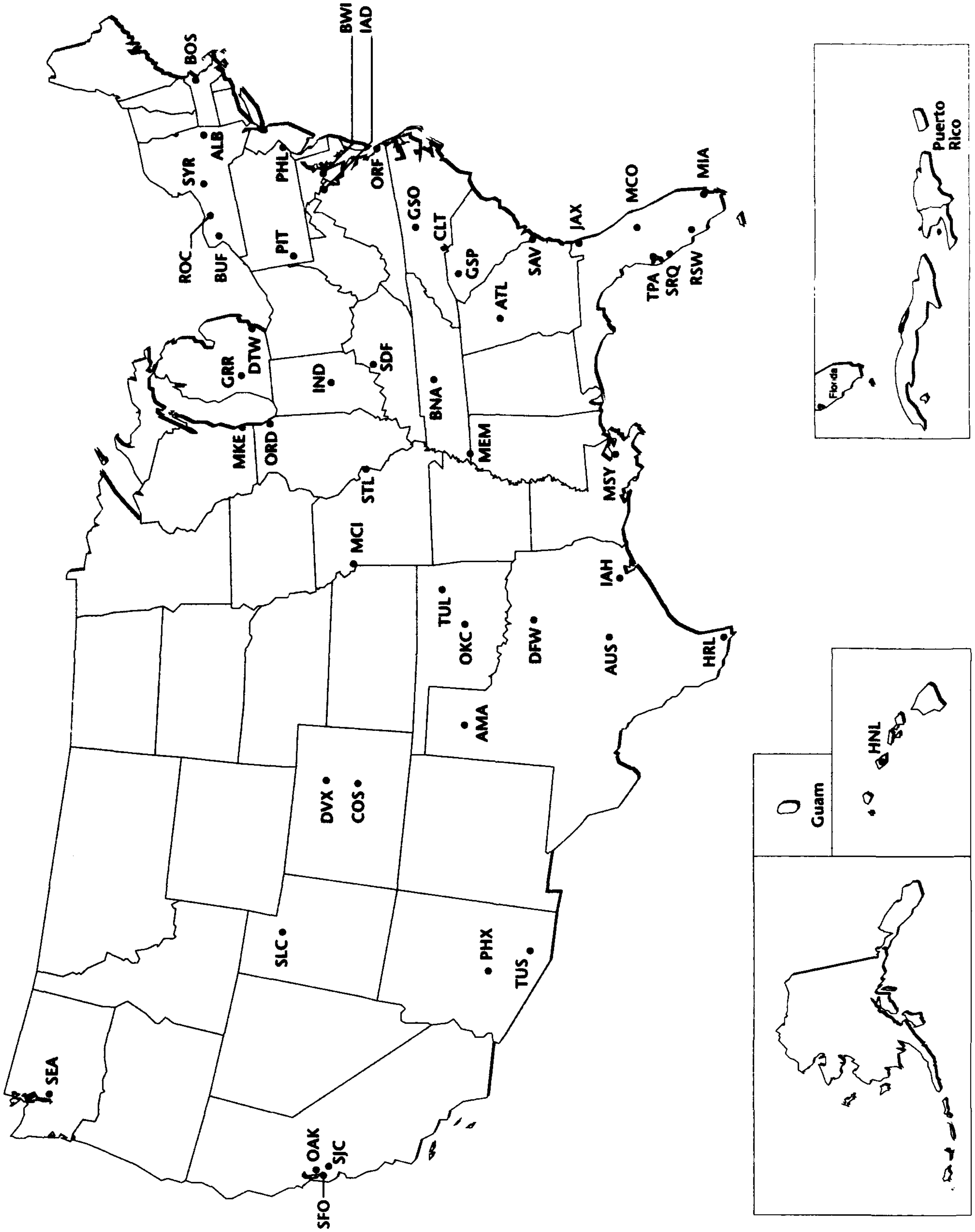


Figure 2-3. New Runways Planned or Proposed Among the Top 100 Airports

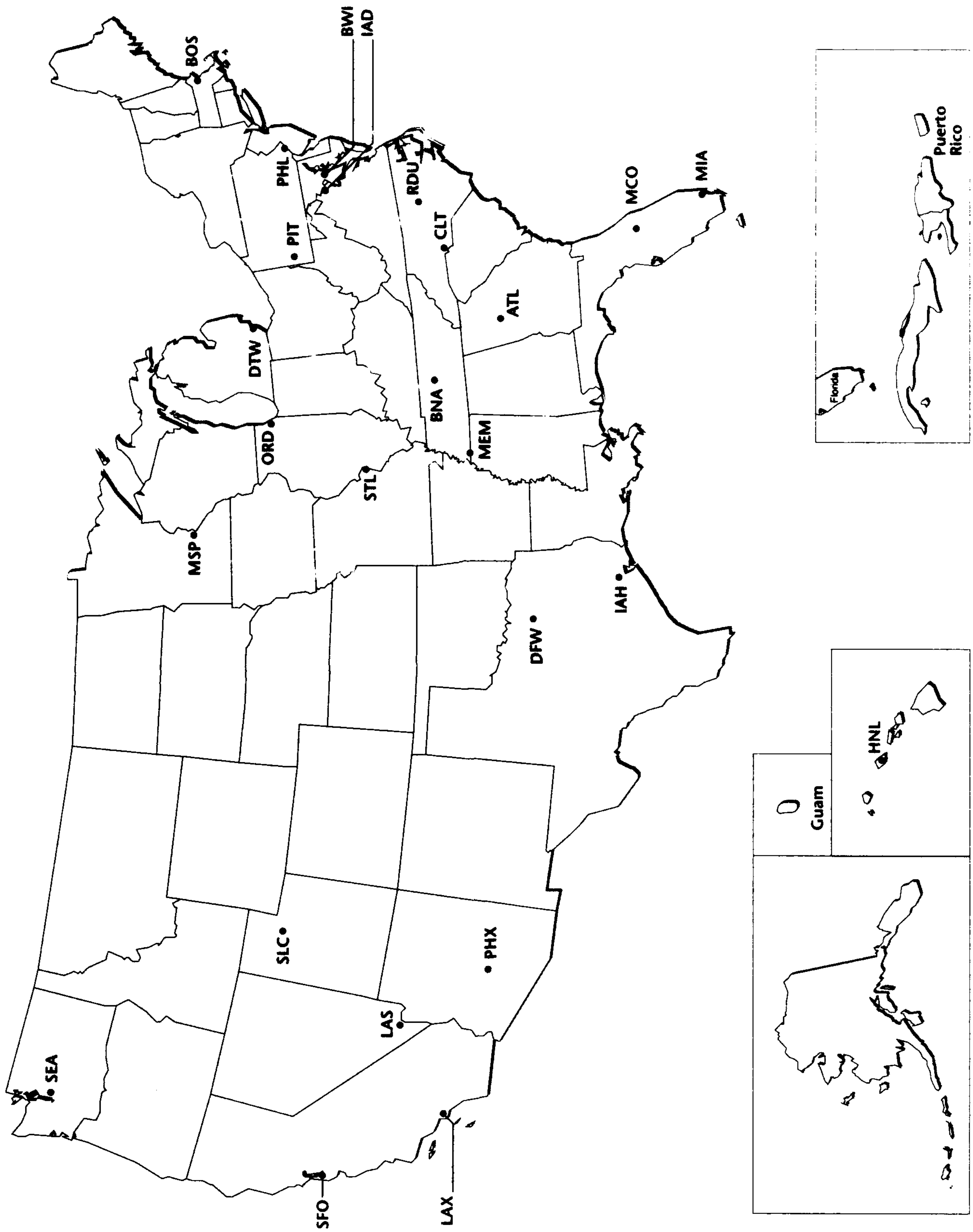


Figure 2-4. New Runways or Extensions Planned/Proposed Among the Top 100 Airports Forecast to Exceed 20,000 Hours of Annual Aircraft Delay in 2001

Table 2-5. New and Extended Runways Planned or Proposed+

Airport	Runway	IFR Capacity (ARR/HR)† New Config.	IFR Capacity (ARR/HR)† Current Best	Est. Cost ($M)	Est. Date Oper.
Albany (ALB)	10/28 extension	29[2]	29[2]	$2	1997
	1R/19L parallel	++	29[2]	$15	2007
Albuquerque (ABQ)	3/21 extension	29[2]	29[2]	$11	1994
Amarillo (AMA)	**13/31 extension**	**++**			**1997**
Atlanta (ATL)	E/W parallel	71[6]	57[1]	$130	1996
Austin New Airport (AUS)	(Bergstrom AFB)	57[11]			1997-8
Baltimore (BWI)	10R/28L parallel	57[11]	29[2]	$48	1996
Birmingham (BHM)	**18/36 extension**	**29[2]**	**29[2]**	**$43**	**1995**
Boston (BOS)	14/32	57[11]	29[2]		
	15L extension	29[2]	29[2]		
Buffalo (BUF)	5L/23R parallel	29[2, 8]	29[2, 8]		1999
	14/32 extension	**29[2, 8]**	**29[2, 8]**	**$4**	**1999**
Charlotte (CLT)	18L/36R extension	57[7, 8]	57[1, 2]	$8	1994
	18W/36W parallel	86[3, 10]	57[1, 8]	$40	1997
	18E/36E parallel	114[10]	57[1, 8]		
Chicago O'Hare (ORD)	**9/27**	**86[3]**	**57[1]**		
	14/32	86[3]	57[1]		
Cincinnati (CVG)	18R/36L extension	57[1]	57[1]		
Cleveland-Hopkins (CLE)	5L/23R replacement	42[4]	29[2]	$42	1998
	5L extension	**29[2]**	**29[2]**	**$10**	**1998**
Colorado Springs (COS)	17L/35R parallel	57[1]	29[2]	$38	1992
Columbus (CMH)	10L/28R replacement	57[7]	42[4]	$46	1995
Dallas-Fort Worth (DFW)	17R/35L extension	57[1]	57[1]	$24	1993
	17L/35R extension	**57[1]**	**57[1]**	**$24**	
	18L/36R extension	57[1]	57[1]	$24	1994
	18R/36L extension	57[1]	57[1]	$24	
	16E/34E	86[3, 10]	57[1]	$110	1996
	16W/34W	**114[10]**	**57[1]**	**$70**	**1997-99**
Dayton (DAY)	6L extension	57[1]	57[1]	$3	1998
Denver Int'l (DIA)	New airport	86[3, 10]	57[1]	$2,972**	1993
Des Moines (DSM)	5/23 extension	29[2]	29[2]	$61	1998
	13R/31L parallel	**57[11]**	**29[2]**	**$150**	**2012**
Detroit (DTW)	9R/27L parallel	57[1]	57[1]	$85	1993
	4/22 parallel	71[6]	57[1]	$90	1998
Fort Lauderdale (FLL)	9R/27L extension	57[1]	29[2]	$96-$263	2000
Fort Myers (RSW)	**6/24 extension**	**29[2]**	**29[2]**	**$23**	**1994**
	6R/24L parallel	57[1]	29[2]	$139	1999
Grand Rapids (GRR)	17/35 replacement	57[1]	29[2]	$46	1997
	8L/26R extension	29[2]	29[2]	$2	1993

Table 2-5. New and Extended Runways Planned or Proposed+

Airport	Runway	IFR Capacity (ARR/HR)† New Config.	IFR Capacity (ARR/HR)† Current Best	Est. Cost ($M)	Est. Date Oper.
Greensboro (GSO)	5L/23R parallel	57[1]	29[2]	$20	2010
	14/32 extension	29[2]	29[2]		
Greer (GSP)	3R/21L parallel	57[1]	29[2]	$25	1999
	3L/21R extension	**29[2]**	**29[2]**	**$12**	**1995**
Harlingen (HRL)	13L/31R parallel	57[7]	29[2]	$5	1995-2000
	13/31 extension	29[2]	29[2]	$7	1995
Houston (IAH)	8L/26R parallel	86[3]	57[1]	$44	1999
	9R/27L parallel	**57[1]**	**57[1]**	**$44**	**2002**
	14R/32L extension	57[1]	57[1]	$8	1997
Indianapolis (IND)	5L/23R replacement	57[1]	42[4]	$42	1996
Islip (ISP)	6/24 extension	29[2]	29[2]		
Jacksonville (JAX)	**7R/25L parallel**	**57[1]**	**29[2]**	**$37**	
	7L/25R extension	29[2]	29[2]	$10	1995
Kansas City (MCI)	1R/19L parallel	57[1]	29[2]	$46	1992
	9R/27L parallel	29[2]	29[2]	$60	1999
	18L/36R parallel	**57[1]**	**29[2]**	**$65**	**2005**
	18R/36L parallel	86[3]	29[2]	$90	2015
Las Vegas (LAS)	1L/19R extension	29[2]	29[2]		1997
Los Angeles (LAX)	6L/24R paved overrun	57[1]	57[1]	$4	1997
Louisville (SDF)	**17R/35L parallel**	**57[1]**	**29[2]**	**$125**	**1995**
	17L/35R parallel	29	29[2]	$125	1996
Lubbock (LBB)	8/26 extension	29[2]	29[2]	$6	1995
Memphis (MEM)	18L/36R parallel	57[7]	42[4]	$105	1995
	18L/36R extension	**42[4]**	**42[4]**	**$10**	**1997**
Midland (MAF)	10/28 extension	57[7]	29[2]	$11	1995
Milwaukee (MKE)	7R/25L parallel	57[7]	29[2]	$150	2003
	1L/19R extension	29[2]	29[2]	$13	1995
Minneapolis (MSP)	**4/22 extension**	**29[2]**	**29[2]**	**$15**	**1994**
Nashville (BNA)	2C/20C extension	57[1]	57[1]	$34	1994
	13/31 extension	57[1]	57[1]		1994
	2E/20E parallel	++	57[1]	$150	
	2R/20L extension	**57[1]**	**57[1]**		
	2L/20R extension	57[1]	57[1]		
New Orleans (MSY)	1L/19R parallel	57[1]	29[2]	$160	2000
	10L/28R parallel	29[2]	29[2]	$40	1995
	10S/28S parallel	**57[1]**	**29[2]**		**2000**
Norfolk (ORF)	5R/23L parallel	29[2]	29[2]	$13	1994
	14/32 extension	29[2]	29[2]	$2	1996
Oakland (OAK)	11R/29L parallel	++	29[2]	$143	2020

Table 2-5. New and Extended Runways Planned or Proposed[+]

Airport	Runway	IFR Capacity (ARR/HR)[†] New Config.	Current Best	Est. Cost ($M)	Est. Date Oper.
Oklahoma City (OKC)	17L/35R extension	57[1]	57[1]	$24	2001
	17R/35L extension	57[1]	57[1]	$20	2001
	17/35 parallel	57[1]	57[1]	$55	2001
Orlando (MCO)	**17L/35R 4th parallel**	**86[3]**	**57[1]**	**$100**	**1997**
Philadelphia (PHL)	8/26 parallel-commuter	57[1]	57[7]	$169	1997
	17/35 extension	57[1]	57[7]	$17	
	relocate 9L/27R	57[1]	57[7]	$109	1997
Phoenix (PHX)	**8S/26S 3rd parallel**	**57[1]**	**29[2]**	**$88**	**1995**
Pittsburgh (PIT)	10C/28C extension	57[1]	57[1]	$10	1995
	4th parallel 10/28	86[3]	57[1]	$100	1996
	14R/32L		57[1]	$100	1995
Raleigh-Durham (RDU)	**Relocate 5R/23L**	**57[1]**	**42[4]**	**$37**	**1996**
	5W/23W	++	42[4]	$75	
	5E/23E	++	42[4]	$75	
Rochester (ROC)	4R/22L parallel	++	29[2]	$5	1997
	4/22 extension	**57[7]**	**29[2]**	**$1**	**1996**
	10/28 extension	57[7]	29[2]	$2	1994
St. Louis (STL)	12L/30R	++	29[2]	$95	
Salt Lake City (SLC)	16/34 west parallel	71[6]	42[4]	$235	1995
San Jose (SJC)	**12L/30R extension**	**29[2]**	**29[2]**	**$8**	**1993**
Sarasota-Bradenton (SRQ)	14L/32R parallel	29[2]	29[2]	$10	1996
	14/32 extension	29[2]	29[2]	$4.5	1995
Savannah (SAV)	9L/27R parallel	57[1]	29[2]	$20	2010
	9R/27L extension	**29[2]**	**29[2]**	**$7**	**1997**
	18/36 extension	29[2]	29[2]	$4	1995
Seattle-Tacoma (SEA)	16W/34W parallel	42[4]	29[2]	$300	2005
Spokane (GEG)	3L/21R	57[1]	29[2]	$11	2000
Syracuse (SYR)	**10L/28R**	**57[1]**	**29[2]**	**$5**	**1997**
Tampa (TPA)	18R/36L 3rd parallel	57[1]	57[1]	$53	1997
Tucson (TUS)	11R/29L parallel	29[2]	29[2]	$143	1997
Tulsa (TUL)	17E/35E parallel	86[3]	57[1]	$100	1998
Washington (IAD)	**1W/19W parallel**	**86[3]**	**57[1]**	**$60**	**2000**
	12/30 parallel	57[1]	57[1]		
	12/30 extension	57[1]	57[1]	$12	1992
West Palm Beach (PBI)	9L/27R extension	29[2]	29[2]	$5	1998
	13/31 extension	**29[2]**	**29[2]**	**$5**	**1995**

Total Available Estimated Costs of Construction: $7.8-7.9 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 Denver airport, $2,972 million. Does not include the cost of projects completed in 1991.

† Estimates of generalized hourly IFR arrival capacity increases are included in Table 2–5. These values have been updated from those originally reported in a 1987 report. The new numbers reflect the approval of 2.5 {for wet runways inside 10 nm}, 3, 4, 5, and 6 nm in-trail separations and 1.5 nm diagonal separation for dependent parallel arrivals. The updated IFR arrival capacity of any single runway that can be operated independently is 29 arrivals per hour (rounded up from 28.5); dependent parallel runways, 42 arrivals per hour; and independent parallels, 57 arrivals per hour (2 times a single runway, 28.5). 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 aircraft fleet mixes) can result in differences from these estimates.

Endnotes

1. Independent parallel approaches [57 IFR arrivals per hour].
2. Single runway approaches [29 IFR arrivals per hour {rounded up from 28.5}].
3. Triple approaches (currently not authorized) [86 IFR arrivals per hour {rounded up from 85.5}].
4. Dependent parallel approaches [42 IFR arrivals per hour].
5. Triple approaches with parallel and converging pairs may permit more than 57 IFR arrivals if procedures are developed.
6. Triple parallel approaches with dependent and independent pairs (currently not authorized) [71 IFR arrivals per hour {This is a rough estimate, obtained by adding 42 & 29 as explained above}].
7. Converging IFR approaches to minima higher than Category (CAT) I ILS [57 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 [114 IFR arrivals per hour].
11. Independent parallel approaches (3,400 ft. to 4,300 ft.) [57 IFR arrivals per hour].

Chapter 3

New Instrument Approach Procedures

Substantial increases in capacity can best be achieved through construction of new airports and new runways at existing airports. However, large projects like these require extensive long-term planning. In an effort to meet the increasing demands on the airport and airspace system in the near-term, the FAA has initiated improvements in air traffic control procedures designed to increase utilization of multiple runways and provide additional capacity at existing airports, while maintaining the current level of safety in aircraft operations.

In FY91, 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 this delay could be eliminated if the approach procedures used during instrument meteorological conditions (IMC) were closer to those observed during visual meteorological conditions (VMC).

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] "Independent" procedures are so called because aircraft arriving along one flight path do not affect arrivals along another flight path. "Dependent" procedures place restrictions on the various arrival streams of aircraft, because their proximity to each other has the potential to cause interference. The testing of these new procedures has been thorough, involving various validation methods, including real-time simulations and live demonstrations at selected airports.

In FY91, more than half of all delays were attributed to adverse weather conditions.

Much of this delay could be eliminated if the approach procedures used during IMC were closer to those observed during VMC.

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 29 arrivals per hour. Hence, two simultaneous approach streams, when operating independently of each other, double arrival capacity to 57 per hour. Three streams would allow 86 hourly arrivals, and so on. Such procedures are called "independent," because the arriving 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 29 and 57 arrivals. In the case of dependent triple streams, the arrival capacity is somewhere between 57 and 86, depending on airport runway configurations.

In the past year, several new national standards have been published that incorporate some of these capacity-enhancing approach procedures.

In the past year, several new national standards have been published that incorporate some of these capacity-enhancing approach procedures.

- Simultaneous (independent) parallel approaches using the Precision Runway Monitor (PRM) to runways separated by 3,400 to 4,300 feet — published November 1991.
- Improved dependent parallel approaches to runways separated by 2,500 to 4,299 feet that reduce the required diagonal separation from 2.0 to 1.5 nm — published June 1992.
- Reduced longitudinal separation on wet runways from 3 to 2.5 nm inside the final approach fix (FAF) — published June 1992.
- Dependent converging instrument approaches using the Converging Runway Display Aid (CRDA) — published November 1992. The ARTS IIIA CRDA software upgrade is available now for installation.
- Simultaneous operations on wet intersecting runways — scheduled for publication late 1993.
- Use of Flight Management System (FMS) computers to transition aircraft from the en route phase of flight to existing charted visual flight procedures (CVFP) and ILS approaches — published December 1992.

The following sections present a brief description of these recently approved procedures and of the most promising approach concepts being developed, including 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 3.8), 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 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.

Better understanding of the properties of wake vortices and of aircraft response to them will result in reduced separation standards based on measured data.

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.

3.2 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 (FAF). The separation distances vary from 2.5 to 6 nm, depending on the relative sizes of the leading and trailing aircraft. The minimum separations are intended to protect the trailing 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.

In 1986, the FAA implemented a procedure that allowed a reduction of separation inside the FAF from 3 nm to 2.5 nm, provided that the runways were clear and dry and the runway occupancy time was 50 seconds or less. An effort was then undertaken to determine if the procedure could be used for arrivals on wet runways. Studies conducted in 1989 at Atlanta Hartsfield International Airport and Dallas-Fort Worth International Airport indicated that wet runway occupancy times are the same or less than dry runway occupancy times.

The FAA then initiated demonstrations at selected airports to determine the feasibility of allowing reduced longitudinal separation inside the FAF when runways are wet. Due to the success of the demonstrations, the FAA amended the national standard in June 1992 to allow reduced in-trail separation of 2.5 nm when runways are wet, and this new minimum separation was extended to a point 10 nm from the airport. The average capacity gain expected from this improvement is 3 to 5 arrivals per hour.

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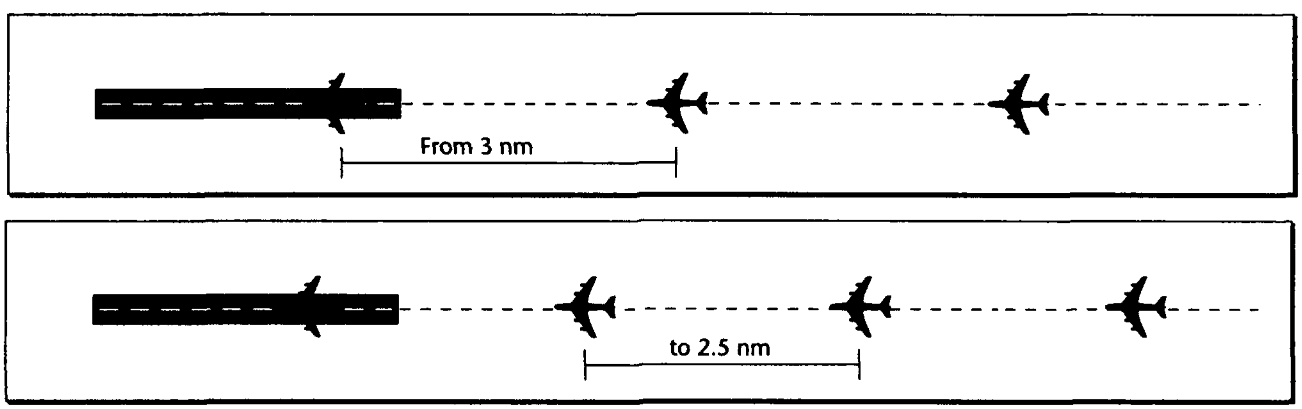
Improved Longitudinal Spacing on Wet Runways



3.3 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. The FAA recently approved a procedure to increase the capacity of dependent runway configurations by reducing the required diagonal separations between aircraft on adjacent runways.

The FAA is actively pursuing ways to reduce the runway spacing required for independent operations to as low as 2,500 feet.

3.3.1 Independent Parallel Instrument Approaches Using Current Radar Systems

Since 1962, the FAA has authorized independent (simultaneous) instrument approaches to dual runways, doubling the arrival capacity of an airport in IMC. Initially, the spacing between the parallel runways was required to be at least 5,000 feet, but, in 1974, this was reduced to 4,300 feet. More than 15 U.S. airports are currently authorized to operate such independent parallel instrument approaches.

Several airports today would benefit from the additional capacity that would result from simultaneous approaches to three or more runways. The use of t iple parallel approaches in IFR conditions would result in a 50 percent increase in arrival capacity, and quadruple parallel approaches, a 100 percent increase compared to dual independent approaches.

The use of triple parallel approaches in IFR conditions would result in a 50 percent increase in arrival capacity, and quadruple parallel approaches, a 100 percent increase compared to dual independent approaches.

Dallas-Fort Worth and the new Denver International Airport are planning to build parallel runways that will give them the capability to conduct triple and quadruple independent parallel approaches. Simulations at the FAA Technical Center in 1988 and 1989 resulted in site-specific 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 in 1988 and 1989 resulted in site-specific approval of triple and quadruple simultaneous parallel approaches at Dallas-Fort Worth.

The success of the Dallas-Fort Worth simulations has led to further simulations to develop generic procedures and standards to allow independent parallel approaches at the closest runway spacing at levels of safety equivalent to or better than current approaches. National standards for triple and quadruple independent parallel approaches are under development. These standards are expected to require a minimum of 5,000 feet between the runways when using the current radar systems. New technology, such as high-update-rate radars or improved controller displays, will allow reduced runway spacings. Such configurations are also being simulated at the FAA Technical Center.

At some airports, combinations of independent parallel and converging instrument approaches could be used to implement triple and quadruple independent approaches with multiple departure streams. Dallas-Fort Worth has an existing configuration for such triple approaches, using two parallel and one converging runways, as does Chicago O'Hare. Work is currently underway to develop procedures to optimize the use of such runways using the current radar systems.

3.3.2 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 29 to 57. If the runways are spaced closer than 4,300 feet, independent approaches are made possible by the use of the Precision Runway Monitor (PRM) (described in Section 5.2.2) 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 were published in 1991. The PRM will be developed into a production system to support these approaches. A contract was let in the spring of 1992 for procurement of five electronically scanned (E-Scan) PRM antenna systems. Delivery of these systems is planned for 1994.

The FAA conducted simulations at the FAA Technical Center of independent approaches down to 3,000 feet of runway spacing using the new technology. These simulations will 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

Demonstrations conducted at Memphis (MEM) and Raleigh-Durham (RDU) showed that independent parallel approaches to runways 3,400 feet apart are possible using the Precision Runway Monitor (PRM).

Procedures to allow independent approaches to parallel runways 3,400 feet apart using the PRM were published in 1991.

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.

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

Runway Separation of 3,400 to 4,299 ft.†	
Atlanta (SS)*	Phoenix
Baltimore (SS)*	Pittsburgh**
Detroit	Raleigh-Durham (SS)
Ft. Lauderdale	Salt Lake City
Memphis (SS)	Tampa
Milwaukee	
Runway Separation of 3,000 to 3,399 ft.†	
Denver (DIA)*	New York Kennedy
Harlingen	Philadelphia*
Long Beach	Portland
Minneapolis-St. Paul (SS)***	
Runway Separation of 2,500 to 2,999 ft.†	
Columbus	Indianapolis
Dallas-Love Field	

† - Some of the airports in each 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.

* - Applicable upon construction of new runway(s).

** - Runways are 5,540 ft. apart; a new runway is planned that will create a parallel set separated by 3,100 ft. or 4,300 ft.

*** - Runways at MSP are 3,380 ft. apart; a waiver is required for PRM.

SS - Selected site.

3.3.3 Independent Parallel Instrument Approaches Using Final Monitor Aid (FMA)

At some airports, independent parallel instrument approaches to runways separated by less than the current standard could be used to implement triple or quadruple arrival streams with multiple departure streams. This concept applies primarily to airports that already have independent or dependent arrival streams to parallel runways. Additional parallel arrival streams would provide an increase of 50 percent for triples and 100 percent for quadruples compared to dual independent approaches.

National standards for triple and quadruple independent approaches are currently under development. The success of the Dallas-Fort Worth simulations of simultaneous independent parallel instrument approaches and the resulting procedures established have led to further simulations to develop generic procedures for independent parallel approaches. The goal is to develop procedures and standards that allow independent parallel approaches at the closest runway spacing at levels of safety equivalent to or better than current procedures.

As a part of the development of national standards, the FAA is also testing the effect of using the Final Monitor Aid (FMA) in independent approaches. The FMA consists of the color digital display and alert features of the PRM system, but it does not include the high-update-rate radar sensor. In these tests, the FMA is combined with existing or planned sensors that have a one to two milliradian accuracy and update rates of 4.8 seconds, consistent with current sensors. Use of the FMA with these existing sensors could improve the controller's ability to monitor parallel approaches at spacings less than the current standard without a PRM system (especially when compared to current analog displays), without the additional expense of the high-update-rate radar.

Use of the FMA with existing sensors could improve the controller's ability to monitor parallel approaches at spacings less than the current standard without a PRM system.

3.3.4 Dependent Parallel Instrument Approaches

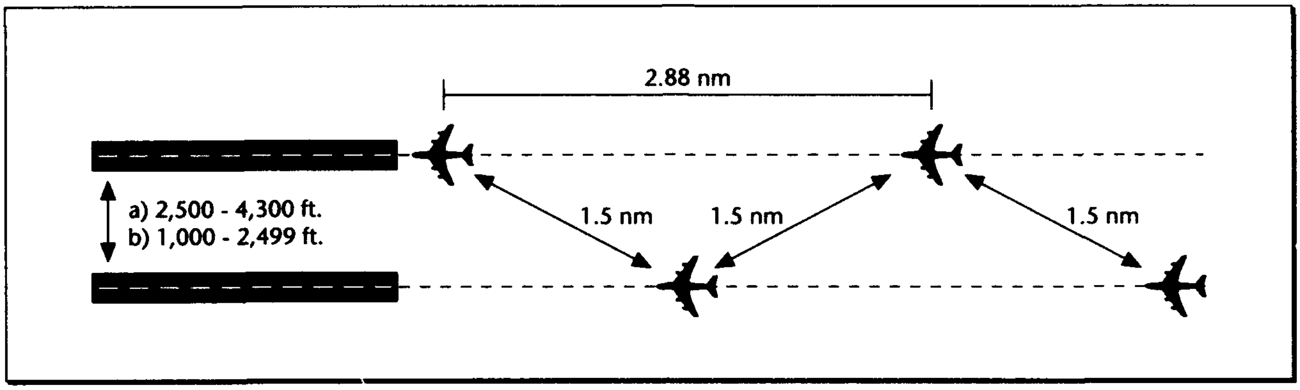
Rules for dependent IFR operations were revised in June 1992. They now require a diagonal separation between aircraft on adjacent approaches of at least 1.5 nm, instead of the previous 2.0 nm, for parallel runways 2,500 to 4,299 feet apart. (Runways spaced 4,300 feet or more apart still require a diagonal separation of 2.0 nm.) This change was approved as a result of successful demonstration programs carried out in 1990 and 1991 showing that this diagonal separation can be safely changed for runways at least

Rules for dependent IFR operations were revised in June 1992. They now require a diagonal separation between aircraft on adjacent approaches of at least 1.5 nm, instead of the previous 2.0 nm, for parallel runways 2,500 to 4,299 feet apart.

2,500 feet apart. This new spacing will permit approximately four additional arrivals per hour compared to 2.0 nm spacing.

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 of 1.5 and 2.0 nm between aircraft, respectively. Work is underway to validate these results and to determine whether such operations are feasible.

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



Dependent Parallel Instrument Approaches

3.4 Converging Approaches

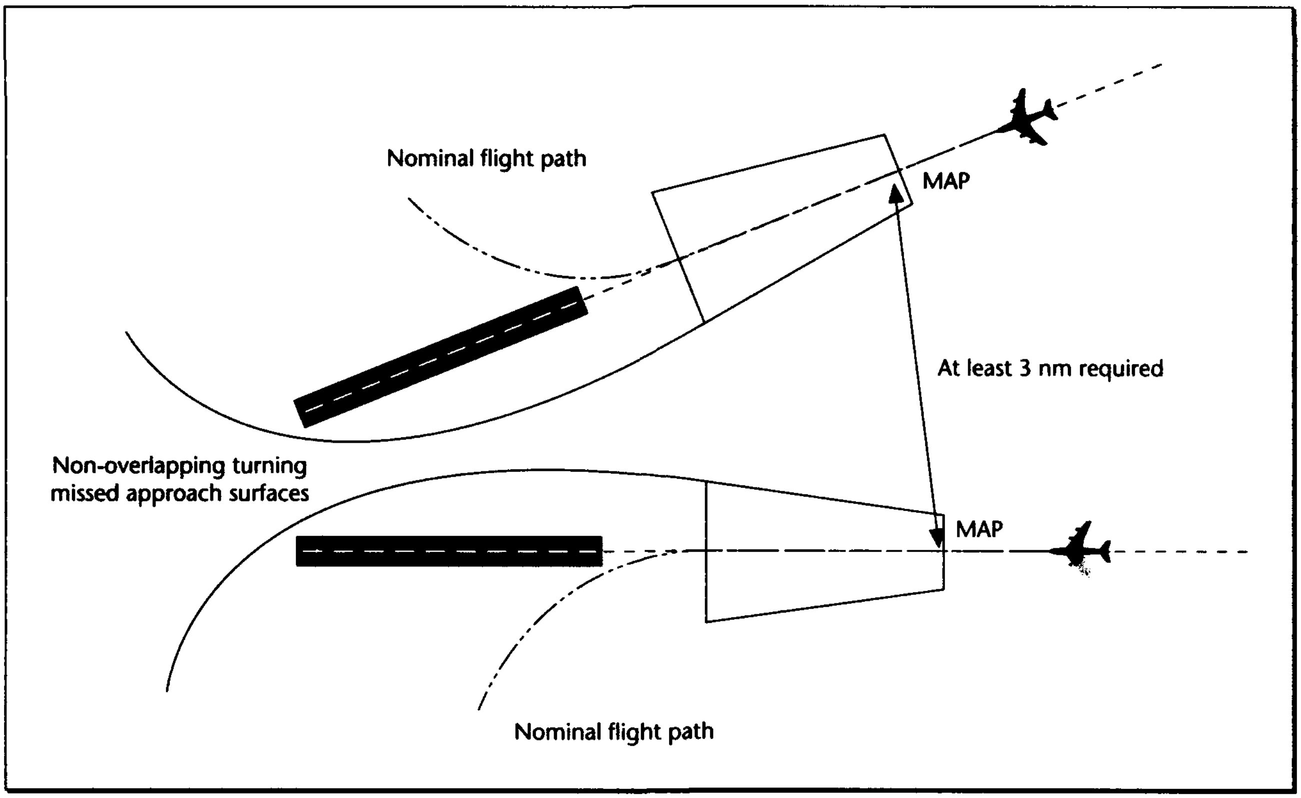
Converging runway approach improvements must take into account the wide variety of converging runway configurations that are in use. Numerous factors must be considered in designing approaches for a particular runway configuration. There is often a tradeoff between the minimum ceiling and visibility 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.

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

3.4.1 Independent Converging Instrument Approaches

Under VFR, it is common to use converging runways for independent streams of arriving aircraft. Because of the reduced ceilings and visibility associated with operations under IFR, the FAA, in 1986, established a procedure for conducting simultaneous instrument approaches to converging runways in instrument meteorological conditions (IMC).

This procedure uses non-overlapping Terminal Instrument Procedures (TERPS) obstacle-clearance surfaces as a means of separation for aircraft executing simultaneous missed approaches. It assumes that each of the aircraft executing a turning missed approach can keep its course within the limits of its respective TERPS obstacle-free surface. Each of the two TERPS surfaces is drawn starting from the respective missed approach point (MAP). This procedure also requires a 3 nm separation between the MAPs on each approach. "TERPS+3" (as this procedure is often called) requires no dependency between the two aircraft on the converging approaches. Hence, it is an independent approach procedure.



Independent Converging Instrument Approaches

In order to keep the two MAPs 3 nm apart and ensure non-overlapping TERPS surfaces, the MAPs have to be moved back, away from the runway thresholds. This increases the separation between the TERPS surfaces and results in higher decision heights.

One limitation of this procedure, however, is that many runway configurations require decision heights greater than 600 feet in order to satisfy the TERPS+3 criteria. This restricts the application of the procedure to operations close to the boundary between VFR and IFR. The procedure cannot be used if the converging runways intersect, unless controllers can establish visual separation and the ceiling and visibility are at or above 700 feet and 2 statute miles.

Recently, the FAA has been investigating the impact of the 3 nm separation and the possibility of reducing it.

3.4.2 Dependent Converging Instrument Approaches

Typically, independent converging IFR approaches using the TERPS+3 criteria are feasible only when ceilings are above 600 feet, depending upon runway geometry. As an alternative precision approach procedure, dependent IFR operations could be conducted to much lower minima, usually down to Category I, thus 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.

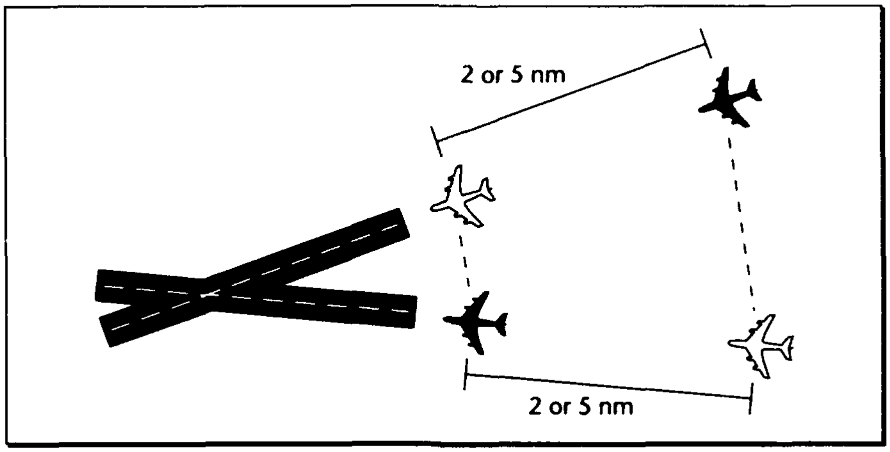
National standards for CRDA were published in November 1992. Capacity increases of approximately 10 arrivals per hour over single-runway operations are achievable using this controller automation aid.

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

A program was conducted 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 5.2.1.1), to maintain aircraft stagger on approach. National standards for this procedure were published in November 1992. It is estimated that capacity increases of approximately 10 arrivals per hour over single-runway operations are achievable with this procedure.

Airport surveys show that there is a high level of interest in the use of the CRDA at the 23 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, such as an improved noise impact, that might not be directly related to capacity.

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.



Dependent Converging Instrument Approaches Using CRDA

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	Minneapolis-St. Paul
Boston	New York Kennedy
Chicago Midway	New York La Guardia
Chicago O'Hare	Newark
Cleveland	Oakland
Dallas-Ft. Worth	Philadelphia
Dayton	Pittsburgh
Denver Stapleton	Portland
Houston Hobby	St. Louis
Memphis	Washington Dulles
Miami	Windsor Locks
Milwaukee	

3.4.3 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). 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 that differentiate between propeller and jet aircraft, between dry and wet runway conditions, and among different aircraft landing configurations.

Restructuring of the six SOIR groups to more closely match the performance characteristics of aircraft, differentiating between propeller and jet aircraft, between dry and wet runway conditions, and among different aircraft landing configurations, would improve capacity on hold short runways

Procedural development is underway, and a national standard for simultaneous operations on wet runways will be issued in late 1993. Sixty of the top 100 airports would be affected by these changes.

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, SOIRs 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 operations. Procedural development is underway, and a national standard for simultaneous operations on wet runways will be issued in late 1993. 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.

Currently, the runway length available on a hold-short runway is measured from the landing threshold to the intersecting runway edge along the landing runway edge closest to the intersecting runway or from the landing threshold to hold-short markings, lights, or signs when installed.

3.5 Simultaneous ILS and LDA Approaches

Procedures are being developed for instrument approaches to STL and SFO for parallel 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.

It is generally recognized that airport capacities in IMC are well below those achieved in 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 multiple approaches. For example, San Francisco International (SFO) uses 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 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 are as low as a 1,200 foot ceiling and 4 miles of visibility.

A similar procedure has been adopted at San Francisco for Runways 28R and 28L.

3.6 Flight Management System (FMS) Transition to Existing Approaches

The FAA has developed a capacity enhancement initiative to demonstrate the use of FMS computers as a means of transitioning aircraft from the en route phase of flight to existing charted visual flight procedures (CVFP) and instrument landing system (ILS) approaches. The demonstration phase at San Francisco International Airport has been completed, and the procedure is now being used on a regular basis.

FMS procedures are expected to allow the reduction of minimums for CVFP and offer alternative arrival paths for FMS-equipped aircraft.

FMS procedures are expected to allow the reduction of minimums for CVFP and offer alternative arrival paths for FMS-equipped aircraft. Implementation of FMS-CVFP is being expanded to include other airports that can benefit from FMS-assisted flight path navigation. National standards were issued in late 1992.

3.7 Independent and Dependent Approaches for Multiple Parallel Runways

Procedures for conducting independent and dependent parallel approaches to three or more runways simultaneously do not currently exist. The result is that some existing airport configurations are not as efficient as they could be and some future airport designs become less attractive.

Two runways whose centerlines are spaced 4,300 feet or more apart qualify for the use of independent approach procedures. However, a third parallel runway whose spacing is less than 4,300 feet does not qualify for the application of dependent parallel approach criteria. As such, controllers and pilots are unable to take advantage of a dependent approach that would allow them to support a third arrival stream and significantly increase the capacity of the airport.

The focus of this long-term effort is to allow a reduction to 1.5 nm diagonal spacing between aircraft operating on adjacent runways when centerline spacings are as close as 2,500 feet. This effort is particularly important to the planning and development of additional runways with reduced centerline spacings and offers the possibility of a viable alternative to siting and building completely new airports.

3.8 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 numbers which are reasonable approximations of real capacity, used for comparison only. The objective of the table is to provide initial information on the applicability of approach procedures being developed by the FAA.

An asterisk (*) indicates that the proposed approach procedure in the column in question is applicable at a given airport, 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 "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, and some 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				
			Dependent Parallel	Independent Parallel	CRDA	TERPS+3	Triples
Agana (Guam)	NGM	29 (S)					
Albany	ALB	29 (S)			34		
Albuquerque	ABQ	29 (S)					
Anchorage	ANC	29 (S)				57	
Atlanta	ATL	57 (IP)	*	*p			71p
Austin (new airport)	BSM	57 (IP)					
Baltimore	BWI	29 (S)		57p	*		
Birmingham	BHM	29 (S)					
Boise	BOI	29 (S)					
Boston	BOS	29 (S)	42		*		
Buffalo	BUF	29 (S)			34		
Burbank	BUR	29 (S)			34		
Charleston	CHS	29 (S)			34		
Charlotte	CLT	57 (IP)			*	*	86p
Chicago	MDW	29 (S)					
Chicago	ORD	57 (IP)				*	86
Cleveland	CLE	29 (S)			34		
Colorado Springs	COS	29 (S)		*p	*	57	
Columbia	CAE	29 (S)			34		
Columbus	CMH	42 (DP)		*		57	
Dallas	DAL	42 (DP)		57			
Dallas-Fort Worth	DFW	57 (IP)				*	86p
Dayton	DAY	57 (IP)			*	*	
Denver (new airport)	DIA	57 (IP)	*				86
Des Moines	DSM	29 (S)			34		
Detroit	DTW	57 (IP)	*	*		*	71p
El Paso	ELP	29 (S)	*			57	
Fort Lauderdale	FLL	29 (S)		57	*		
Fort Myers	RSW	29 (S)		57p			
Grand Rapids	GRR	29 (S)		57p			
Greensboro	GSO	29 (S)		57p	*		
Greer	GSP	29 (S)		57p			
Harlingen	HRL	29 (S)		*	*	57	
Hilo	ITO	29 (S)			34		
Honolulu	HNL	57 (IP)			*		
Houston Hobby	HOU	29 (S)			34		
Houston Intercont'l	IAH	57 (IP)				*	86p
Indianapolis	IND	42 (DP)			*		

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: Dependent Parallel	Independent Parallel	CRDA	TERPS+3	Triples
Islip	ISP	29 (S)			34		
Jacksonville	JAX	29 (S)				57	
Kahului	OGG	29 (S)			34		
Kailua-Kona	KOA	29 (S)					
Kansas City	MCI	29 (S)		*p		57	
Knoxville	TYS	29 (S)	42				
Las Vegas	LAS	29 (S)			34		
Lihue	LIH	29 (S)			*	57	
Little Rock	LIT	57 (IP)					
Long Beach	LGB	29 (S)	*	57	*		
Los Angeles	LAX	57 (IP)					
Louisville	SDF	29 (S)		57p	*		
Lubbock	LBB	29 (S)					
Memphis	MEM	42 (DP)		*	*	57	
Miami	MIA	57 (IP)			*	*	
Midland	MAF	29 (S)	*		*	57	
Milwaukee	MKE	29 (S)	*	*	*	57	
Minneapolis-St. Paul	MSP	42 (DP)		57	*		
Nashville	BNA	57 (IP)	*		*		
New Orleans	MSY	29 (S)		*p		57	
New York Kennedy	JFK	42 (DP)		*	*	57	
New York La Guardia	LGA	29 (S)			34		
Newark	EWR	29 (S)			*	57	
Norfolk	ORF	29 (S)			34		
Oakland	OAK	29 (S)	*			57	
Oklahoma City	OKC	57 (IP)				*	
Omaha	OMA	29 (S)	42		*		
Ontario	ONT	29 (S)					
Orlando	MCO	57 (IP)	*				86p
Philadelphia	PHL	57 (IC)	*	*p	*		
Phoenix	PHX	29 (S)		57			
Pittsburgh	PIT	57 (IP)	*	*	*		71p
Portland, OR	PDX	42 (DP)		57	*		
Portland, ME	PWM	29 (S)			34		
Providence	PVD	29 (S)	42		*		
Raleigh-Durham	RDU	42 (DP)		*	*		71p
Reno	RNO	29 (S)			34		
Richmond	RIC	29 (S)				57	

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: Dependent Parallel	Independent Parallel	CRDA	TERPS+3	Triples
Rochester	ROC	29 (S)			*	57	
Sacramento	SMF	57 (IP)					
Salt Lake City	SLC	42 (DP)		*		*	71p
San Antonio	**SAT**	**29 (S)**			*	**57**	
San Diego	SAN	29 (S)					
San Francisco	SFO	29 (S)			34		
San Jose	SJC	29 (S)					
San Juan	**SJU**	**29 (S)**				**57**	
Santa Ana	SNA	29 (S)					
Sarasota-Bradenton	SRQ	29 (S)					
Savannah	SAV	29 (S)		57p	*		
Seattle-Tacoma	**SEA**	**29 (S)**	**42p**				
Spokane	GEG	29 (S)		57p			
St. Louis	STL	29 (S)	*		*	57	
Syracuse	SYR	29 (S)		57p	*		
Tampa	**TPA**	**57 (IP)**		*	*	*	
Tucson	TUS	29 (S)					
Tulsa	TUL	57 (IP)			*		86p
Washington National	DCA	29 (S)			34		
Washington Dulles	**IAD**	**57 (IP)**				*	**86p**
West Palm Beach	PBI	29 (S)			34		
Wichita	ICT	57 (IP)				*	
Windsor Locks	BDL	29 (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:

   DC - Dependent Converging Instrument Approaches

   DP - Dependent Parallel runways

   IC - Independent Converging runways

   IP - Independent Parallel runways

   S - Single runway

- 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.

Chapter 4

Airspace Development

Airspace design requires extensive coordination between air traffic controllers and airspace planners, and several efforts are underway to improve the efficiency of the airspace system. Airspace Capacity Studies, for example, have been completed or are underway at 20 major areas in the United States.

Airspace Capacity Studies, a joint effort among the Office of System Capacity and Requirements, Air Traffic, Regional Headquarters, have been completed or are underway at 20 major areas in the United States.

These Airspace Capacity Studies are a joint effort among the Office of System Capacity and Requirements, Air Traffic, Regional Headquarters, and a contractor that conducts the simulation modeling. Air Traffic, normally at the Regional level, develops the alternatives that will be tested in the simulation runs. These studies sometimes reflect community involvement and FAA's responsiveness to community-developed alternatives. Most of the studies take a "systematic" approach, examining the proposed alternatives in an ARTCC-wide context.

A variety of computer models have been used to analyze a broad spectrum of capacity solutions. Since 1986, the Office of System Capacity and Requirements has been applying SIMMOD, the FAA's Airport and Airspace Simulation 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. 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 redesign, 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 to capacity and delay problems have generally involved additional runways, but efficiencies have also been identified in airspace design. At Dallas-Ft. Worth, for example, effects of the Metroplex plan (see Section 4.4) were studied both with and without new runway construction. Results indicated an immediate savings from airspace changes alone.

Airspace Studies serve to illustrate the "system" nature of the delay problem and to emphasize the need for an integrated approach that develops capacity improvements throughout the aviation system.

Table 4-1 summarizes the airspace studies discussed in this chapter by listing the generalized categories of the various alternatives studied. The majority of the studies considered new arrival and departure routes, modifications to ARTCC traffic, and redefinition of TRACON boundaries among their alternatives. Two studies, at Denver and Houston-Austin, analyzed a new airport with its associated airspace, while three studies, at Kansas City, Dallas-Ft.

Worth, and Chicago, analyzed new runways at existing airports. Four of the studies, Houston-Austin, Oakland, Dallas-Ft. Worth, and Los Angeles, modeled military traffic, restricted airspace, special use airspace, or the interactions of a military airfield with the civilian airport. This summary serves to illustrate the "system" nature of the delay problem and to emphasize the need for an integrated approach that develops capacity improvements throughout the aviation system.

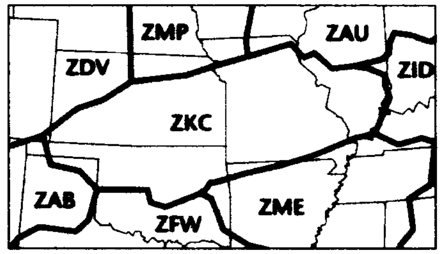
The FAA plans to institutionalize these airspace modeling activities by expanding the capability of its Technical Center in Atlantic City, N.J. Under the guidance of a policy level work group in Washington, the Technical Center, and soon the National Simulation Capability, will provide the FAA with the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

What follows are excerpts from the airspace studies completed to date. It should be noted that these studies only considered the technical and operational feasibility of the proposed alternatives. Environmental, socioeconomic, and political issues will be addressed in future planning studies.

Table 4-1. Summary of Airspace Improvement Alternatives Analyzed.

Studied Alternatives / Airspace Regions	Chicago	Dallas-Ft. Worth	Denver	Expanded East Coast Plan	Houston-Austin	Kansas City	Los Angeles	Oakland
Relocating arrival fixes	√	√				√		
New arrival routes		√	√	√	√	√		√
New departure routes	√		√	√	√	√	√	√
Modifications to ARTCC traffic		√		√	√	√	√	√
New airport			√		√			
Hub/non-hub alternatives					√			
Change in metering restrictions	√			√				√
Redifining TRACON boundaries		√		√	√		√	√
Military traffic considered		√			√		√	√
New runways at existing airports	√	√				√		
Specific modeling of 2 or more airports for interactions analysis	√	√				√		

4.1 Kansas City Area Airspace Project[1,2,3]



The purpose of the Kansas City Airspace Capacity Project was to evaluate proposed operational alternatives in the St. Louis and Kansas City TRACONs and Kansas City ARTCC airspaces. The Kansas City Airspace Capacity Project consisted of three simulation analyses. Results of each were analyzed with respect to increasing capacity, reducing delay, and improving efficiency.

4.1.1 St. Louis TRACON Operational Alternatives

The first simulation analysis considered delay and capacity impacts at Lambert-St. Louis International Airport (STL) associated with relocating arrival fixes based on a four cornerpost VOR concept, implementing dual arrival routes over the cornerposts, and developing new departure routes.

Two options for the St. Louis TRACON were studied. The first alternative considered a dual arrival route system with no other modifications to the existing TRACON or Kansas City ARTCC airspace and traffic systems.

The second alternative considered a four cornerpost VOR system, relocating arrival fixes, providing dual arrival routes, adding new departure gates for St. Louis TRACON, and making significant Kansas City ARTCC routing changes. Greater delay savings were realized from the second alternative than from the first as a result of the proposed airspace changes. These proposed changes reduce restrictions on aircraft flowing through the arrival fixes and increase the number of departure routes available, thus making use of previously unused runway capacity at STL due to increased airspace capacity in the St. Louis TRACON.

A recommendation of the study was that runway capacity expansion at STL should be considered if the potential benefits of a new airspace network are to be realized during IFR conditions.

The Lambert-St. Louis International Airport Capacity Enhancement Plan, completed in 1988, addressed this issue. The goals of the study were to increase IFR capacity at the airport to equal VFR capacity. The recommendations of the St. Louis Task Force Study are listed in Appendix C.

1. Kansas City Airspace Capacity Project (May 1991)
2. Lambert-St. Louis International Airport Capacity Enhancement Plan (June 1988)
3. Kansas City International Airport Capacity Plan (September 1990)

Recommendations for St. Louis designed for airfield improvement included: constructing a new runway parallel to Runway 12L/30R, constructing angled exits on Runway 12L/30R, and constructing three major taxiway extensions parallel to Runway pairs 12R/30L and 12L/30R and Runway 6/24.

Facility and equipment improvements recommended included: installing a CAT III ILS system on Runways 12L and 30R, installing a precision approach system on Runway 6 to lower landing minimums on Runway 6 and also to support approaches during IFR weather conditions to Runways 30R and 30L, and installing runway alignment indicator lights (RAILs) and centerline lights on Runway 24 to lower approach minimums and support converging approaches during IFR to Runways 24, 30L, and 30R.

4.1.2 Kansas City TRACON Operational Alternatives

The second simulation analysis evaluated proposed airport/airspace improvements designed to increase capacity at Kansas City International Airport (MCI). This analysis considered three alternatives. The first alternative added a new north/south parallel runway at MCI. The second alternative analyzed a four cornerpost VOR system, relocated arrival fixes, and provided dual arrival routes for MCI. The third alternative included the four cornerpost VOR system, relocated the arrival fixes, added dual arrival routes, and added a new north/south parallel runway at MCI.

Simulation results of the second alternative showed that there would be daily savings in delay gained by using the proposed four cornerpost VOR system. The delay savings, though, are only realized during VFR weather conditions.

The third alternative resulted in added delay savings for both VFR and IFR weather conditions. The capacity increases afforded by dual runways and dual arrival routes significantly increased airfield capacity, especially at the 200 percent traffic demand level.

Runway capacity expansion at Kansas City International Airport is to be strongly considered and was a major objective of the Kansas City Capacity Design Team in its report of September 1990. Recommendations that directly relate to increasing runway capacity under IFR weather conditions are listed in Appendix C.

Recommendations for Kansas City designed for airfield improvement included: independent 9,500 foot parallel Runway 1R/19L, independent 10,000 foot parallel Runway 18R/36L, high speed exits for Runways 1L and 19R, and high speed exits for Runway 27R.

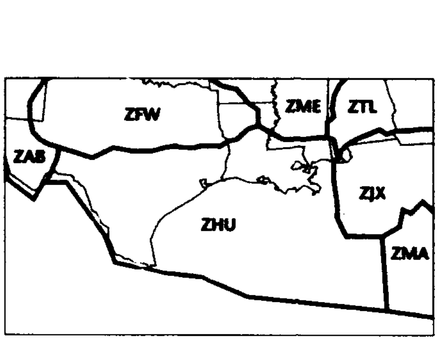
Facility and equipment improvements recommended included: installing a CAT III ILS for Runway 1R, installing a CAT I ILS for Runway 19L to allow for simultaneous approaches to Runways 19L and 19R, installing an ILS/MLS for Runway 27R to provide precision approaches and allow for simultaneous converging approaches to Runway 27R and north/south runways in IFR without the application of visual separation, and upgrading Runway 1L ILS to CAT III.

4.1.3 Kansas City En Route Airspace Alternatives

The third simulation analyzed modifications of Kansas City ARTCC traffic flows to align with the St. Louis and Kansas City TRACON arrival and departure changes made in the first two simulations, rerouted overflight traffic based on specific destination criteria, and raised the ceiling on low altitude sectors from FL230 to FL270.

Simulation results show that raising the low altitude ceilings to FL270 would provide immediate delay savings at the baseline demand level and as overflight traffic increases within Kansas City ARTCC. Higher ceilings for low altitude sectors should provide a more balanced distribution of traffic by sector.

4.2 Houston/Austin Airspace Project[4]



The purpose of the Houston/Austin Airspace Capacity Project was to support the FAA Southwest Region in their planning efforts and quantitatively evaluate the impacts of proposed operational alternatives in the Houston and Fort Worth Air Route Traffic Control Centers (ARTCCs), terminal airspace operations in the Austin Terminal Radar Approach Control (TRACON), and airfield operations at the existing Robert Mueller Airport and at the proposed new Manor Airport in Austin.

The Austin TRACON provides air traffic control services in the terminal airspace surrounding Robert Mueller Airport. Austin TRACON airspace has Robert Mueller Airport located near the center and Bergstrom Air Force Base located southeast of Robert Mueller Airport. In addition to Robert Mueller Airport, the primary airport, there are 11 satellite airports within the Austin TRACON.

4. Houston/Austin Airspace Capacity Project (May 1991)

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

4.2.1 New Austin Airport/Airspace System

The runway system for the existing Austin Municipal Airport, Robert Mueller Airport, consists of three runways: two parallel diagonal runways and a north/south runway. The existing airspace system uses a combination of radar vectors and preferential arrival routes for arriving aircraft bound for airports within the Austin terminal area. In addition, an approach is available for Bergstrom AFB high performance jet arrivals. Aircraft depart the Austin TRACON airspace via radar vectors, preferential departure routes, or the jet airway structure.

The proposed system incorporates several major airspace and procedural modifications. The new airport will be located near the town of Manor, which is approximately 11 miles northeast of Mueller Airport, around which the existing airspace and procedures were designed. The new proposed Manor Airport consists of two parallel air carrier runways, spaced 5,800 feet apart. The spacing between the two runways allows simultaneous independent IFR approaches. In order to accommodate the new airport's traffic patterns and extended final approach courses, Austin TRACON airspace will be expanded 5 miles northward and eastward to a point approximately 35 miles east of the Manor Airport.

A modified four cornerpost system is proposed for arrivals, providing for segregated traffic, both vertically and laterally separated on parallel arrival routes from three directions. The departure route design is based on major traffic flows allowing for segregation by destination. The plan allows for multiple departure routes diverging at or near the airport resulting in an increased departure capacity. With about 70 percent of Bergstrom Air Force Base traffic operating to the west, a separate departure route dedicated to military operations was created, thereby segregating very high performance aircraft from other types.

Traffic demand schedules were generated for two scenarios. The first projected traffic growth without the development of an airline hub at the new Manor Airport, and the second scenario projected traffic growth with the development of an airline hub. Each scenario assumed little or no change in general aviation and military operations, moderate growth in commuter operations, and significant growth in air carrier operations.

Weather conditions strongly influence the capacity at Mueller Airport due to impacts on runway utilization and dependencies, procedures, and separation criteria. Under IFR, capacity decreases at both the existing and proposed airports primarily because arriving aircraft must conduct instrument approaches, thus increasing separation requirements for arriving aircraft and between successive departure operations. At the existing airport, decreases result due to the inability to run simultaneous approaches to the closely-spaced parallel runways and to the dependency of departure operations from the two runways. In addition, converging approaches at the existing airport are impractical. At the new proposed Manor Airport, on the other hand, the runways are spaced far enough apart that there is no dependency between departure operations, and criteria for simultaneous ILS approaches are met, resulting in a higher capacity operation than that at the existing airport.

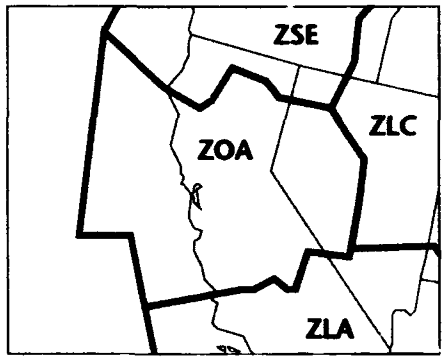
Simulation results indicate that airspace restructuring and the construction of a new airport at Austin with two new independent air carrier runways would result in significant increased capacity and cost savings when compared to the existing airfield and airspace structure. Delay and cost savings would be realized for both the hub and non-hub projections in traffic growth.

4.2.2 East Coast Traffic Rerouting Option

The second simulation analysis evaluated proposed rerouting of specific Austin-bound East Coast traffic. East Coast jet traffic arriving at Austin from the direction of Atlanta, Georgia, is currently routed entirely through Houston Center. An alternative route under consideration involves routing the traffic through Fort Worth Center at high altitude with the jet traffic bound for the DFW area. The flights bound for Austin would descend southwest bound to enter Houston Center south of the Waco VORTAC, in-trail with other Austin arrivals from the DFW area. Air traffic operations in the Houston and Fort Worth Centers for three demand levels under VFR were simulated. The new Austin airport/airspace system was assumed to be in place, with an airline hub serving the East Coast established at Manor Airport, by the second traffic demand level.

Simulation results for the hub scenario traffic demand levels provided results for assessing the delay impact of the routing alternatives. The overall system-wide delay associated with routing the east coast traffic through Houston Center was compared with the corresponding delay associated with routing the traffic through Fort Worth Center. Simulation results indicate that flights incur less travel time when routed via the present route through Houston Center instead of the alternative route through Fort Worth Center.

4.3 Oakland Airspace Project[5,6]



The purpose of the Oakland Center Airspace Analysis Project was to evaluate the delay and capacity impacts of proposed operational alternatives aimed at increasing capacity, reducing delay, and improving the overall efficiency of air traffic operations within the Oakland Air Route Traffic Control Center (ARTCC), terminal airspace operations in the Bay and Sacramento Terminal Radar Approach Controls (TRACONs), and airfield operations at San Francisco International (SFO), Metropolitan Oakland International (OAK), San Jose International (SJC), and Sacramento Metropolitan (SMF) Airports.

The Oakland Air Route Traffic Control Center (ARTCC) adjoins three other domestic ARTCCs and has an oceanic control area to the west, which provides air traffic services to transpacific flights. Air traffic operations within Oakland Center airspace are very complex. There exists a significant east to west and north to south traffic flow, several interactive, high density airports, considerable military activity, and numerous geographical constraints restricting radar coverage, radio communications, and air traffic movement. Traffic handled by the Oakland Center includes overflights, arrivals, departures, and intra-center traffic. Due to its geographical location, the majority of flights within the Oakland ARTCC are either climbing or descending. The three Bay Area airports account for over 55 percent of the total Oakland Center IFR operations.

The Oakland Center Airspace Analysis Project consisted of four major simulation analysis tasks. Results of each were analyzed with respect to increasing capacity, reducing delay, and improving the overall efficiency of air traffic operations and are summarized below.

5. Oakland Center Airspace Analysis Project (June 1991)
6. San Francisco Bay Area Airports Task Force Capacity Study of SFO, SJC, and OAK International Airports (December 1987)

4.3.1 Sector 11 Initiative

The first simulation analysis task involved evaluating two proposed airspace realignment and routing alternatives to alleviate complexity and saturation problems associated with Oakland Center Sector 11.

Sector 11 is one of 25 en route sectors located within the Oakland Center. The base of Sector 11 airspace commences at the surface and attains its highest altitude at FL230. Some shelving exists at the lower altitudes, mainly where Sector 11 interfaces with Bay TRACON, Monterey Approach Control, and Stockton Approach Control. Sector 11 is a relatively small sector, encompassing the majority of the area south of San Jose International Airport, approximately 45 miles north to south and 60 miles east to west.

Alternative A involved an extension of the lateral and vertical confines of Bay TRACON, Monterey Approach Control, and Stockton Approach Control; a modification to the major San Jose International Airport jet arrival routes to conform with proposed boundary and procedure changes between Bay TRACON and Oakland ARTCC Sector 11; and a reduction in metering restrictions to San Jose International Airport from the Los Angeles Basin and southwestern U.S. Alternative B included the changes proposed in Alternative A, plus it extended the ceilings of Monterey and Stockton Approach Controls.

Both improvement options proposed under the Oakland Sector 11 Initiative result in capacity gains and delay savings, though Alternative B results in greater delay savings when compared to baseline operations. This is due to fewer aircraft impacting Oakland Center Sector 11 and reduced in-trail separation standards required within approach control airspace. Besides the operating cost savings realized under the Sector 11 improvement alternatives, additional benefits would include: reduced Sector 11 complexity and traffic density; increased sequencing flexibility for Bay TRACON to merge traffic; reduced en route traffic metering; reduced inter-facility and intra-facility coordination; and a more efficient airspace alignment, resulting in an increased capacity to handle future traffic demand with reduced delay.

There is a narrowing of the margin between the delay and cost savings benefits between the alternatives in future demand levels when compared to the baseline and to each other due to limited runway capacity at San Jose International Airport. Future runway capacity expansion at San Jose International Airport should be a serious consideration if the potential benefits of any new airspace network are to be fully realized for increased traffic demands and IFR conditions.

The San Francisco Bay Area Airports Capacity Task Force's major objective, in its report of December 1987, was to develop an action plan to increase capacity and efficiency and to reduce aircraft delays at the three Bay Area international airports. Recommendations for San Jose designed to maximize the benefits of redesigned airspace include: creating staging areas at Runways 30L and 30R, extending and upgrading Runways 30R and 29, creating angled exits for Runway 12R, promoting use of reliever ILS training facilities, installing MLS on Runway 30L, and implementing simultaneous departures with Moffett Field.

4.3.2 Northern California Combined Radar Facility (NORCAL CRF) Airspace Redesign

The second task in this analysis involved analyzing the system capacity and air traffic delay impacts associated with combining several approach control facilities and delegating airspace from Oakland ARTCC to form the proposed Northern California Combined Radar Facility (NORCAL CRF). The proposed operational changes required: combining Bay TRACON, Travis RAPCON, Sacramento Approach Control, Stockton Approach Control, and portions of Oakland ARTCC into a single radar approach control facility; expanding Monterey Approach Control's area of jurisdiction; developing new sectors and modifying existing sectors within all facilities to conform with the proposed airspace changes; extending Runway 30R at San Jose International Airport to 7,460 feet for specific improvement options; and modifying arrival and departure routes to coincide with the proposed airspace changes. Results were analyzed for VFR and IFR conditions.

Simulation results show that the consolidation of facilities to establish the NORCAL CRF would result in capacity gains, delay savings, and aircraft operating cost savings. Potential benefits associated with establishing the NORCAL CRF facility include: increased sequencing flexibility to merge traffic using terminal in-trail separation criteria; expansion of available TRACON airspace for vectoring of arrival and departure traffic; improved efficiency in merging traffic with Oakland Center; reduced inter- and intra-facility coordination, and a more efficient airspace alignment resulting in increased capacity to handle future traffic demands with reduced delay. The extension of Runway 30R at San Jose International Airport would provide increased capacity to more efficiently accommodate current traffic demand as well as future traffic growth at the airport. Extending Runway 30R at San Jose

International Airport in conjunction with implementing the NORCAL CRF airspace redesign produces even greater delay savings and cost benefits than separately adding together the delay benefits and cost savings of each option.

4.3.3 Sacramento Airspace Routings Analysis

The third simulation analysis task involved evaluating alternative routings and procedures proposed to alleviate noise problems in the Sacramento Metropolitan area. Analyses were performed to determine the impact that these routings might have on current traffic flows within the Sacramento TRACON and Oakland Center. Four routing options were analyzed (one northwind and three southwind operations); a combination of the northwind alternative with each of the southwind alternatives was also analyzed.

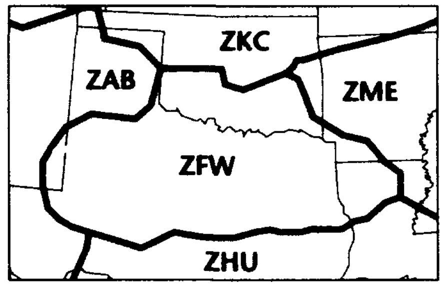
Simulation results show that the four alternative options do not yield any significant arrival delay changes for the baseline traffic demand at Sacramento Metropolitan Airport.

4.3.4 Fallon Special Use Airspace Impact Analysis

The fourth simulation analyzed the capacity and delay impacts associated with rerouting specific traffic to evaluate a proposed reconfiguration of the Fallon Range Training Complex. The proposed operational changes included raising the ceiling on the Fallon area and rerouting civilian traffic currently overflying the Fallon military airspace onto existing routes that circumvent the Fallon training area.

The expansion of the Fallon Range Training Complex significantly reduces Sector 43's airspace previously available for the vectoring of traffic to relieve congestion. The proposed expansion of the Fallon Range Training Complex is situated on a major west to east air traffic corridor. Requiring traffic to be rerouted around or clear of the proposed Fallon Range Training Complex restricts the majority of the departure traffic to using two primary departure routes. This rerouting of traffic results in increased ground delay at impacted airports due to the necessity to provide in-trail separation on airway specific routes instead of utilizing vectors and/or direct routes to expedite traffic movement.

4.4 Dallas-Fort Worth Metroplex Project[7]



The objective of the Dallas-Ft. Worth (DFW) Metroplex Air Traffic Analysis Project was to address a variety of capacity and delay problems and issues in the Dallas/Ft. Worth area, including development of plans for increasing airport and airspace capacity.

This project focused on three primary areas: (1) evaluation of the new airspace design for the DFW area, (2) assessment of the need for and alternatives for providing and utilizing new runway capacity at DFW Airport, and (3) evaluation of the capacity and delay impacts of airspace interactions among traffic from various airports in the DFW area.

These analyses relating to the new DFW airspace were aimed at evaluating and refining routings and procedures for the new airspace design, analyzing the capacity of the new airspace design to accommodate future traffic volumes and expanded airport capacity, and assessing the capability of the new airspace to support procedures for four simultaneous ILS approaches to DFW Airport. Analyses relating to the new runway capacity at DFW Airport were aimed at analyzing new runway alternatives in terms of the type of runway (commuter or air carrier), timing of construction, location on the airfield, use configurations, and operating procedures. Airspace interaction problems analyzed included the interaction between departures from Dallas Love Field and DFW Airport under both North Flow and South Flow operations, and the interactions between DFW Airport arrivals and Navy Dallas Airfield departures and arrivals during North Flow operations.

4.4.1 New Airspace Design for the DFW Area

Simulation analyses were conducted to analyze the capacity of the new DFW airspace system being designed by the DFW Metroplex Program Office of the FAA's Southwest Region. Major modifications to the old system include: expand TRACON airspace from 30 nm to 40 nm by relocating cornerposts and adding two new VORTACs, establish dual jet routing for arrivals over each cornerpost, establish additional terminal departure routings, segregate jet, turboprop, and prop traffic, segregate some military flights from civilian traffic, revise nominal radar vector paths within the TRACON, and revise arrival and departure routings in the Fort Worth Center.

7. The Dallas/Ft. Worth Metroplex Air Traffic Analysis Project (November 1989)

Simulation results show that the maximum benefits from the new airspace design will be realized in the future, with expected airport capacity improvements and increased demand levels, but the airspace design will also yield significant delay reductions and cost savings under current demand levels with existing airport facilities. Furthermore, the simulation results verify that the new airspace system provides the capacity to efficiently accommodate the increased traffic levels forecast through year 2010, including traffic associated with two new air carrier runways at DFW Airport. The new airspace structures and procedures provide the throughput to feed four simultaneous ILS approaches to DFW Airport.

4.4.2 New Runway Capacity at DFW Airport

The simulation of increased levels of traffic clearly indicate that existing runway facilities at DFW Airport do not provide adequate capacity to accommodate forecast traffic demand in the upcoming decade. Without new runway capacity, delays will increase to levels that result in severe economic penalties to aircraft operators and will be too expensive to support planned operations.

Potential airfield improvements at DFW Airport included north extensions on each of the north/south runways on either side of the terminal area with departure staging areas, a new eastside runway with associated taxiways, a new westside runway with associated new taxiways, new terminal facilities, and relocation of the general aviation parking area. The changes that were assumed to be in place depended on the demand year and runway options under consideration in the various simulation runs.

The results from the simulation runs indicated that to maintain the baseline (1987) level of service at DFW Airport (i.e., without increasing flight delays), a new commuter runway will be needed in 1990, a new air carrier runway in the mid 1990's, a new commuter runway and a new air carrier runway around 2000, and two new air carrier runways around the year 2005. In addition, the operational benefits that can be realized by a new north/south air carrier runway on the westside of DFW Airport depends on its location relative to the existing westside diagonal runway. The two options for locating a new westside air carrier runway were an intersecting option and a non-intersecting option. It was assumed that triple independent IFR approaches can be conducted when one new runway is available and quadruple approaches can be conducted when two new runways are available. Increased cost savings will be realized if the new westside runway is non-intersecting. In addition, the complexity of operations and controller workload would be less for the non-intersecting alternative. These savings must be weighed against the greater construction costs for a new non-intersecting runway.

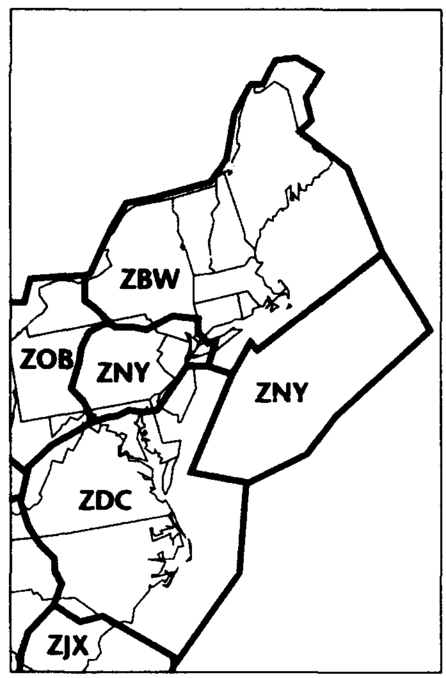
4.4.3 Airspace Interactions between DFW Airport and Satellite Airport Traffic

Simulation analyses were conducted to evaluate the capacity and delay impacts of airspace interactions among traffic from various airports in the DFW area. Airspace interaction problems analyzed included the interaction between departures from Dallas Love Field and DFW Airport under both North Flow and South Flow operations, and the interaction between DFW Airport arrivals and Dallas Naval Air Station (NAS) departures and arrivals during North Flow operations.

Simulation results indicate that potential interactions between departures from DFW Airport and Dallas Love Field during South Flow operations are particularly critical. Substantial delay savings result from using routings and procedures that minimize airspace interactions between DFW Airport and Dallas Love Field departures and should be strongly encouraged.

4.5 Expanded East Coast Plan[8]

The purpose of the Airport and Airspace Simulation Model (SIMMOD) application to the Expanded East Coast Plan (EECP) was to support the FAA in its planning efforts to restructure airspace operations on the East Coast of the United States to increase capacity, reduce delays, and improve overall efficiency of the air traffic system.



The application effort was concerned with New England's portion of the EECP, which focused on airspace operations in the Boston Air Route Traffic Control Center (ARTCC). Simulation efforts focused on redesigning traffic routings, ATC procedures, and airspace sectors that would properly interface with other portions of the EECP (i.e., the New York area), and that would yield increased capacity and reduced delays in the Boston ARTCC airspace.

Boston Center airspace operations are complex, involving significant East/West and North/South flows. Of the more than 100 airports underlying the Boston Center airspace, Logan International Airport flights account for almost 25 percent of Boston Center total traffic. Traffic handled by the Boston Center includes overflights, arrivals, departures, and intra-center traffic. Because of

8. Airport and Airspace Simulation Model (SIMMOD) Application to the Expanded East Coast Plan (October 1987)

the geographic location, most flights in the Boston Center are climbing or descending, including intra-center flights, oceanic traffic, and traffic accepted from and handed to adjacent facilities. The climbs, descents, routings, and other airspace maneuvering required by these flights contribute to the complexity of air traffic operations. Adjacent to Boston Center to the southwest is New York Center. Just within the New York Center airspace is a major "hub area," including Kennedy, LaGuardia, and Newark Airports. Many flights departing from or arriving at these airports must transit through Boston Center airspace. Montreal Centre is adjacent to Boston Center to the north. Due to the close proximity of Montreal area airports to the center boundary, much of the traffic to and from Montreal is climbing or descending.

Simulation runs were conducted for both the current Boston ARTCC operations (routes, sectors, and procedures) as well as new proposed EECP operations for a baseline traffic demand schedule.

4.5.1 Current Operations

Operational procedures used under the current system to control aircraft in Boston Center airspace rely primarily on maintaining minimum en route separation requirements. Certain flights, however, have added restrictions placed upon them in the form of specific routing, altitude, and miles-in-trail separation requirements.

For the current system simulation, the standard restrictions that are routinely in effect on a daily basis were assumed. They include miles-in-trail restrictions on aircraft entering Sardi, Stewart, and Pawling sectors for certain periods of the day, and miles-in-trail restrictions on specific Boston Center flights being handed to New York Center and Cleveland Center.

A traffic demand schedule was developed for a baseline day of operations in Boston Center airspace in 1987 which included air carrier, military, air taxi, and general aviation departures, arrivals, and overflights.

4.5.2 Proposed Operations

Major modifications to the current system include:

(1) Boston Center airways were restructured to provide direct routings for established traffic flows with less radar vectoring,

(2) Boston Center departure routes were realigned with revised New York Center EECP routings,

(3) More efficient routings for arrivals into the Boston Center were provided,

(4) Boston Center airspace sectors were revised to efficiently accommodate traffic flows and uniformly distribute the traffic load among sectors,

(5) Airspace sectors were made less complex by reducing the amount of "shelving," i.e., variation of sector shape with altitude, and

(6) TRACONs were delegated more airspace to enhance the efficient use of Tower En Route Control (TEC) routings.

In addition, procedures for metering arrivals into Logan Airport were identified for potential implementation in the proposed EECP system.

Several simulation cases were run. The first analysis was one where no runway constraints were present. It was assumed that the airports can accept arrivals at the rate the airspace can deliver the aircraft to the runway, subject to all airspace route, procedure, and separation constraints. Another case involved having representative airport arrival acceptance rate (AAR) constraints imposed. Two AARs for Logan Airport were selected for the analysis. The first was an AAR of 60 which allowed 34 arrivals per hour on the primary runway and 26 on the secondary runway. The second was an AAR of 36 which allowed 26 arrivals per hour on the primary runway and 10 arrivals on the secondary runway.

It was also decided to evaluate the impacts of arrival sequencing and spacing procedures on delay. In the current system, the primary method for spacing arrivals is to set independent miles-in-trail constraints on the various arrival flows which feed the runways at Logan Airport, so as to stay within the AAR constraints. The use of coordinated arrival metering procedures is being considered for use in the proposed EECP system. Thus, the simulation cases included the AAR 60 and AAR 36 cases, with and without arrival metering.

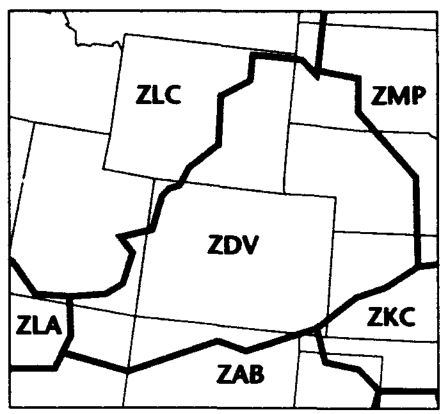
Simulation results indicate that from a purely airspace point of view, the new proposed EECP airspace routings and sectorizations will result in substantial efficiency and capacity gains. Flight time savings increase as the AAR level is decreased. Additional delay reductions are realized when coordinated arrival metering procedures are used.

An analysis was conducted to evaluate the capacity of the proposed EECP system to handle increased levels of traffic demand, compared to that of the current system.

Simulation results show that the amount of delay at all traffic levels is significantly less for the proposed system than for the current system. It was also found that the proposed system is able to absorb approximately ten percent more traffic before it reaches the same overall delay level experienced in the current system.

Based on an analysis of the sector occupancy statistics, it can be concluded that the proposed EECP system will reduce the intensity of traffic in airspace sectors. The reduced traffic congestion has the potential to alleviate sector saturation, reduce controller workload, and enhance aviation safety.

4.6 New Denver Airport/Airspace Study[9]



The purpose of the New Denver Airport/Airspace Study was to help the FAA's Northwest Mountain Region in their plans to realign en route and Terminal Radar Control (TRACON) airspace so that air traffic operations can be efficiently accommodated at the new Denver Airport. The New Denver Airport/Airspace Study consisted of two airspace options and two runway use plans. Each alternative was analyzed with respect to increasing capacity, reducing delay, and improving efficiency.

Stapleton International Airport is nearing capacity and will not be able to accommodate traffic forecasts of 1,900 operations per day in 1993. The city of Denver, Colorado is planning to replace Stapleton International Airport with a new airport in order to accommodate the forecast increases in traffic. The new Denver airport will be located approximately 10 miles northeast of Stapleton International Airport and is scheduled to open in 1993 with five runways. Existing plans for the new airport include expansion to twelve runways as the traffic demand increases to 3,600 operations per day.

9. New Denver Airport/Airspace Study (October 1989)

The six runway configuration consists of four north/south runways (two on either side of the terminal area) and two east/west runways. One is located north of the two runways on the right side of the terminal area and the other is located south of the runways on the left side of the terminal area. All runways are 12,000 feet long with the exception of one runway that is 16,000 feet long. The runway spacing is large enough for three simultaneous ILS approaches during IFR conditions. The airport is primarily a north/south flow airport; the two east/west runways are used as offload runways during north or south flow operations.

The new Denver Terminal Radar Approach Control (TRACON) will be operated as an arrival/departure gate system. Two arrival/departure gate options and two runway utilization plans were analyzed.

4.6.1 Terminal Airspace Design Evaluation

The TRACON airspace for the New Denver Airport is bound by a circle, centered at the New Denver Airport, with a radius of 30 nautical miles, and extends from the ground to 20,000 feet in altitude. The basic design involves four arrival and four departure gates to accommodate traffic associated with the New Denver Airport and satellite airports (Jeffco, Centennial, and Front Range). Two options for placement of the arrival/departure gates were analyzed. Option 1 involves roughly symmetric distribution of arrival and departure gates around the boundary of the TRACON. The arrival gates are placed so that existing airways that feed the arrival gates at Stapleton International Airport can be used. In Option 2, the arrival gates are moved so that the north and south departure gates are smaller.

Simulation results show that Option 1 provides more capacity and more efficient operations than Option 2. Delay reductions and more efficient airspace routings result in substantial savings in aircraft operating time for Option 1.

4.6.2 Runway Use Analysis

The New Denver Airport is scheduled to open in 1993 with a five-runway configuration. Two runway use plans were evaluated. The plans differ in terms of criteria for offloading aircraft from the primary runways during arrival and departure peaks. Plan 1 assumes the use of procedures similar to those currently used at Stapleton International Airport. Plan 2 involves more demand-responsive use of runways, with the number of arrival and departure runways varying with demand, and with balanced utilization of available runway capacity.

The runway utilization for departure rushes under Plan 1 is the same for VFR and IFR operations, where up to four runways are available to handle the departure rush. During a VFR arrival rush, up to five arrival runways are available, depending on the size of the arrival rush. The runway use is balanced so that arrivals are evenly allocated to the arrival runways, and departures are evenly allocated to departure runways. The main difference between VFR and IFR operations is the number of arrival runways. Only three arrival runways are available for IFR operations because the east/west runways become departure runways.

Under Plan 2, the departure rush runway utilization is the same for VFR and IFR operations as it is for Plan 1. During a VFR arrival rush, four runways are always available for arrivals. The arrival and departure usc is not balanced. As in Plan 1, only three IFR arrival runways are used.

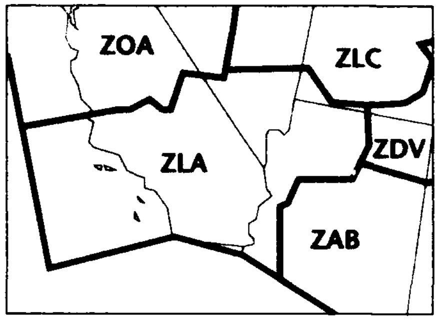
Simulation results show that substantial benefits may be realized using Plan 2 instead of Plan 1.

4.6.3 New Denver Airport and Terminal Airspace Capacity Analysis

The traffic demand at the New Denver Airport is forecast to be 1,900 daily operations when it opens in 1993. This was used as the baseline demand. An analysis was conducted to evaluate the capacity of the New Denver Airport and terminal airspace using airspace Option 1 and runway use Plan 2. The analysis was conducted for VFR and IFR operations with baseline and increased demand in increments of 10 percent, up to a 50 percent increase over the baseline demand.

Simulation results show that there is sufficient airspace and runway capacity to accommodate future growth with six runways when the runways are used efficiently. The use of airspace Option 1 and runway use Plan 2 will provide adequate capacity to accommodate expected future traffic growth of up to 30 percent over baseline demand with modest increases in annual delay. For demand increases greater than 30 percent over baseline, additional runway capacity at the New Denver Airport will be required to avoid substantial increases in delay.

4.7 Los Angeles Airspace Project[10,11]



The purpose of the Los Angeles Airspace Capacity Project was to support the FAA Western-Pacific Region in their planning efforts and analyze several critical capacity and delay problems and issues in the Southern California area.

Los Angeles Center airspace operations are complex, involving significant East/West and North/South flows. Traffic handled by the Los Angeles Center includes overflights, arrivals, departures, and intra-center traffic. Because of its geographic location, most flights in the Los Angeles Center are climbing or descending. Los Angeles International Airport flights account for almost 30 percent of Los Angeles Center total traffic.

Immediately adjacent to and to the north of Los Angeles Center is Oakland Center. Flights between Oakland Center and Los Angeles Center departing from or arriving at Los Angeles Basin airports must transit the Ventura/Palmdale corridor, one of four primary corridors available for ingress or egress into the Los Angeles Basin area. These corridors are a result of the numerous Special Use Airspaces (SUAs) which exist within and immediately adjacent to Los Angeles Center. The Ventura/Palmdale corridor is one of the busiest in the world and requires special flow management to maintain maximum capacity usage during peak traffic periods.

The Los Angeles Airspace Capacity Project consisted of three major simulation analysis tasks. They are: (1) Los Angeles International Airport capacity analysis; (2) Los Angeles Center airspace choke point delay analysis; and (3) Los Angeles Basin airspace realignment analysis. Results of each were analyzed with respect to increasing capacity, reducing delay, and improving the overall efficiency of air traffic operations and are summarized below.

4.7.1 Los Angeles International Airport Capacity Analysis

The objective of this task was to determine the arrival and departure capacity of Los Angeles International Airport under various operating conditions and the sensitivity of the airport capacity to variations in key operational parameters.

10. Los Angeles Airspace Capacity Project (December 1988)
11. Los Angeles International Airport, Airport Capacity Enhancement Plan (September 1992)

Simulation results show that under baseline operating conditions, the maximum arrival/departure capacity of Los Angeles International Airport was 138 operations per hour during IFR conditions and 166 operations per hour under VFR conditions. However, high levels of delay would occur if the airport were operated at capacity. For baseline operating conditions, the level of operations under which delays remain small are approximately 116 operations per hour under IFR conditions and 140 operations per hour under VFR conditions.

The goal of the Capacity Design Team at Los Angeles International Airport was to develop an action plan of alternatives to increase airport capacity, improve airport efficiency, and reduce aircraft delays. These must coincide with improvements mentioned above if maximum capacity is to be realized. Those recommendations that directly relate to airport capacity at the airport can be found in Appendix C.

Recommendations for Los Angeles International Airport designed for airfield improvements included: constructing departure pads (staging areas) at ends of runways, extending taxiways, constructing high-speed taxiways, and extending Runway 24R. Facility and equipment improvements recommended included upgrading the ILS on Runway 25L to CAT III.

4.7.2 Airspace Choke Point Delay Analysis

The flow of traffic in the Los Angeles Basin is affected by large areas of Special Use Airspace. There are four major choke points through which traffic to and from the Los Angeles Basin must pass due to Special Use Airspace.

The fact that these choke points cause delay for flights transiting these corridors has been observed by the FAA for some time. Speed reductions, path stretching, and other controller techniques initiated during peak traffic demand periods provide evidence that delay does occur.

Simulation results show that substantial delays are incurred by traffic passing through choke points in Los Angeles ARTCC airspace. Modest increases in traffic volume will result in substantial increases in delay unless choke point constraints are released to increase capacity.

4.7.3 Los Angeles Basin Airspace Realignment Analysis

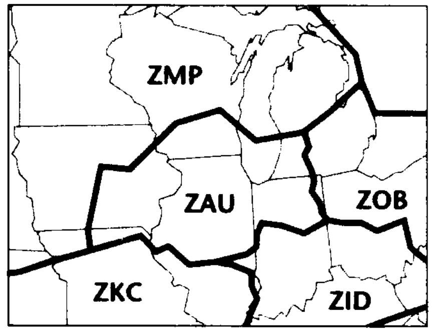
A saturation problem exists in the Los Angeles Center which constrains the capacity of the airspace structure. It is primarily due to the complexity and intensity of operations in Sector 21 of the Los Angeles Center. Sector 21 is a relatively small sector encompassing, at its maximum, a distance of approximately 35 miles from north to south and 50 miles from east to west. The bottom of Sector 21 airspace commences at an altitude of 7,000 feet and reaches its highest altitude at FL230.

The workload complexity factors associated with Sector 21 traffic flow are as a result of the fact that (1) the majority of traffic tends to converge to one point within Sector 21; (2) the closure rate between aircraft is significantly high, especially in head-on situations; (3) lower performance aircraft must be interleaved with the higher performance jet traffic, which complicates operations; and (4) within the limited airspace available, traffic flows must be merged to satisfy minimum separation standards required under the en route airspace environment.

Potential airspace and routing changes for Sectors 21 and 22, and Los Angeles and Coast TRACONs were defined. Major modifications to the old system included expanding the lateral boundaries of Coast TRACONs, establishing a common ceiling of 13,000 feet for Coast and Los Angeles TRACONs, and rerouting departures from Los Angeles International, Orange County, and Long Beach Airports to the Coast TRACON.

Simulation results show that realignment of the Los Angeles Basin airspace will relieve the airspace saturation in Los Angeles ARTCC Sector 21 and result in substantial improvements in efficiency. Airspace capacity will be substantially increased in the new airspace realignment enabling increased volumes of traffic to be handled with less delay. For the near-term traffic demand, delay will be five times greater under the existing airspace structure than with the new realigned airspace and at a level of 40 percent increase in traffic (the nominal forecast projection), the delay is nine times greater under the old system than the new system. The airspace realignment will increase traffic loading for both Los Angeles and Coast TRACONs. This increased traffic can be accommodated without increased delay, assuming that sufficient controller staffing is available to provide adequate sectorization of the terminal airspace.

4.8 Chicago Airspace Project[12,13]



The purpose of the Chicago Airport/Airspace Capacity Project was to support the planning efforts of the FAA's Great Lakes Region in evaluating alternatives addressing capacity and delay problems in the greater Chicago metropolitan area. Potential solutions involved operational alternatives that included airspace realignment, route redesign, new runways, and revised procedures to enhance the efficiency and safety of air traffic operations. The operations of primary concern were en route and terminal airspace operations in the Chicago Air Route Traffic Control Center (ARTCC), terminal airspace operations in the Chicago Terminal Radar Approach Control (TRACON), and airfield operations at Chicago O'Hare (ORD) and Midway (MDW) Airports.

The Chicago TRACON provides air traffic control services in the terminal airspace encompassing O'Hare Airport and several other satellite airfields. In addition to O'Hare Airport, the primary airport, there are 23 satellite airports controlled by the different control positions within Chicago TRACON.

The simulation analysis involved various scenarios using the existing airfield facilities, proposed airfield improvements at O'Hare Airport, and the existing and proposed airspace systems. Various weather conditions and traffic demand levels were simulated to provide an adequate assessment of the relative benefits or drawbacks of the various airfield/airspace options. The runway options and alternatives for O'Hare Airport that were simulated included existing runways and the potential options of adding one or two new air carrier runway(s), including changes in operational procedures and realignment of Chicago Center airspace.

4.8.1 Baseline Operations

The existing airfield of Chicago's O'Hare International Airport consists of three sets of parallel runways: a pair of northeast/southwest runways, a pair of southeast/northwest runways, and a pair of east/west runways. In addition, a smaller general aviation commuter north/south runway is located north of the terminal area, but is used only sparingly.

12. Chicago Airport/Airspace Capacity Project (June 1990)
13. Chicago Delay Task Force: Delay Reduction/Efficiency Enhancement Final Report (April 1991)

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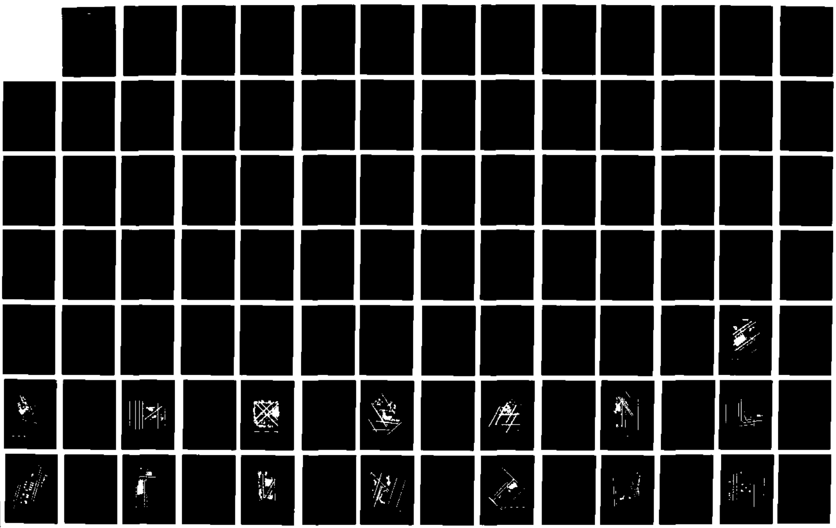

AIIM

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The existing airspace system utilizes a four "cornerpost" design for arriving aircraft bound for airports within the Chicago TRACON. The en route system uses a network of airways to merge O'Hare Airport traffic entering the terminal area over the four cornerposts. Aircraft depart the Chicago TRACON airspace in the existing airspace system initially on the four cardinal directions, i.e., north, south, east, and west. Traffic departing satellite airports, with a few exceptions, are provided in-trail spacing with O'Hare departures proceeding over a common fix.

Simulation results of baseline operations show that the predominantly east and west direction of flow of inbound flights to O'Hare Airport, along with the present location of the four cornerposts, results in uneven loading of two cornerposts during peak arrival periods. These traffic flow imbalances at the arrival fixes result in delay as inbound traffic is constrained during these uneven loading situations.

O'Hare Airport arrival traffic on the baseline day was not allowed to free flow through the four cornerposts, that is, special miles-in-trail (MIT) separation restrictions between successive arrivals over a cornerpost were used. Output results revealed that the imposition of MIT restrictions on arrivals over the cornerposts will result in delay increases.

Additional runs were made to evaluate delay impacts of future traffic demand projections, for the short term and the long term, using the baseline airport/airspace system. Simulation results indicate that capacity of the baseline airport/airspace system is not sufficient to accommodate anticipated traffic growth at O'Hare and Midway Airports, thus resulting in substantial delay penalties.

4.8.2 Short-Term Operational Alternatives

The specific alternatives evaluated involved a set of short term airspace realignment and procedural changes that could be implemented over several months. These changes, which were aimed at reducing traffic complexity and workload in the Chicago area airspace to enhance safety, while maintaining the efficiency of operations, included:

(1) rotating the four arrival cornerposts by 45 degrees to the four cardinal directions: north, south, east, and west,

(2) raising the ceiling of the TRACON airspace,

(3) removing holding patterns from the TRACON airspace to provide a dedicated departure corridor for Midway Airport,

(4) establishing merge points for arrivals farther from the TRACON boundary,

(5) eliminating the WHETT departure fix to allow a dedicated departure corridor for Midway traffic, and

(6) establishing a dedicated departure corridor for Midway traffic.

Simulation results show that substantial delay and cost savings would be realized using the short term airspace realignment and procedural changes (without MIT restrictions) described above.

4.8.3 Long-Term Operational Alternatives

The long term options, aimed at increasing capacity and reducing delays in the Chicago area, included building one or two new runways at O'Hare Airport and/or rotating the four arrival cornerposts by 45 degrees to the cardinal directions (as analyzed in the short term alternatives). The benefits of the new runways include capacity gains due to utilizing triple independent approaches in both VFR and IFR. The rotation of the O'Hare TRACON arrival cornerposts increases the number of south satellite arrival fixes by 50 percent (three versus two), allows departures to the south to operate independent of O'Hare Airport traffic, and provides added vectoring-sequencing airspace within the O'Hare TRACON. High performance jet traffic destined to Midway Airport, approaching from a northerly direction would be able to remain at higher altitudes longer, resulting in an operating cost savings for those Midway Airport arrivals.

Simulation results show that delay savings are realized by utilizing the proposed cornerpost rotation and are a result of additional aircraft flowing through arrival fixes and taking advantage of previously unused runway capacity at O'Hare Airport. Delay savings are realized only during VFR operations, because, during operations under IFR, the runway capacity available at O'Hare Airport is not sufficient to take advantage of the airspace capacity gains afforded by the rotated cornerposts. Thus, runway capacity at O'Hare must be increased if the potential benefits of the new airspace capacity are to be realized during IFR conditions.

The addition of two new runways at O'Hare Airport, while utilizing the existing airspace system, provides a reduction in operational complexity, yielding potential safety enhancements, large gains in airport capacity when operating under IFR, and equalized airport capacity during VFR and IFR operations.

Rotation of the arrival cornerposts and addition of two new runways at O'Hare Airport result in substantial delay savings under both VFR and IFR operations. Under VFR, the capacity increases afforded by the new rotated airspace allow full utilization of the new runway capacity. Under IFR, the new airspace provides added flexibility for balancing the use of the new runways, thus yielding greater delay savings than with the existing airspace system.

Additional simulation runs involved assessing the impact of adding only one new runway at O'Hare Airport, while still maintaining the existing four cornerpost system and the case where the arrival fixes are rotated 45 degrees and one new runway is added at O'Hare Airport.

The Final Report of the Chicago Delay Task Force identifies constraints which currently exist in the Chicago airport and airspace operating environment and defines options to explore further which will alleviate these constraints, thereby reducing delays at Chicago's airports. The Chicago Delay Task Force's recommendations are outlined in Appendix C.

The Chicago Delay Task Force issued its final report in April 1991. Since that time, the FAA Great Lakes Region and the City of Chicago have organized the Chicago/FAA Delay Task Force Implementation Team. That team consists of the Airport Technical Working Group and the ATC Technical Working Group.

The Airport Technical Working Group was developed to facilitate implementation of Delay Task Force airport improvement recommendations. The projects selected for the near term are: flow-through aircraft hold pads, Runway 4R angled exit taxiway, and northward relocation of Runways 9L/27R and 4L/22R.

The ATC Technical Working Group was formed to facilitate implementation of Delay Task Force airspace recommendations. The projects currently being analyzed include restructuring of the Chicago airspace and additional CAT II/III approach capability.

4.9 Studies in Progress

Currently, the FAA Office of System Capacity and Requirements has four airspace projects underway: analysis projects in the New York and Jacksonville Centers, the Los Angeles Regulatory Airspace Simplification Project, and a Chicago MLS study.

The New York area airspace analysis is the most ambitious project undertaken to date. It will require an extensive analysis of portions of the New York, Washington, Boston, and Cleveland Centers. It calls for the integration of ARTS and SAR data from 18 approach controls and 86 en route sectors. It will extend from Boston to Richmond and will analyze problems in the New York arrival and departure flows and the integration of Stewart International Airport into the New York airspace complex.

The Jacksonville Center analysis will analyze flow restrictions in Florida airspace created by delegations of Special Use Airspace in the northern Florida and southern Georgia area. It will extend into Washington Center far enough to join with the southern extreme of the New York airspace analysis database. It will also connect with a data base created for an analysis project of the Atlanta Center currently under negotiation. These combined projects will provide the three-Center build necessary to address Congressional concerns with Charlotte and Raleigh-Durham airspace.

The Los Angeles regulatory airspace simplification project does not, as currently envisioned, involve the use of SIMMOD. It will be a three-dimensional depiction of the regulatory and control airspace with the underlying geography and the actual radar track data interfaced. The objective is to determine whether there is regulated airspace that is not used by a significant number of IFR aircraft. If so, that airspace could then be released to allow less restricted VFR flights through the Los Angeles area. This project is being coordinated through the Western Pacific Region with the Southern California Airspace Users Group (SCAG). Any follow-on modeling analysis required will also be accommodated.

The Chicago MLS analysis is an application of a database from an earlier airspace study. The MLS Program Office requested a quantification of the effects of the installation of an MLS at Midway Airport in order to validate the savings benefits computed by their studies at NASA Ames Research Center. It will also study the inter-airport effect of MLS procedures in the Chicago area.

Chapter 5

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 an integrated approach to capacity improvement through effective coordination of the various programs. At an overall level, this integration will be accomplished through the activities of the National Simulation Capability described in Section 5.4.1.

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. The impact of each initiative will be enhanced by an integrated approach to capacity improvement through effective coordination of the various programs. This integration will be accomplished through the activities of the National Simulation Capability.

Section 5.1 covers technologies applicable to airport surface operations. Section 5.2 discusses programs that apply to 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 Chapter 3. Section 5.3 discusses technologies applicable to the en route airspace, including oceanic airspace. Section 5.4 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 G. 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.

5.1 Airport Surface Capacity Technology

Nearly 80 percent of all flights are delayed 1 to 14 minutes in taxi-in and taxi-out phases of flight. Taxiway interference, separation at intersections, departure sequencing, and the like, all contribute to surface-related flight delays. The Airport Surface Traffic Automation System will provide automation that will make ground operations safer and more efficient.

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5.1.1 Airport Surface Traffic Automation Program

The purpose of the Airport Surface Traffic Automation (ASTA) program is to increase aviation safety by reducing runway incursions and surface collisions in the airport movement area and to provide controllers with automated aids to reduce delays and improve the efficiency of surface movement.

The ASTA program comprises five elements: a runway status light system, a surveillance data link, aural and visual warnings, data tags, and a traffic planner. The program will develop an enhanced surface safety system using the Airport Surface Detection Equipment (ASDE-3) primary ground sensor radar, Automated Radar Terminal System (ARTS), Differential (corrected) Global Positioning System (DGPS), and Airport Movement Safety System (AMASS). ASTA will provide controllers with automatically generated alerts and cautions as well as data tags to identify all aircraft and special vehicles on the airport movement area in all-weather conditions. Future enhancements will include a traffic planner and Cockpit Display of Surface Traffic Information (CDTI). The ASTA program examines the roles and responsibilities of controllers, pilots, and ground vehicle operators when operating on the airport.

The AMASS is an automation enhancement to the ASDE-3 primary ground sensor radar that provides an initial safety capability on runways and connecting taxiways. After determining that a group of ASDE-3 radar returns make up a target, the AMASS then analyzes that target's position and motions with respect to other targets and the defined airport operational configuration to determine if there are any conflicts among targets or with defined operations. If there are conflicts, a verbal and graphical alert is given to the controllers in the tower cab. The AMASS also has an interface with the Automated Radar Terminal System (ARTS) in order to include airborne aircraft on final approach in the check for conflicting target operations on the airport surface. All airports slated to receive ASDE-3/AMASS equipment will also receive ASTA. For those airports not equipped with ASDE-3/AMASS, ASTA will use other potential ground movement sensors, such as DGSP surveillance data link to detect aircraft and vehicles.

The ASTA program will share information with the Terminal Air Traffic Control Automation (TATCA) program to create an interrelated runway incursion prevention system. When completed, the ASTA program will provide an all-weather, automated capability that allows for safe, higher capacity airport operations.

5.2 Terminal Airspace Capacity Technology

There are a number of programs that will improve the capacity of an airport's surrounding terminal airspace. 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 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 support enhanced air traffic 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.

The Center-TRACON Automation System will aid the controller in merging traffic as it flows into the terminal area.

5.2.1 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.

5.2.1.1 Converging Runway Display Aid

The CRDA displays an aircraft at its actual location and simultaneously displays 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 function is now implemented in version A3.05 of the ARTS IIIA system.

Actual operations have shown that CRDA is effective in increasing capacity by allowing multiple runways to be used simultaneously under IFR.

Actual operations have shown that this aid is effective in increasing capacity by allowing multiple runways to be used simultaneously under IFR. At St. Louis, the FAA has conducted a demonstration of this tool to measure its effect on dependent precision converging approaches in near Category I minima. (This is discussed further in Section 3.4.2.) Results from field testing at St. Louis have shown an increase in arrival rates from 36 arrivals per hour to 48 arrivals per hour, an increase of 33 percent. National standards for CRDA were published in November 1992.

5.2.1.2 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, which leads to higher controller workload and increased fuel burn to maintain separation, or with significant gaps, which in turn reduces 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.

CTAS is designed to improve system capacity by helping the controller smooth out and coordinate traffic flow efficiently, while maintaining the same level of safety present in today's system.

CTAS is designed to improve system performance (e.g., efficiency, capacity, controller workload), while maintaining at least the same level of safety present in today's system, by helping the controller smooth out and coordinate traffic flow efficiently. The earliest CTAS product is the Traffic Management Advisor (TMA), with one TMA specifically designed for the Center environment (CTMA) and one for the TRACON (TTMA). The TMA determines the optimum sequence and schedule for arrival traffic, and coordination between air traffic control facilities such as a Center and a TRACON is managed via the TMAs for the respective facility. Other CTAS products are the Final Approach Spacing Tool (FAST) for the TRACON and a Descent Advisor (DA) for the ARTCC. FAST aids TRACON controllers in merging arrival traffic into an efficient flow to the final approach path and also supports controllers in efficiently merging missed approach and pop-up traffic into the final approach stream. DA assists Center controllers in meeting precise arrival times efficiently while maintaining separation.

A CTAS functionality under concept exploration is Expedite Departure Path (EDP). EDP is intended to accurately model aircraft ascent up to cruise altitude. Ultimately this knowledge can be used in the terminal and en route environments to interleave departing aircraft into the existing flow of en route aircraft.

The field-test deployment of TMA has already begun, and a TMA is operating continuously at Denver Center. A TTMA is installed at Denver TRACON and is to undergo field development and evaluation. TTMA capability must be in place for FAST operations, and CTMA must precede DA operations. Longer-term CTAS activities focus on integration of terminal automation with other ATC automation and cockpit automation activities.

5.2.2 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 spacing are discussed in Section 3.3.2.) Current criteria allow independent approaches to parallel runways separated by 4,300 feet or more. This standard was established based in part on the surveillance update 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 update rate and the radar display accuracy were improved, and special software was developed to provide the monitor controller with alerts. Conventional airport surveillance radars update the target position every 4.8 seconds.

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

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 update rates than the current terminal ASR, a processing system that monitors all approaches and generates controller alerts when an aircraft appears to be entering the "no transgression zone" (NTZ) between the runways, and a high resolution display system. One version uses an electronically scanned antenna that is capable of updating aircraft positions every half a second, and the other uses two mechanically rotating antennas mounted back-to-back that together update aircraft positions every 2.4 seconds.

Procedures to allow independent parallel operations for runways as close as 3,400 feet apart were published in 1991. 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 3,000 feet apart.

A contract was let in the spring of 1992 for procurement of five electronically scanned (E-Scan) PRM antenna systems, with delivery planned for 1994.

5.2.3 Microwave Landing System (MLS)

The curved approach capability provided by MLS will provide a solution to the interdependency of proximate airports. The MLS/ RNAV capability will permit the design of instrument approach procedures that more closely approximate traffic patterns used during VMC.

The Instrument Landing System (ILS) has provided dependable precision approach service for many years. However, inherent characteristics of the ILS cause difficulties in congested terminal areas. Of particular concern from an air traffic perspective is the long straight-in flight path required by ILS. Although not a major concern for isolated airports without obstruction problems, 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.

In general, the MLS/RNAV capability with wide-area coverage will provide more flexibility in the terminal airspace. For aircraft equipped with MLS/RNAV, 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 will also enable the FAA to provide precision approach capability for runways at which an ILS could not be used 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.

It may 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 runways 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 computed-centerline capability will provide for more flexible ground siting of equipment to compensate for terrain irregularities that do not permit a centerline siting. Additionally, MLS does not require as extensive a site preparation as ILS glide slope, since MLS does not form guidance signals through ground reflection. MLS computed centerline will also provide the capability to compute an approach to secondary runways, both parallel and intersecting, that lie within the coverage volume of the instrumented runway.

A contract was awarded in 1992 for development of an MLS design to meet Category (CAT) II and III requirements. A production decision is expected in 1995, with deliveries in 1997.

5.2.4 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 category aircraft by the end of 1993. At the current time, about 75 percent of U.S. transport aircraft are already equipped. Because of the situational 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.

TCAS is an airborne system that provides the pilot with advisories concerning nearby transponder-equipped aircraft. A program is expected to begin in FY94 to investigate the use of TCAS to support reduced spacing on final approach

A program is expected to begin in FY94 to investigate the use of TCAS to extend approach procedures to lower minima, 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 TCAS-based parallel approach monitoring, TCAS-based self-spacing, and other more advanced applications.

Some conceptual definition work has been performed in the area of TCAS support for reduced spacing on final approach. The concept and a computer-based demonstration have been briefed to the FAA, the pilot and controller communities, and a symposium held at Embry-Riddle Aeronautical University.

5.2.5 Wake Vortex Avoidance/Advisory System (WVAS)

A better understanding of wake-vortex strength, duration, and movement could result in the reduction of aircraft separation criteria. Revised wake-vortex separation criteria may increase airport capacity by 12 to 15 percent in instrument meteorological conditions (IMC), thereby enhancing airspace use and decreasing delays.

Several vortex detection and measurement systems will be deployed at selected airports to monitor wake-vortex strength, transport characteristics, and decay. Wake vortex data obtained from these airports will be combined with data from tower fly-by tests already completed to provide a basis for reviewing existing separation standards and recommending modifications to those standards. The feasibility of increasing the small aircraft category weight limit from 12,000 to 19,000 pounds will be determined.

Plans include cockpit simulations to determine if separation standards for heavy aircraft operating behind heavy aircraft can be reduced from four miles in trail to three miles. This will be followed by examining the separation for large-behind-large and issues relating to closely spaced runways, departure delays, and departure sequencing which would interconnect with terminal automation.

5.3 En Route Airspace Capacity Technology

En route airspace congestion is being identified increasingly as a factor in restricting the flow of traffic at certain airports. 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.

Initiatives designed to reduce delays, match traffic flow to demand, and increase users' freedom to fly user-preferred routes are underway.

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

The need for increased efficiency in 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.

5.3.1 Advanced Traffic Management System (ATMS)

The purpose of the ATMS is to research automation tools 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.

Automation tools shown to be beneficial through the ATMS research and development program will be implemented and fielded for operational use in the Enhanced Traffic Management System (ETMS).

The Aircraft Situation Display (ASD) was the first capability developed by ATMS. The ASD generates a graphic 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, selected TRACONs, and two Canadian locations.

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 assists traffic management specialists in planning arrival flows for airports that are close to ARTCC boundaries, resulting in smoother arrival flows and better airport utilization. It allows traffic management specialists to detect and effect solutions

The purpose of the ATMS is to research automation tools to minimize the effects of NAS overload on user preferences without compromising safety.

Capabilities developed or under development by ATMS include the Aircraft Situation Display, Monitor Alert, Automated Demand Resolution, Dynamic Special Use Airspace, Strategy Evaluation, and Automated Execution.

Automation tools shown to be beneficial will be implemented and fielded for operational use in the Enhanced Traffic Management System.

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 second capability developed by ATMS was the Monitor Alert, which predicts 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.

Four future capabilities that are being developed through ATMS are Automated Demand Resolution, Dynamic Special Use Airspace, Strategy Evaluation, and Automated Execution. 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. Dynamic Special Use Airspace will provide automation to allow consideration of actual and scheduled military operations in the national flow management decision making process. Strategy Evaluation will provide a tool to evaluate alternative flow management strategies. Automated Execution will generate and distribute facility and aircraft-specific directives to implement selected strategies.

In addition to domestic flow management capabilities, research is being conducted for oceanic flow management capabilities. Track Generation will define a set of tracks for a prescribed region of airspace. Track Advisory will advise oceanic traffic managers of the most efficient tracks available to individual aircraft approaching the track system. Oceanic Traffic Display will assist the oceanic traffic manager in routing aircraft. Further development will concentrate on the integration of domestic and oceanic capabilities.

5.3.2 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 in coordination with traffic flow management. 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

AERA will help increase airspace capacity by improving the ATC system's ability to manage more densely populated airspace.

because of congestion or weather conditions, AERA will assist the controller in finding the open route closest to the preferred one.

Laboratory facilities for the AERA program were established in 1987. This laboratory has been used for prototyping and analyzing systems and concepts to develop operational and specification requirements, as well as supporting technical documentation. Initial algorithmic and performance specifications and trial ATC procedures were completed in 1991. These specifications were updated in 1992 to reflect the transition strategy adopted to implement AERA capabilities. This strategy will minimize disruption of ongoing operations and encourage effective assimilation of AERA capabilities by the controller work force.

In subsequent phases of the program, the FAA Technical Center will evaluate software and operational procedures changes developed to implement AERA capability enhancements. The operational AERA software and ATC procedures will then be upgraded as a result of the operational evaluation. Design of the software is expected to begin in 1993, and the operational evaluation is expected to start in 1997.

AERA concepts are being introduced in project planning and development for oceanic system automation, traffic flow management, and integration of en route and terminal ATC. In more advanced AERA applications, the integration of ground-based ATC and cockpit automation will be investigated to fully exploit the potential for computer-aided interactive flight planning between controller and pilot.

5.3.3 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 is largely manual and procedural and operates with very little, and often delayed, information. It depends upon hourly reports transmitted via High Frequency (HF) voice radio, which is subject to interference. 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 from the aircraft, via a satellite data link, to air traffic control facilities.

ADS will be a part of an Oceanic ATC System to support trans-oceanic flights over 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 1989 and in the New York ARTCC in 1992. Real-time position reporting via ADS and a limited set of direct pilot-controller data link messages will be added to the system in 1994. In 1995, a complete set of pilot-controller data link messages will be available.

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

5.3.4. Communications, Navigation, and Surveillance

New technology enhancements in communications, navigation, and surveillance provide the basis for dramatic improvements in aviation system performance, including improved safety, reduced delay, increased capacity, and greater efficiency. These three functional areas represent key elements of the air traffic management infrastructure.

5.3.4.1 Aeronautical Data Link Communications

Data link services should relieve congestion on voice communications channels and provide controllers with an ability to handle more traffic during peak periods while providing pilots with unambiguous information and clearances. This benefit has been demonstrated during the interaction of pre-departure clearances via data link.

Data link applications are being developed based on inputs from the air traffic and aviation user communities. These applications include weather products, en route, terminal, and tower ATC communications, and other aeronautical services. The Aeronautical Telecommunications Network (ATN) allows use of many data link sub-networks (e.g., satellite, Mode S, VHF, etc.) in a way that is transparent to the users.

Domestic standards are being developed with RTCA, and the international standards, with ICAO. The en route, terminal, and tower ATC services are being developed and evaluated by a team of air traffic controllers. The operational aspects and benefits of data link applications will be verified using contractor and FAA Technical Center test beds. Pilot inputs will be gathered by connecting cockpit simulators and live aircraft to the test beds during evaluations.

5.3.4.2 Satellite Navigation

Efforts are underway to extend the Department of Defense's Global Positioning System (GPS) to provide service for civil aviation for oceanic, en route, terminal, non-precision and precision approaches, auto-landing, and airport surface navigation. Highly accurate satellite signals will provide a three-dimensional position fix. This satellite navigation technology will provide more aircraft the ability to fly direct paths instead of being confined to specific routes, and thus provide for the use of more airspace. This technology can also be used as a source for accurate position reporting without separate surveillance systems and enable reduced separation minimums resulting in increased capacity throughout the system.

Satellite navigation technology will provide more aircraft the ability to fly direct paths instead of being confined to specific routes, and thus provide for the use of more airspace. This technology can also be used as a source for accurate position reporting without separate surveillance systems and enable reduced separation minimums resulting in increased capacity throughout the system.

The goal of the satellite navigation program is to integrate GPS with the Instrument Landing System (ILS) and the Microwave Landing System (MLS) and with the Advanced Traffic Management System (ATMS). Demonstrations will be conducted on the accuracy of GPS for precision navigation. If feasible, GPS may provide a near Category I instrumented landing capability that may be sufficient at many airports.

5.3.4.3 Terminal Area Surveillance System

Although air traffic accidents may occur during any phase of flight, the largest percentage occur during takeoff and landing. Currently, there are many airports without surveillance radars, and the airport surveillance radar being procured by the FAA, the Airport Surface Detection Equipment-3 (ASDE-3), will not be available at all airports due to cost considerations. It is important, therefore, to develop affordable sensors to provide a reliable surveillance source for terminal operations and to support automation development and airport capacity initiatives.

Requirements for a new terminal area surveillance radar have been identified and include modular, cost-effective primary and secondary radar systems with application for flexible, high capacity data links, improved surveillance accuracy, improved runway monitoring, improved wind shear detection and dissemination, and improved wake vortex tracking. Efforts will focus on adapting commercial technology in order to develop a radar that meets the validated requirements in a cost-effective manner.

5.3.5 Aviation Weather

Weather is the single most important factor in delays and a major factor in aircraft accidents and incidents. Improved weather forecasts offer the potential for increasing system capacity more cost effectively than many other alternatives. Improved weather information can not only increase system capacity, but also enhance flight safety, improve flight efficiency, reduce ATC and pilot workload, improve flight planning, and result in fuel and cost savings.

Improved weather forecasts offer the potential for increasing system capacity more cost effectively than many other alternatives.

Efforts are underway to enhance our understanding and ability to predict a range of aviation weather phenomena: icing, en route and transition turbulence; ceiling and visibility; thunderstorms and microbursts; en route and terminal wind; and oceanic weather of all kinds. Models and algorithms are being developed for understanding weather and generating short-term forecasts.

To help in the understanding of weather, airborne meteorological sensors are being developed to measure humidity and turbulence. These sensors will be carried aboard aircraft to provide near-real and real-time three-dimensional weather data that is currently not available.

Wind shear is a major cause of weather-related fatalities in the air carrier community. Research is underway to develop advanced wind shear warning systems and flight crew decision aids. The technology will be transferred to manufacturers and operators to accelerate the development of these systems. Once developed, flight tests will be conducted to evaluate onboard airborne wind shear sensor performance by flying the test aircraft into wind shear. Also, a wind shear training program will be developed for air taxis, commuter operators, and general aviation.

5.4 System Planning, Integration, and Control Technology

The following sections describe technologies that support planning to integrate various improvements into the NAS. Both operational improvements and new technologies need to be evaluated so that they can be developed and implemented effectively, ensuring the 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.

5.4.1 National Simulation Capability

The National Simulation Capability (NSC) will aid and support the R,E&D and systems engineering missions of the FAA by horizontally integrating the various R,E&D program elements across the National Airspace System (NAS) environment. The capability to integrate future ATC subsystems during the conceptual stage of a project will allow early validation of requirements, identification of problems, development of solutions to those problems, and demonstration of system capabilities. It will also permit early injection of human factors and system user inputs into the concept formulation process. The net result is a reduction of risk in the development of products for the NAS, faster infusion of new technology, earlier acceptance of new NAS concepts by system users, and greater efficiency in performing the R,E&D and systems engineering missions.

The National Simulation Capability will aid and support the R,E&D and systems engineering missions of the FAA by integrating various program elements across the National Airspace System environment. The capability to integrate future ATC subsystems during the conceptual stage of a project will allow early validation of requirements, identification of problems, development of solutions to those problems, and demonstration of system capabilities.

The NSC will be a unique capability that will exploit the latest simulation technology. Horizontal integration will bring together diverse system components such as terminal automation, en route automation, oceanic control, aircraft flight management systems, and mixes of aircraft types and performance in a flexible, interchangeable, and dynamic simulation environment. It will provide an ability to assess the suitability and capability of future ATC system components before production investment decisions are made. The NSC will permit the evaluation of new operational concepts, human interfaces, and failure modes in a realistic, real-time, interactive ATC environment capable of simulating new or modified systems at forecast traffic levels. Simulation capabilities will be expanded through an interface with various remote research centers that possess nationally unique facilities and expertise.

5.4.2 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.

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.

5.4.2.1 Airport Network Simulation Model (AIRNET)

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.

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

5.4.2.2 Airport and Airspace Simulation Model (SIMMOD)

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.

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

5.4.2.3 Airfield Delay Simulation Model (ADSIM) and Runway Delay Simulation Model (RDSIM)

The Airfield 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, limiting its scope to the final approach, runway, and runway exit.

5.4.2.4 The Airport Machine

The Airport Machine is a PC-based interactive model with graphics that is used to evaluate proposed changes to airfield and terminal configurations, schedules, and aircraft movement patterns. This model has been licensed for use within the FAA and has been used in studies of a number of major airports. Its primary output is extensive data on delays to aircraft movement.

The Airport Machine, a PC-based model, is used to evaluate proposed changes to airfield and terminal configurations, schedules, and aircraft movement patterns.

5.4.2.5 National Airspace System Performance Analysis Capability (NASPAC)

The NASPAC Project provides a long-term analysis capability to assist the FAA in developing, designing and managing the nation's airspace on a system-wide level through the application of modern tools of operations research and computer modeling. The focal point of the NASPAC Project is the NASPAC Simulation Modeling System (SMS). The NASPAC SMS is a simulation of the entire NAS that models the movement of individual aircraft as they move through the nationwide network of airports, en route sectors, routes, navigation fixes, and flow control restrictions. The model has been used to study the current and projected performance of the NAS and to study system improvements such as new airports, new runways and airspace changes as well as projected demand changes such as the creation of new air carrier hubs. The model has been improved to make it easier for analysts to use and to extend the range of applications in which it can be applied effectively.

NASPAC is a simulation of the entire NAS, modeling the movement of individual aircraft as they move through the nationwide network of airports, en route sectors, routes, navigation fixes, and flow control restrictions.

5.4.2.6 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. This computer model allows the user to input either the current design or the proposed replacement. It also allows the user to interactively make changes to the design shown graphically on the computer screen.

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

The model allows the user to play recorded traffic data against either the actual design or the proposed replacement. It also allows the user to modify traffic data interactively in order to evaluate alternative designs under postulated future traffic loading. The model computes measures of workload and conflict potential for the specified sector or group of sectors. This will allow designers to obtain a better balance in workload between sectors, reducing controller workload and increasing airspace capacity. 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 loading.

The development of the SDAT has been underway for approximately three years. Procedures for extracting and displaying (in 2D and 3D) all the requisite data from available FAA data files and computing the expected demand for separation assurance actions have been developed. The development of a fully capable controller workload model is underway. SDAT will be field tested at two selected sites in FY93.

A procedure for using the SDAT as an airspace model (assuming that controller workload is the limiting factor) is under development. This will be combined with an on-line Critical Sector Detector for traffic flow management.

5.4.2.7 Terminal Airspace Visualization Tool (TAVT)

Terminal airspace differs from en route airspace in that it tends to have 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 prototype is to explore the potential for computer-based assistance to such a task force that will support a more rapid evaluation of alternatives.

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

The TAVT prototype displays a three-dimensional representation of the airspace on a large computer screen to allow the user/operator to view the airspace from any perspective. It also provides an easy-to-use interface that permits the user to modify the airspace according to permissible alternatives. The results of this effort are being evaluated for incorporation into the specifications of a follow-on terminal airspace design tool based on SDAT.

5.4.2.8 Graphical Airspace Design Environment (GRADE)

GRADE is a computer graphics tool for displaying, analyzing, and manipulating airspace design and other aviation related data. Radar data (from both ARTS and SAR) are stripped from their recording media and loaded into GRADE's underlying relational database along with the appropriate airspace geometries, terrain maps, National Airspace System (NAS) data, descriptions of routes, and any other data required in the analysis. GRADE can then be used to test proposed terminal instrument procedures (TERPS), standard terminal arrival routes (STARs) and standard instrument departures (SIDs), airspace design changes, and instrument approach procedures.

GRADE, a computer graphics tool for displaying, analyzing, and manipulating airspace design and other aviation related data, provides a high quality, three-dimensional presentation, is relatively easy to use, and can be quickly modified to facilitate the comparison of existing and proposed airspace designs and procedures.

GRADE can display radar data in three dimensions, along with the attendant flight plan information, for any given time slice. GRADE also includes a set of algorithms designed to measure interactions between the radar data and any other elements of the database. These measurements can then be displayed as histograms and compared. GRADE provides a high quality, three-dimensional presentation, is relatively easy to use, and can be quickly modified to facilitate the comparison of existing and proposed airspace designs and procedures.

GRADE is currently limited to airspace design applications, but could easily be adapted to other applications, such as noise analysis, interaction with existing airport and airspace computer simulation models, accident/incident investigation (particularly for aircraft without flight data recorders), and training in lessons learned and alternate air traffic control techniques.

5.4.3 National Control Facility (NCF)

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

- 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.

The proposed NCF is intended to provide a traffic management function, to provide the national direction and airspace management of the air traffic control system; modeling and analysis function to provide the FAA with tactical recommendations and forecasts; and a management development function to familiarize users with the capabilities of the air traffic control system.

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.

5.4.4 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 workload, 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 time and fuel 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.

5.5 Vertical Flight Program

The Vertical Flight Program will help improve the safety and efficiency of vertical flight operations and increase the capacity of the NAS through research, engineering, and development into air traffic rules and operational procedures, heliport/vertiport design and planning, and aircraft/aircrew certification and training.

The term vertical flight (VF) includes conventional rotorcraft (helicopters) as well as advanced technology designs for aircraft with the ability to hover and take off and land vertically, such as the tiltrotor, tiltwing, fan-in-wing, and vectored-thrust aircraft. The Rotorcraft Master Plan (RMP) envisions advanced VF technologies, such as the tiltrotor, providing scheduled short-haul passenger and cargo service for up to 10 percent of projected domestic air transportation needs. Recognizing the potential for advanced VF aircraft to provide passenger service, Public Law 102-581 requested that a Civil Tiltrotor (CTR) Development Advisory Committee be established to evaluate the technical feasibility and economic viability of developing CTR aircraft and infrastructure to support the incorporation of tiltrotor technology into the national transportation system.

VF research will be conducted in the following areas: air and ground infrastructures to permit VF operations under visual and instrument meteorological conditions en route and in the terminal area; VF operations safety; VF operations noise reduction; VF training and certification procedures; integration of maturing advanced technologies into VF operations; and analysis of the economic viability and potential benefits of CTR technology.

Air infrastructure research will focus on the ability to operate at heliports and vertiports in terminal airspace without interfering with fixed-wing traffic flow. Much of the initial work relating to emerging technologies, such as tiltrotor, will be done through simulation, to be validated with actual flight test data as the aircraft become available.

Ground infrastructure research will provide R,E&D into heliport and vertiport design and planning issues, including the terminal area facilities and ground-based support systems that will be needed to implement safe, all-weather, 24-hour flight operations. Developing obstacle avoidance capabilities is a critical design-related effort. Research will include applying lessons learned from detailed accident and rotorcraft operations analyses. Simulation will be used to collect data, analyze scenarios, and provide training to facilitate safe operations.

Aircraft/aircrew research will develop minimum performance criteria for visual scenes and motion-based simulators; evaluate state-of-the-art flight performance for cockpit design technology; and develop crew and aircraft performance standards for display and control integration requirements. Research will also be conducted to develop certification standards for both conventional and advanced technology VF aircraft.

Chapter 6

Marketplace Solutions

Marketplace solutions rely primarily on competitive, free-market influences. Examples of marketplace solutions to airport capacity problems include the development of new hub airports, the expanded use of existing commercial service airports, the expanded use of reliever airports, the joint civilian and military use of existing military airfields, and the conversion of former military airfields to civilian use. By their very nature, marketplace solutions involve the interests of the airlines, local government and airport authorities, and local communities. In addition, both local and national economic factors are involved. This diversity of special interests makes predicting and managing these solutions inherently difficult.

Airlines and other airport users will seek other solutions for a delay-problem airport when the delays there are no longer tolerable. But before such a decision is made, it must make operational and economic sense. Marketing surveys and feasibility studies are conducted to verify such things as the adequacy of the origin and destination market and the economic viability of an airline's investment. Airport authorities, local communities, and other interested members of the aviation industry can facilitate an airline's decision process. But, in addition to conducting their own surveys and studies, they must advertise and market within the industry not only the characteristics of their airport that make it a good choice for the airlines, but also the willingness of their local community to absorb the increased traffic.

6.1 New Hubs at Existing Airports

As one solution to the growth in flight delays at traditional connecting hub airports, airlines may develop new hubs at existing airports. Hub airports developed since airline deregulation have exhibited the following characteristics:

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

More than two dozen potential new hub airports have been identified that are located more than 50 miles from airports with forecast delay problems and that have potential runway capacity to accommodate significantly increased airport operations. 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 would be 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 in the vicinity of airports with forecast delay-problems. 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 consequences 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 were used in the analysis. As Figure 6-1 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 6-2 shows the relationship between capacity and delay at San Francisco for various arrival capacities. The figure

1. *A Case Study of Potential New Connecting Hub Airports, Report to Congress, March, 1991.* The other airports described in that study are Huntsville International Airport (HSV), Port Columbus International Airport (CMH), and Oklahoma City (OKC).

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.

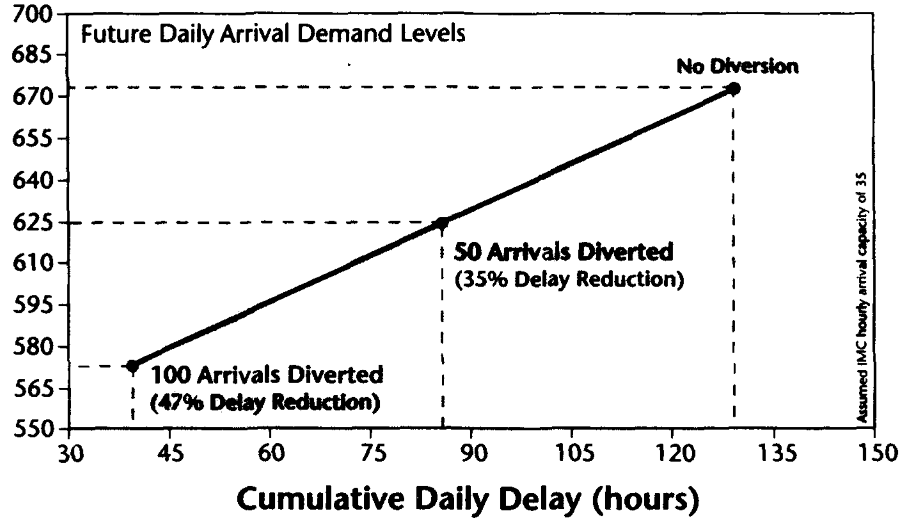


Figure 6-1. Total Delay for Varying Arrival Demand at San Francisco

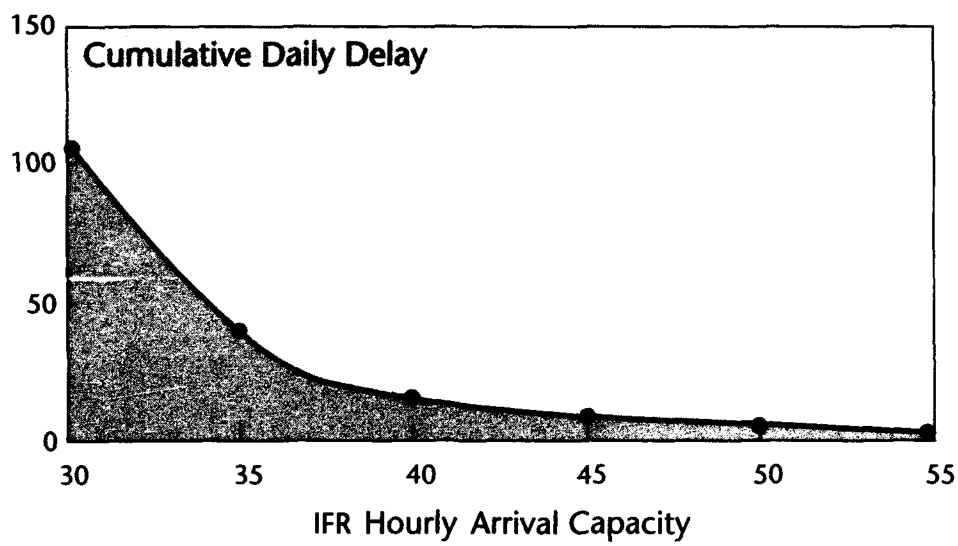


Figure 6-2. Capacity Delay Curve for San Francisco Assuming a New Connecting Hub at Sacramento

6.2 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.

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 6-1. A number of military airports and airports not currently served by commercial air traffic have been 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.

Expanded use of existing commercial service airports located within 50 miles of current delay-problem airports can ease congestion in a particular market.

6.3 Expanded Use of Reliever Airports

Reliever airports ease capacity problems at primary airports by attracting general aviation aircraft away from delay-problem airports. The segregation of aircraft operations by size increases effective capacity at each airport because required time and distance separations are reduced between planes of similar size.

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 36 airports forecast to exceed 20,000 hours of annual aircraft delay in 2001 without further improvements, about one third have 25 percent or more general aviation operations.

The segregation of aircraft operations by size increases effective capacity at each airport because required time and distance separations are reduced between planes of similar size. Reliever airports can be expected to play significant roles in reducing congestion and delay at delay-problem airports.

6.4 Civilian Use of Military Airfield Capacity

Although new airports or new runways and runway extensions at existing airports offer the greatest potential for increasing system capacity, a combination of community opposition, competing residential and commercial interests, environmental concerns, and cost factors have significantly constrained the development of new airports and, in some cases, the expansion of existing facilities.

As one part of its overall strategy to enhance system capacity, the FAA is pursuing a series of initiatives with the Department of Defense and state and local governments for the implementation of joint civilian and military use of existing military airfields and the conversion of former military facilities to civilian use.

As one part of its overall strategy to enhance system capacity, the FAA is pursuing a series of initiatives with the Department of Defense and state and local governments for the implementation of joint civilian and military use of existing military airfields and the conversion of former military facilities to civilian use.

The 21 joint-use facilities now in operation have had a modest impact on system capacity. For example, Charleston Air Force Base provides the primary commercial service airport for Charleston, South Carolina. Myrtle Beach Air Force Base, also in South Carolina, provides primary air service for a community that might not otherwise have local access to the commercial air system. Similarly, Dillingham Army Airfield, Hawaii, and Rickenbacker Air National Guard Base, Columbus, Ohio, provide congestion relief to the airports at Honolulu and Port Columbus, respectively.

Currently, 25 military air bases are available for conversion to civil airports. These air bases represent a federal investment of about $25 billion in airfields and associated infrastructure. If the airfield or other portions of the base are not conveyed for public purposes, the military services propose to sell these areas and use the proceeds to assist them in the realignment and closure of other military facilities. Some of these bases have the long runways and related facilities that make them ideal locations for large commercial aircraft capable of long-stage hauls carrying large numbers of passengers and heavy cargo loads. For example, Pease Air Force Base in New Hampshire, located about 60 miles north of Boston, is being converted to civilian use. Orlando International Airport is an extremely successful example of conversion of a former military air base. It has grown from only a few passengers in the early 1970's to over 16 million passengers today. Austin, Texas, is currently considering using Bergstrom Air Force Base as a replacement for Mueller Municipal Airport. In addition, some of the smaller air bases available for conversion would be ideal as general aviation reliever airports for the nearby commercial service airports serving scheduled air carrier operations. Tipton Army Air Field near Baltimore, Maryland, and Moffett Naval Air Station in the San Francisco Bay area are being considered as general aviation relievers.

To help support these initiatives, the Military Airport Program (MAP), established under the Airport Improvement Program (AIP), provides funding set asides from general AIP funds to implement development. The MAP allows for the designation of current or former military airfields by the Secretary of Transportation to participate in the program. Parties wishing to participate apply to the FAA. 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; (5) existing facilities; and (6) any other appropriate factors.

Seven current or former military airports have been designated thus far to participate in the MAP. These are Stewart International Airport near Newburgh, New York; Ellington Field at Houston, Texas; Albuquerque International Airport, New Mexico; Agana Naval Air Station, Guam; Manchester Municipal Airport, New Hampshire; Scott Air Force Base, in Illinois; and Myrtle Beach Air Force Base, in South Carolina. Under the MAP, these seven airports will each receive funds ranging from $2.1 to $5.0 million, for a total of $27 million, to support programs to conduct master plan studies, rehabilitate runways, taxiways, and aprons, acquire land for development and approaches, improve access roads, install instrument approach aids, improve drainage, etc.

To be eligible for federal grant funds, the most important first step in setting up a joint-use facility or in converting a former or closing military air base is to establish the state or local government sponsorship for the proposed civilian airport. The joint civilian and military use of existing airfields and the conversion of former military airfields is not a panacea for aviation system capacity problems, but it is an important component in the FAA's strategy to maximize the safe utilization of the Nation's aviation system.

Table 6-1. A Preliminary List of Airports Located Near the 23 Delay-Problem Airports

Delay-problem Airport[2]		Supplemental Airport
Atlanta Hartsfield	ATL	Athens
		Macon
		Columbus (100 mi)
		Chattanooga, TN (100 mi)
Boston	BOS	Manchester
		Pease International Trade Port
		Portland, ME
		Providence, RI
		Worcester
		Hanscom AFB
Charlotte	CLT	Hickory
		Greensboro (90 mi)
		Greer, SC (90 mi)
		Winston-Salem (60 mi)
Chicago O'Hare	ORD	Aurora
		Chicago Midway
		Meigs Field
		Rockford
		Waukegan
		West Chicago (Du Page)
		Wheeling
		Gary, IN
		Glenview NAS
Dallas-Ft. Worth	DFW	Carswell AFB
		Dallas-Love Field
		Denton
		Fort Worth Meacham
		McKinney
		Mesquite
		Waco (80 mi)
Denver	DEN	Colorado Springs (80 mi)
Detroit	DTW	Detroit City
		Flint
		Pontiac
		Lansing (80 mi)
		Toledo, OH (60 mi)
		Selfridge ANG
		Willow Run
		Windsor, Ontario, Canada
Honolulu	HNL	Kailua
Houston	IAH	Corpus Christi
		Ellington
		Galveston
		Houston Hobby
Los Angeles	LAX	Burbank
		Long Beach
		Norton AFB
		Ontario
		Oxnard
		Palmdale
Miami	MIA	Ft. Lauderdale
Minneapolis	MSP	St. Paul (Downtown)
		Mankato (60 mi)
		Rochester (77 mi)
		Eau Claire, WI (85 mi)
New York	JFK	Farmingdale
		Garden City
		Islip
		Long Island
		Stewart/Newburgh (60 mi)
		White Plains
Newark	EWR	Trenton
		Stewart/Newburgh, NY (60 mi)
		White Plains, NY
Orlando	MCO	Daytona Beach
		Ft. Pierce (100 mi)
		Melbourne (60 mi)
		Tampa (70 mi)
		Vero Beach (90 mi)
Philadelphia	PHL	Allentown
		Lancaster (70 mi)
		Reading (60 mi)
		Willow Grove NAS
		Trenton, NJ
		Wilmington, DE
Phoenix	PHX	Prescott (80 mi)
		Williams AFB
Pittsburgh	PIT	Johnstown
		Latrobe
		Morgantown, WV (60 mi)
San Francisco	SFO	Concord
		Oakland
		San Jose
		Santa Rosa
		Moffett Field NAS
		Hamilton Field
St. Louis	STL	Scott AFB
Seattle	SEA	Everett/Paine Field
		McChord AFB
Washington National	DCA	Baltimore, MD
		Hagerstown, MD (60 mi)
		Charlottesville, VA (100 mi)
		Richmond, VA (100 mi)
		Andrews AFB
Washington Dulles	IAD	Baltimore, MD
		Hagerstown, MD (60 mi)
		Charlottesville, VA (100 mi)
		Richmond, VA (100 mi)
		Andrews AFB

2. Airports having greater than 20,000 hours of delay for 1991 as reported by FAA Office of Policy and Plans.

Chapter 7

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 capacity problem in terms of flight delays, rather than dealing with a more abstract "definition of capacity." While it is relatively simple to compute an airport's hourly throughput capacity (the number of flight operations which can be handled under 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 1991, 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 2002 is projected to grow from 23 to 33.

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 reduction in flight delays if a percentage of small aircraft operations could be shifted to reliever airports; however, some of the forecast 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 the reduction of flight delays.

Having first identified forecast 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 have been completed at Atlanta, Boston, Charlotte, Chicago, Detroit, Honolulu, Kansas City, Los Angeles, Memphis, Miami, Nashville, New Orleans, Oakland, Orlando, Philadelphia, Phoenix, Pittsburgh, Raleigh-Durham, St. Louis, Salt Lake City, San Antonio, 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 13 could benefit from triple IFR approaches. Demonstration programs have been completed or are underway for these new approach procedures. In the past year, several new national standards have been published that incorporate these capacity-enhancing 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 66 percent of all flights delayed 15 minutes or more in 1991. 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 new 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 surface. 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. The Airport and Airspace Simulation Model (SIMMOD), National Airspace Performance Analysis Capability (NASPAC), Sector Design Analysis Tool (SDAT), and Terminal Airspace Visualization Tool (TAVT) 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 Capability (NSC), the National Control Facility (NCF), and Dynamic Special-Use Airspace Management.

The "ground up" view encompasses en route airspace. This 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. New York, Washingon D.C., Cleveland, 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 building 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 five runways, and is scheduled to open in late 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 1991, 17 are in the process of constructing or planning the construction of new runways or extensions to existing runways. Of the 33 delay-problem airports forecast for the year 2002, 25 propose to build new runways or runway extensions. The total anticipated cost of completing these new runways and runway extensions exceeds $7.7 billion.

The FAA is also pursuing initiatives for the joint civilian and military use of current military airfields and the conversion of former military air bases to civilian use for capacity enhancement to the overall aviation system.

System capacity must continue to grow in order to maintain the same level of service quality. The majority of cities with air service prior to de-regulation in 1978 received more frequent service in 1991. 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. 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, 1990 and 1991[1]

City-Airport	Airport ID	Rank	Enplanements[2] (000s) CY90	Enplanements[2] (000s) CY91	Operations[3] (000s) FY90	Operations[3] (000s) FY91
Chicago O'Hare Int'l	ORD	1	25,636	25,872	811	809
Dallas-Fort Worth Int'l	DFW	2	22,899	22,656	725	731
Los Angeles Int'l	LAX	3	18,438	18,303	669	661
Atlanta Hartsfield Int'l	**ATL**	**4**	**22,666**	**17,691**	**779**	**640**
San Francisco Int'l	SFO	5	13,475	14,026	437	435
Denver Stapleton Int'l	DEN	6	11,962	12,314	475	491
Phoenix Sky Harbor Int'l	PHX	7	10,727	10,972	497	499
Newark Int'l	**EWR**	**8**	**9,854**	**9,737**	**384**	**382**
Detroit Metro Wayne County	DTW	9	9,903	9,618	391	391
St. Louis Lambert Int'l	STL	10	9,332	9,352	443	413
Miami Int'l	MIA	11	9,226	9,310	463	481
New York LaGuardia	**LGA**	**12**	**10,725**	**9,195**	**365**	**333**
Minneapolis-St. Paul	MSP	13	8,837	8,863	382	383
Boston Logan Int'l	BOS	14	9,550	8,862	448	441
Honolulu Int'l	HNL	15	9,002	8,772	407	394
New York Kennedy Int'l	**JFK**	**16**	**9,687**	**8,245**	**342**	**304**
Las Vegas McCarran	LAS	17	7,796	8,222	395	399
Houston Intercontinental	IAH	18	7,544	7,814	310	310
Pittsburgh Int'l	PIT	19	7,912	7,707	385	386
Seattle-Tacoma	**SEA**	**20**	**7,386**	**7,696**	**354**	**340**
Charlotte Douglas Int'l	CLT	21	7,077	7,669	452	441
Orlando Int'l	MCO	22	7,678	7,605	278	275
Washington National	DCA	23	7,035	6,631	320	298
Philadelphia Int'l	**PHL**	**24**	**6,971**	**6,381**	**405**	**383**
Salt Lake City Int'l	SLC	25	5,388	5,470	302	302
San Diego Lindbergh	SAN	26	5,261	5,387	212	206
Washington Dulles Int'l	IAD	27	4,449	4,709	240	267
Tampa Int'l	**TPA**	**28**	**4,781**	**4,338**	**227**	**234**
Cincinnati Int'l	CVG	29	3,908	4,314	285	298
Raleigh-Durham Int'l	RDU	30	4,361	4,310	283	271
Baltimore-Washington Int'l	BWI	31	4,420	4,250	304	282
Nashville Metro	**BNA**	**32**	**3,404**	**3,902**	**259**	**274**
Houston Hobby	HOU	33	3,972	3,766	267	267
San Juan Luis Muñoz Marín Int'l	SJU	34	3,618	3,739	205	200
Cleveland Hopkins Int'l	CLE	35	3,836	3,545	273	245
Memphis Int'l	**MEM**	**36**	**3,887**	**3,495**	**330**	**322**

1. At the top 100 airports, ranked by 1991 enplanements.

Table A-1. Airport Operations and Enplanements, 1990 and 1991 (continued)[1]

City-Airport	Airport ID	Rank	Enplanements[2] (000s) CY90	CY91	Operations[3] (000s) FY90	FY91
Fort Lauderdale Int'l	FLL	37	3,875	3,452	224	210
Kansas City Int'l	MCI	38	3,358	3,289	162	168
Portland (OR) Int'l	PDX	39	3,025	3,164	272	265
New Orleans Int'l	**MSY**	**40**	**3,361**	**3,152**	**152**	**152**
San Jose Int'l	SJC	41	3,128	3,150	320	337
Oakland Metro Int'l	OAK	42	2,671	2,956	389	414
Chicago Midway	MDW	43	3,547	2,937	322	302
Ontario Int'l	**ONT**	**44**	**2,641**	**2,837**	**151**	**156**
Dallas Love	DAL	45	2,883	2,793	214	208
Indianapolis Int'l	IND	46	2,602	2,586	225	234
Santa Ana John Wayne	SNA	47	2,204	2,573	523	551
San Antonio Int'l	**SAT**	**48**	**2,594**	**2,520**	**219**	**214**
West Palm Beach Int'l	PBI	49	2,609	2,356	239	224
Albuquerque Int'l	ABQ	50	2,385	2,351	226	212
Windsor Locks Bradley Int'l	BDL	51	2,312	2,107	182	171
Sacramento Metro	**SMF**	**52**	**1,737**	**2,105**	**162**	**152**
Kahului	OGG	53	2,094	2,092	179	182
Austin Robert Mueller	AUS	54	2,055	2,021	193	183
Burbank	BUR	55	1,699	1,822	235	229
Dayton Int'l	**DAY**	**56**	**1,845**	**1,758**	**197**	**193**
Milwaukee Mitchell Int'l	MKE	57	1,915	1,757	209	206
El Paso Int'l	ELP	58	1,673	1,670	179	164
Fort Myers SW Florida Regional	RSW	59	1,713	1,586	69	67
Port Columbus Int'l	**CMH**	**60**	**1,685**	**1,580**	**224**	**214**
Buffalo Int'l	BUF	61	1,637	1,543	140	128
Reno Cannon Int'l	RNO	62	1,344	1,516	164	106
Oklahoma City Will Rogers Wld	OKC	63	1,520	1,457	145	149
Tulsa Int'l	**TUL**	**64**	**1,483**	**1,399**	**195**	**188**
Anchorage	ANC	65	1,362	1,321	219	228
Lihue	LIH	66	1,265	1,254	114	110
Norfolk Int'l	ORF	67	1,255	1,169	161	143
Tucson Int'l	**TUS**	**68**	**1,264**	**1,167**	**229**	**235**
Jacksonville Int'l	JAX	69	1,267	1,146	148	155
Rochester Monroe County	ROC	70	1,155	1,067	184	183
Omaha Eppley	OMA	71	994	1,058	153	164
Syracuse Hancock Int'l	**SYR**	**72**	**1,167**	**1,037**	**183**	**182**

1. At the top 100 airports, ranked by 1991 enplanements.

Table A-1. Airport Operations and Enplanements, 1990 and 1991 (concluded)[1]

City-Airport	Airport ID	Rank	Enplanements[2] (000s) CY90	Enplanements[2] (000s) CY91	Operations[3] (000s) FY90	Operations[3] (000s) FY91
Kailua-Kona Keahole	KOA	73	977	995	59	58
Providence Green State	PVD	74	1,061	954	180	152
Birmingham Municipal	BHM	75	1,002	933	199	185
Little Rock Adams	LIT	76	951	932	149	140
Louisville Standiford	SDF	77	938	894	160	158
Sarasota-Bradenton	SRQ	78	990	883	168	174
Guam Agana Field	NGM	79	771	830	67	61
Richmond Int'l	RIC	80	864	820	160	141
Greensboro Regional	GSO	81	895	810	151	137
Spokane Int'l	GEG	82	747	792	121	112
Albany	ALB	83	878	762	184	156
Des Moines	DSM	84	659	678	146	145
Hilo General Lyman	ITO	85	651	660	100	89
Long Beach	LGB	86	693	650	483	461
Colorado Springs Municipal	COS	87	552	609	177	189
Charleston (SC) AFB Int'l	CHS	88	632	592	132	131
Grand Rapids Kent County Int'l	GRR	89	614	583	169	171
Boise	BOI	90	525	548	168	153
Lubbock Int'l	LBB	91	611	542	133	122
Wichita Mid-Continent	ICT	92	561	533	175	174
Midland Int'l	MAF	93	581	519	97	92
Knoxville McGhee-Tyson	TYS	94	478	496	167	153
Savannah Int'l	SAV	95	521	479	109	101
Columbia (SC) Metro	CAE	96	513	476	113	111
Harlingen Rio Grande Int'l	HRL	97	529	463	60	53
Harrisburg	MDT	98	437	452	140	102
Charlotte Amalie St. Thomas (VI)	STT	99	357	451	105	108
Portland Int'l Jetport (ME)	PWM	100	472	450	112	112
Total			417,387	407,272	25,790	25,108

Sources:
Enplanement data: *Airport Activity Statistics of Certificated Route Air Carriers, 1990, and preliminary 1991 data.*
Operations data: *Terminal Area Forecasts FY92–2005, FAA-APO-92-5, July 1992, for FY90 data.*

1. At the top 100 airports, ranked by 1991 enplanements.
2. Enplanements include originating, stopover, and transfer passengers of U.S. scheduled and non-scheduled commercial air carriers including commuter, regional, and air taxi operators.
3. Operations are the total number of operations at the airport and include the sum of the itinerant and local operations. Every takeoff and landing is counted as an aircraft operation.

Table A-2. Airport Enplanements, 1990 and Forecast 2005 [4]

City-Airport	Airport ID	Rank	Enplanements (000s) FY90	FY2005	% Growth
Chicago O'Hare Int'l	ORD	1	27,949	42,250	51.2
Dallas-Fort Worth Int'l	DFW	2	24,270	40,860	68.4
Atlanta Hartsfield Int'l	ATL	3	24,134	35,678	47.8
Los Angeles Int'l	LAX	4	22,277	34,277	53.9
San Francisco Int'l	SFO	5	14,694	28,570	94.4
New York Kennedy Int'l	JFK	6	14,451	22,283	54.2
Denver Stapleton Int'l[5]	DEN	7	12,767	26,555	108.0
Miami Int'l	MIA	8	12,192	21,672	77.8
New York LaGuardia	LGA	9	11,410	16,371	43.5
Boston Logan Int'l	BOS	10	11,085	18,888	70.4
Newark Int'l	EWR	11	11,012	23,048	109.3
Phoenix Sky Harbor Int'l	PHX	12	10,877	24,281	123.2
Detroit Metro Wayne County	DTW	13	10,555	19,304	82.9
Honolulu Int'l	HNL	14	10,417	15,546	49.2
St. Louis Lambert Int'l	STL	15	10,057	18,838	87.3
Minneapolis-St. Paul	MSP	16	9,715	17,005	75.0
Las Vegas McCarran	LAS	17	9,301	19,832	113.2
Orlando Int'l	MCO	18	8,684	16,733	92.7
Pittsburgh Int'l	PIT	19	8,531	16,907	98.2
Houston Intercontinental	IAH	20	8,127	15,164	86.6
Philadelphia Int'l	PHL	21	8,001	13,683	71.0
Seattle-Tacoma	SEA	22	7,863	14,720	87.2
Washington National	DCA	23	7,809	9,452	21.0
Charlotte Douglas Int'l	CLT	24	7,784	13,298	70.8
Salt Lake City Int'l	SLC	25	5,580	9,605	72.1
San Diego Lindbergh	SAN	26	5,488	11,725	113.6
Tampa Int'l	TPA	27	5,307	12,059	127.2
Washington Dulles Int'l	IAD	28	5,112	13,256	159.3
Baltimore-Washington Int'l	BWI	29	5,028	8,469	68.4
Raleigh-Durham Int'l	RDU	30	4,601	10,815	135.1
Cincinnati Int'l	CVG	31	4,538	11,866	161.5
Fort Lauderdale Int'l	FLL	32	4,427	8,833	99.5
Memphis Int'l	MEM	33	4,231	8,589	103.0
Cleveland Hopkins Int'l	CLE	34	4,188	6,477	54.7
Houston Hobby	HOU	35	3,990	7,953	99.3

4. At the top 100 airports, ranked by 1990 enplanements.
5. Assumes development of a new airport at Denver and increased hubbing activity in 1993–1995.

Table A-2. Airport Enplanements, 1990 and Forecast 2005 (continued) [4]

City-Airport	Airport ID	Rank	Enplanements (000s) FY90	FY2005	% Growth
San Juan Luis Muñoz Marín Int'l	SJU	36	3,923	8,108	106.7
Chicago Midway	MDW	37	3,855	7,442	93.0
Nashville Metro	BNA	38	3,662	7,597	107.5
Kansas City Int'l	**MCI**	**39**	**3,478**	**9,000**	**158.8**
New Orleans Int'l	MSY	40	3,439	7,728	124.7
San Jose Int'l	SJC	41	3,345	8,605	157.2
Portland (OR) Int'l	PDX	42	3,179	6,126	92.7
Dallas Love	**DAL**	**43**	**2,885**	**7,087**	**145.6**
Indianapolis Int'l	IND	44	2,831	4,653	64.4
West Palm Beach Int'l	PBI	45	2,787	5,580	100.2
Oakland Metro Int'l	OAK	46	2,721	5,867	115.6
San Antonio Int'l	**SAT**	**47**	**2,682**	**4,692**	**74.9**
Ontario Int'l	ONT	48	2,670	12,440	365.9
Albuquerque Int'l	ABQ	49	2,516	5,030	99.9
Windsor Locks Bradley Int'l	BDL	50	2,475	4,922	98.9
Santa Ana John Wayne	**SNA**	**51**	**2,291**	**4,896**	**113.7**
Milwaukee Mitchell Int'l	MKE	52	2,174	5,120	135.5
Kahului	OGG	53	2,150	3,506	63.1
Austin Robert Mueller	AUS	54	2,139	6,909	223.0
Dayton Int'l	**DAY**	**55**	**2,074**	**3,841**	**85.2**
Port Columbus Int'l	CMH	56	1,815	3,111	71.4
Sacramento Metro	SMF	57	1,807	5,217	188.7
Fort Myers SW Florida Regional	RSW	58	1,781	5,249	194.7
Buffalo Int'l	**BUF**	**59**	**1,738**	**3,228**	**85.7**
Burbank	BUR	60	1,729	3,274	89.4
El Paso Int'l	ELP	61	1,677	3,696	120.4
Anchorage	ANC	62	1,600	2,858	78.6
Reno Cannon Int'l	**RNO**	**63**	**1,548**	**3,090**	**99.6**
Oklahoma City Will Rogers Wld	OKC	64	1,545	3,645	135.9
Tulsa Int'l	TUL	65	1,490	2,976	99.7
Jacksonville Int'l	JAX	66	1,356	2,980	119.8
Norfolk Int'l	**ORF**	**67**	**1,346**	**2,625**	**95.0**
Tucson Int'l	TUS	68	1,330	3,148	136.7
Lihue	LIH	69	1,265	2,021	59.8
Rochester Monroe County	ROC	70	1,261	2,619	107.7

4. At the top 100 airports, ranked by 1990 enplanements.

Table A-2. Airport Enplanements, 1990 and Forecast 2005 (concluded) [4]

City-Airport	Airport ID	Rank	Enplanements (000s) FY90	FY2005	% Growth
Omaha Eppley	OMA	71	1,031	1,748	69.5
Syracuse Hancock Int'l	SYR	72	1,324	2,641	99.5
Providence Green State	PVD	73	1,217	1,797	47.7
Albany	ALB	74	1,175	2,130	81.3
Guam Agana Field	NGM	75	1,092	1,865	70.8
Birmingham Municipal	BHM	76	1,041	2,034	95.4
Louisville Standiford	SDF	77	1,039	1,975	90.1
Sarasota-Bradenton	SRQ	78	1,027	1,613	57.1
Kailua-Kona Keahole	KOA	79	978	2,010	105.5
Little Rock Adams	LIT	80	975	1,848	89.5
Richmond Int'l	RIC	81	932	1,995	114.1
Greensboro Regional	GSO	82	923	2,101	127.6
Spokane Int'l	GEG	83	806	1,926	139.0
Des Moines	DSM	84	694	1,215	75.1
Long Beach	LGB	85	693	1,747	152.1
Grand Rapids Kent County Int'l	GRR	86	689	1,210	75.6
Charleston (SC) AFB Int'l	CHS	87	680	1,506	121.5
Hilo General Lyman	ITO	88	656	972	48.2
Lubbock Int'l	LBB	89	620	1,164	87.7
Harrisburg	MDT	90	613	1,352	120.6
Colorado Springs Municipal	COS	91	600	1,226	104.3
Midland Int'l	MAF	92	585	1,203	105.6
Wichita Mid-Continent	ICT	93	584	1,204	106.2
Knoxville McGhee-Tyson	TYS	94	583	1,101	88.9
Portland Int'l Jetport (ME)	PWM	95	571	1,209	111.7
Columbia (SC) Metro	CAE	96	556	1,180	112.2
Harlingen Rio Grande Int'l	HRL	97	532	1,516	185.0
Savannah Int'l	SAV	98	532	947	78.0
Boise	BOI	99	525	1,025	95.2
Charlotte Amalie St. Thomas (VI)	STT	100	491	2,155	338.9
Total			**460,780**	**861,363**	

Source:
Terminal Area Forecasts FY92-2005, FAA-APO-92-5, July 1992.

4. At the top 100 airports, ranked by 1990 enplanements.

Table A-3. Total Airport Operations, 1990 and Forecast 2005 [6]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY2005	% Growth
Chicago O'Hare Int'l	ORD	1	811	848	4.6
Atlanta Hartsfield Int'l	ATL	2	779	950	22.0
Dallas-Fort Worth Int'l	DFW	3	725	1,198	65.2
Los Angeles Int'l	LAX	4	669	856	27.9
Santa Ana John Wayne	SNA	5	523	730	39.6
Phoenix Sky Harbor Int'l	PHX	6	497	646	30.0
Long Beach	LGB	7	483	551	14.1
Denver Stapleton Int'l	DEN	8	475	655	37.9
Miami Int'l	MIA	9	463	644	39.1
Charlotte Douglas Int'l	CLT	10	452	566	25.2
Boston Logan Int'l	BOS	11	448	552	23.2
St. Louis Lambert Int'l	STL	12	443	550	24.2
San Francisco Int'l	SFO	13	437	722	65.2
Honolulu Int'l	HNL	14	407	509	25.1
Philadelphia Int'l	PHL	15	405	540	33.3
Las Vegas McCarran	LAS	16	395	509	28.9
Detroit Metro Wayne County	DTW	17	391	543	38.9
Oakland Metro Int'l	OAK	18	389	609	56.6
Pittsburgh Int'l	PIT	19	385	556	44.4
Newark Int'l	EWR	20	384	449	16.9
Minneapolis-St. Paul	MSP	21	382	579	51.6
New York LaGuardia	LGA	22	365	381	4.4
Seattle-Tacoma	SEA	23	354	430	21.5
New York Kennedy Int'l	JFK	24	342	397	16.1
Memphis Int'l	MEM	25	330	503	52.4
Chicago Midway	MDW	26	322	408	26.7
San Jose Int'l	SJC	27	320	550	71.9
Washington National	DCA	28	320	356	11.3
Houston Intercontinental	IAH	29	310	458	47.7
Baltimore-Washington Int'l	BWI	30	304	416	36.8
Salt Lake City Int'l	SLC	31	302	406	34.4
Cincinnati Int'l	CVG	32	285	548	92.3
Raleigh-Durham Int'l	RDU	33	283	454	60.4
Orlando Int'l	MCO	34	278	588	111.5
Cleveland Hopkins Int'l	CLE	35	273	303	11.0

6. At the top 100 airports, ranked by 1990 operations.

Table A-3. Total Airport Operations, 1990 and Forecast 2005 (continued) [6]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY2005	% Growth
Portland (OR) Int'l	PDX	36	272	367	34.9
Houston Hobby	HOU	37	267	382	43.1
Nashville Metro	BNA	38	259	375	44.8
Washington Dulles Int'l	IAD	39	240	395	64.6
West Palm Beach Int'l	PBI	40	239	255	6.7
Burbank	BUR	41	235	301	28.1
Tucson Int'l	TUS	42	229	491	114.4
Tampa Int'l	TPA	43	227	367	61.7
Albuquerque Int'l	ABQ	44	226	467	106.6
Indianapolis Int'l	IND	45	225	730	224.4
Fort Lauderdale Int'l	FLL	46	224	383	71.0
Port Columbus Int'l	CMH	47	224	286	27.7
Anchorage	ANC	48	219	280	27.9
San Antonio Int'l	SAT	49	219	380	73.5
Dallas Love	DAL	50	214	410	91.6
San Diego Lindbergh	SAN	51	212	345	62.7
Milwaukee Mitchell Int'l	MKE	52	209	268	28.2
Islip Long Island MacArthur	ISP	53	209	336	60.8
San Juan Luis Muñoz Marín Int'l	SJU	54	205	287	40.0
Birmingham Municipal	BHM	55	199	278	39.7
Dayton Int'l	DAY	56	197	321	62.9
Tulsa Int'l	TUL	57	195	285	46.2
Austin Robert Mueller	AUS	58	193	378	95.8
Albany	ALB	59	184	234	27.2
Rochester Monroe County	ROC	60	184	295	60.3
Syracuse Hancock Int'l	SYR	61	183	279	52.5
Windsor Locks Bradley Int'l	BDL	62	182	337	85.2
Providence Green State	PVD	63	180	189	5.0
El Paso Int'l	ELP	64	179	335	87.2
Kahului	OGG	65	179	271	51.4
Colorado Springs Municipal	COS	66	177	234	32.2
Wichita Mid-Continent	ICT	67	175	320	82.9
Grand Rapids Kent County Int'l	GRR	68	169	265	56.8
Boise	BOI	69	168	324	92.9
Sarasota-Bradenton	SRQ	70	168	222	32.1

6. At the top 100 airports, ranked by 1990 operations.

Table A-3. Total Airport Operations, 1990 and Forecast 2005 (concluded) [6]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY2005	% Growth
Knoxville McGhee-Tyson	TYS	71	167	200	19.8
Reno Cannon Int'l	RNO	72	164	244	48.8
Sacramento Metro	SMF	73	162	313	93.2
Kansas City Int'l	**MCI**	**74**	**162**	**355**	**119.1**
Norfolk Int'l	ORF	75	161	241	49.7
Louisville Standiford	SDF	76	160	221	38.1
Richmond Int'l	RIC	77	160	213	33.1
Omaha Eppley	**OMA**	**78**	**153**	**201**	**31.4**
New Orleans Int'l	MSY	79	152	236	55.3
Greensboro Regional	GSO	80	151	220	45.7
Ontario Int'l	ONT	81	151	454	200.7
Little Rock Adams	**LIT**	**82**	**149**	**257**	**72.5**
Jacksonville Int'l	JAX	83	148	196	32.4
Des Moines	DSM	84	146	280	91.8
Oklahoma City Will Rogers Wld	OKC	85	145	215	48.3
Buffalo Int'l	**BUF**	**86**	**140**	**184**	**31.4**
Harrisburg	MDT	87	140	190	35.7
Lubbock Int'l	LBB	88	133	208	56.4
Charleston (SC) AFB Int'l	CHS	89	132	187	41.7
Spokane Int'l	**GEG**	**90**	**121**	**228**	**88.4**
Lihue	LIH	91	114	150	31.6
Columbia (SC) Metro	CAE	92	113	217	92.0
Portland Int'l Jetport (ME)	PWM	93	112	156	39.3
Savannah Int'l	**SAV**	**94**	**109**	**172**	**57.8**
Charlotte Amalie St. Thomas (VI)	STT	95	105	128	21.9
Hilo General Lyman	ITO	96	100	115	15.0
Midland Int'l	MAF	97	97	182	87.6
Amarillo	**AMA**	**98**	**86**	**129**	**50.0**
Fort Myers SW Florida Regional	RSW	99	69	158	129.0
Greer Greenville-Spartanburg	GSP	100	69	104	50.7
Total			**25,968**	**37,986**	

Sources:
Terminal Area Forecasts FY92-2005, FAA-APO-92-5, July 1992.

6. At the top 100 airports, ranked by 1990 operations.

Table A-4. Growth in Enplanements From 1990 to 1991 [7]

City-Airport	Airport ID	Rank	Enplanements (000s) CY90	CY91	% Growth
Charlotte Amalie St. Thomas (VI)	STT	1	357	451	26.3
Sacramento Metro	SMF	2	1,737	2,105	21.2
Santa Ana John Wayne	SNA	3	2,204	2,573	16.7
Nashville Metro	**BNA**	**4**	**3,404**	**3,902**	**14.6**
Reno Cannon Int'l	RNO	5	1,344	1,516	12.8
Oakland Metro Int'l	OAK	6	2,671	2,956	10.7
Cincinnati Int'l	CVG	7	3,908	4,314	10.4
Colorado Springs Municipal	**COS**	**8**	**552**	**609**	**10.3**
Charlotte Douglas Int'l	CLT	9	7,077	7,669	8.4
Guam Agana Field	NGM	10	771	830	7.6
Ontario Int'l	ONT	11	2,641	2,837	7.4
Burbank	**BUR**	**12**	**1,699**	**1,822**	**7.2**
Omaha Eppley	OMA	13	994	1,058	6.4
Spokane Int'l	GEG	14	747	792	6.0
Washington Dulles Int'l	IAD	15	4,449	4,709	5.8
Las Vegas McCarran	**LAS**	**16**	**7,796**	**8,222**	**5.5**
Portland (OR) Int'l	PDX	17	3,025	3,164	4.6
Boise	BOI	18	525	548	4.4
Seattle-Tacoma	SEA	19	7,386	7,696	4.2
San Francisco Int'l	**SFO**	**20**	**13,475**	**14,026**	**4.1**
Knoxville McGhee-Tyson	TYS	21	478	496	3.8
Houston Intercontinental	IAH	22	7,544	7,814	3.6
Harrisburg	MDT	23	437	452	3.4
San Juan Luis Muñoz Marín Int'l	**SJU**	**24**	**3,618**	**3,739**	**3.3**
Denver Stapleton Int'l	DEN	25	11,962	12,314	2.9
Des Moines	DSM	26	659	678	2.9
San Diego Lindbergh	SAN	27	5,261	5,387	2.4
Phoenix Sky Harbor Int'l	**PHX**	**28**	**10,727**	**10,972**	**2.3**
Kailua-Kona Keahole	KOA	29	977	995	1.8
Salt Lake City Int'l	SLC	30	5,388	5,470	1.5
Hilo General Lyman	ITO	31	651	660	1.4
Chicago O'Hare Int'l	**ORD**	**32**	**25,636**	**25,872**	**0.9**
Miami Int'l	MIA	33	9,226	9,310	0.9
San Jose Int'l	SJC	34	3,128	3,150	0.7
Minneapolis-St. Paul	MSP	35	8,837	8,863	0.3

7. At the top 100 airports based on 1991 enplanement data, ranked by growth in total enplanments.

Table A-4. Growth in Enplanements From 1990 to 1991 (continued) [7]

City-Airport	Airport ID	Rank	Enplanements (000s) CY90	CY91	% Growth
St. Louis Lambert Int'l	STL	36	9,332	9,352	0.2
Kahului	OGG	37	2,094	2,092	-0.1
El Paso Int'l	ELP	38	1,673	1,670	-0.2
Indianapolis Int'l	**IND**	**39**	**2,602**	**2,586**	**-0.6**
Los Angeles Int'l	LAX	40	18,438	18,303	-0.7
Lihue	LIH	41	1,265	1,254	-0.9
Orlando Int'l	MCO	42	7,678	7,605	-1.0
Dallas-Fort Worth Int'l	**DFW**	**43**	**22,899**	**22,656**	**-1.1**
Raleigh-Durham Int'l	RDU	44	4,361	4,310	-1.2
Newark Int'l	EWR	45	9,854	9,737	-1.2
Albuquerque Int'l	ABQ	46	2,385	2,351	-1.4
Austin Robert Mueller	**AUS**	**47**	**2,055**	**2,021**	**-1.7**
Little Rock Adams	LIT	48	951	932	-2.0
Kansas City Int'l	MCI	49	3,358	3,289	-2.1
Pittsburgh Int'l	PIT	50	7,912	7,707	-2.6
Honolulu Int'l	**HNL**	**51**	**9,002**	**8,772**	**-2.6**
San Antonio Int'l	SAT	52	2,594	2,520	-2.9
Detroit Metro Wayne County	DTW	53	9,903	9,618	-2.9
Dallas Love	DAL	54	2,883	2,793	-3.1
Anchorage	**ANC**	**55**	**1,362**	**1,321**	**-3.0**
Baltimore-Washington Int'l	BWI	56	4,420	4,250	-3.9
Oklahoma City Will Rogers Wld	OKC	57	1,520	1,457	-4.1
Portland Int'l Jetport (ME)	PWM	58	472	450	-4.7
Louisville Standiford	**SDF**	**59**	**938**	**894**	**-4.7**
Dayton Int'l	DAY	60	1,845	1,758	-4.7
Wichita Mid-Continent	ICT	61	561	533	-5.0
Grand Rapids Kent County Int'l	GPR	62	614	583	-5.1
Richmond Int'l	**RIC**	**63**	**864**	**820**	**-5.1**
Houston Hobby	HOU	64	3,972	3,766	-5.2
Tulsa Int'l	TUL	65	1,483	1,399	-5.7
Buffalo Int'l	BUF	66	1,637	1,543	-5.7
Washington National	**DCA**	**67**	**7,035**	**6,631**	**-5.7**
Long Beach	LGB	68	693	650	-6.2
Port Columbus Int'l	CMH	69	1,685	1,580	-6.2
New Orleans Int'l	MSY	70	3,361	3,152	-6.2

7. At the top 100 airports based on 1991 enplanement data, ranked by growth in total enplanments.

Table A-4. Growth in Enplanements From 1990 to 1991 (concluded) [7]

City-Airport	Airport ID	Rank	Enplanements (000s) CY90	CY91	% Growth
Charleston (SC) AFB Int'l	CHS	71	632	592	-6.3
Birmingham Municipal	BHM	72	1,002	933	-6.9
Norfolk Int'l	ORF	73	1,255	1,169	-6.9
Columbia (SC) Metro	**CAE**	**74**	**513**	**476**	**-7.2**
Boston Logan Int'l	BOS	75	9,550	8,862	-7.2
Fort Myers SW Florida Regional	RSW	76	1,713	1,586	-7.4
Rochester Monroe County	ROC	77	1,155	1,067	-7.6
Cleveland Hopkins Int'l	**CLE**	**78**	**3,836**	**3,545**	**-7.6**
Tucson Int'l	TUS	79	1,264	1,167	-7.7
Savannah Int'l	SAV	80	521	479	-8.1
Milwaukee Mitchell Int'l	MKE	81	1,915	1,757	-8.3
Philadelphia Int'l	**PHL**	**82**	**6,971**	**6,381**	**-8.5**
Windsor Locks Bradley Int'l	BDL	83	2,312	2,107	-8.9
Tampa Int'l	TPA	84	4,781	4,338	-9.3
Greensboro Regional	GSO	85	895	810	-9.5
Jacksonville Int'l	**JAX**	**86**	**1,267**	**1,146**	**-9.6**
West Palm Beach Int'l	PBI	87	2,609	2,356	-9.7
Providence Green State	PVD	88	1,061	954	-10.1
Memphis Int'l	MEM	89	3,887	3,495	-10.1
Midland Int'l	**MAF**	**90**	**581**	**519**	**-10.7**
Sarasota-Bradenton	SRQ	91	990	883	-10.8
Fort Lauderdale Int'l	FLL	92	3,875	3,452	-10.9
Syracuse Hancock Int'l	SYR	93	1,167	1,037	-11.1
Lubbock Int'l	**LBB**	**94**	**611**	**542**	**-11.3**
Harlingen Rio Grande Int'l	HRL	95	529	463	-12.5
Albany	ALB	96	878	762	-13.2
New York LaGuardia	LGA	97	10,725	9,195	-14.3
New York Kennedy Int'l	**JFK**	**98**	**9,687**	**8,245**	**-14.9**
Chicago Midway	MDW	99	3,547	2,937	-17.2
Atlanta Hartsfield Int'l	ATL	100	22,666	17,691	-21.9
Total			**407,272**	**408,794**	

Sources:
Enplanement data: Airport Activity Statistics of Certificated Route Air Carriers, 1990, and preliminary 1991 data.

7. At the top 100 airports based on 1991 enplanement data, ranked by growth in total enplanments.

Table A-5. Growth in Operations From 1990 to 1991 [8]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY91	% Growth
Washington Dulles Int'l	IAD	1	240	267	11.3
Islip Long Island MacArthur	ISP	2	209	225	7.7
Omaha Eppley	OMA	3	153	164	7.2
Colorado Springs Municipal	**COS**	**4**	**177**	**189**	**6.8**
Oakland Metro Int'l	OAK	5	389	414	6.4
Nashville Metro	BNA	6	259	274	5.8
Santa Ana John Wayne	SNA	7	523	551	5.4
San Jose Int'l	**SJC**	**8**	**320**	**337**	**5.3**
Jacksonville Int'l	JAX	9	148	155	4.7
Cincinnati Int'l	CVG	10	285	298	4.6
Anchorage	ANC	11	219	228	4.1
Indianapolis Int'l	**IND**	**12**	**225**	**234**	**4.0**
Miami Int'l	MIA	13	463	481	3.9
Kansas City Int'l	MCI	14	162	168	3.7
Sarasota-Bradenton	SRQ	15	168	174	3.6
Denver Stapleton Int'l	**DEN**	**16**	**475**	**491**	**3.4**
Ontario Int'l	ONT	17	151	156	3.3
Tampa Int'l	TPA	18	227	234	3.1
Charlotte Amalie St. Thomas (VI)	STT	19	105	108	2.9
Oklahoma City Will Rogers Wld	**OKC**	**20**	**145**	**149**	**2.8**
Tucson Int'l	TUS	21	229	235	2.6
Kahului	OGG	22	179	182	1.7
Grand Rapids Kent County Int'l	GRR	23	169	171	1.2
Las Vegas McCarran	**LAS**	**24**	**395**	**399**	**1.0**
Dallas-Fort Worth Int'l	DFW	25	725	731	0.8
Minneapolis-St. Paul	MSP	26	382	383	0.3
Pittsburgh Int'l	PIT	27	385	386	0.3
Portland Int'l Jetport (ME)	**PWM**	**28**	**112**	**112**	**0.0**
New Orleans Int'l	MSY	29	152	152	0.0
Houston Hobby	HOU	30	267	267	0.0
Salt Lake City Int'l	SLC	31	302	302	0.0
Houston Intercontinental	**IAH**	**32**	**310**	**310**	**0.0**
Detroit Metro Wayne County	DTW	33	391	391	0.0
Chicago O'Hare Int'l	ORD	34	811	809	-0.2
Phoenix Sky Harbor Int'l	PHX	35	497	499	-0.4

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

Table A-5. Growth in Operations From 1990 to 1991 (continued) [8]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY91	% Growth
Syracuse Hancock Int'l	SYR	36	183	182	-0.5
Rochester Monroe County	ROC	37	184	183	-0.5
Newark Int'l	EWR	38	384	382	-0.5
San Francisco Int'l	**SFO**	**39**	**437**	**435**	**-0.5**
Wichita Mid-Continent	ICT	40	175	174	-0.6
Des Moines	DSM	41	146	145	-0.7
Charleston (SC) AFB Int'l	CHS	42	132	131	-0.8
Orlando Int'l	**MCO**	**43**	**278**	**275**	**-1.1**
Los Angeles Int'l	LAX	44	669	661	-1.2
Louisville Standiford	SDF	45	160	158	-1.3
Milwaukee Mitchell Int'l	MKE	46	209	206	-1.4
Boston Logan Int'l	**BOS**	**47**	**448**	**441**	**-1.6**
Columbia (SC) Metro	CAE	48	113	111	-1.8
Dayton Int'l	DAY	49	197	193	-2.0
San Antonio Int'l	SAT	50	219	214	-2.3
San Juan Luis Muñoz Marín Int'l	**SJU**	**51**	**205**	**200**	**-2.4**
Memphis Int'l	MEM	52	330	322	-2.4
Charlotte Douglas Int'l	CLT	53	452	441	-2.4
Burbank	BUR	54	235	229	-2.6
Portland (OR) Int'l	**PDX**	**55**	**272**	**265**	**-2.6**
San Diego Lindbergh	SAN	56	212	206	-2.8
Dallas Love	DAL	57	214	208	-2.8
Fort Myers SW Florida Regional	RSW	58	69	67	-2.9
Honolulu Int'l	**HNL**	**59**	**407**	**394**	**-3.2**
Amarillo	AMA	60	86	83	-3.5
Lihue	LIH	61	114	110	-3.5
Tulsa Int'l	TUL	62	195	188	-3.6
Seattle-Tacoma	**SEA**	**63**	**354**	**340**	**-4.0**
Raleigh-Durham Int'l	RDU	64	283	271	-4.2
Port Columbus Int'l	CMH	65	224	214	-4.5
Long Beach	LGB	66	483	461	-4.6
Midland Int'l	**MAF**	**67**	**97**	**92**	**-5.2**
Austin Robert Mueller	AUS	68	193	183	-5.2
Philadelphia Int'l	PHL	69	405	383	-5.4
Little Rock Adams	LIT	70	149	140	-6.0

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

Table A-5. Growth in Operations From 1990 to 1991 (concluded) [8]

City-Airport	Airport ID	Rank	Operations (000s) FY90	FY91	% Growth
Windsor Locks Bradley Int'l	BDL	71	182	171	-6.0
Sacramento Metro	SMF	72	162	152	-6.2
Albuquerque Int'l	ABQ	73	226	212	-6.2
Chicago Midway	MDW	74	322	302	-6.2
Fort Lauderdale Int'l	FLL	75	224	210	-6.3
West Palm Beach Int'l	PBI	76	239	224	-6.3
St. Louis Lambert Int'l	STL	77	443	413	-6.8
Washington National	DCA	78	320	298	-6.9
Birmingham Municipal	BHM	79	199	185	-7.0
Baltimore-Washington Int'l	BWI	80	304	282	-7.2
Savannah Int'l	SAV	81	109	101	-7.3
Spokane Int'l	GEG	82	121	112	-7.4
Lubbock Int'l	LBB	83	133	122	-8.3
Knoxville McGhee-Tyson	TYS	85	167	153	-8.4
El Paso Int'l	ELP	84	179	164	-8.4
Buffalo Int'l	BUF	86	140	128	-8.6
New York LaGuardia	LGA	87	365	333	-8.8
Boise	BOI	88	168	153	-8.9
Greensboro Regional	GSO	89	151	137	-9.3
Cleveland Hopkins Int'l	CLE	90	273	245	-10.3
Hilo General Lyman	ITO	91	100	89	-11.0
New York Kennedy Int'l	JFK	92	342	304	-11.1
Norfolk Int'l	ORF	93	161	143	-11.2
Richmond Int'l	RIC	94	160	141	-11.9
Greer Greenville-Spartanburg	GSP	95	69	60	-13.0
Albany	ALB	96	184	156	-15.2
Providence Green State	PVD	97	180	152	-15.6
Atlanta Hartsfield Int'l	ATL	98	779	640	-17.8
Harrisburg	MDT	99	140	102	-27.1
Reno Cannon Int'l	RNO	100	164	106	-35.4
Total			25,968	25,148	

Sources:
Operations data: *Terminal Area Forecasts FY92–2005, FAA-APO-92-5, July 1992, for FY90 data.*
FAA Air Traffic Activity FY91, for FY91 data.

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

Table A-6. Growth in Operations and Enplanements [9]

City-Airport	Airport ID	% Growth in Enplanements CY90 to CY91	% Growth in Operations FY90 to FY91
Albany	ALB	-13.2	-15.2
Albuquerque Int'l	ABQ	-1.4	-6.2
Anchorage	ANC	-3.0	4.1
Atlanta Hartsfield Int'l	ATL	-21.9	-17.8
Austin Robert Mueller	AUS	-1.7	-5.2
Baltimore-Washington Int'l	BWI	-3.9	-7.2
Birmingham Municipal	BHM	-6.9	-7.0
Boise	BOI	4.4	-8.8
Boston Logan Int'l	BOS	-7.2	-1.6
Buffalo Int'l	BUF	-5.7	-8.6
Burbank	BUR	7.2	-2.6
Charleston (SC) AFB Int'l	CHS	-6.3	-0.8
Charlotte Amalie St. Thomas (VI)	STT	26.3	2.9
Charlotte Douglas Int'l	CLT	8.4	-2.4
Chicago Midway	MDW	-17.2	-6.2
Chicago O'Hare Int'l	ORD	0.9	-0.2
Cincinnati Int'l	CVG	10.4	4.6
Cleveland Hopkins Int'l	CLE	-7.6	-10.3
Colorado Springs Municipal	COS	10.3	6.8
Columbia (SC) Metro	CAE	-7.2	-1.8
(Port) Columbus Int'l	CMH	-6.2	-4.5
Dallas-Fort Worth Int'l	DFW	-1.1	0.8
Dallas Love	DAL	-3.1	-2.8
Dayton Int'l	DAY	-4.7	-2.0
Denver Stapleton Int'l	DEN	2.9	3.4
Des Moines	DSM	2.9	-0.7
Detroit Metro Wayne County	DTW	-2.9	0.0
El Paso Int'l	ELP	-0.2	-8.4
Fort Lauderdale Int'l	FLL	-10.9	-6.3
Fort Myers SW Florida Regional	RSW	-7.4	-2.9
Grand Rapids Kent County Int'l	GRR	-5.1	1.2
Greensboro Regional	GSO	-9.5	-9.3
Guam Agana Field	NGM	7.6	-9.0
Harlingen Rio Grande Int'l	HRL	-12.5	-11.7
Harrisburg	MDT	3.4	-27.1

9. At the top 100 airports based on 1991 enplanement data, listed in alphabetical order.

Table A-6. Growth in Operations and Enplanements (continued) [9]

City-Airport	Airport ID	% Growth in Enplanements CY90 to CY91	% Growth in Operations FY90 to FY91
Hilo General Lyman	ITO	1.4	-11.0
Honolulu Int'l	HNL	-2.6	-3.2
Houston Hobby	HOU	-5.2	0.0
Houston Intercontinental	**IAH**	**3.6**	**0.0**
Indianapolis Int'l	IND	-0.6	4.0
Jacksonville Int'l	JAX	-9.6	4.7
Kahului	OGG	-0.1	1.7
Kailua-Kona Keahole	**KOA**	**1.8**	**-1.7**
Kansas City Int'l	MCI	-2.1	3.7
Knoxville McGhee-Tyson	TYS	3.8	-8.4
Las Vegas McCarran	LAS	5.5	1.0
Lihue	**LIH**	**-0.9**	**-3.5**
Little Rock Adams	LIT	-2.0	-6.0
Long Beach	LGB	-6.2	-4.6
Los Angeles Int'l	LAX	-0.7	-1.2
Louisville Standiford	**SDF**	**-4.7**	**-1.3**
Lubbock Int'l	LBB	-11.3	-8.3
Memphis Int'l	MEM	-10.1	-2.4
Miami Int'l	MIA	0.9	3.9
Midland Int'l	**MAF**	**-10.7**	**-5.2**
Milwaukee Mitchell Int'l	MKE	-8.3	-1.4
Minneapolis-St. Paul	MSP	0.3	0.3
Nashville Metro	BNA	14.6	5.8
Newark Int'l	**EWR**	**-1.2**	**-0.5**
New Orleans Int'l	MSY	-6.2	0.0
New York Kennedy Int'l	JFK	-14.9	-11.1
New York LaGuardia	LGA	-14.3	-8.8
Norfolk Int'l	**ORF**	**-6.9**	**-11.2**
Oakland Metro Int'l	OAK	10.7	6.4
Oklahoma City Will Rogers Wld	OKC	-4.1	2.8
Omaha Eppley	OMA	6.4	7.2
Ontario Int'l	**ONT**	**7.4**	**3.3**
Orlando Int'l	MCO	-1.0	-1.1
Philadelphia Int'l	PHL	-8.5	-5.4
Phoenix Sky Harbor Int'l	PHX	2.3	-0.4

9. At the top 100 airports based on 1991 enplanement data, listed in alphabetical order.

Table A-6. Growth in Operations and Enplanements (concluded) [9]

City-Airport	Airport ID	% Growth in Enplanements CY90 to CY91	% Growth in Operations FY90 to FY91
Pittsburgh Int'l	PIT	-2.6	0.3
Portland (OR) Int'l	PDX	4.6	-2.6
Portland Int'l Jetport (ME)	PWM	-4.7	0.0
Providence Green State	**PVD**	**-10.1**	**-15.6**
Raleigh-Durham Int'l	RDU	-1.2	-4.2
Reno Cannon Int'l	RNO	12.8	-35.4
Richmond Int'l	RIC	-5.1	-11.9
Rochester Monroe County	**ROC**	**-7.6**	**-0.5**
Sacramento Metro	SMF	21.2	-6.2
Salt Lake City Int'l	SLC	1.5	0.0
San Antonio Int'l	SAT	-2.9	-2.3
San Diego Lindbergh	**SAN**	**2.4**	**-2.8**
San Francisco International	SFO	4.1	-0.5
San Jose Int'l	SJC	0.7	5.3
San Juan Luis Muñoz Marín Int'l	SJU	3.3	-2.4
Santa Ana John Wayne	**SNA**	**16.7**	**5.4**
Sarasota-Bradenton	SRQ	-10.8	3.6
Savannah Int'l	SAV	-8.1	-7.3
Seattle-Tacoma Int'l	SEA	4.2	-4.0
Spokane Int'l	**GEG**	**6.0**	**-7.4**
St. Louis Lambert Int'l	STL	0.2	-6.8
Syracuse Hancock Int'l	SYR	-11.1	-0.5
Tampa Int'l	TPA	-9.3	3.1
Tucson Int'l	**TUS**	**-7.7**	**2.6**
Tulsa Int'l	TUL	-5.7	-3.6
Washington Dulles Int'l	IAD	5.8	11.3
Washington National	DCA	-5.7	-6.9
West Palm Beach Int'l	**PBI**	**-9.7**	**-6.3**
Wichita Mid-Continent	ICT	-5.0	-0.6
Windsor Locks Bradley Int'l	BDL	-8.9	-6.0

Sources:
Enplanement data: *Airport Activity Statistics of Certificated Route Air Carriers, 1990, and preliminary 1991 data.*
Operations data: *Terminal Area Forecasts FY92–2005, FAA-APO-92-5, July 1992, for FY90 data.*
FAA Air Traffic Activity FY91, for FY91 data.

9. At the top 100 airports based on 1991 enplanement data, listed in alphabetical order.

Appendix B

Airport Layout Directory of the Top 100 Airports

State	Airport	ID	Where
Alaska	Anchorage Int'l	ANC	Appendix E
Alabama	Birmingham Municipal	BHM	Appendix D
Arkansas	Little Rock Adams Field	LIT	Appendix E
Arizona	Phoenix Sky Harbor Int'l	PHX	Appendix C, Appendix D
	Tucson Int'l	TUS	Appendix D
California	Burbank-Glendale-Pasadena	BUR	Appendix E
	Long Beach	LGB	Appendix E
	Los Angeles Int'l	LAX	Appendix C, Appendix D
	Oakland Metro Int'l	OAK	Appendix C, Appendix D
	Ontario Int'l	ONT	Appendix E
	Sacramento Metropolitan	SMF	Appendix E
	San Diego Lindbergh	SAN	Appendix E
	San Francisco Int'l	SFO	Appendix C
	San Jose Int'l	SJC	Appendix C, Appendix D
	Santa Ana John Wayne	SNA	Appendix E
Colorado	Colorado Springs Municipal	COS	Appendix D
	Denver Int'l Airport (new)	DIA	Appendix D
	Denver Stapleton Int'l	DEN	Appendix E
Connecticut	Windsor Locks Bradley Int'l	BDL	Appendix E
District of Columbia	Washington Dulles Int'l	IAD	Appendix C, Appendix D
	Washington National	DCA	Appendix E
Florida	Fort Lauderdale Int'l	FLL	Appendix C, Appendix D
	Fort Myers SW Florida Regional	RSW	Appendix D
	Jacksonville Int'l	JAX	Appendix D
	Miami Int'l	MIA	Appendix C
	Orlando Int'l	MCO	Appendix C, Appendix D
	Sarasota-Bradenton	SRQ	Appendix D
	Tampa Int'l	TPA	Appendix D
	West Palm Beach Int'l	PBI	Appendix D
Georgia	Atlanta Hartsfield Int'l	ATL	Appendix C, Appendix D
	Savannah Int'l	SAV	Appendix D
Hawaii	Hilo General Lyman	ITO	Appendix E
	Honolulu Int'l	HNL	Appendix C
	Kahului	OGG	Appendix E
	Kailua-Kona Keahole	KOA	Appendix E
	Lihue	LIH	Appendix E

State	Airport	ID	Where
Iowa	Des Moines Int'l	DSM	Appendix D
Idaho	Boise Air-Terminal	BOI	Appendix E
Illinois	Chicago Midway	MDW	Appendix C
	Chicago O'Hare Int'l	ORD	Appendix C, Appendix D
Indiana	Indianapolis Int'l	IND	Appendix C, Appendix D
Kansas	Wichita Mid-Continent	ICT	Appendix E
Kentucky	Louisville Standiford Field	SDF	Appendix D
Louisiana	New Orleans Int'l	MSY	Appendix C, Appendix D
Massachusetts	Boston Logan Int'l	BOS	Appendix C, Appendix D
Maryland	Baltimore-Washington Int'l	BWI	Appendix D
Maine	Portland Int'l Jetport	PWM	Appendix E
Michigan	Detroit Metro Wayne County	DTW	Appendix C, Appendix D
	Grand Rapids Kent County Int'l	GRR	Appendix D
Minnesota	Minneapolis-St. Paul Int'l	MSP	Appendix D
Missouri	Kansas City Int'l	MCI	Appendix C, Appendix D
	Lambert St. Louis Int'l	STL	Appendix C, Appendix D
North Carolina	Charlotte Douglas Int'l	CLT	Appendix C, Appendix D
	Greensboro Piedmont Int'l	GSO	Appendix D
	Raleigh-Durham Int'l	RDU	Appendix C, Appendix D
Nebraska	Omaha Eppley Airfield	OMA	Appendix E
New Jersey	Newark Int'l	EWR	Appendix E
New Mexico	Albuquerque Int'l	ABQ	Appendix C, Appendix D
Nevada	Las Vegas McCarran Int'l	LAS	Appendix D
	Reno Cannon Int'l	RNO	Appendix E
New York	Albany County	ALB	Appendix D
	Buffalo Int'l	BUF	Appendix D
	Islip	ISP	Appendix D
	John F. Kennedy Int'l	JFK	Appendix E
	LaGuardia	LGA	Appendix E
	Rochester Monroe County	ROC	Appendix D
	Syracuse Hancock Int'l	SYR	Appendix D
Ohio	Cincinnati Int'l	CVG	Appendix D
	Cleveland Hopkins Int'l	CLE	Appendix D
	Dayton Int'l	DAY	Appendix D
	Port Columbus Int'l	CMH	Appendix C, Appendix D
Oklahoma	Oklahoma City Will Rogers	OKC	Appendix D
	Tulsa Int'l	TUL	Appendix D
Oregon	Portland Int'l	PDX	Appendix E

State	Airport	ID	Where
Pennsylvania	Harrisburg Int'l	MDT	Appendix E
	Philadelphia Int'l	PHL	Appendix C, Appendix D
	Pittsburgh Int'l	PIT	Appendix D
Rhode Island	Providence Green State	PVD	Appendix E
South Carolina	Charleston Int'l	CHS	Appendix E
	Columbia Metropolitan	CAE	Appendix E
	Greer Greenville-Spartanburg	GSP	Appendix D
Tennessee	Knoxville McGhee-Tyson	TYS	Appendix D
	Memphis Int'l	MEM	Appendix C, Appendix D
	Nashville Int'l	BNA	Appendix C, Appendix D
Texas	Amarillo	AMA	Appendix D
	Austin Robert Mueller Municipal	AUS	Appendix E
	Bergstrom AFB (new Austin)	BSM	Appendix D
	Dallas-Fort Worth Int'l	DFW	Appendix D
	Dallas Love Field	DAL	Appendix E
	El Paso Int'l	ELP	Appendix E
	Harlingen Rio Grande Int'l	HRL	Appendix D
	Houston Hobby	HOU	Appendix E
	Houston Intercontinental	IAH	Appendix C, Appendix D
	Lubbock Int'l	LBB	Appendix D
	Midland Int'l	MAF	Appendix D
	San Antonio Int'l	SAT	Appendix C
Utah	Salt Lake City Int'l	SLC	Appendix C, Appendix D
Virginia	Norfolk Int'l	ORF	Appendix D
	Richmond Int'l	RIC	Appendix E
Washington	Seattle-Tacoma Int'l	SEA	Appendix C, Appendix D
	Spokane Int'l	GEG	Appendix D
Wisconsin	Milwaukee Mitchell Int'l	MKE	Appendix D
Guam	Agana Field	NGM	Appendix E
Puerto Rico	San Juan Luis Muñoz Marín Int'l	SJU	Appendix C
Virgin Islands	Charlotte Amalie St. Thomas	STT	Appendix E

Appendix C

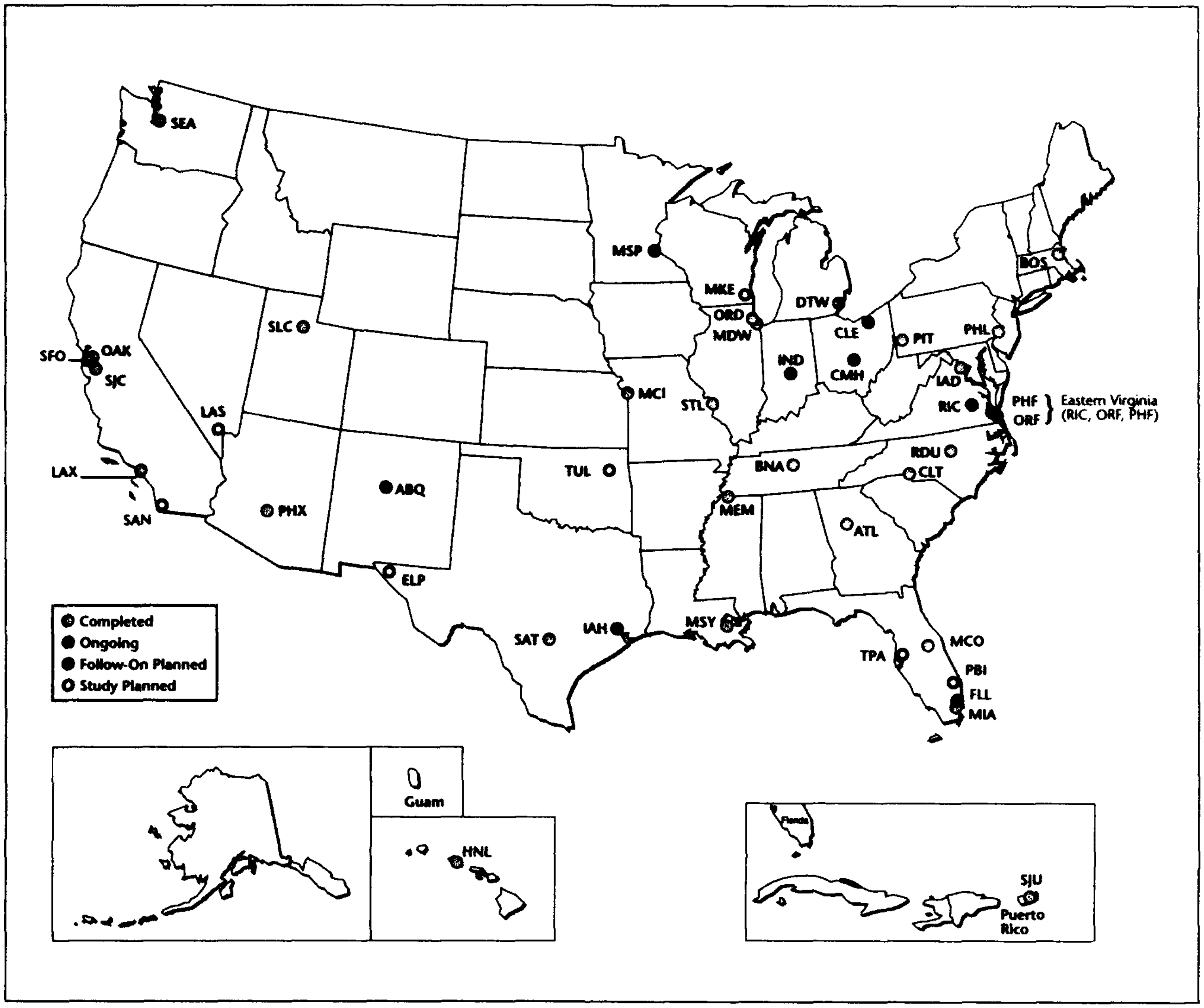
Airport Capacity Design Team Project Summaries[1]

The Airport Capacity Design Teams identify and evaluate various corrective actions, which, if implemented, would increase capacity, improve operational efficiency, and reduce delay at the airports under study. The Capacity Teams examine each alternative to determine its 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 example, the Lambert St. Louis and Memphis International Airport studies were completed in 1988 and there have been significant changes since that time. The current runway plans at these and the other top 100 airports are contained in Appendix D. For those airports where the Capacity Team's analysis is still in progress, the capacity improvement alternatives listed may well change as the study evolves.

The individual recommendations for each airport were developed by the Capacity Teams to be implemented when aircraft operations reached specified levels of demand. For further information on implementation plans, consult the *Airport Capacity Enhancement Plan* for each airport.

1. As of 2-1-93.



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.

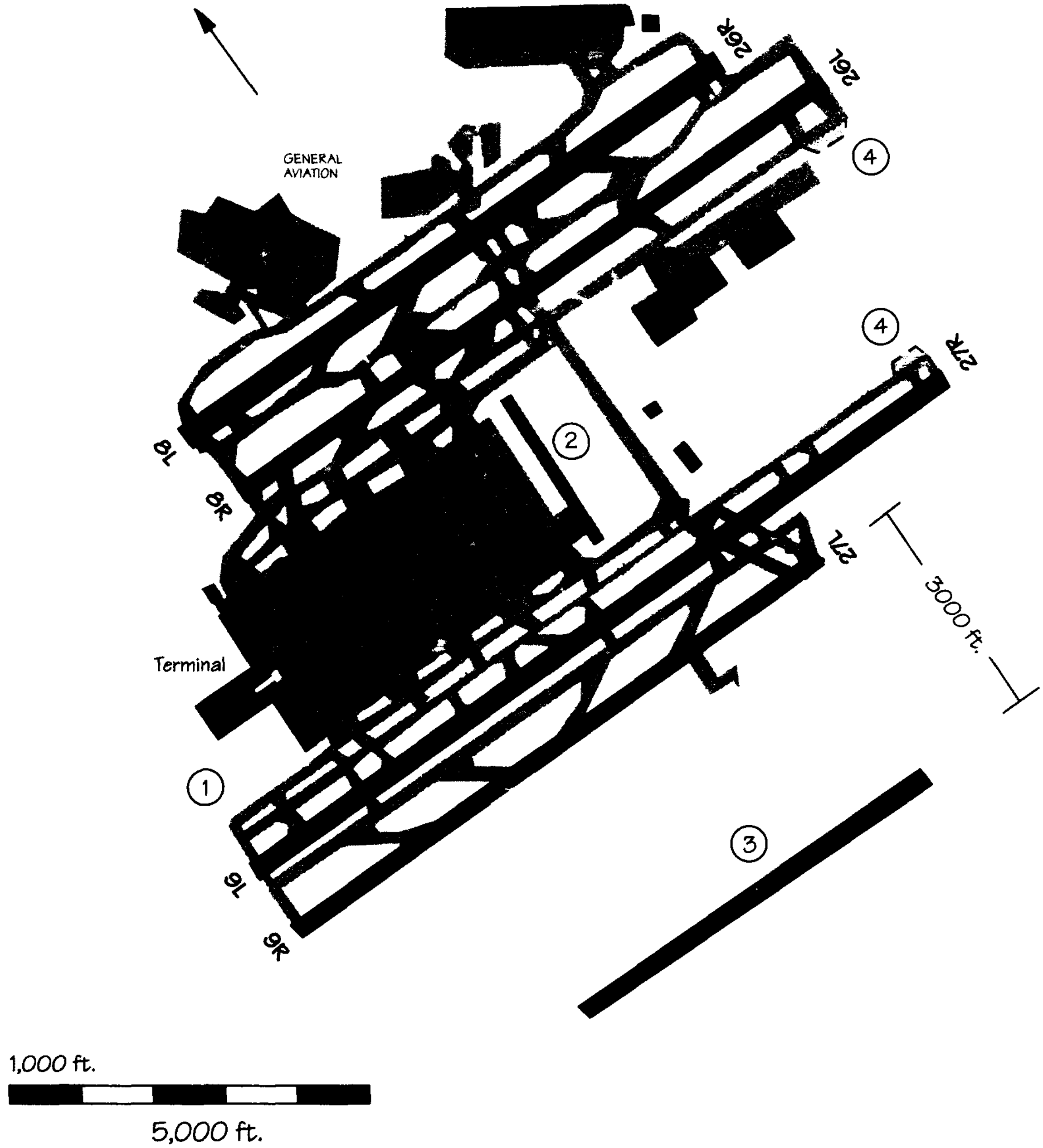
1,000 ft.

5,000 ft.

Completed

Ongoing

The following design teams were recently initiated and proposed alternatives had not been formulated at press time: Cleveland, Minneapolis, and Eastern Virginia.


GENERAL AVIATION
26R
26L
4
4
27R
8L
2
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

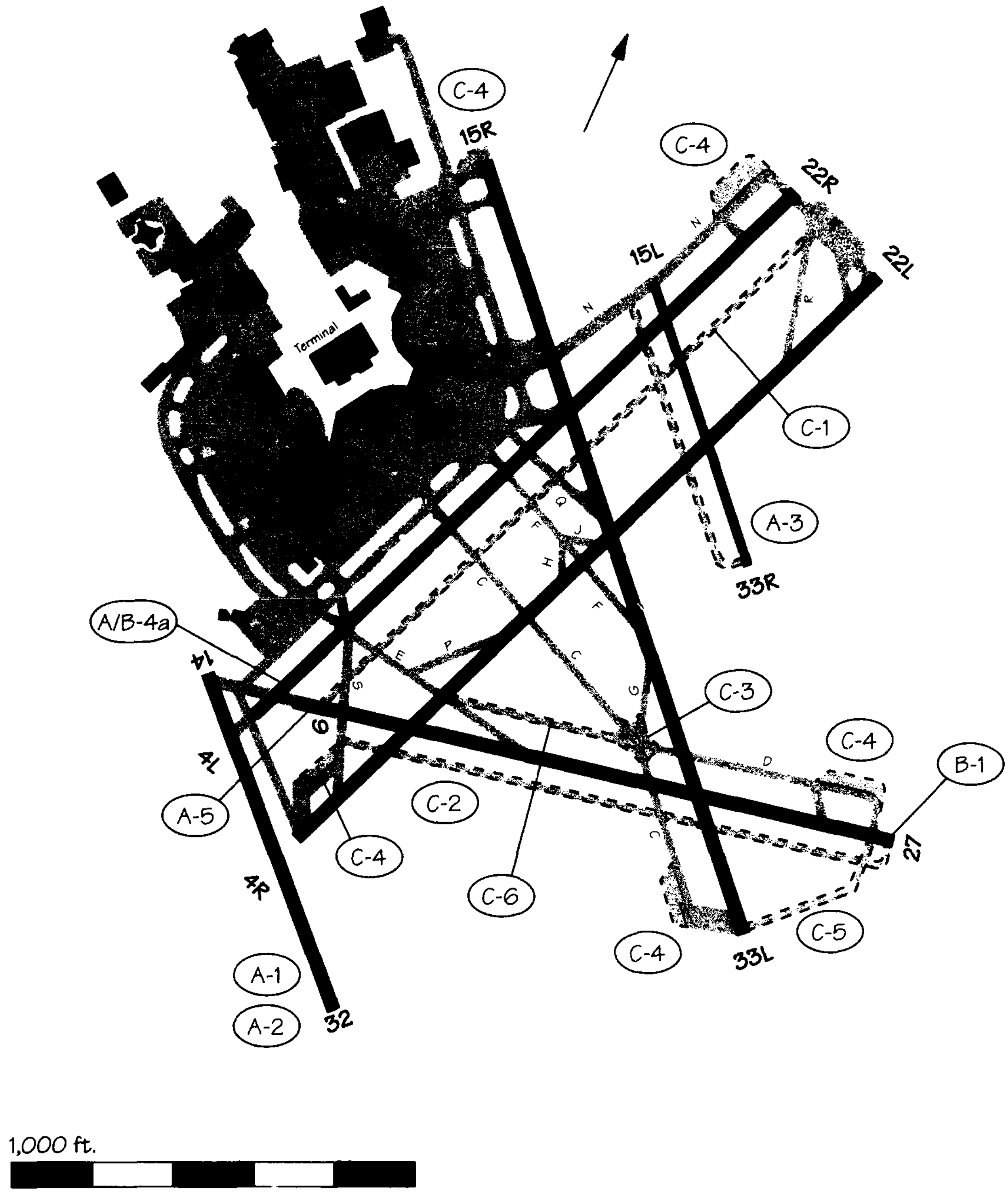
7. Expedite development and installation of wake vortex forecasting and avoidance systems
8. Upgrade NAVAIDs and approach lights on Runway 26R and 27L to Category II
9. Update terminal approach radar
10. Upgrade RVR system to CAT IIIB and ICAO standards
11. Install ASDE-3 with tracking
12. Install touchdown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


C-4
15R
C-4
22R
15L
22L
N
N
Terminal
C-1
A-3
33R
A/B-4a
14
9
4L
A-5
C-3
C-4
B-1
27
C-2
C-4
4R
C-6
C-4
C-5
33L
A-1
A-2
32
1,000 ft.
5,000 ft.

Boston Logan International Airport Capacity Design Team Project Summary

Recommendations

Strategy A: Separate the operation of smaller aircraft from large jet aircraft

A-1	New commuter Runway 14/32, unidirectional (with arrivals only on Runway 32)
A-2	New commuter Runway 14/32, bi-directional
A-3	Extend Runway 15L/33R to 3,500' with new taxiway
A-3a	Combine alternatives A-1 and A-3
A-3b	Combine alternatives A-2 and A-3
A-4/B-4	Removal of noise restrictions to arrivals on Runway 22R
A-5	400' westward extension of Runway 9 to permit commuters to land on Runway 9 and hold short of Runway 15R during daylight, VFR, dry, conditions
A-6/D-2	Use of MLS technology for high-angle commuter approaches to avoid wake turbulence, missed approach guidance off Runway 32, and offset approach courses for independent IFR descents into VFR conditions
A-7	Simultaneous LDA parallel "point-in-space" approaches to Runway 33L, circle to land Runway 4L in marginal IFR (IFR-I) and calm winds

Strategy B: Expand the number of runways on which jets can operate independently under VFR and IFR conditions

B-1	Extend Runway 27 200' to the east to allow landings holding short of Runway 22L in daylight, VFR, dry conditions
B-2	Simultaneous approaches to Runways 4R and 4L and Runways 22R and 22L in less than VFR-V conditions
B-3	Modify ATC procedures to allow simultaneous approaches to Runways 27 and 22L and to Runways 4L and 33L under IFR conditions
A-4/B-4	Removal of noise restrictions on Runway 4L departures
A-4a/B-4a	Removal of noise restrictions on Runway 4L combined with an extension of Runway 4L to a new taxiway B
B-5	Side-step approaches from Runway 4R to Runway 4L
B-6	Use of fan headings for aircraft departing Runways 22L and 22R
B-7	Use of hold-short procedures under VFR, wet conditions for turbo-jet aircraft on Runway 15R (hold short of 09), 22L (hold short of 27), and 33L (hold short of 4L)

Strategy C: Improve taxiway circulation to expedite ground movement and improve departure sequencing

C-1	New parallel taxiway between Runways 4L/22R and 4R/22L
C-2	New south exit parallel taxiway for Runway 27
C-3	Add fillets at intersection of taxiways D and C with Runway 15R/33L
C-4	Add staging areas at the ends of Runways 15R/33L, 27, 4R, and 22R, and at the intersection of taxiway G with Runway 33L
C-5	New taxiway from the end of Runway 27 to the end of Runway 33L
C-6	Extend taxiway D to Runway 4R/22L

Strategy D: Lower minimum visibility requirements for IFR approaches

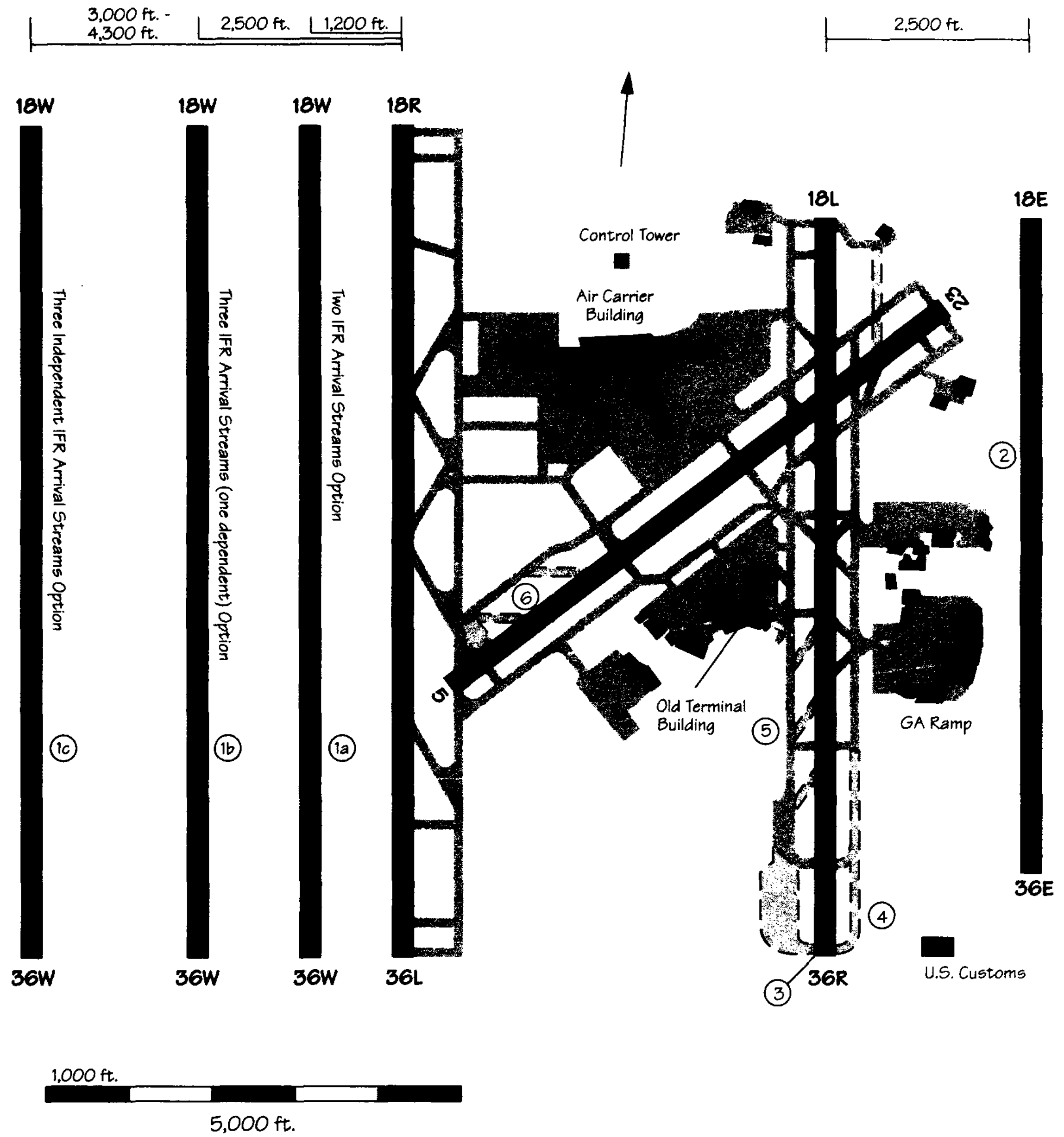
D-1	Install CAT II/III ILS on Runways 15R, 22L, 27 and 33L
D-2	Use of Microwave Landing System (MLS) technology
D-3	Reduce minimums to 250' and 3/4 mile on Runway 22L for Category I approaches

Strategy E: Adopt policies which manage demand so that existing and future demand is used more efficiently

E-1	Increase the percentage of large jet aircraft in the fleet mix
E-2	Redistribute airline schedules within the hour

Strategy F: Develop more efficient use of the airspace around Logan and Boston Approach Control

F-1	Improve metering, spacing, and segregation of heavy jets
F-2	Use WVAS and VAS to decrease separation standards



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
23
5
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
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

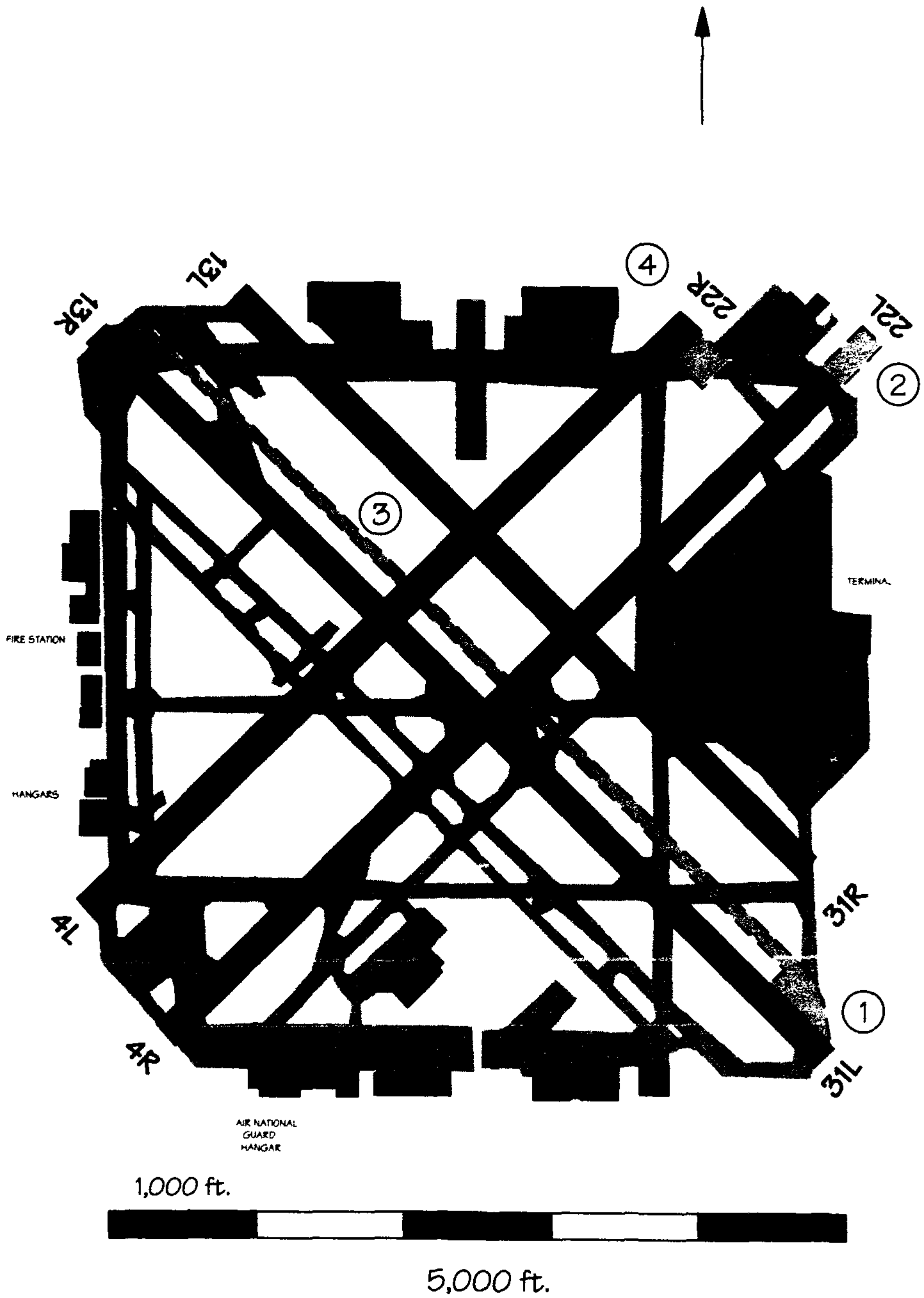
9. Install Category I ILS on Runway 23
10. Install Category II/III ILS on Runway 18R
11. Install Category II/III ILS on Runway 18L
12. Install Category II/III ILS on Runway 36R
13. Install Airport Surface Detection Equipment (ASDE)
14. Expand the Charlotte TRACON and ARTS-IIIA
15. Acquire the Aircraft 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 on 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%)



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

Chicago Midway Airport
Capacity Design Team Project Summary

Recommendations

Airfield Improvements

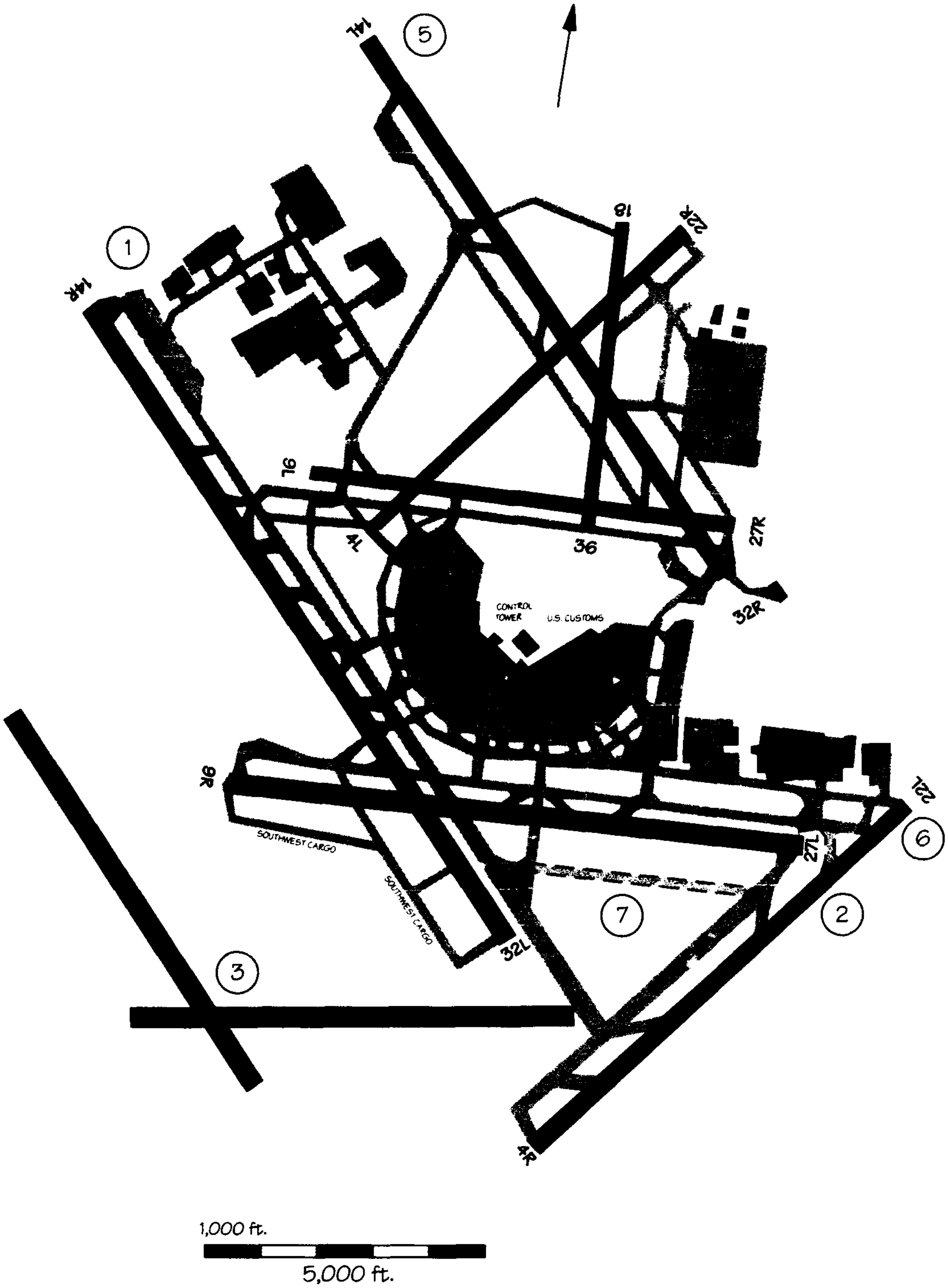
1. Runway 31L hold pad
2. Extension to Runway 22L
3. Parallel taxiway between Runways 13R/31L and 13L/31R
4. Runway 22L hold pad
5. Expand apron/gate area
6. Rehabilitation of Runway 13L/31R
7. Reduce arrival minimums for Runways 4R and 31L
8. Commission general aviation Runway 13/31

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
CONTROL TOWER
U.S. CUSTOMS
9R
22L
6
SOUTHWEST CARGO
27L
SOUTHWEST CARGO
7
2
32L
3
4R
1,000 ft.
5,000 ft.

Chicago O'Hare International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

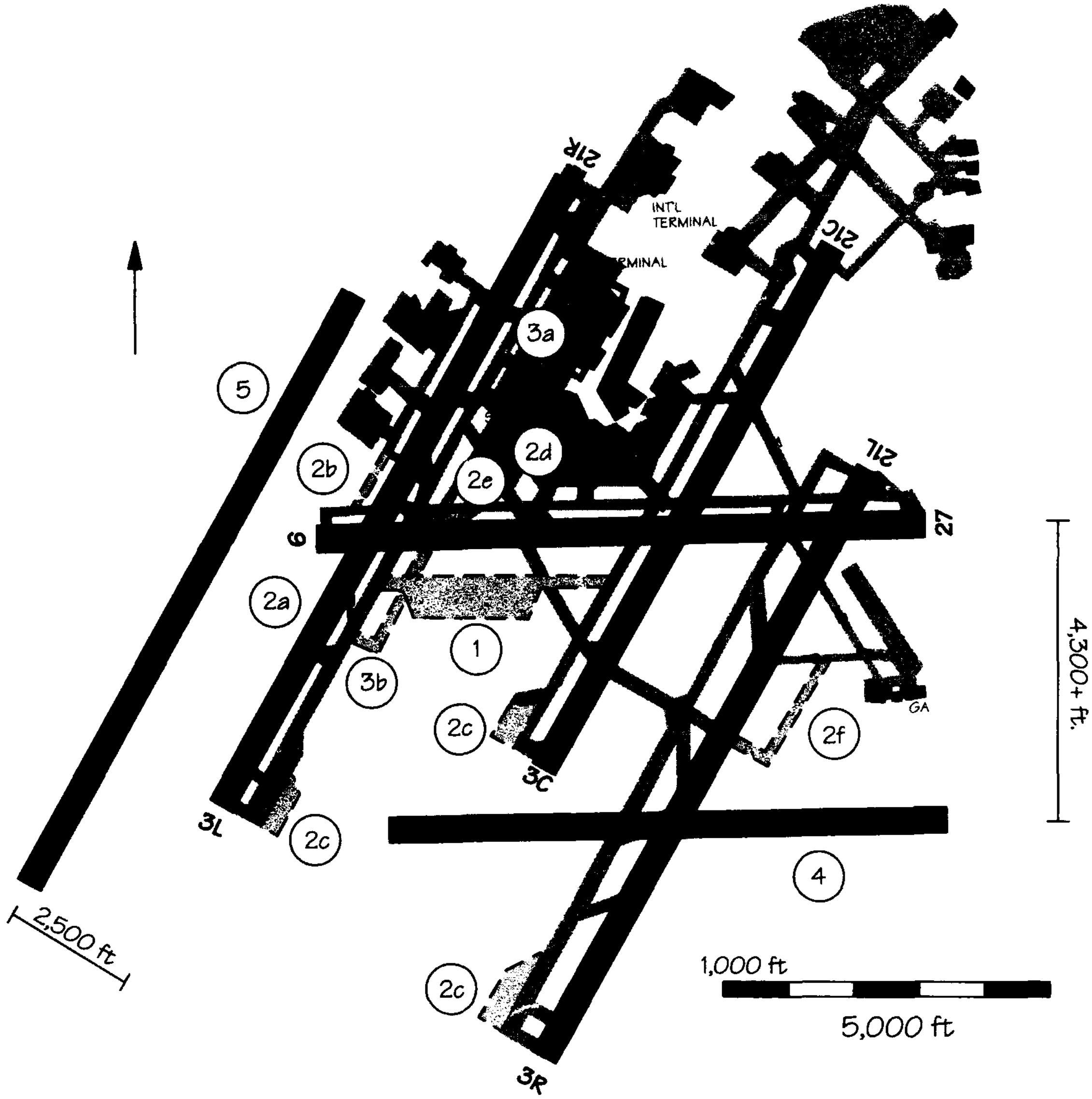
1. Large flow-through aircraft holding areas ("Chicago hold pads")
2. Runway 4R angled exit
3. New Runways 14/32 and 9/27
4. Northward relocation of Runways 9L/27R and 4L/22R
5. Extension to Runway 14L
6. Extension to Runway 22L
7. Southern Runway 9R/27L parallel taxiway
8. Additional Category II/III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



21R
INT'L
TERMINAL
RMINAL
21C
21L
27
9
3L
3C
3R
1
2a
2b
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

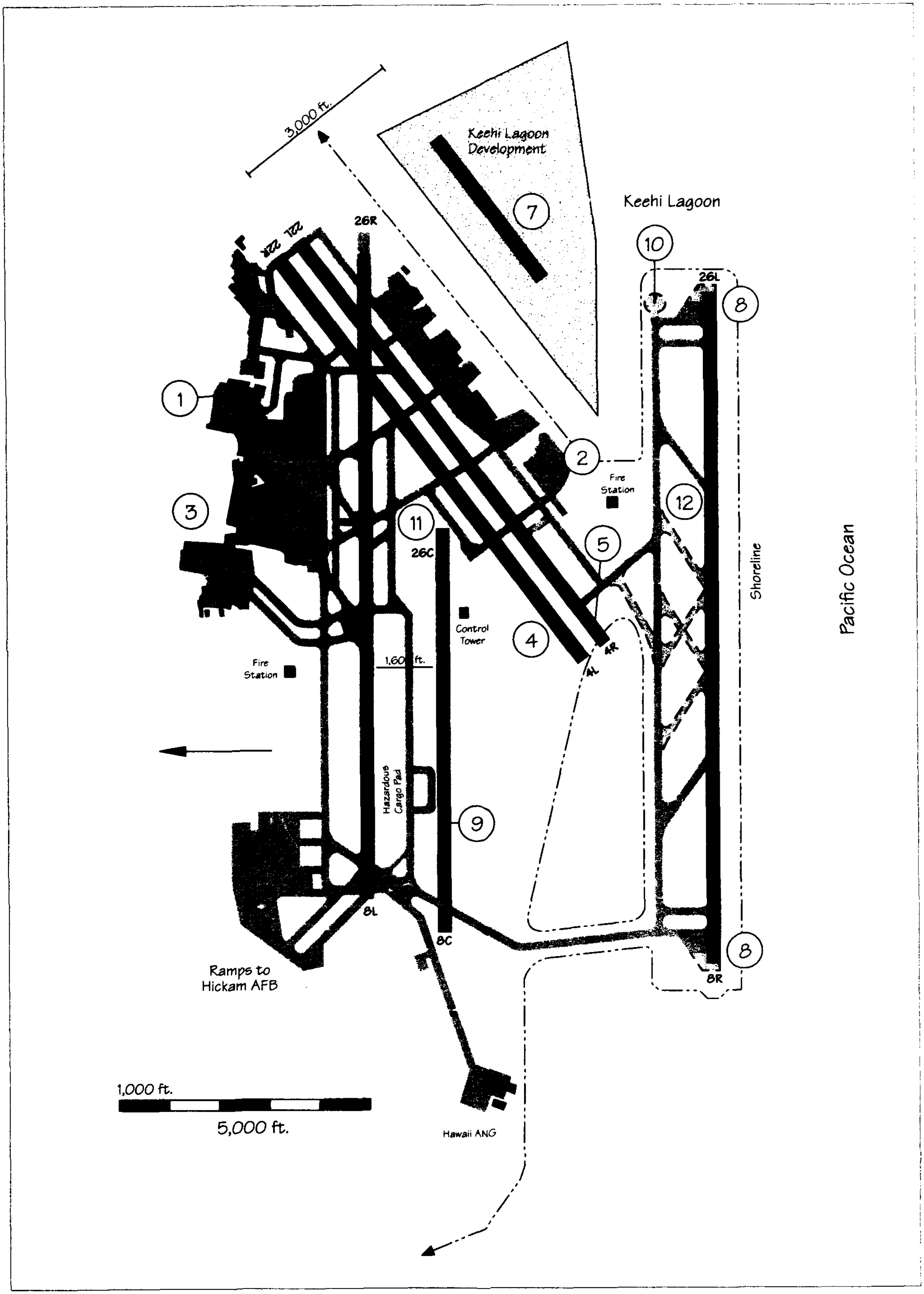
7. Upgrades on Runway 3C
   - 7a. ILS, MLS, and approach lights on existing Runway 3C
   - 7b. RVR for existing Runway 3C
8. ASDE
9. Terminal Doppler Weather Radar (TDWR)
11. RVR and centerline lights on Runway 27
12. Expedite development and installation of wake vortex forecasting and avoidance system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


3,000 ft.
Keehi Lagoon Development
7
Keehi Lagoon
10
26L
8
26R
22L
22R
1
2
Fire Station
3
12
11
26C
5
Shoreline
Pacific Ocean
Control Tower
4
4R
4L
Fire Station
1,600 ft.
Hazardous Cargo Pad
9
8L
8C
8
8R
Ramps to Hickam AFB
1,000 ft.
5,000 ft.
Hawaii ANG

Honolulu International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

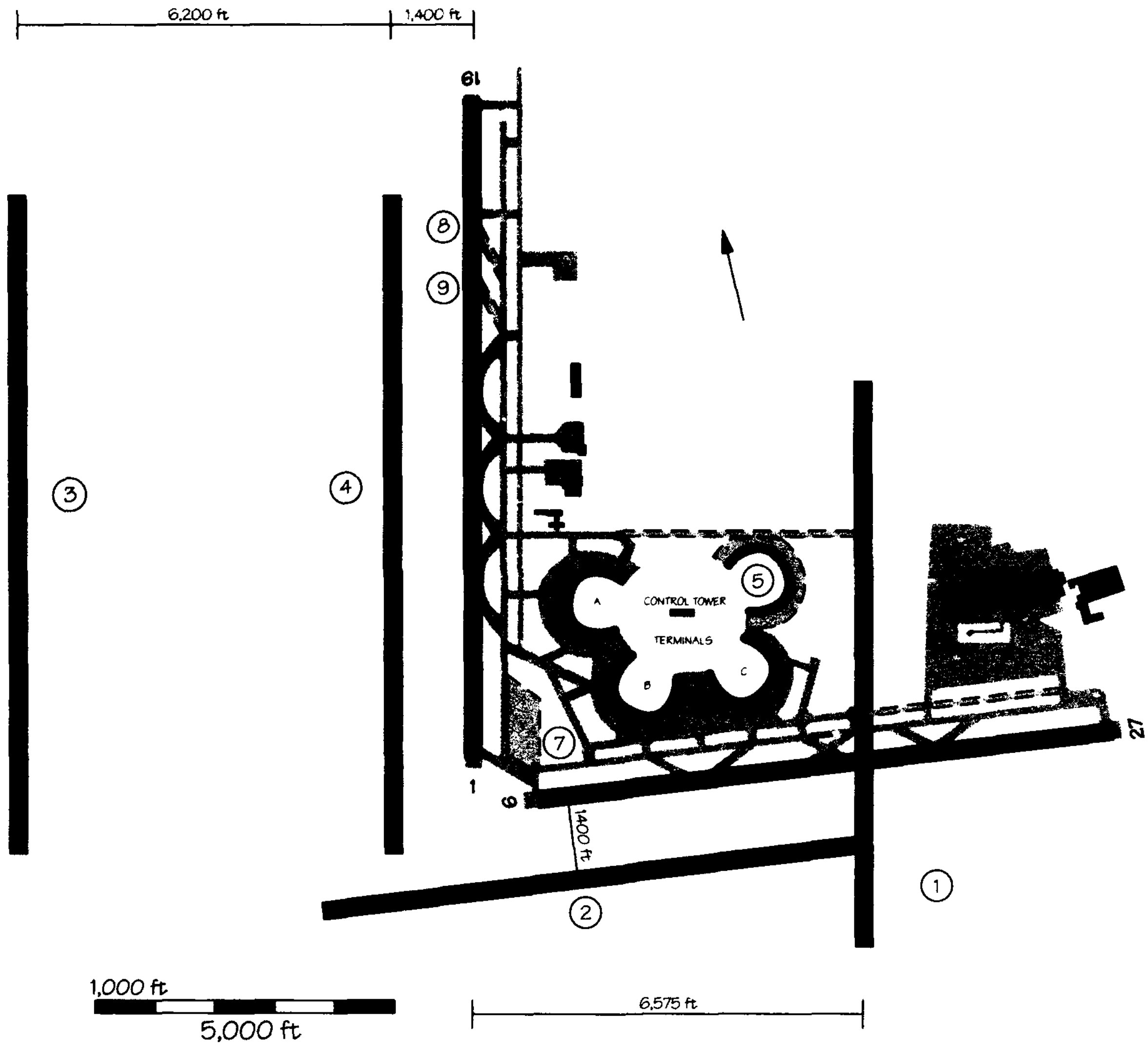
1. Effect of new international terminal
2. Relocate and consolidate general aviation (GA) on the south side
3. Relocate commuter terminal
4. Extend Runway 4L/22R to the southwest to 10,000 feet
5. Extend Runway 4R/22L to the southwest to 10,000 feet
6. Extend both Runway 4L/22Rand Runway 4R/22L to the southwest to 10,000 feet
7. Construct new GA runway in Keehi Lagoon
8. Extend Runway 8R/26L 1,000 feet
9. Construct new Runway 8C/26C
10. Construct engine run-up pad at east end of Taxiway RA
11. Construct arrival holding area
12. Construct angled exits on Runways 4R, 8L, and 26L

Facilities and Equipment Improvements

13. Install Category II ILS on Runway 8L
14. Install Microwave Landing System (MLS) on Runways 8L, 8R, and 26L

Operational Improvements

15. Increase use of Runway 8R for arrivals
16. Effect of noise abatement procedures
17. Distribute traffic more uniformly within the hour
18. Relocate general aviation (GA) to reliever airports
    - 18a. Relocate 50% of GA
    - 18b. Relocate 100% of GA
19. Relocate military aircraft
    - 19a. Relocate 50% of military aircraft
    - 19b. Relocate 100% of military aircraft
    - 19c. Increase military to 150% of current level and relocate 100 % of GA


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

Kansas City International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

1. Independent 9,500' 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

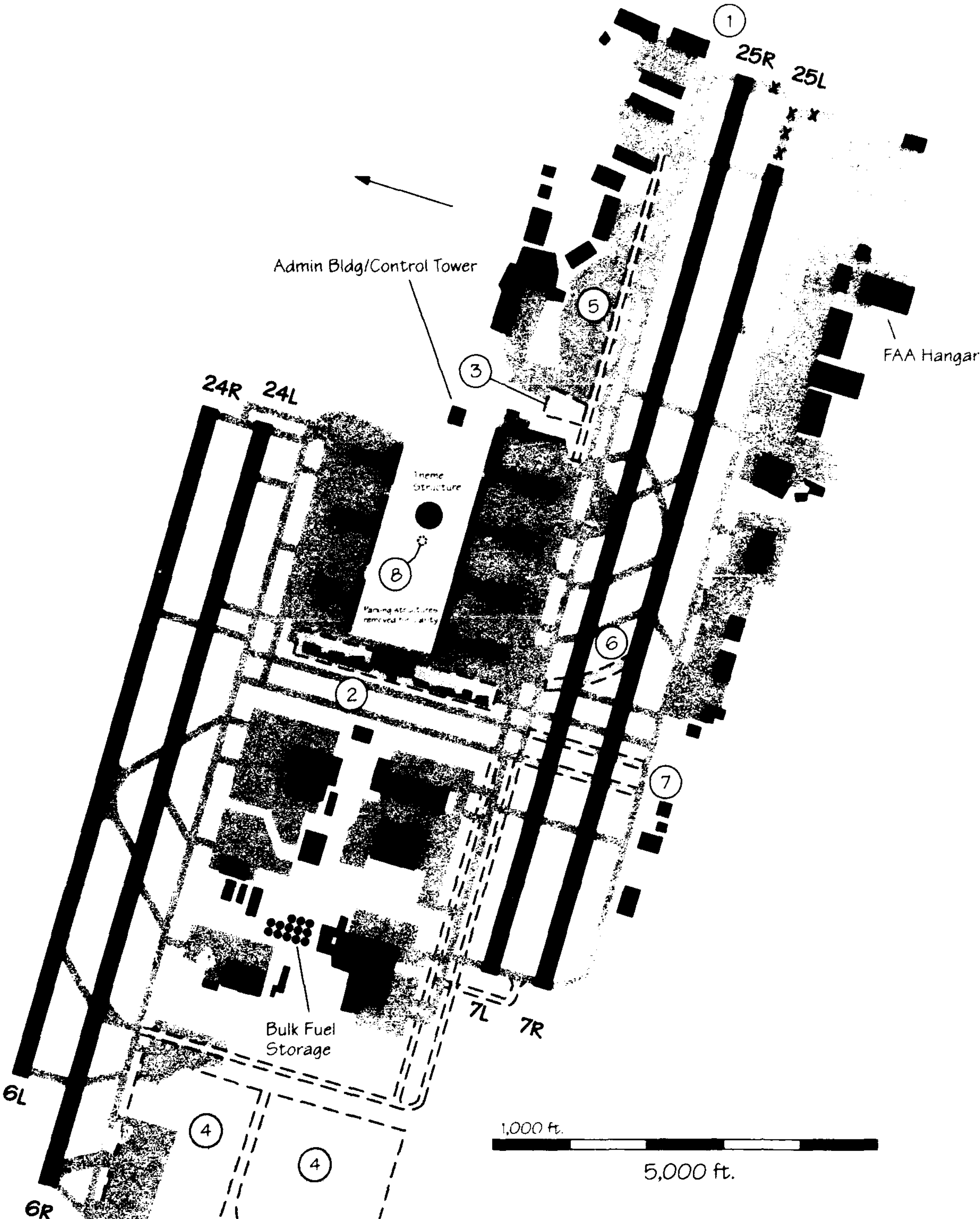
12. CAT III ILS on Runway 1R
13. CAT I ILS on Runway 19L
14. Install ILS/MLS for Runway 27R
15. DME for Runways 1L/19R and 1R/19L
16. RVR for Runway 1R/19L
17. Upgrade Runway 1L ILS to CAT III
18. Benefit of ASDE

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 ROTs 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
8
6
2
7
Bulk Fuel
Storage
7L
7R
6L
4
4
6R
1,000 ft.
5,000 ft.

Los Angeles International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

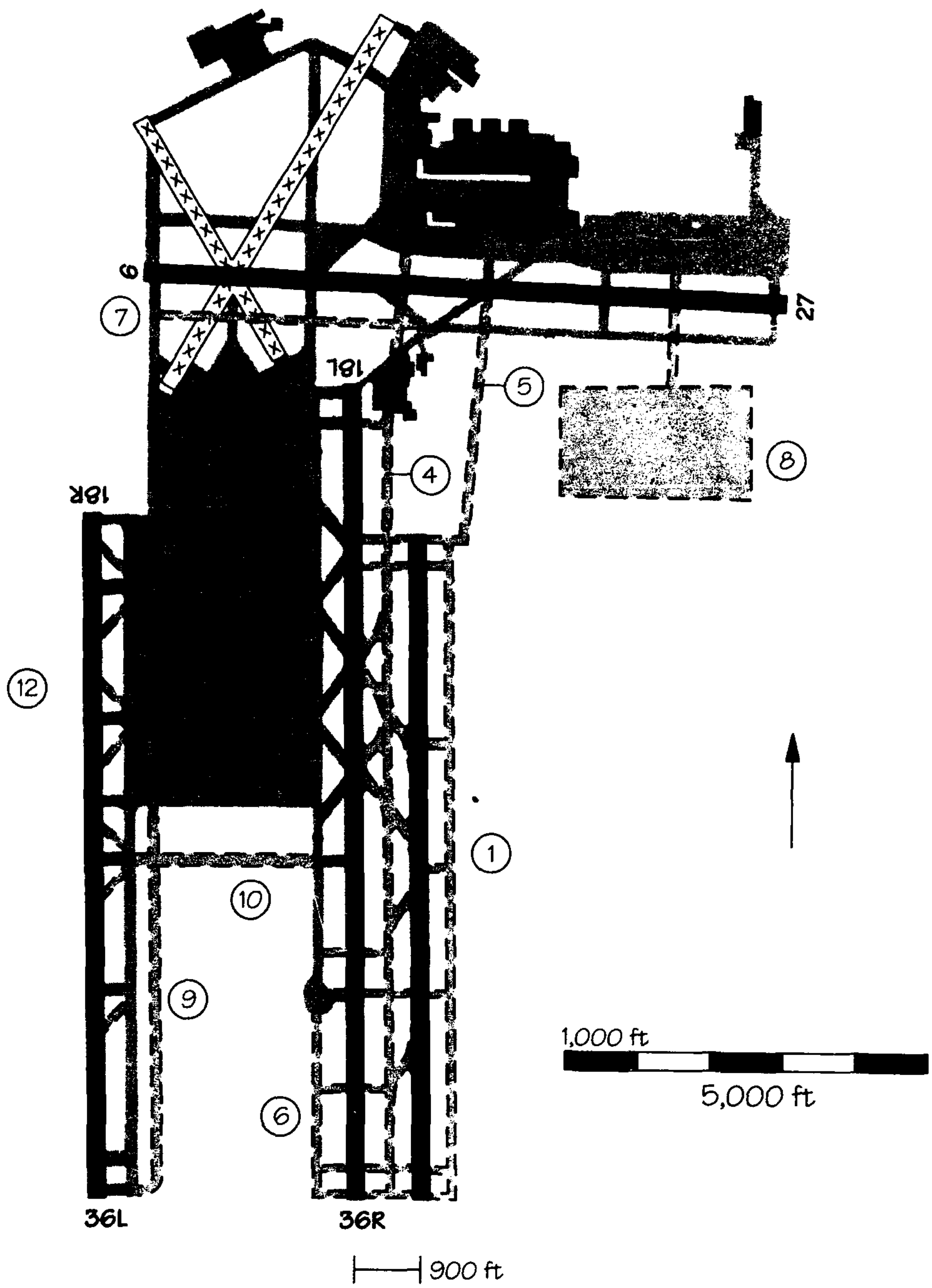
1. Construct departure pads (staging areas) at ends of runways
2. Construct new gates west side of Tom Bradley International Terminal (TBIT)
3. Construct 11-gate domestic terminal (east of Sepulveda) and 24-gate international terminal on the west end
4. West end development
   - 4a. Construct 24 remote 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


9
27
7
18L
5
4
8
18R
12
1
10
9
1,000 ft
5,000 ft
6
36L
36R
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

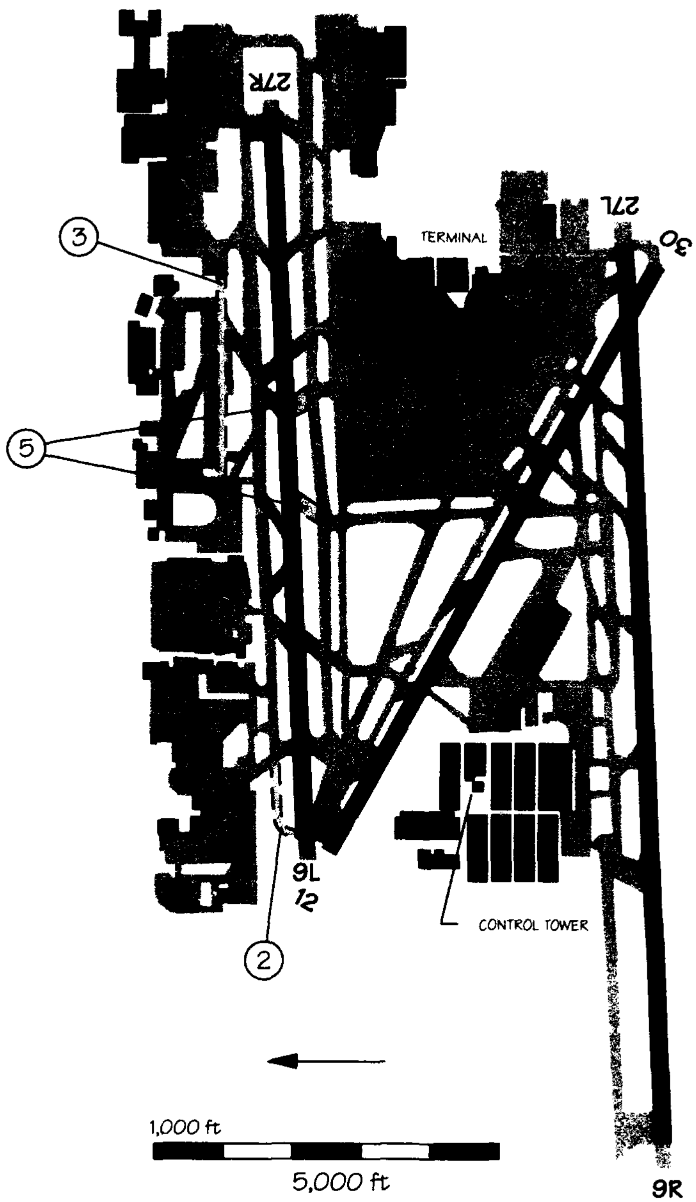
13. CAT II/III ILS on Runway 36R
14. CAT II/III ILS on Runway 36E
15. CAT II/III ILS on Runways 18R, 18L, and 18E
16. Install Airport Surface Detection Equipment (ASDE)
17. Re-route high altitude traffic away from MEM VORTAC

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 nm 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
TERMINAL
27L
30
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

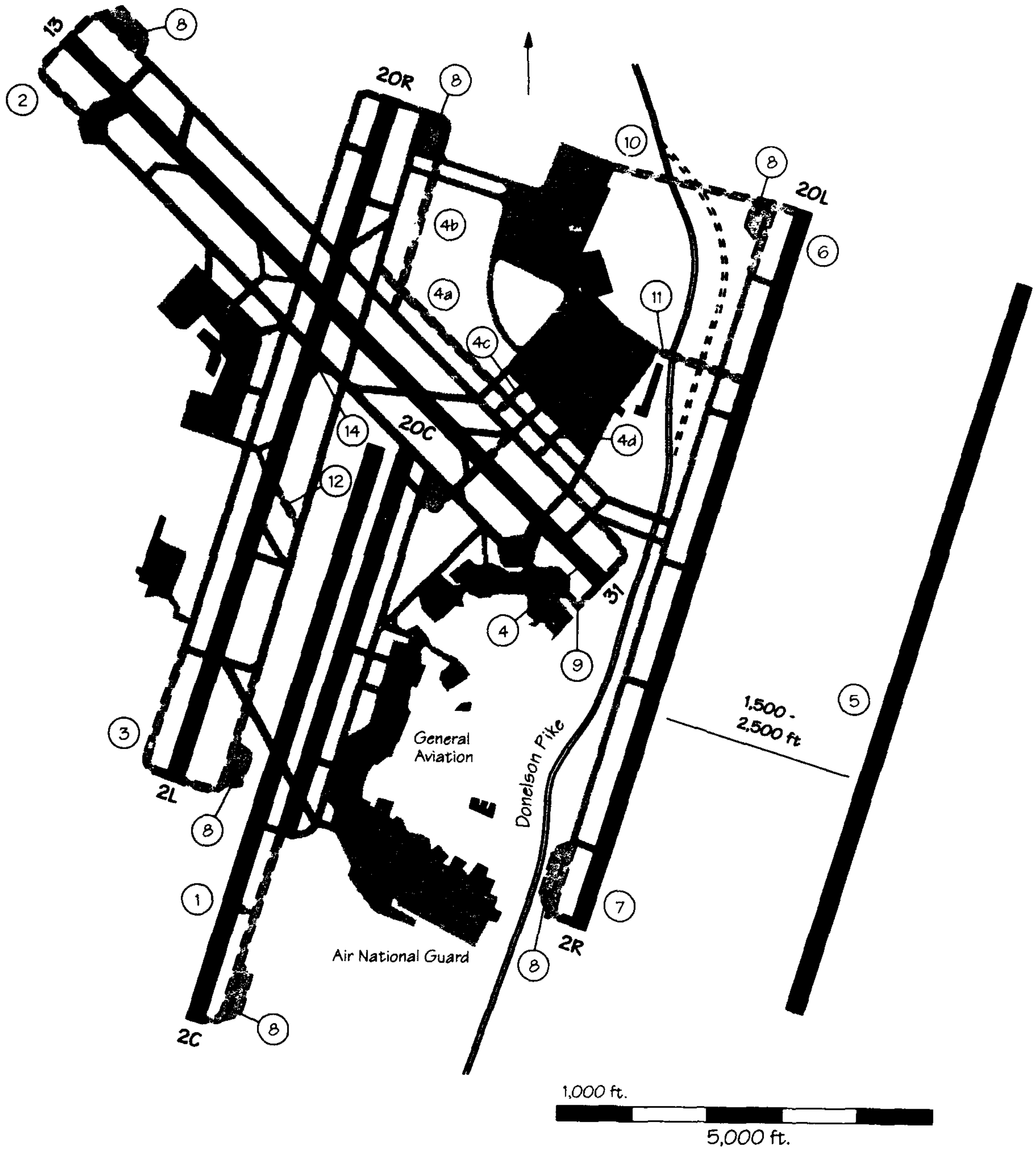
1. Dual taxiway around Concourse H (remove 2 end gates)
2. Extend Taxiway L to Runway 9L end
3. Construct new partial dual Taxiway K
4. Develop improved exits for Runway 9L/27R northside
   4a. Strengthen/reconstruct Runway 9L/27R
5. Improve Exits M4 and M5 on Runway 9L/27R

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
8
2
20R
8
10
8
20L
6
4b
4a
11
4c
14
20C
4d
12
31
4
9
3
General
Aviation
1,500 -
2,500 ft
5
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

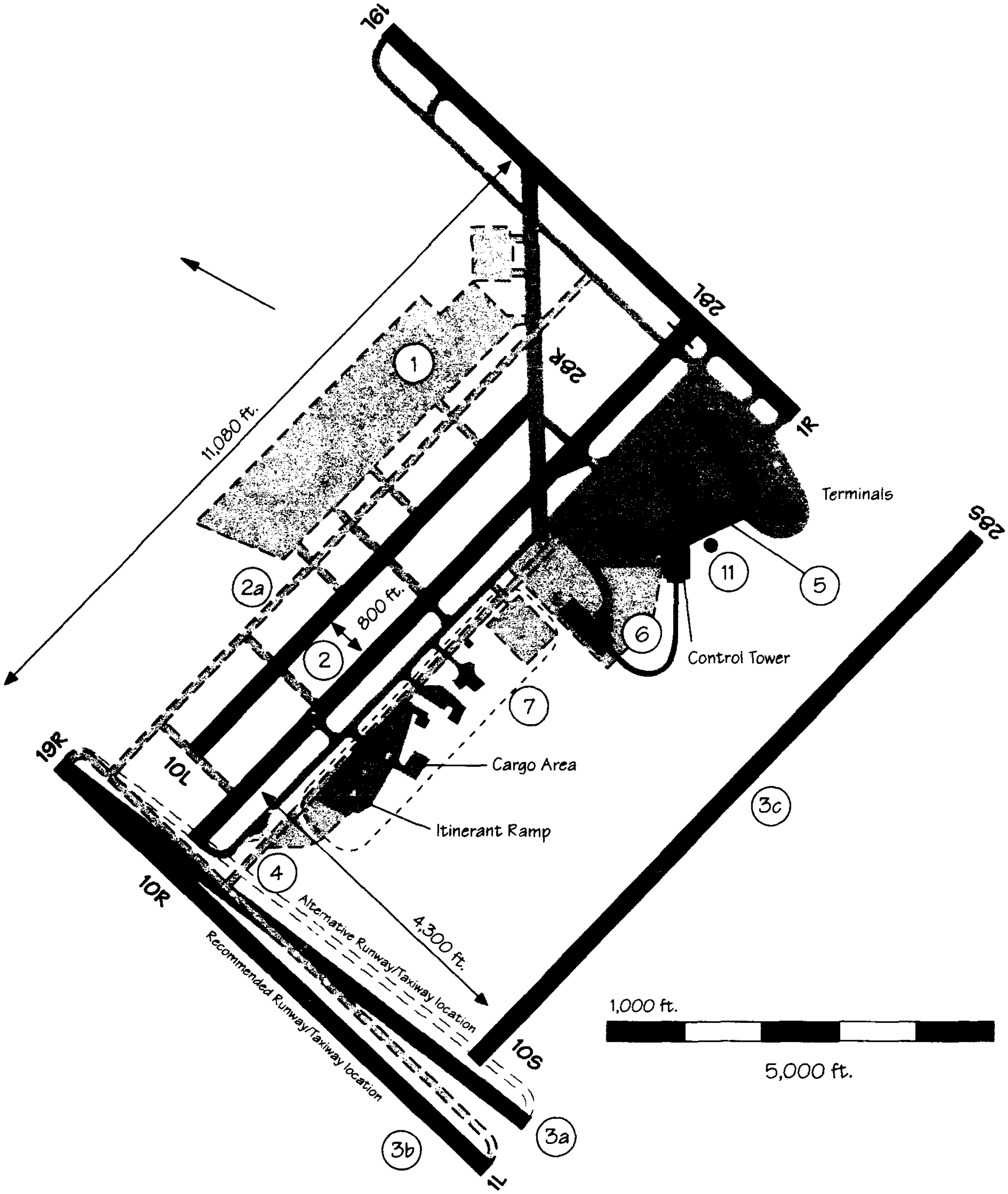
1. Relocate Runway 2C and extend to 8,000 ft.
2. Extend Runway 13 to the northwest
3. Extend Runway 2L 1,300 ft. or more to the south
4. Improve terminal taxiways and ramp
   - 4a. Extend Taxiway I
   - 4b. Extend Taxiway B
   - 4c. Construct dual lane at Taxiway T-4
   - 4d. Construct dual lane at Taxiway 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)



19L
28L
1R
28R
Terminals
28S
11,080 ft.
1
2a
2
800 ft.
11
5
6
Control Tower
7
Cargo Area
Itinerant Ramp
19R
10L
10R
4
3c
Alternative Runway/Taxiway location
4,300 ft.
Recommended Runway/Taxiway location
1,000 ft.
5,000 ft.
10S
3a
3b
1L

New Orleans International Airport Capacity Design Team Project Summaries

Recommendations

Airfield Improvements

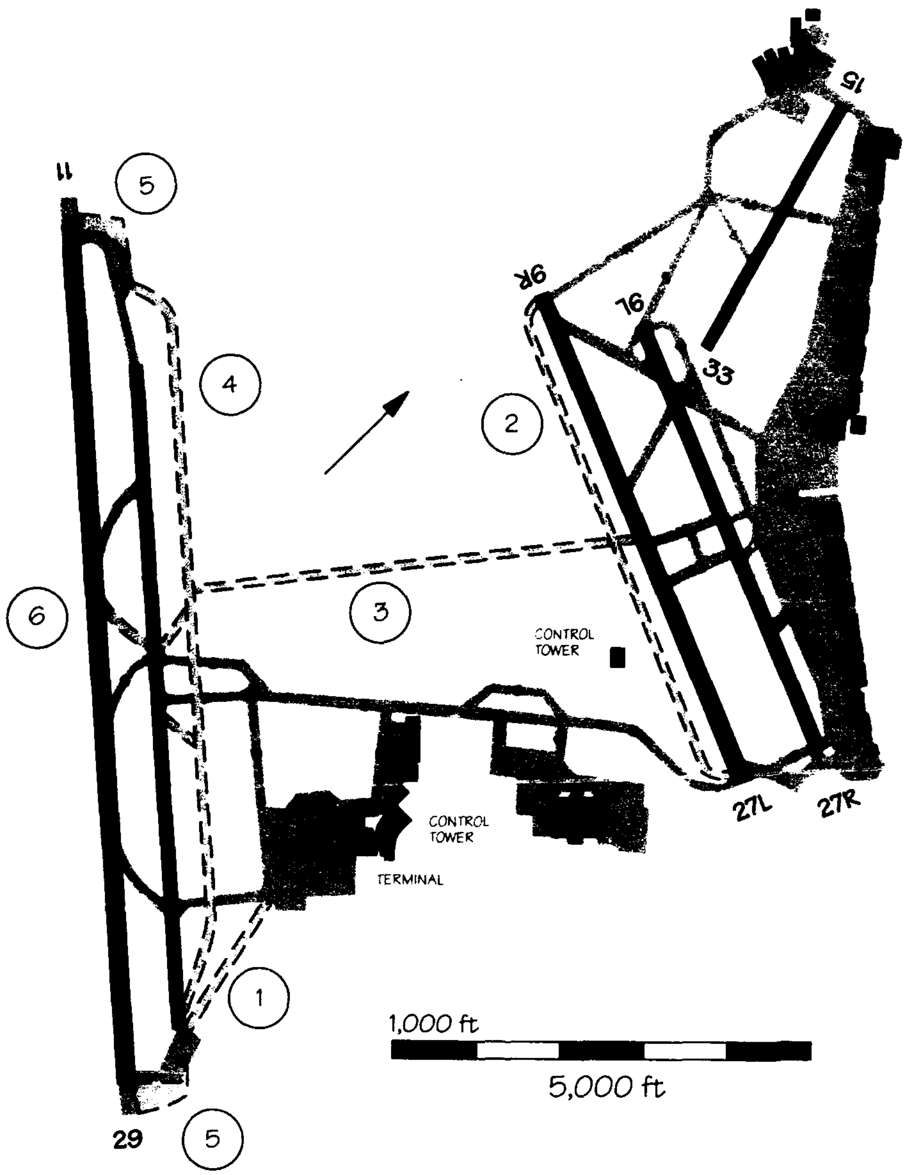
1. Construct new general aviation (GA) complex and east/west taxiway on north side
2. Convert north parallel east/west taxiway into new commuter/GA Runway 10L/28R
   2a. Construct parallel taxiway north of Runway 10L/28R
3. Construct new air carrier runway
   3a. Construct dependent non-parallel Runway 1L/19R
   3b. Construct independent parallel Runway 1L/19R
   3c. Construct independent parallel Runway 10S/28S
4. Construct east/west dual taxiway south of Runway 10R/28L
5. Construct new international and domestic gates and renovate one gate on Concourse C
6. Construct new Concourse E (20 gates) for air carrier operations
7. Develop air cargo complex and associated aprons
   7a. Develop Area 1 — Stage I east air cargo apron
   7b. Develop Area 2 — existing and south-of-existing GA areas
   7c. Develop Area 3 — Stage II east air cargo apron
   7d. Develop Area 4 — west air cargo apron
8. Construct perimeter road
9. Study requirement for new airport

Facilities and Equipment Improvements

10a. Move VORTAC from current location in lake, possibly to New Orleans International Airport
10b. Install additional VOR
11. Construct new airport traffic control tower (ATCT)

Operational Improvements

12. Effects of noise constraints
13. Develop and implement converging instrument approaches
    13a. "TERPS plus 3" approach procedure to Runways 10R and 19L and Runways 10R and 1R
    13b. Dependent IFR approaches to Runways 10R and 19L and Runways 10R and 1R
14. Use 2.5 nm spacing between similar class, non-heavy aircraft
15. Conduct an airspace capacity design project and restructure terminal airspace
16. Study effects of existing public-use heliport
17. Enhance GA reliever airports
    17a. Reduce GA traffic by 25%
    17b. Reduce GA traffic by 50%
    17c. Reduce GA traffic by 75%


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

Oakland International Airport
Capacity Design Team Project Summary

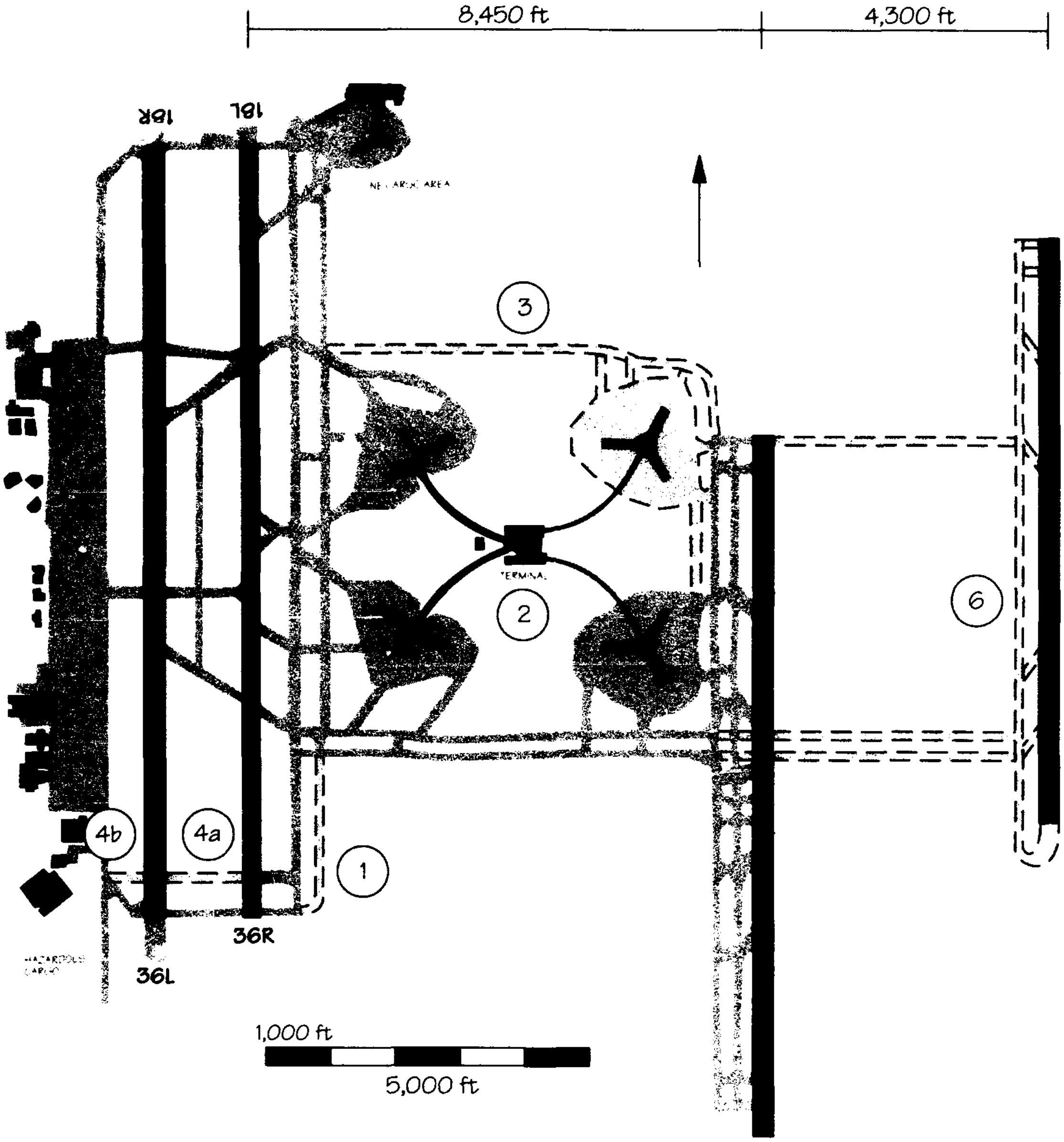
Recommendations

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
36L
36R
TERMINAL
1
2
3
4a
4b
6
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

AD-A276 958 1993 AVIATION SYSTEM CAPACITY PLAN (1993)(U) FEDERAL 3/4
AVIATION ADMINISTRATION WASHINGTON DC OFFICE OF SYSTEM
CAPACITY AND R 1993 DOT/FAA/ASC-93-1 XH-XD

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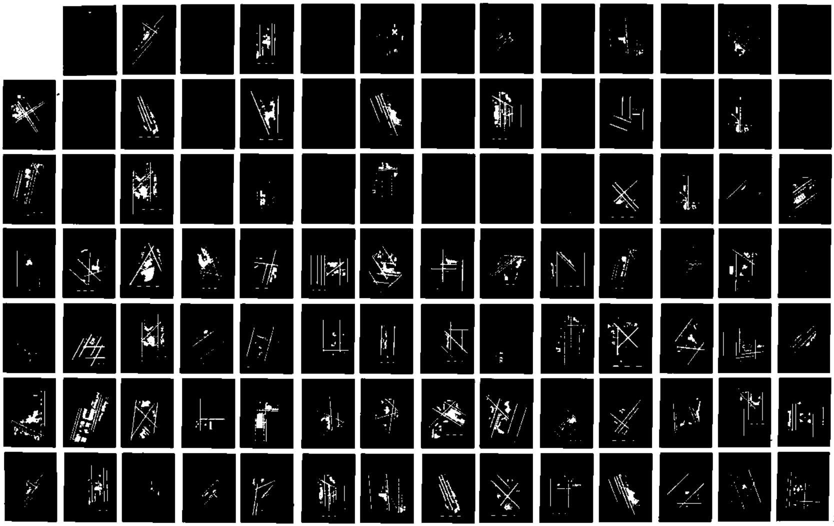

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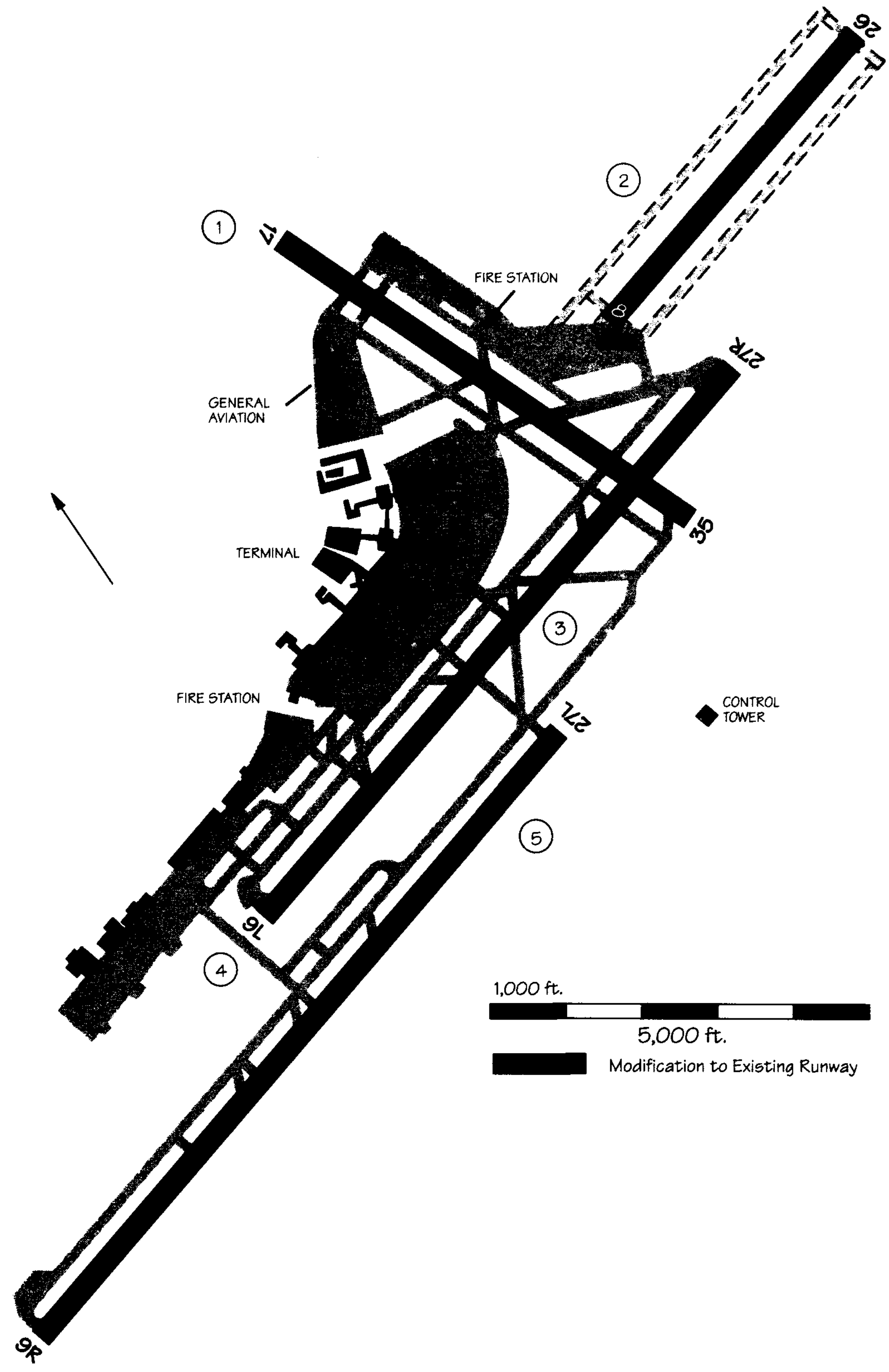


1
2
3
4
5
17
35
26
8
27R
27L
9L
9R
FIRE STATION
GENERAL AVIATION
TERMINAL
FIRE STATION
CONTROL TOWER
1,000 ft.
5,000 ft.
Modification to Existing Runway

Philadelphia International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

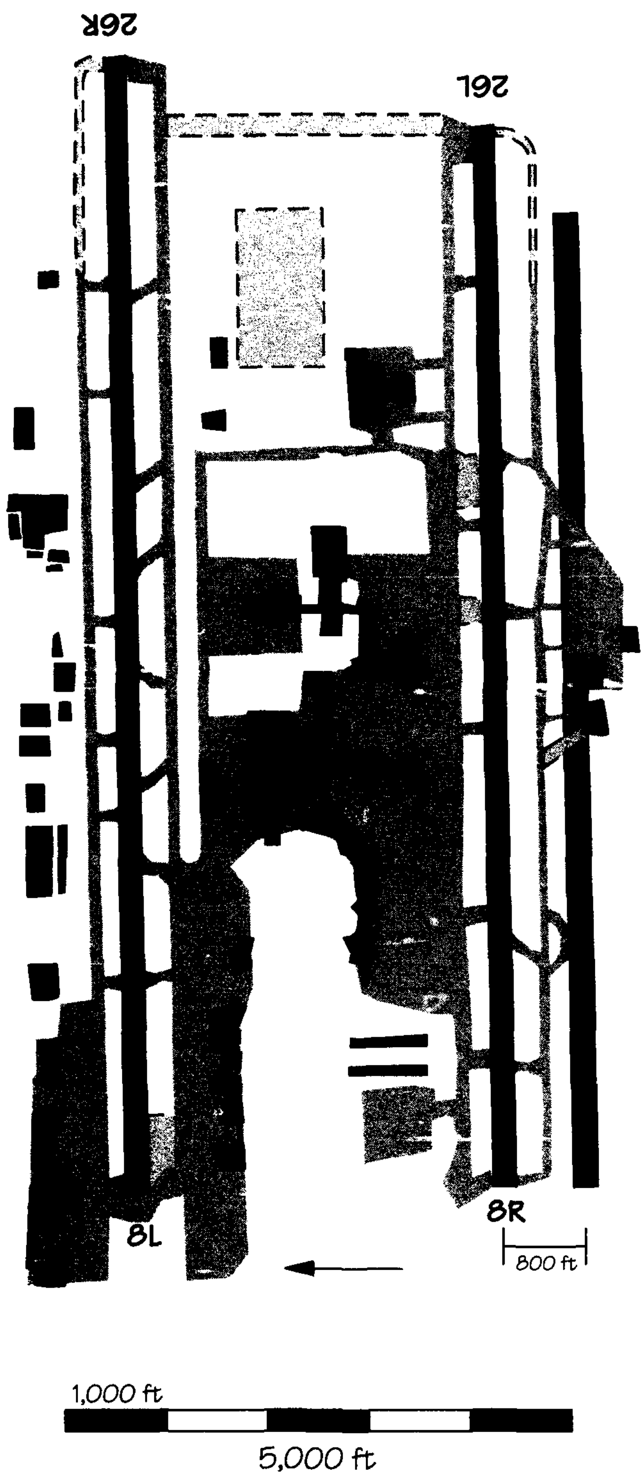
1. Extend Runway 17/35 600 ft. to the north
2. Construct new 5,000-ft. commuter Runway 8/26 3,000 ft. north of Runway 9R/27L
3. Relocate Runway 9L/27R (laterally) 400 ft. to the south with associated parallel and apron taxiways
4. Relocate Runway 9L/27R (longitudinally) 2,735 ft. to the west
5. Relocate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

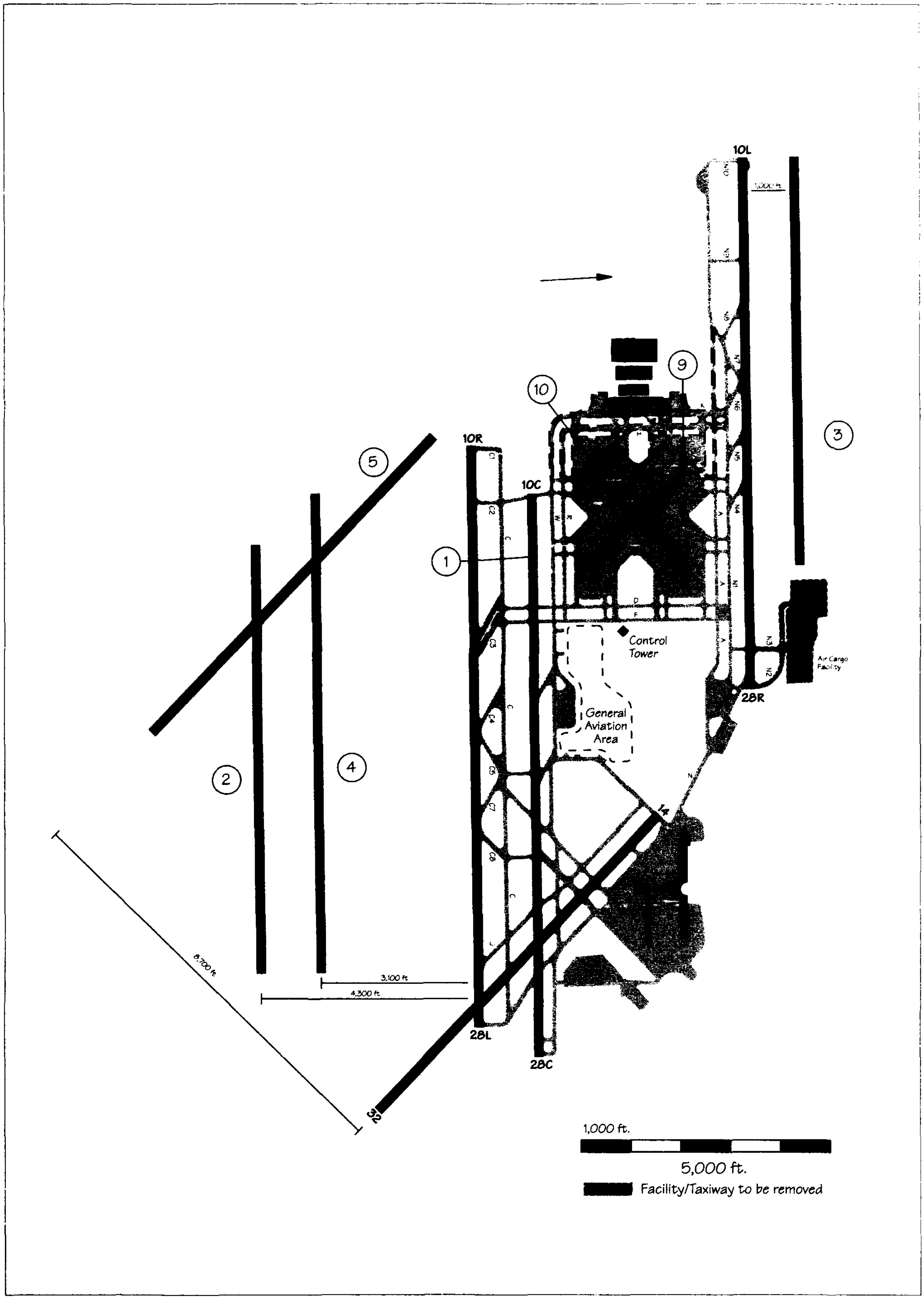
14. TVOR/VORTAC (Carefree) in northern valley
15. ILS (CAT I) for Runway 26R
16. Precision approach for Runway 8L
17. Precision approach for Runway 8S/26S
18. Potential benefits of MLS at Sky Harbor
19. VORTAC near airport

Operational Improvements

20. Reduce in-trail separations to 2.5 nm
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


10L
1,000 ft
10R
10C
28R
28L
28C
14
32
Control Tower
General Aviation Area
Air Cargo Facility
3,100 ft
4,300 ft
8,700 ft
1
2
3
4
5
9
10
1,000 ft.
5,000 ft.
Facility/Taxiway to be removed

Greater Pittsburgh International Airport Capacity Design Team Project Summary

Recommendations

Airfield 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/28L
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

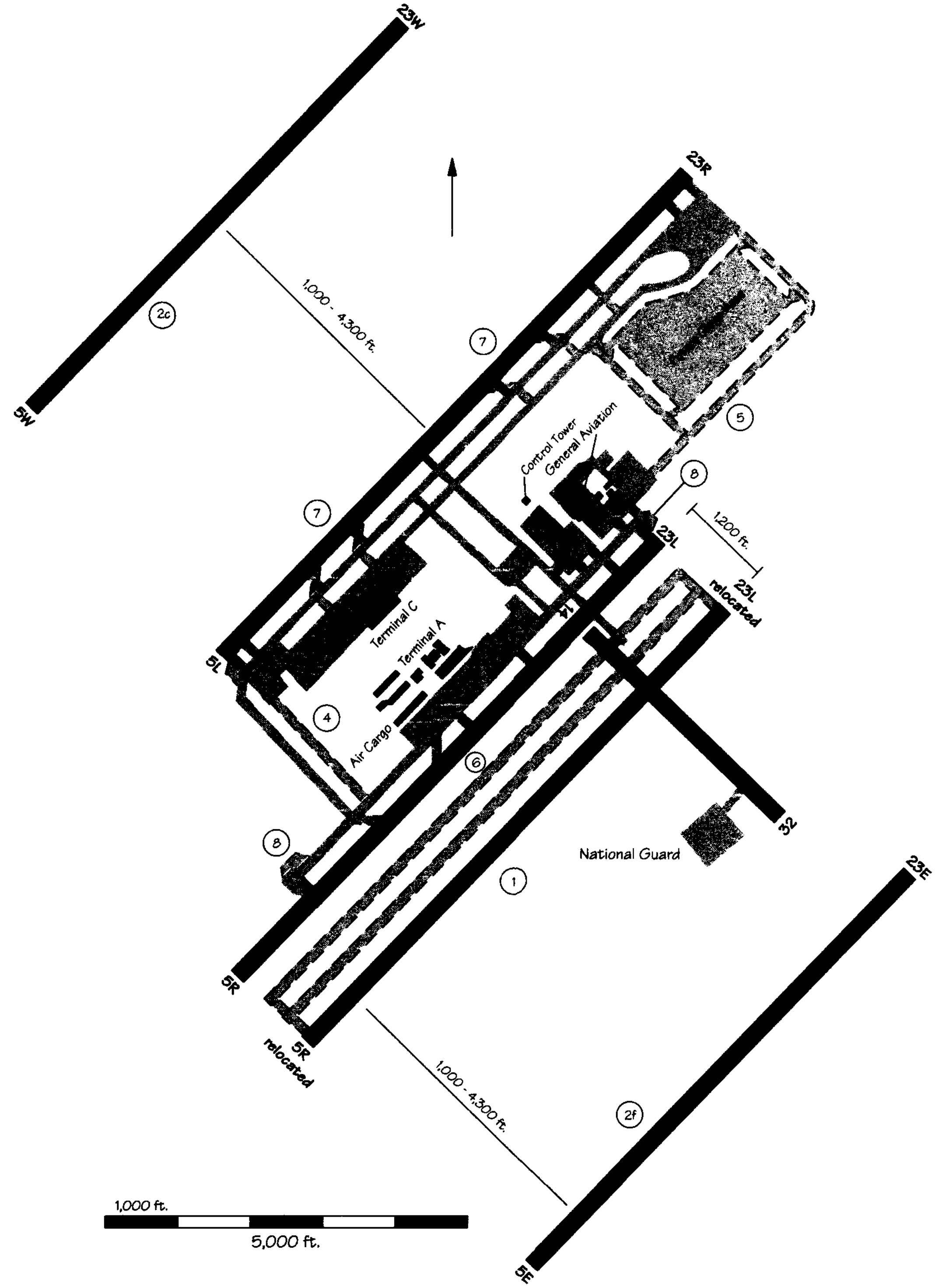
9. Add new gates to northwest finger of new Midfield Terminal and improve Taxiway H to Taxiway R
10. Add new gates to southwest finger of new Midfield Terminal and improve Taxiway K from Taxiway W to A

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


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

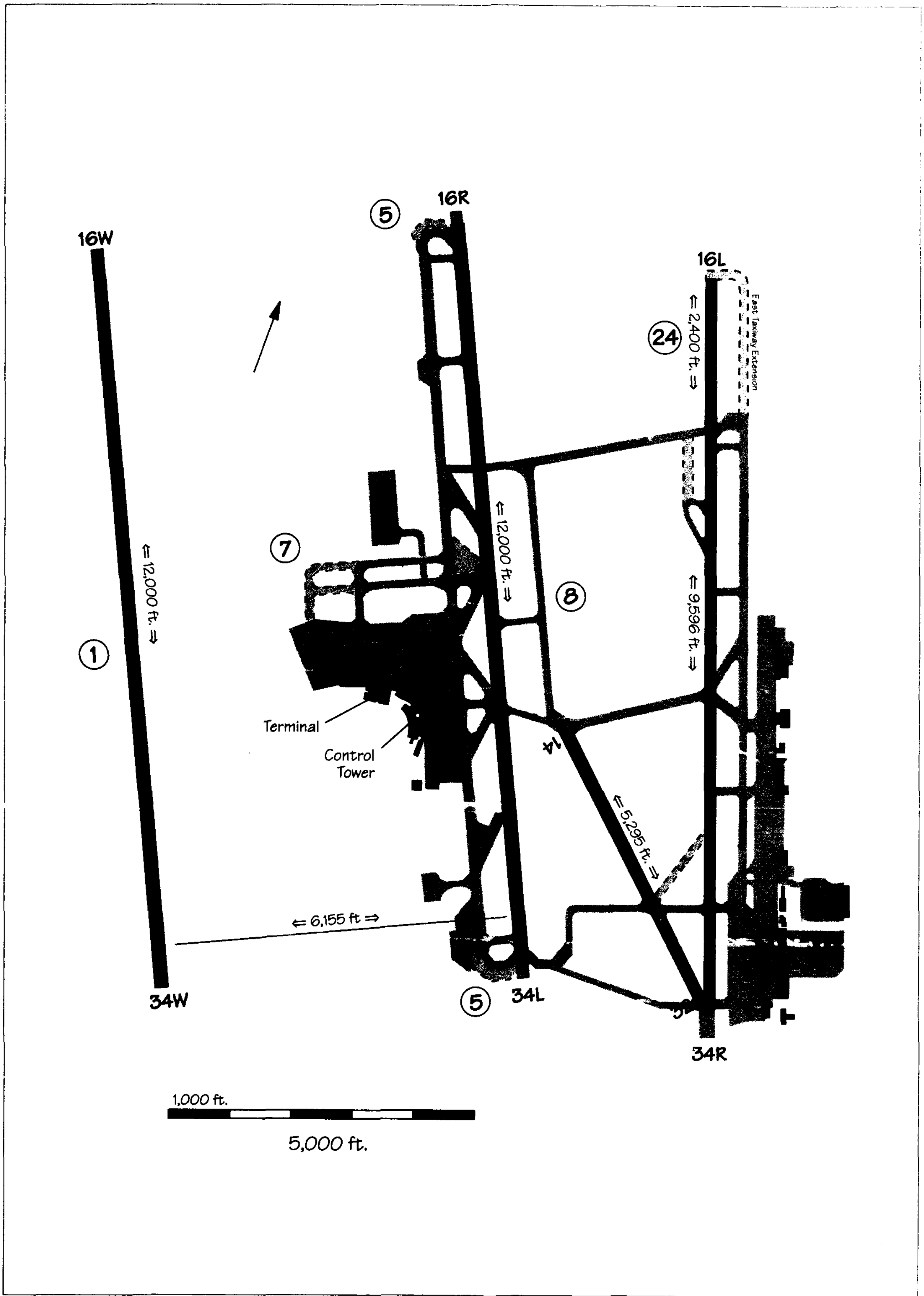
   3b. Triple independent arrivals
4. Construct dual parallel taxiway near feeder Taxiway E
5. Construct taxiway from new cargo complex to Runway 5R/23L
6. Construct full-length dual parallel taxiways for Runway 5R
7. Construct angled exits on Runway 5L/23R
8. Expand holding and sequencing pads and bypass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


16W
16R
16L
5
24
⇐ 2,400 ft. ⇒
East Taxiway Extension
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
32
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. Revise 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

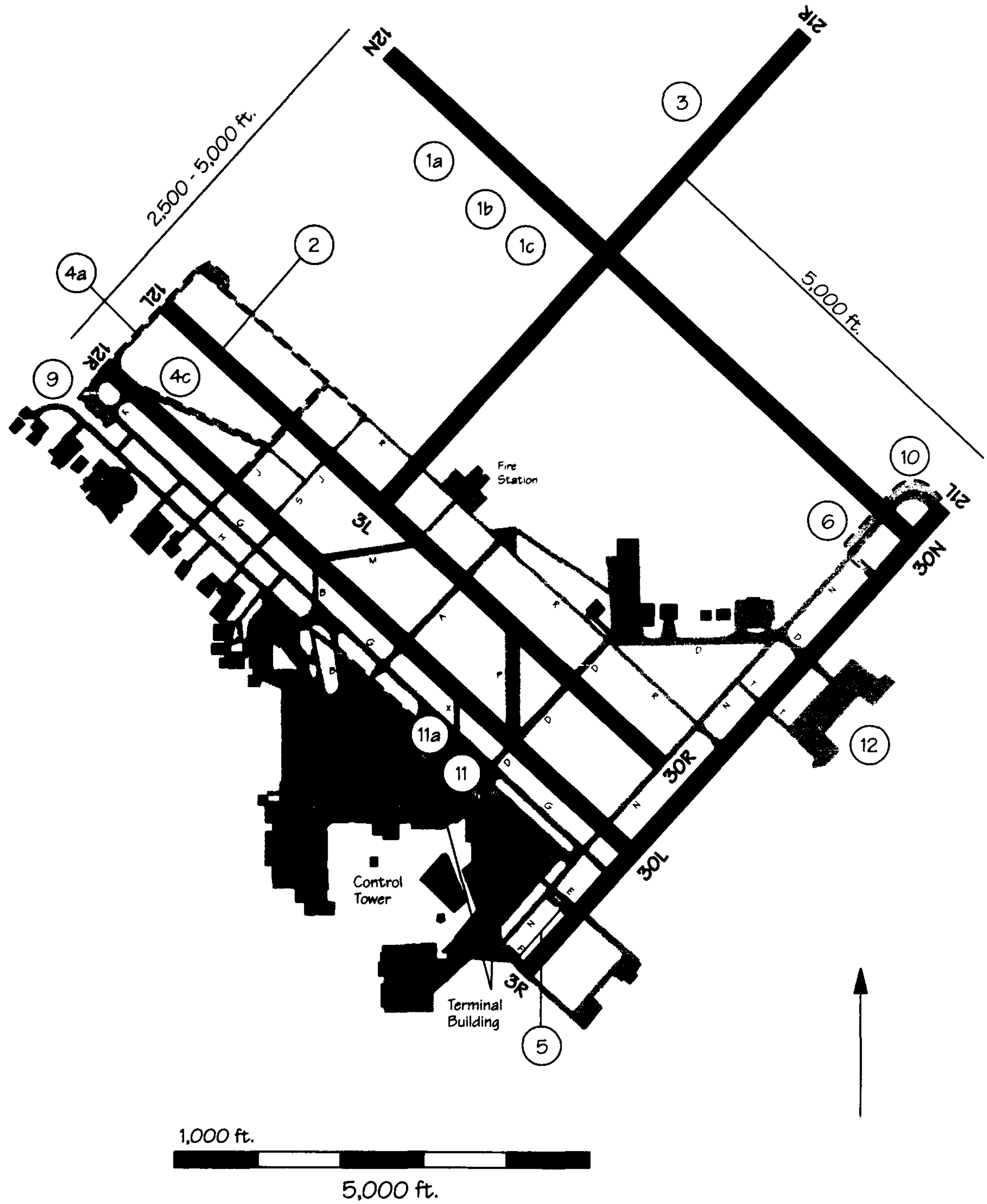
10. CAT I ILS on Runway 34R
11. LDA approach to Runway 34R
12. CAT III ILS on Runway 16R
13. Install Precision Runway Monitor (PRM)
14. Install Microwave Landing System (MLS)
15. Install runway visual range (RVR) equipment on Runway 34R
16. Install Airport Surface Detection Equipment (ASDE)
17. Install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


12N
21R
3
1a
1b
1c
2
2,500 - 5,000 ft.
5,000 ft.
4a
12L
12R
9
4c
Fire Station
3L
10
21L
6
30N
30R
30L
12
11a
11
Control Tower
3R
Terminal Building
5
1,000 ft.
5,000 ft.

San Antonio International Airport Capacity Design Team Project Summary

Recommendations

Airfield Improvements

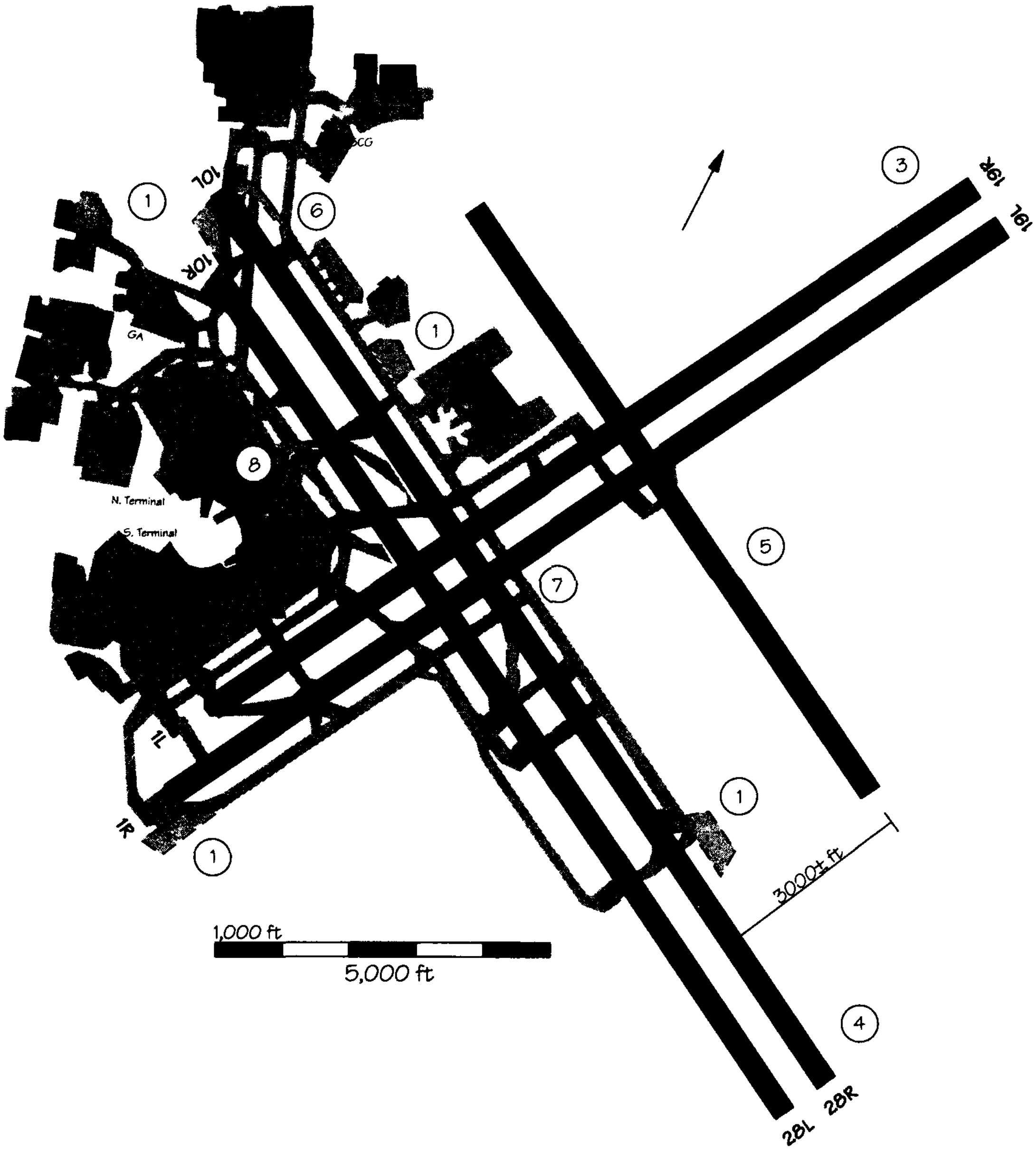
1. Construct new Runway 12N/30N northeast of Runway 12R/30L
   - 1a. Construct independent air carrier length Runway 12N/30N
   - 1b. Construct dependent air carrier length Runway 12N/30N
   - 1c. Construct independent regional air carrier/general aviation (GA) Runway 12N/30N
2. Extend Runway 12L/30R to air carrier length and operate without noise restrictions
   - 2a. Extend Runway 12L/30R and operate with noise restrictions
3. Construct independent air carrier Runway 3L/21R
4. Construct new and improve existing taxiway system to extended Runway 12L/30R
   - 4a. Widen and strengthen Taxiway K and extend to Taxiway R
   - 4b. Improve Taxiways M and P and part of Taxiway N near end of Runway 30L
   - 4c. Construct new diagonal Taxiway J1 at end of Runway 12R
5. Widen Taxiway F and Taxiway E west to ramp at end of Runway 3
6. Construct new Taxiway N1 at end of Runway 21
7. Construct new or extend existing taxiway system to new Runway 12N/30N and extended Runway 12L/30R
8. Provide shoulders for Taxiway G to accommodate four-engine jets
9. Construct holding pads at departure ends of Runways 12R, 3, and 30L
10. Construct holding pads at departure end of Runway 21
11. Expand Terminal to 60 gates
    - 11a. Construct Taxiway H1 to support terminal expansion
12. Expand east cargo ramp
13. Construct arrival holding areas
14. Improve exit turnoffs for existing runways
15. Provide stabilized shoulders for Runway 12R/30L

Facilities and Equipment Improvements

16. Install doppler radar for wind shear detection
17. Install Precision Runway Monitor (PRM)
18. Install Airport Surface Detection Equipment (ASDE)
19. Upgrade ILS on Runway 12R to Category III
20. Install Category II/III ILS on Runway 12N and Category I ILS on Runway 30N with associated approach light system (ALS) and runway visual range (RVR)
21. Install Category I ILS on extended Runway 12L/30R with associated ALS and RVR
22. Install Microwave Landing System (MLS) on Runway 21
23. Install Localizer Directional Aid (LDA) on Runway 12L/30R
24. Install dual Runway Visual Range (RVR) on Runway 3

Operational Improvements

25. Reduce in-trail arrival separations to 2.5 nm
26. Segregate traffic on runways
    - 26a. Segregate by aircraft type
    - 26b. Segregate by arrivals and departures
27. Install Wake Vortex Advisory System (WVAS) (existing configuration)
    - 27a. Install WVAS (with Runway 12L/30R extension)
28. Relocate general aviation (GA)/fixed base operator (FBO) areas to northwest side of Runway 12L
29. Relocate non-air carrier operations
    - 29a. Relocate 25% of non-air carrier operations
    - 29b. Relocate 50% of non-air carrier operations
30. Distribute traffic more uniformly
31. Conduct an airspace capacity design project and re-structure San Antonio area airspace
32. New commercial airport planning



10L
10R
1
6
CG
GA
1
3
19R
19L
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

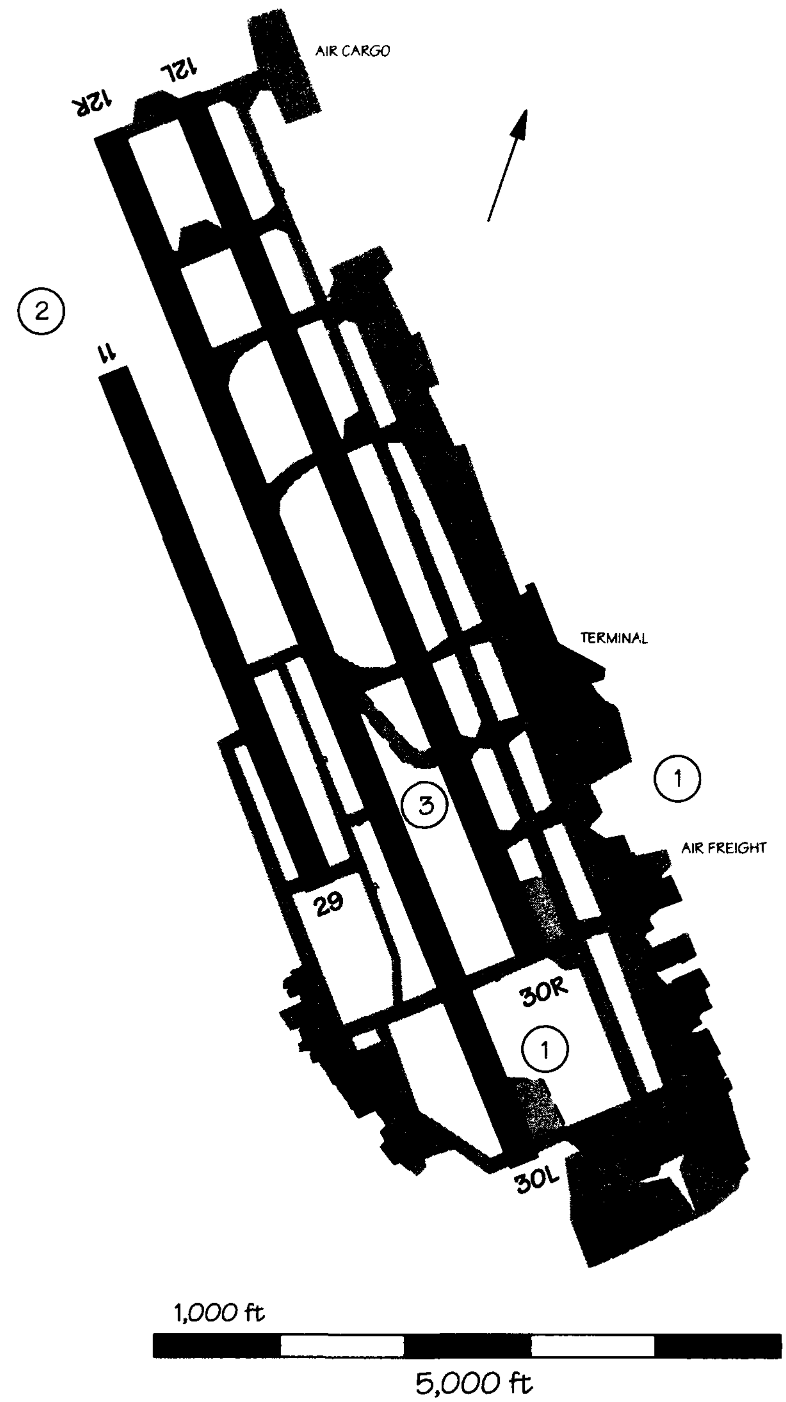
Recommendations

Airfield Improvements
1. Create holding areas near Runways 10L, 10R, 1R, and 28R
2. Improve noise barrier for Runway 1R
3. Extend Runways 19L and 19R
4. Extend Runways 28L and 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 Runways 10L and 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

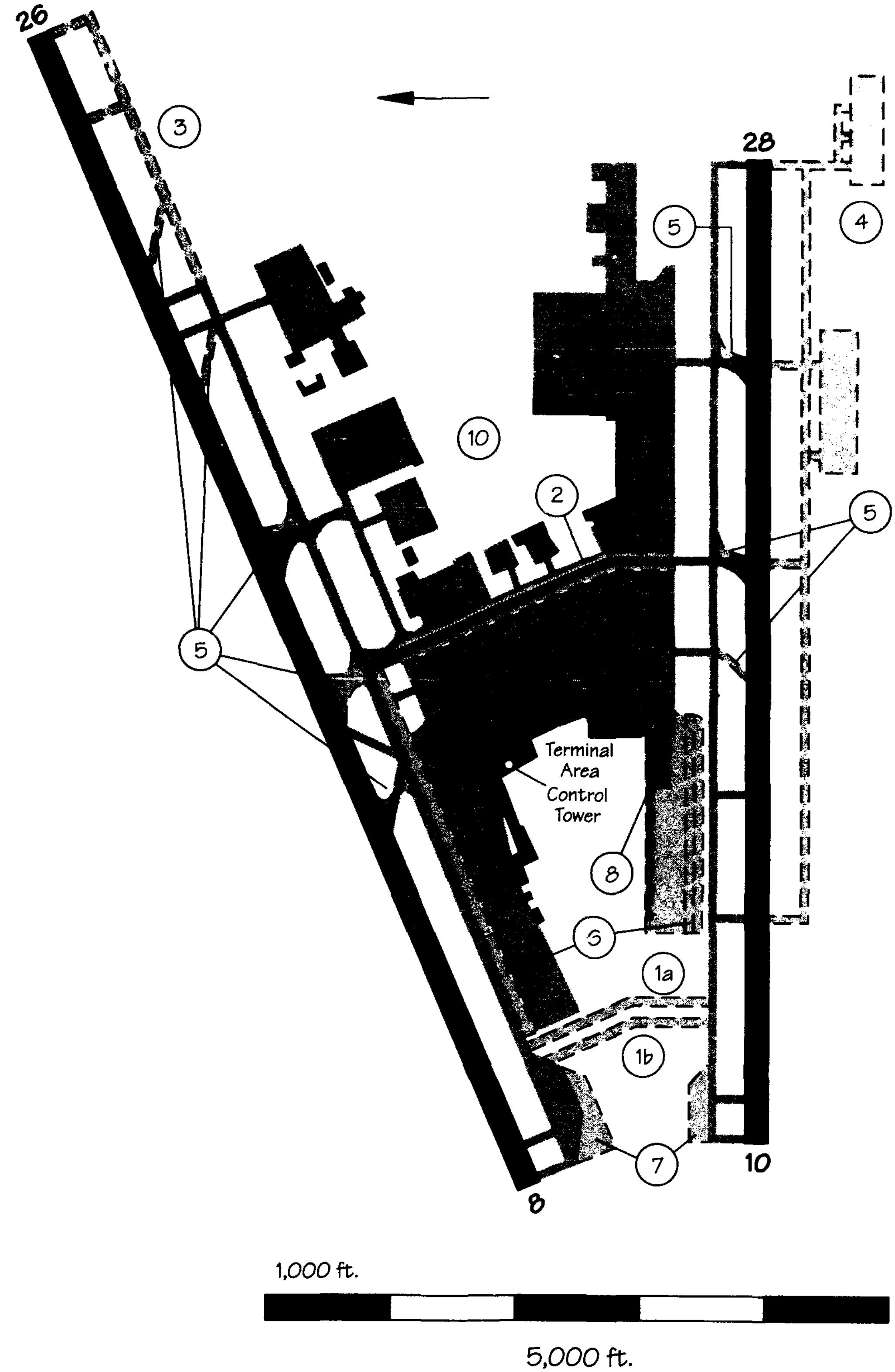
1. Create staging area at Runway 30L
1. Create staging area at Runway 30R
2. Extend and upgrade Runway 11/29
   2a. Extension of Runway 30R
3. Create angled exits for Runway 12R

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
10
8
3
4
5
5
5
5
10
2
Terminal Area Control Tower
8
6
1a
1b
7
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

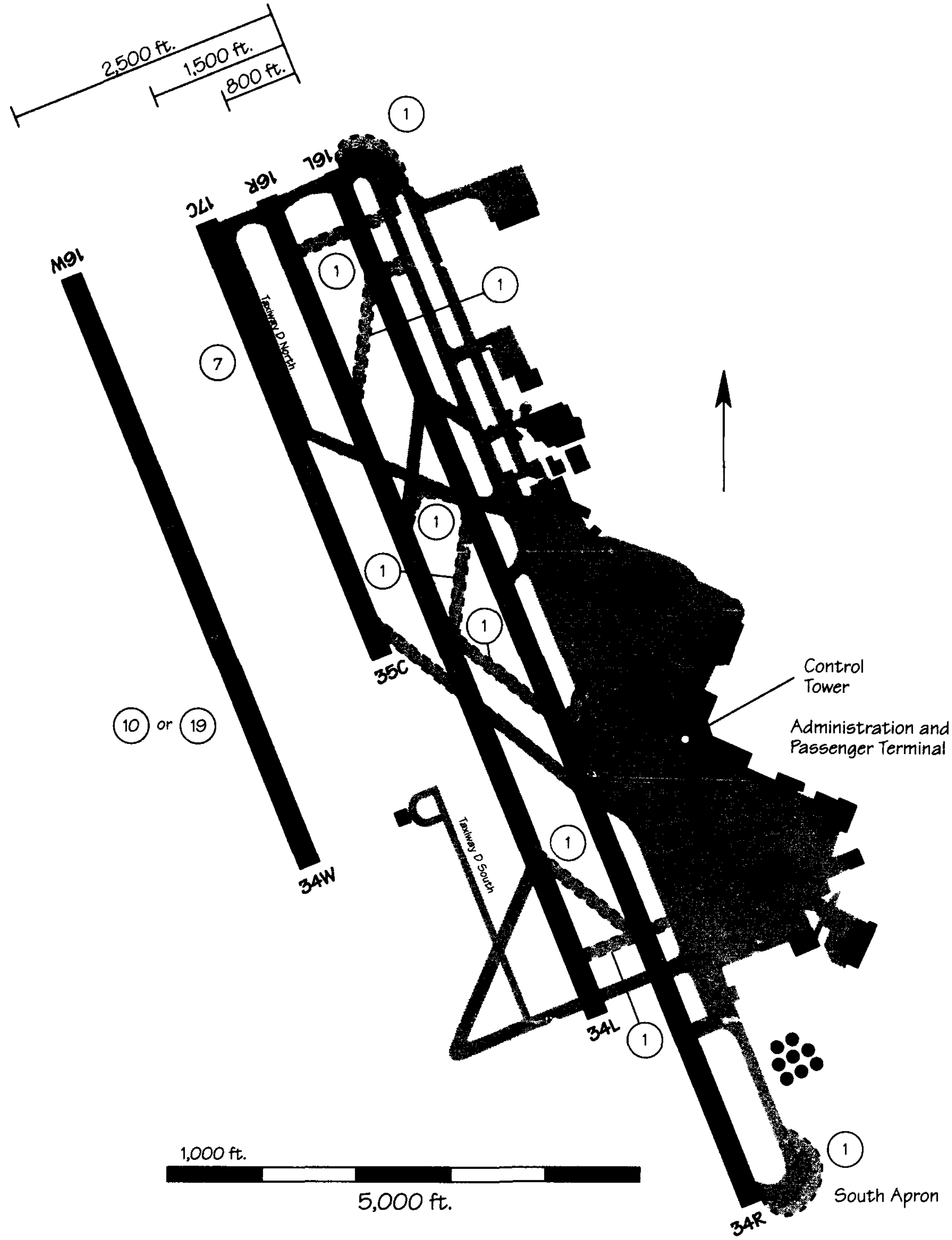
9. Upgrade VOR to include doppler
10. Construct new air traffic control tower
11. Install wake vortex advisory system
12. Install terminal ATC automation (TATCA) enhancements
13. Install improved approach aids on Runway 26
    13a. Install Precision Approach Path Indicator (PAPI)

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

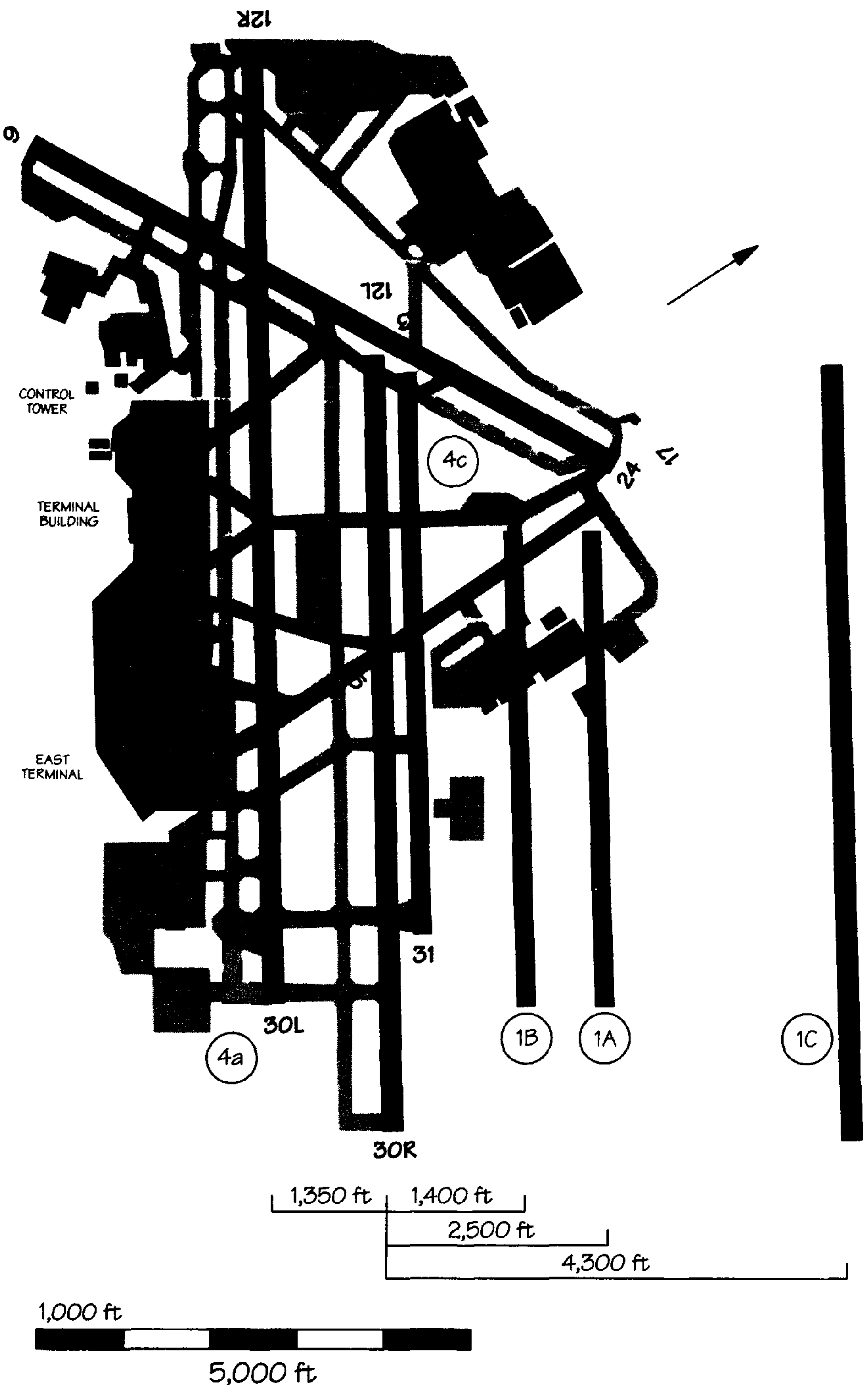
10. Air carrier (dependent) Runway 16W/34W
11. LDA approaches to Runway 16W/34W
12. CAT I ILS on Runway 16W (IFR-1)
13. CAT II ILS on Runway 16W (over CAT I)
14. CAT I ILS on Runway 34W (IFR-1)
15. Staggered approaches to Runways 16L & 16W and 34R & 34W - 2.0 nm stagger
16. Staggered approaches to Runways 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
CONTROL TOWER
TERMINAL BUILDING
EAST TERMINAL
4c
24
17
31
30L
30R
4a
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 2,500 ft. from Runway 12L/30R
   - 1b. Alternate 2: new dependent commuter runway 1,400 ft. 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

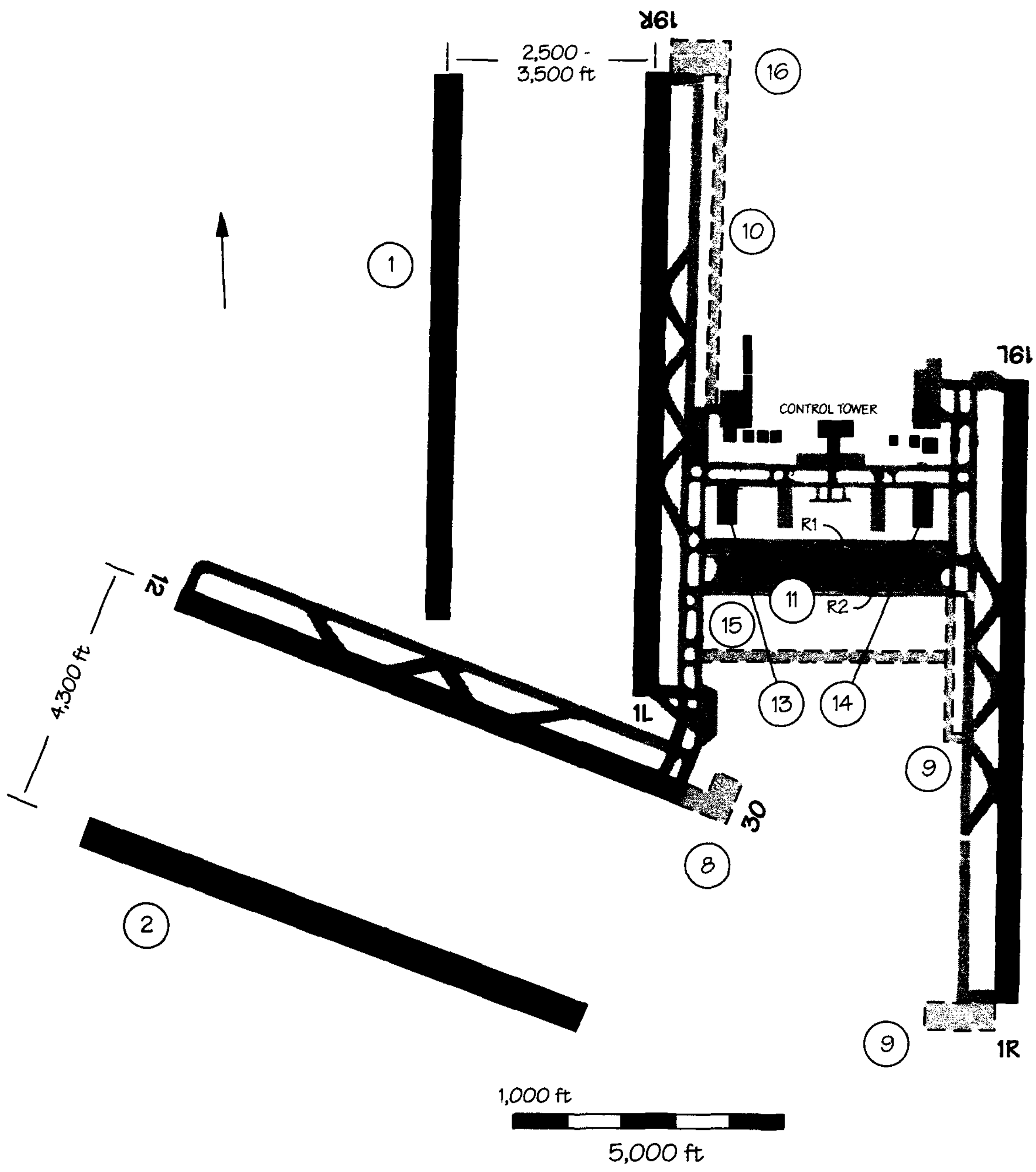
9. Install marker lights and parking lanes in center field remote holding area
10. Install wake vortex advisory system
11. Install CAT III ILS to reduce approach minima on Runways 12L and 12R
12. IFR approaches with additional instrumentation on Runway 6
13. IFR approaches with additional instrumentation 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
11
R2
15
13
14
1L
12
4,300 ft
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

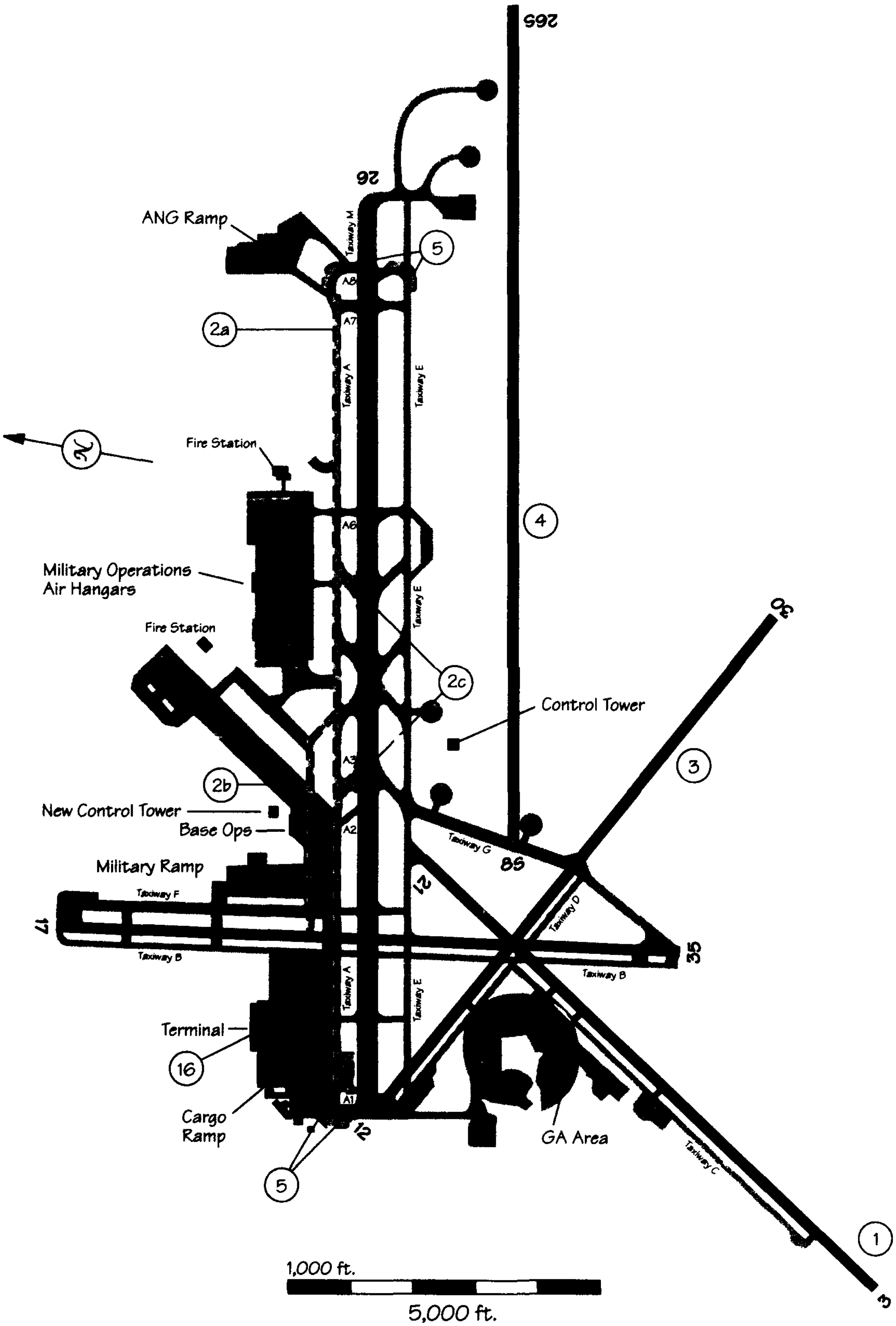
16. Touchdown RVR and touchdown zone lights on Runway 1L
17. Touchdown RVR and centerline lights on Runways 12 and 30 and touchdown zone lights on Runway 12

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%


26S
26
ANG Ramp
Taxiway M
5
A8
A7
2a
Taxiway A
Taxiway E
Fire Station
4
A6
Military Operations
Air Hangars
30
Fire Station
2c
Control Tower
A3
3
2b
New Control Tower
Base Ops
A2
Taxiway G
8S
Military Ramp
21
Taxiway F
17
Taxiway D
35
Taxiway B
Taxiway B
Taxiway A
Taxiway E
Terminal
16
A1
Cargo
Ramp
12
GA Area
Taxiway C
5
1
1,000 ft.
5,000 ft.
3

Albuquerque International Airport Capacity Design Team Project Summary

Proposed Alternatives

Airfield Improvements

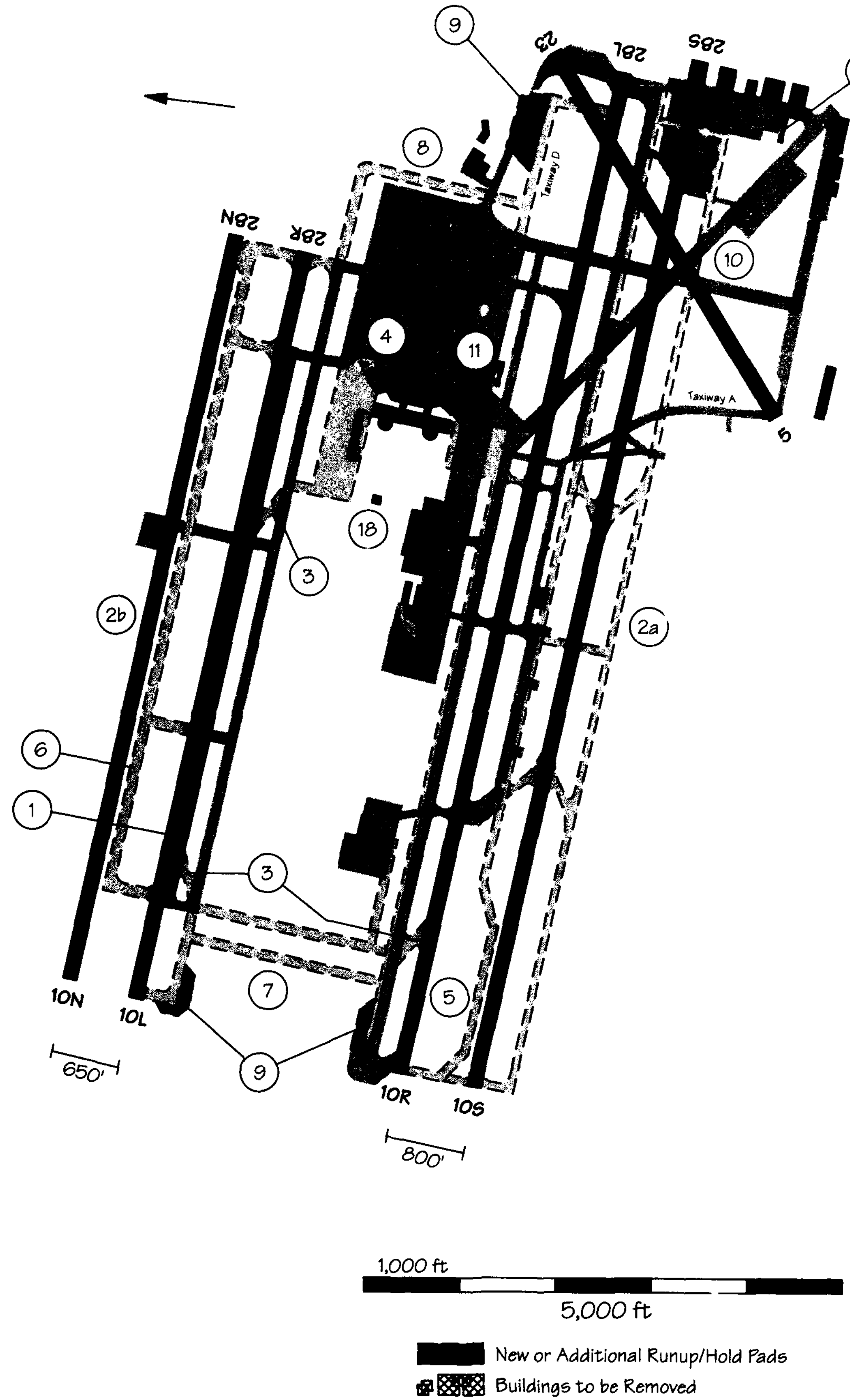
1. Extend, widen, and strengthen Runway 3/21 and operate as a 10,000-foot air carrier runway
2. Construct new and improve existing taxiways and exits
   - 2a. Widen and strengthen Taxiway A along full length, parallel to and north of Runway 8/26
   - 2b. Construct 4,000 ft. Taxiway AA parallel to and north of Taxiway A, from Runway 17/35 to Exit A4
   - 2c. Improve or add angled (high-speed) exits on Runway 8/26 to Taxiway A
3. Extend Runway 12/30 to the southeast and operate as a 10,000-foot air carrier runway
4. Construct new parallel air carrier runway south of Runway 8/26
   - 4a. Operate as a dependent IFR runway
   - 4b. Operate as an independent IFR runway
5. Construct holding areas for Runway 8/26

Facilities and Equipment Improvements

6. Install ILS on Runway 3
7. Install CAT II/III ILS on Runway 8
8. Install ILS on Runway 35
9. Install TVOR/DME
10. Install ILS on Runway 30

Operational Improvements

11. Benefit of MLS procedures to Runway 26
12. Reduce in-trail separations to 2.5 nm from 3 nm in IFR
13. Evaluate impact of noise abatement procedures
14. Implement dependent converging approaches with ILS on Runways 3 and 8
15. Enhance GA reliever airports
16. Terminal expansion (added gates)
17. Assign designated areas for civil helicopters



9
23
28L
28S
11
8
Taxiway D
28N
28R
10
4
11
Taxiway A
5
18
3
2b
2a
6
1
3
7
5
10N
10L
9
650'
10R
10S
800'
1,000 ft
5,000 ft
New or Additional Runup/Hold Pads
Buildings to be Removed

Port Columbus International Airport Capacity Design Team Project Summary

Proposed Alternatives

Airfield Improvements

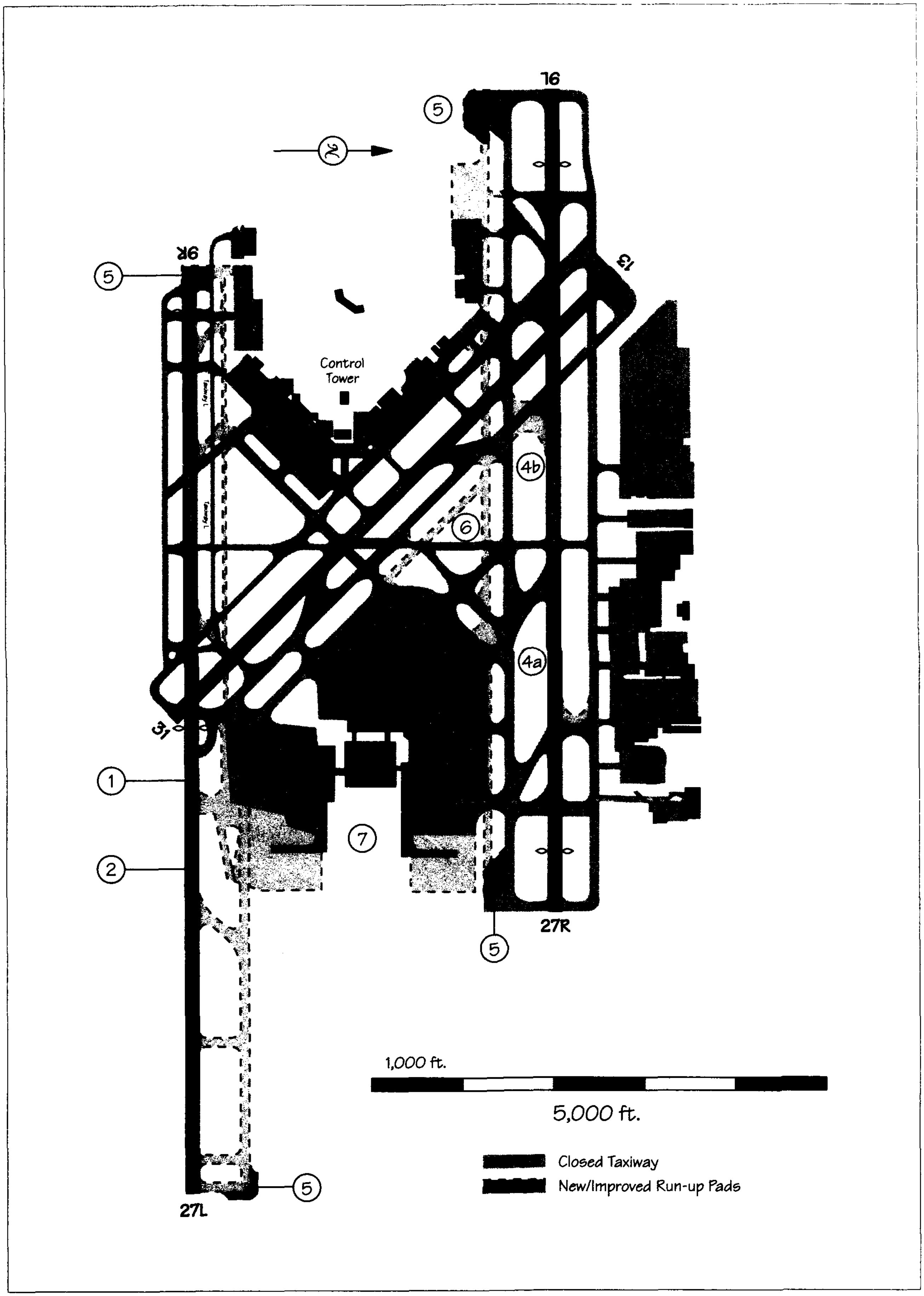
1. Relocate and extend Runway 10L/28R
   1a. Extend Runway 10L 1,000 ft. east
   1b. Extend Runway 28R 1,000 ft. west
   1c. Extend Runway 10L/28R to 8,000 ft.
2. Build a third parallel runway 800 ft. south of Runway 10L/28R; use existing Runway 10L/28R as a departure runway; build fourth runway 600 ft. north of Runway 10L/28R
3. Improve or add angled exits
4. Expand passenger terminal
   4a. Add 10 gates on west side
   4b. Add 6 gates on east side
   4c. Add 10 additional gates
5. Relocate west end of Taxiway B
6. Build north parallel taxiway for Runway 10L/28R
7. Build crossover taxiway at west end between Runway 10L/28R and Runway 10R/28L
   7a. Build one-way taxiway
   7b. Build two-way taxiway
8. Build bypass taxiway on east side
9. Build run-up pads at all air carrier runway ends
10. Reconstruct/strengthen Taxiway G south of Runway 10R/28L
11. Build blast area for engine runups north and south of Runway 28L

Facilities and Equipment Improvements

12. Install CAT I ILS on Runways 10L/28R and 10R/28L (with centerline lights)
13. Install CAT II ILS
14. Install Microwave Landing System (MLS) on Runway 28R
15. Install Precision Runway Monitor (PRM)
16. Install Airport Surface Detection Equipment (ASDE)
17. Install Distance Measuring Equipment (DME) on Runway 28L
18. Build new Airport Traffic Control Tower (ATCT)
19. Install additional NAVAIDS

Operational Improvements

20. Impact of noise reduction procedures
    20a. Effect of Stage III aircraft
    20b. Unrestricted use Runway 10L/28R
21. Provide 1.5 nm staggered approaches to Runways 10R/28L and 10L/28R in IFR
22. Provide 2.5 nm in-trail separations between similar class aircraft
23. Redistribute traffic more uniformly within the hour
24. Enhance GA reliever airports
25. Conduct airspace capacity design project and restructure area airspace


9R
16
13
31
27L
27R
Control Tower
5
2
4b
6
4a
1
7
1,000 ft.
5,000 ft.
Closed Taxiway
New/Improved Run-up Pads

Fort Lauderdale International Airport Capacity Design Team Project Summary

Proposed Alternatives

Airfield Improvements

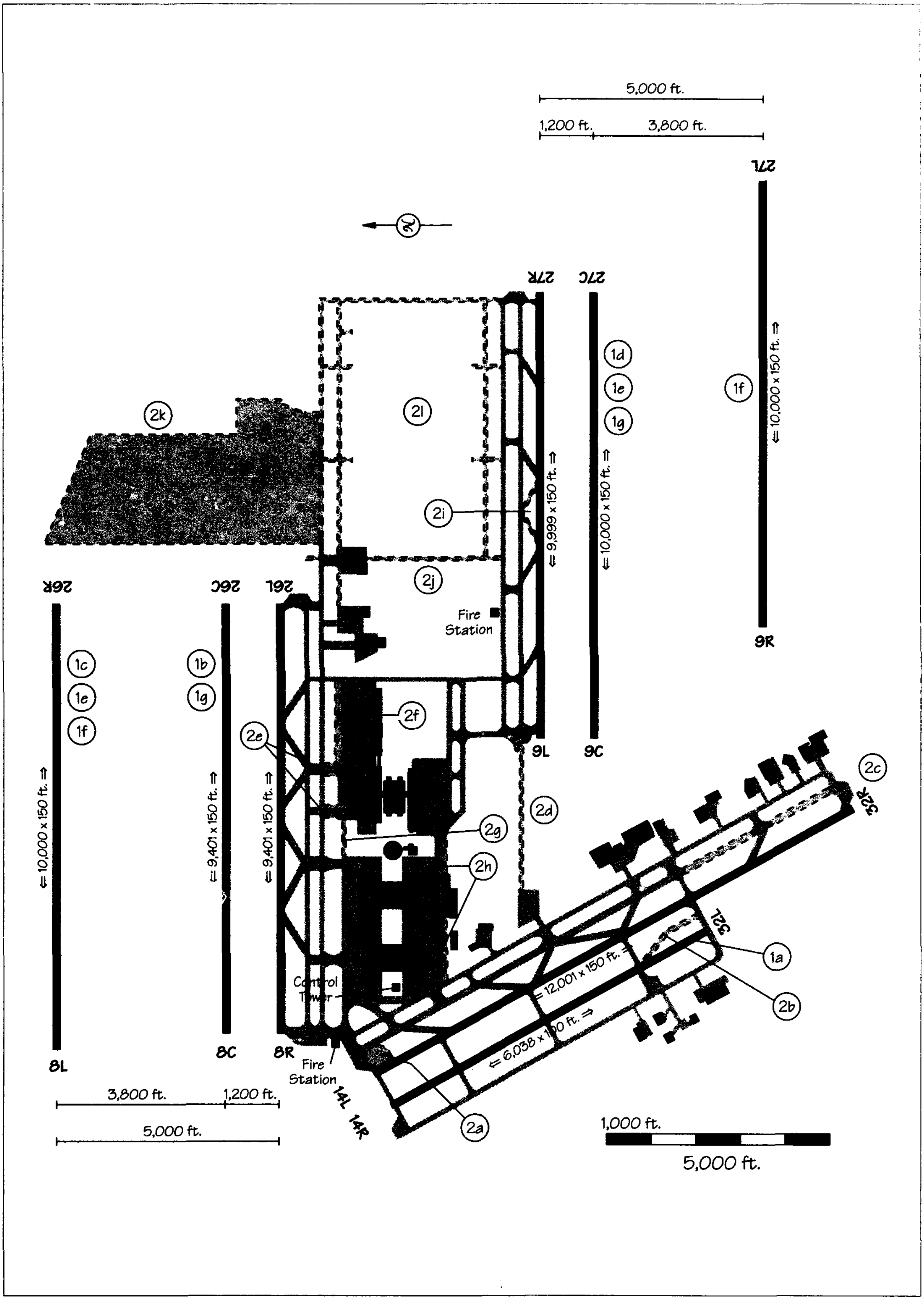
1. Extend Runway 9R/27L— 6,000 ft. long, 150 ft. wide, and CAT I ILS
   - 1a. 2 nm stagger in IFR
   - 1b. 1.5 nm stagger in IFR
   - 1c. Simultaneous parallel IFR approaches (with PRM)
   - 1d. Simultaneous approaches and 2.5 nm minimum in IFR (1c and 16)
2. Extend Runway 9R/27L — 10,000-ft. long, 150 ft. wide, and CAT I ILS
   - 2a. 2 nm stagger in IFR
   - 2b. 1.5 nm stagger in IFR
   - 2c. Simultaneous parallel IFR approaches (with PRM)
   - 2d. Simultaneous approaches and 2.5 nm minimum in IFR (2c and 16)
3. Extend Runway 9R/27L to 10,000 ft; operate under restricted use
   - 3a. With 2 nm stagger in IFR
   - 3b. Simultaneous parallel IFR approaches (with PRM)
4. Improve angled exits
   - 4a. Widen fillets at Exit Q on Runway 9L
   - 4b. Widen angled exit Runway 27R, south, at Taxiway F
5. Add or expand run-up pads to stage departures
6. Taxiway and exit improvement package
7. Expand terminal (international and air carrier)

Facilities and Equipment Improvements

8a. CAT I ILS on Runway 9R
8b. CAT I ILS on Runway 27L
9. CAT I ILS on Runway 31
10. CAT II/IIIA ILS on Runway 27R
11. Precision Runway Monitor (PRM) — when south runway extended
12. Upgrade FLL radar — commission ASR-9
13. Relocate TVOR/VOR off Airport
14. Vortex Advisory System (VAS)
15. Low Level Wind Shear Alert System (LLWAS)

Operational Improvements

16. Reduce minimum in-trail separations to 2.5 nm
17. Reduce stagger to 1.5 nm in IFR
18. Unrestricted use of Runway 13/31 for departures (cost of noise restrictions on use of Runway 13/31)
19. Unrestricted use of Runway 13 (impact of Ft. Lauderdale Executive Airport (FXE) operations)
20. Conduct a study of South Florida airspace and implement airspace management
21. Increase/enhance reliever airports
22. Redistribute traffic more uniformly within the hour



5,000 ft.
1,200 ft.
3,800 ft.
27L
27R
27C
1d
1e
1g
1f
⇐ 10,000 x 150 ft. ⇒
2k
2l
2i
⇐ 9,999 x 150 ft. ⇒
⇐ 10,000 x 150 ft. ⇒
2j
26R
26C
26L
Fire Station
9R
1c
1e
1f
1b
1g
2f
2e
9L
9C
2c
32R
2d
⇐ 10,000 x 150 ft. ⇒
⇐ 9,401 x 150 ft. ⇒
⇐ 9,401 x 150 ft. ⇒
2g
2h
32L
1a
12,001 x 150 ft.
Control Tower
2b
6,038 x 100 ft. ⇒
8L
8C
8R
Fire Station
14L
14R
2a
3,800 ft.
1,200 ft.
5,000 ft.
1,000 ft.
5,000 ft.

Houston Intercontinental Airport
Capacity Design Team Project Summaries

Proposed Alternatives

Airfield Runway Improvements

1a. Extend, widen, and strengthen Runway 14R/32L for air carrier departures, with arrivals on Runways 26L and 27R
1b. Construct air carrier Runway 8C/26C 1,200 ft. north of Runway 8R/26L
1c. Construct air carrier Runway 8L/26R to support triple independent approaches
1d. Construct air carrier Runway 9C/27C 1,200 ft. south of Runway 9L/27R
1e. Construct both Runway 8L/26R and Runway 9C/27C
1f. Construct both Runway 8L/26R and new air carrier Runway 9R/27L to support quadruple independent approaches
1g. Construct both Runway 8C/26C and Runway 9C/27C

Airfield Taxiway Improvements

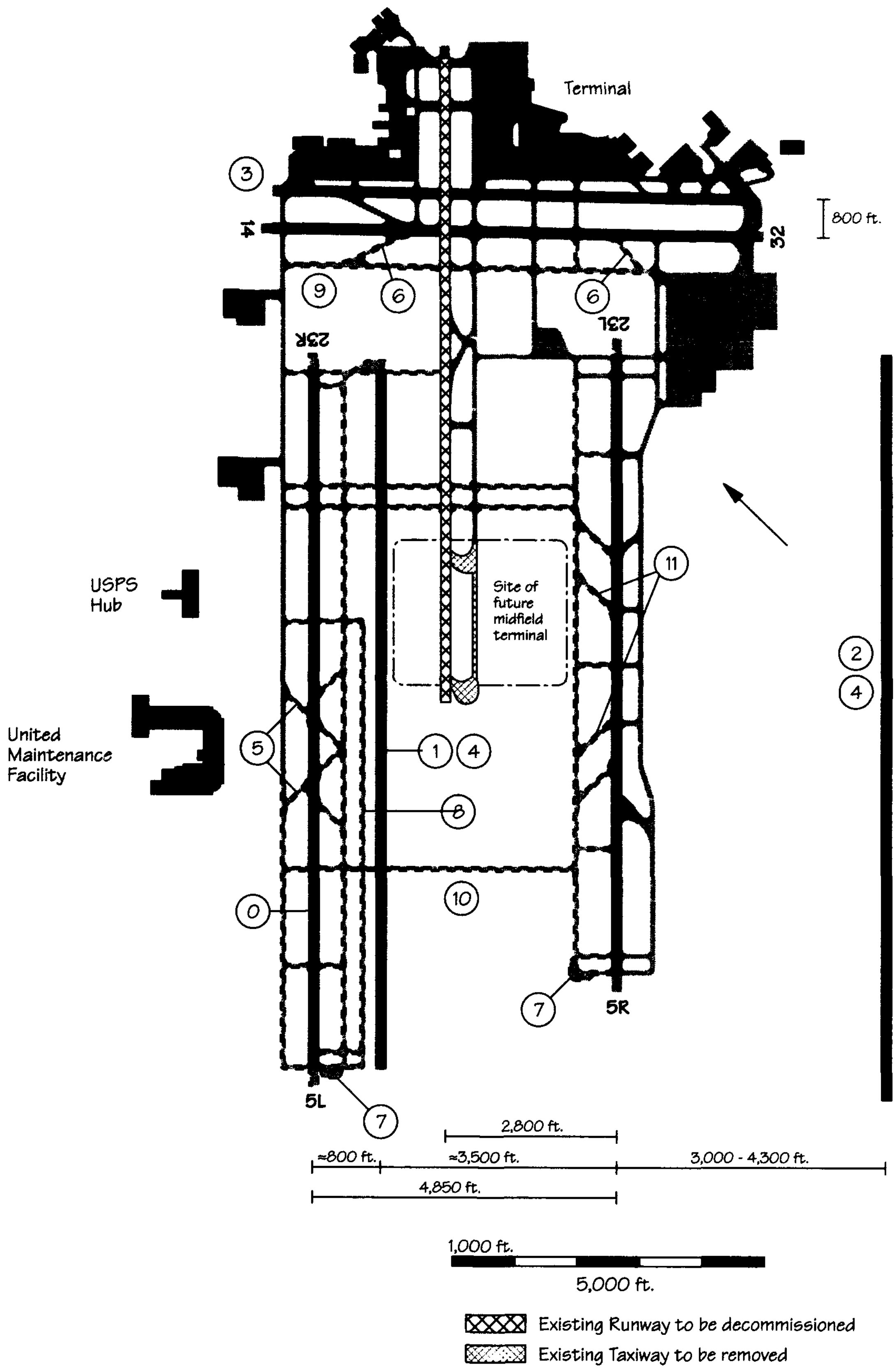
2a. Add independent taxiway and departure holding pads to existing Runway 14R/32L
  2a.1. With current runway assignments
  2a.2. As air taxi/commuter runway only
2b. Add high speed exit off Runway 14R
2c. Extend Taxiway WA from Taxiway WL to Taxiway WB to allow two-way traffic
2d. Extend Taxiway WH to Taxiway SA (bridging over JFK Boulevard)
2e. Widen Taxiways NJ and NK to allow two-way traffic
2f. Extend Mickey LeLand Memorial International Airlines Building (IAB) Ramp
2g. Extend North Ramp to connect Terminals B and C
2h. Add dual taxiway at South Terminal Ramp (bridging over JFK Boulevard)
2i. Add high speed exits at Taxiways SG and SH
2j. Add second crossfield taxiway at midfield to provide two-way flow
2k. Construct cargo gate and taxiway complex north side
2l. Construct new terminal

Facilities and Equipment Improvements

3a. Upgrade to CAT III ILS on Runway 27R

Operational Improvements

3b. Conduct dependent IFR approaches to Runways 14L & 9L and 14L & 26
4. Distribute traffic more uniformly during peak periods
5. Construct new reliever airport on west side
6. Add a public-use heliport at IAH
7. Construct additional airline hub at Terminal B


Terminal
3
14
32
800 ft.
9
6
6
23R
23L
USPS Hub
Site of future midfield terminal
11
2
4
United Maintenance Facility
5
1
4
8
10
0
7
5R
5L
7
2,800 ft.
≈800 ft.
≈3,500 ft.
3,000 - 4,300 ft.
4,850 ft.
1,000 ft.
5,000 ft.
Existing Runway to be decommissioned
Existing Taxiway to be removed

Indianapolis International Airport Capacity Design Team Project Summaries

Proposed Alternatives

Airfield Improvements

0. Replace runway 5L/23R
1. Build third dependent runway 800 ft. east of Runway 5L/23R
2. Build third independent northeast/southwest runway (with Precision Runway Monitor (PRM))
3. Build a second northwest/southeast dependent runway 800 ft. northeast of Runway 14/32
4. Build both third dependent runway and fourth independent northeast/southwest runway (combines 1 and 2)
5. Add angled exits to Taxiway F for future Runway 5L/23R
6. Add angled exits Runway 14/32
7. Build departure sequencing pads for Runways 5L and 5R
8. Build dual taxiway system for future Runway 5L/23R
9. Build northeast crossover Taxiway C
10. Build fourth crossfield taxiway at southwest end
11. Add angled exits for Runway 5R/23L

Facilities and Equipment Improvements

12. Add centerline lights Runway 14/32
13. Install touchdown runway visual range (RVR) Runway 14
14. Install Airport Surface Detection Equipment (ASDE) radar
15. Install surface movement guidance and control system
16. Install Aircraft Situation Display (ASD)
17. Install approach light system (ALSF-2) on Runway 14/32
18. Upgrade low-level wind shear advisory system
19. Upgrade RVR to CAT IIIB and ICAO standards in Runways 5R and 5L
20. Install doppler weather radar

Operational Improvements

21. End-fire glide slope for Runways 23R and 14
22. Reduce in-trail separations to 2.5 nm
23. Develop dependent converging approaches
24. Effect of noise restrictions
25. Reduce runway occupancy times
26. Continue enhancement of reliever airports to accomodate a reduction in small/slow aircraft operations at IND

Appendix D

New Runway Construction Projects at Major U.S. Airports

Legend

Existing Runway

Existing Taxiway/Apron

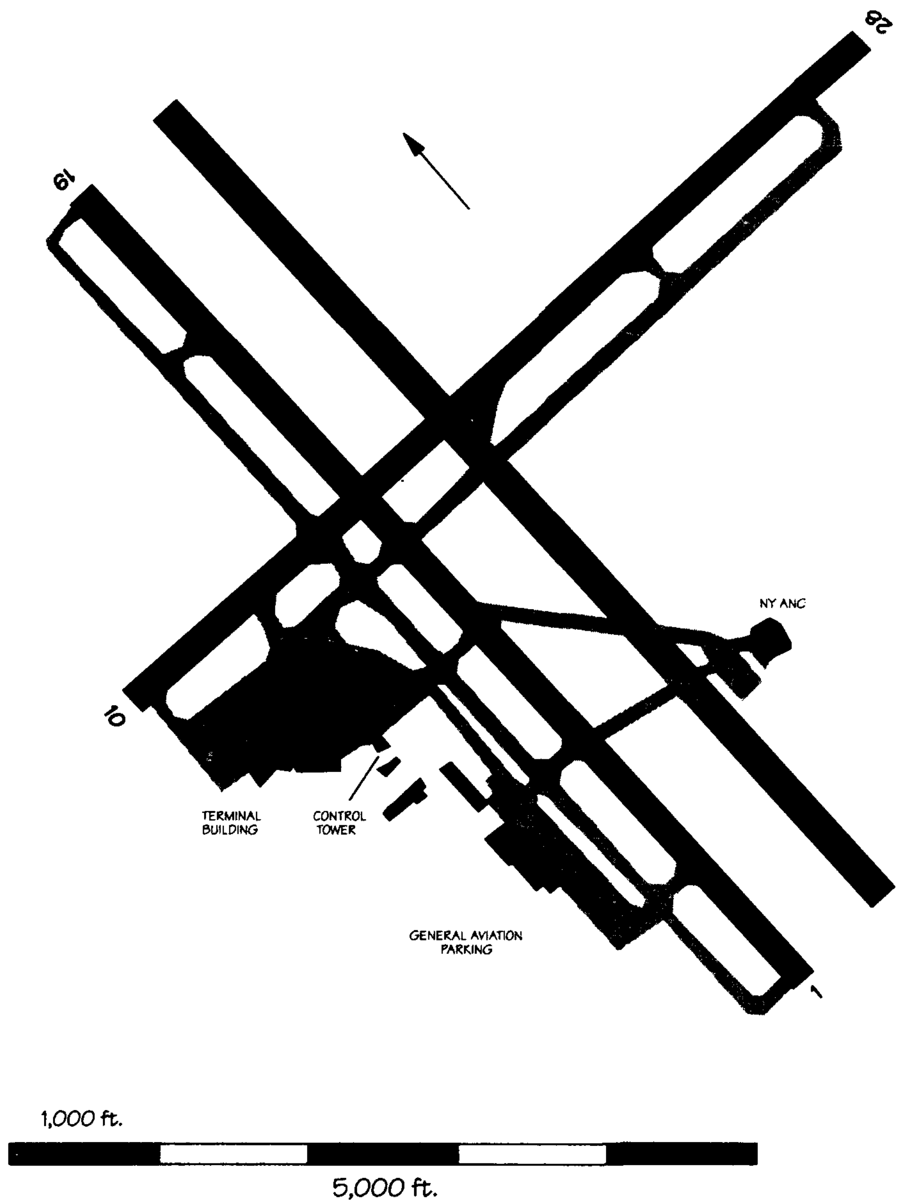
Proposed Runway/Runway Extension

Proposed Taxiway/Apron/Facility Improvements

Buildings

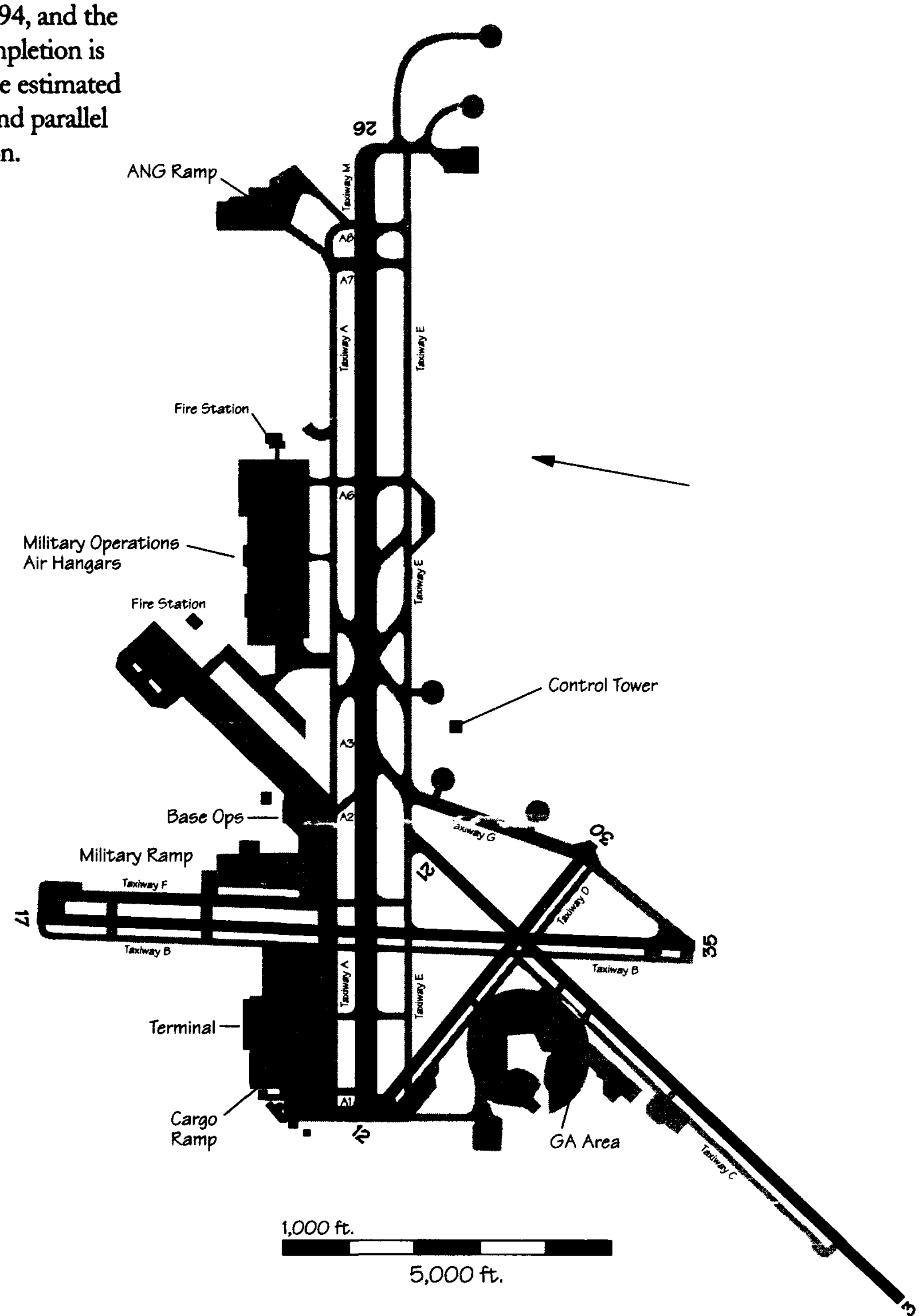
Albany (ALB)

Construction of an extension to Runway 10/28 is expected to start in 1996 and should be completed sometime in 1997. The estimated cost of construction is $2 million. A new parallel Runway 1R/19L is also planned. With construction scheduled to begin in 2006, the new runway should be operational in 2007. The estimated cost is $15 million.



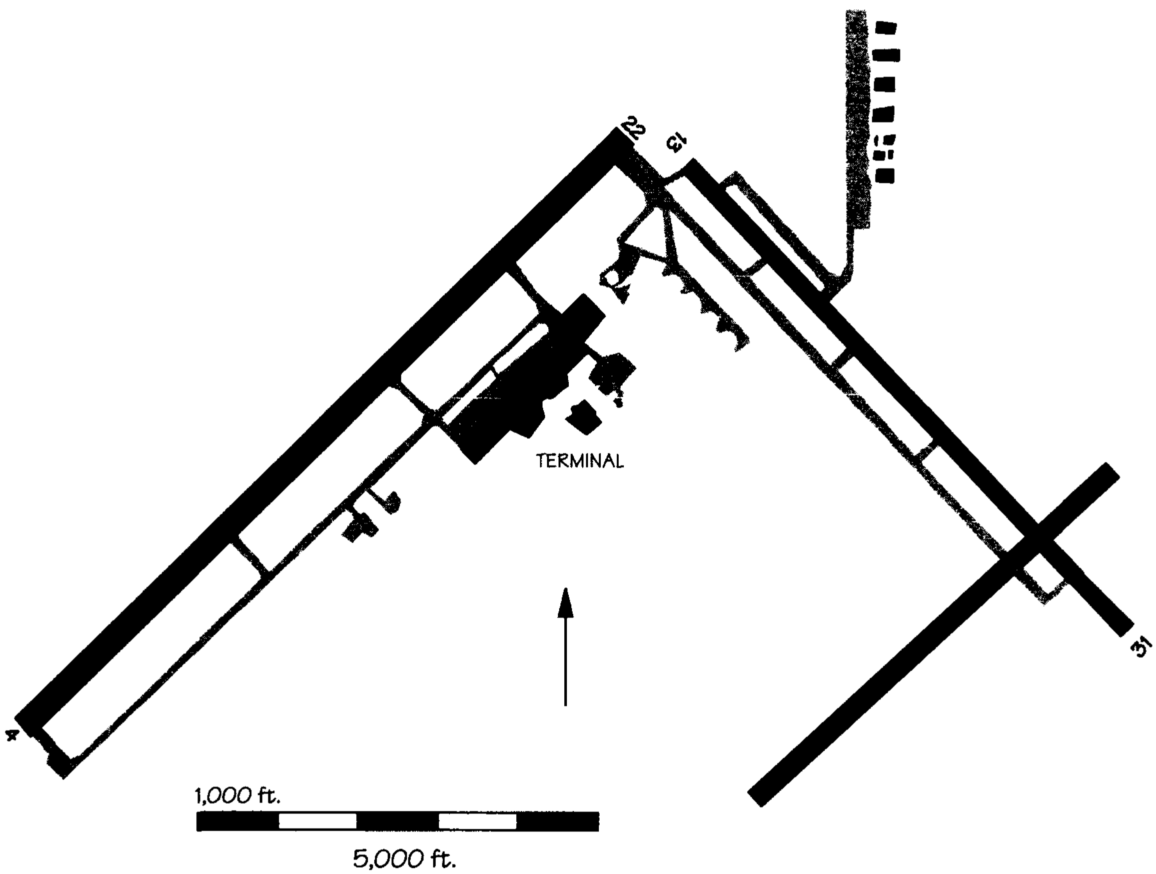
Albuquerque (ABQ)

A 1,500 foot extension to Runway 3/21 will provide an 8,800 foot runway, eliminating the intersection with Runway 8/26. Construction is scheduled to start in March 1994, and the expected date of completion is December 1994. The estimated cost of the runway and parallel taxiway is $11 million.



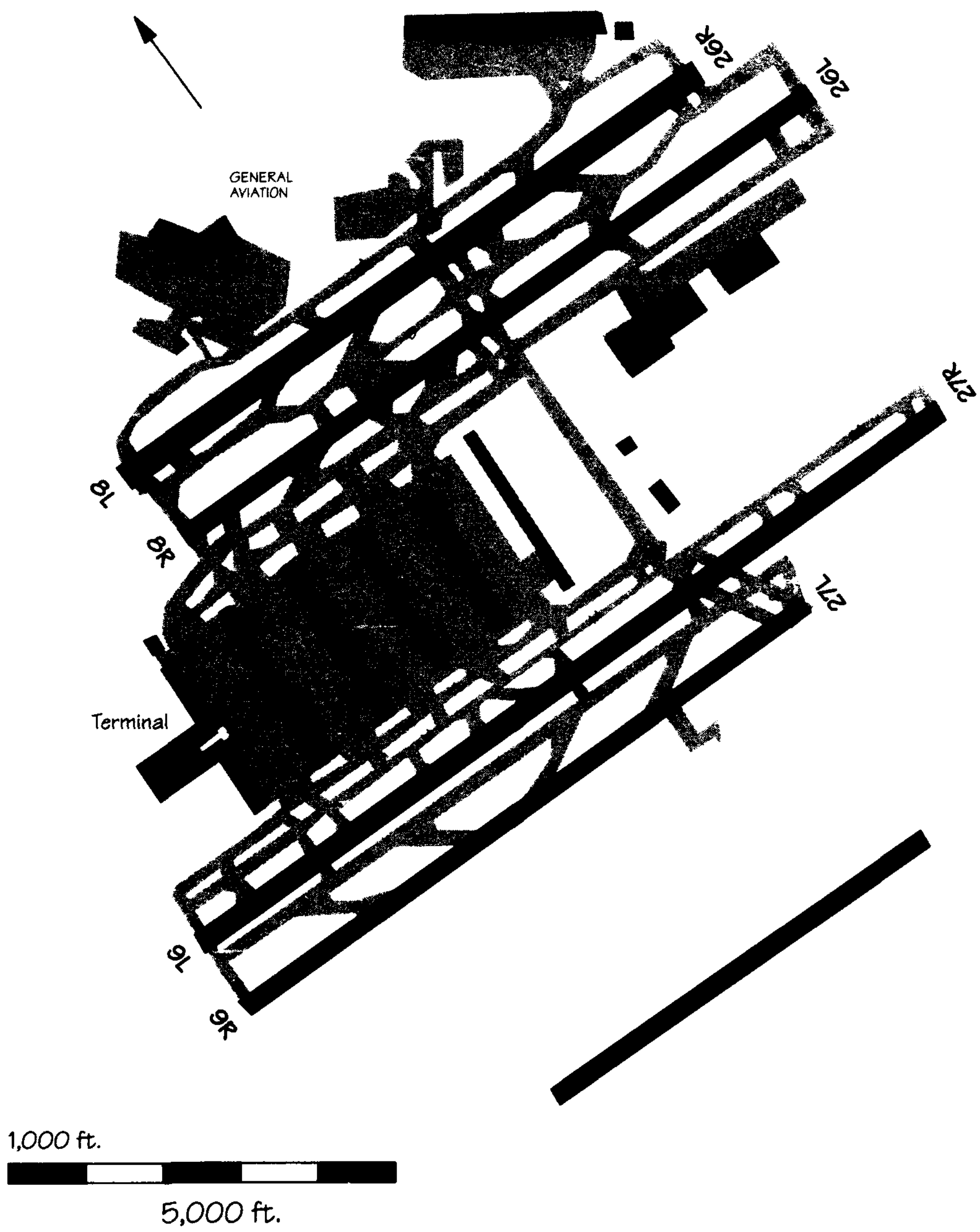
Amarillo (AMA)

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



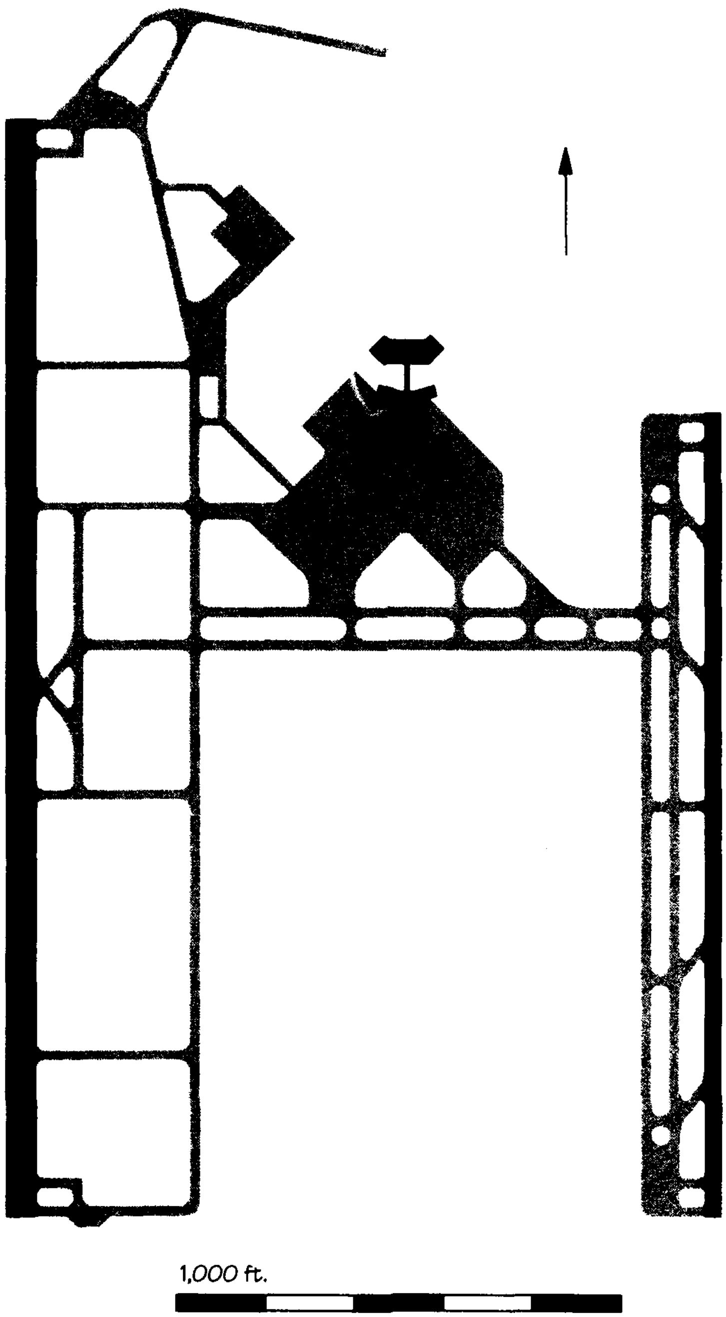
Atlanta (ATL)

A fifth parallel runway, 5,500 feet long and 3,500 feet south of Runway 9R/27L, is being planned. The total estimated cost is $130 million. Construction is scheduled to start in 1994, and the estimated operational date is 1996.



Austin (AUS)

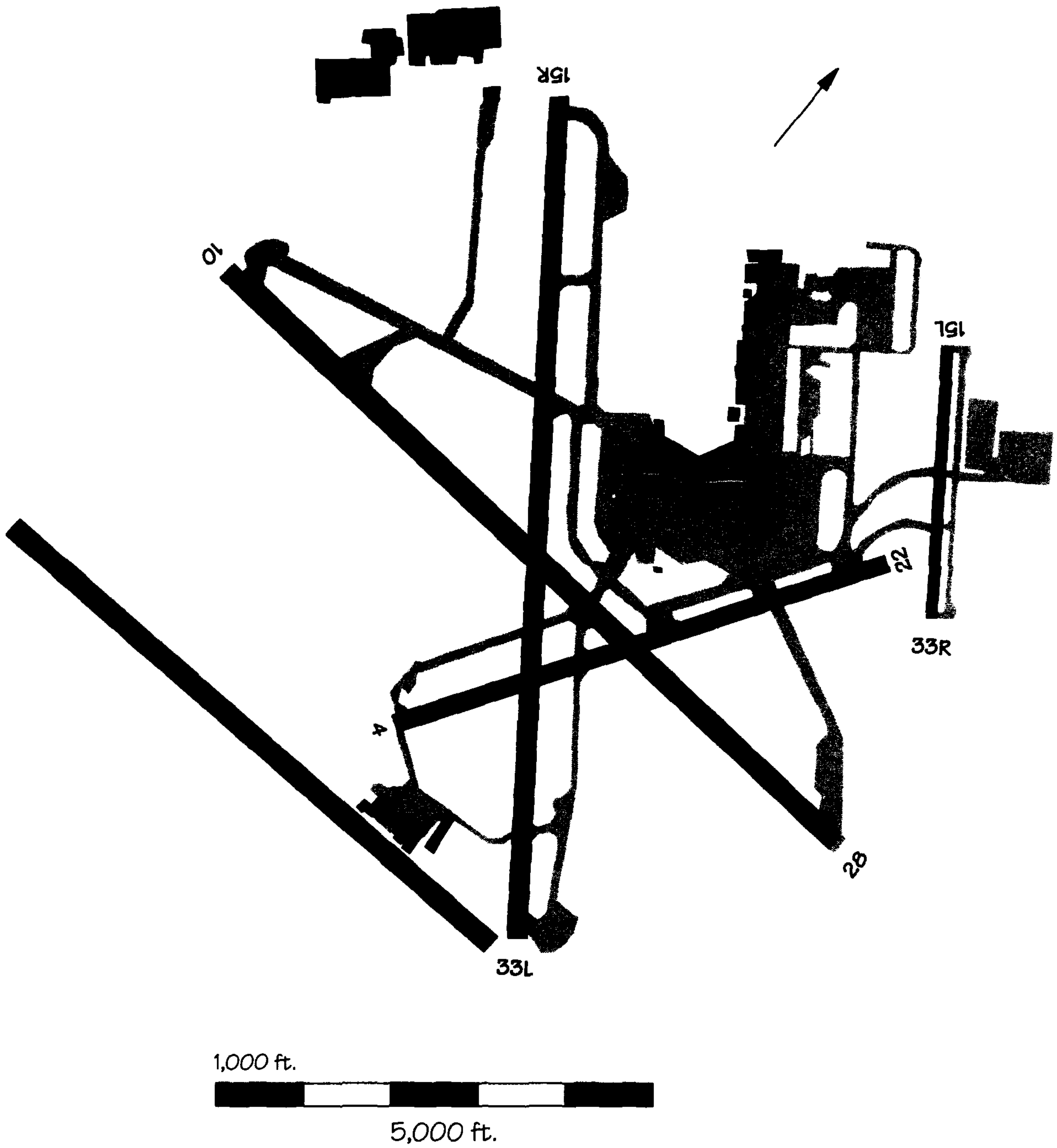
The community has approved the sale of revenue bonds for the levelopment of a new airport. The present Robert Mueller Airport cannot be expanded. Bergstrom Air Force Base (AFB) will be transferred to the city in 1993, and the city is now planning to construct a new parallel runway and relocate all commercial activity there in 1997-1998. The city has an Airport Master Plan under development. Environmental studies are in progress by the Air Force and the city. Since Robert Mueller Airport will close upon completion of the new airport, no capacity enhancements are planned at Mueller.



Bergstrom Air Force Base Conversion

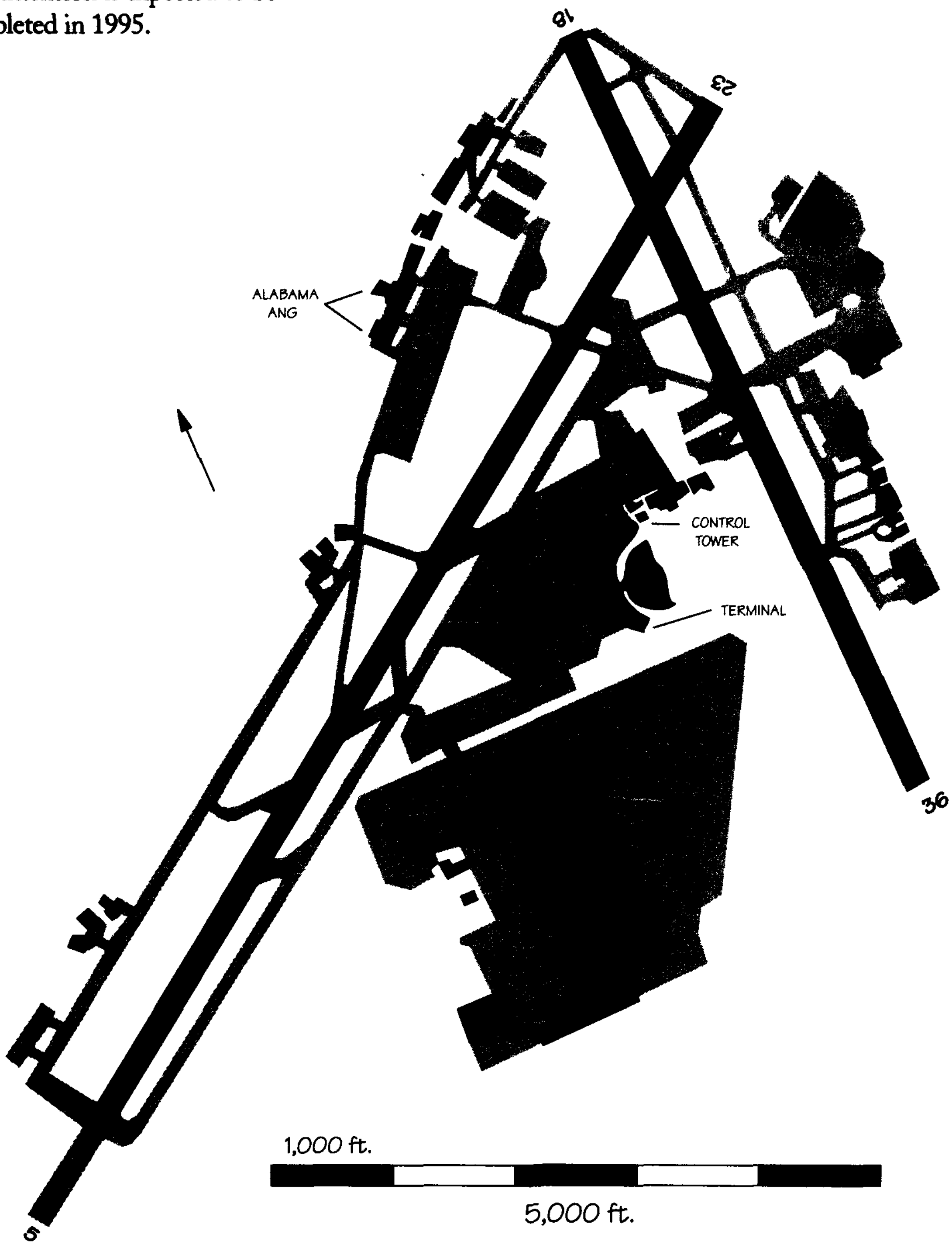
Baltimore-Washington (BWI)

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 1995 and should be completed in 1996 at a cost of $48 million. When Runway 10R/28L is constructed, Runway 4/22 will be converted to a taxiway.



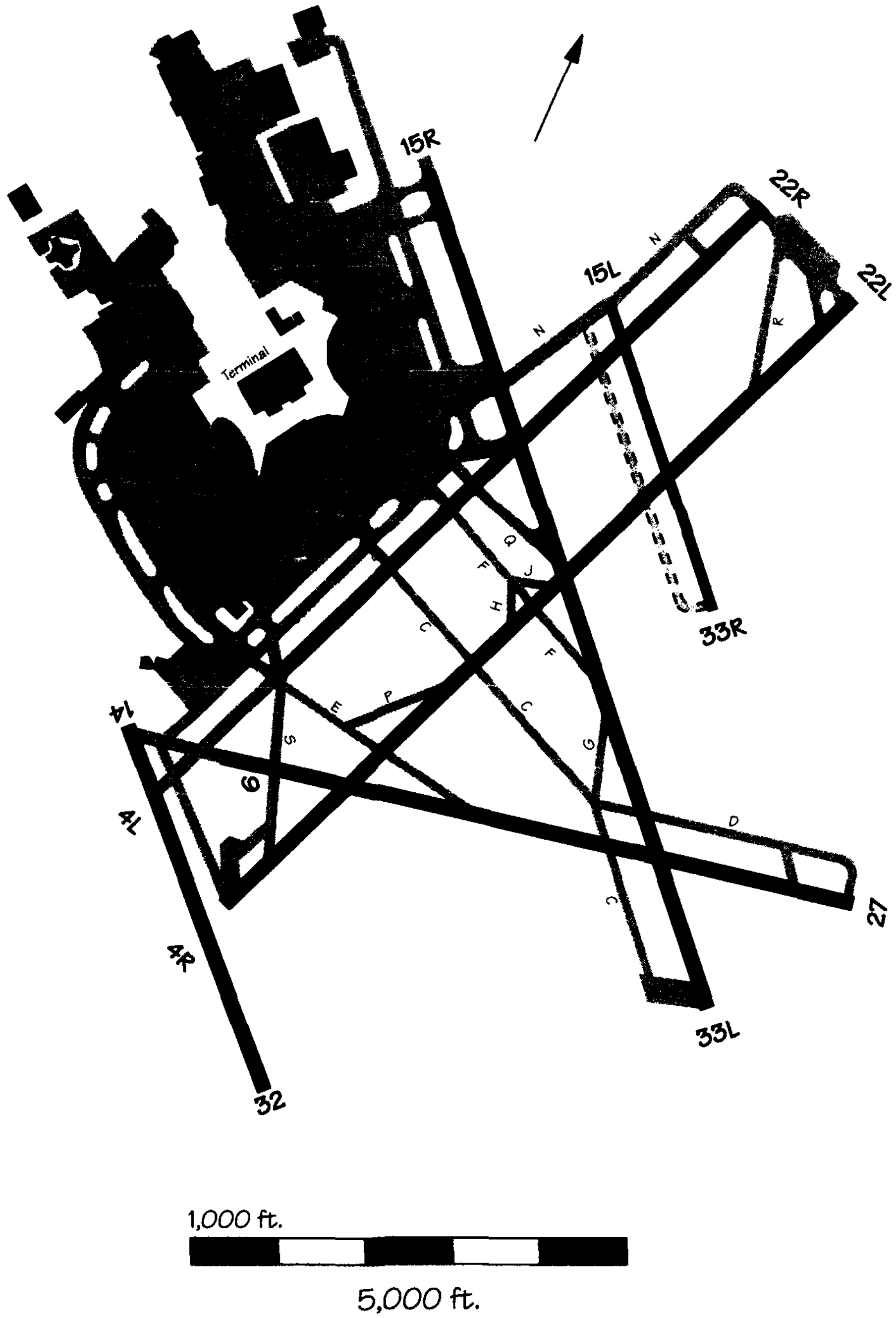
Birmingham (BHM)

Runway 18/36 will be extended from 4,800 feet to 7,500 feet. The estimated cost of construction is $42.5 million. The extension is expected to be completed in 1995.



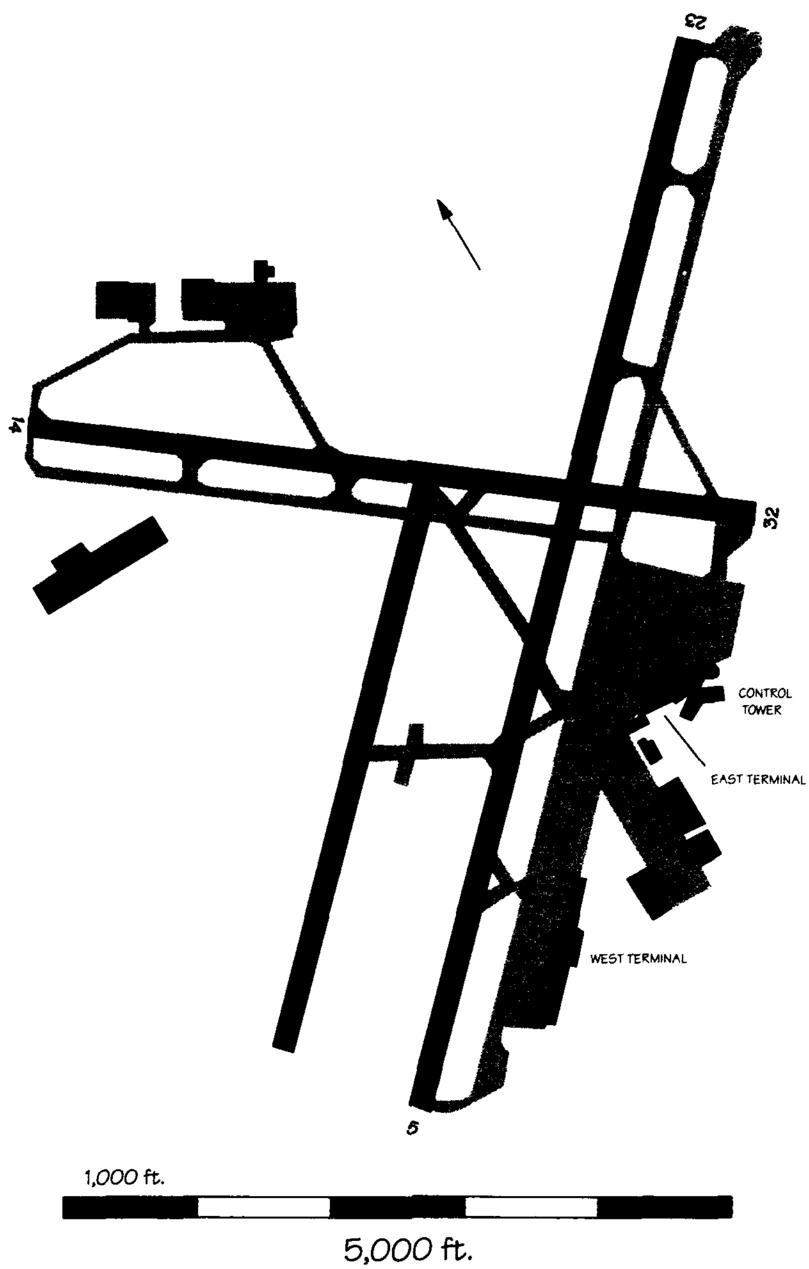
Boston (BOS)

A new uni-directional commuter runway (Runway 14/32) 4,300 feet from Runway 15R/33L, an extension of Runway 15L/33R to 3,500 feet, and a 400-foot extension of Runway 9 are being considered.



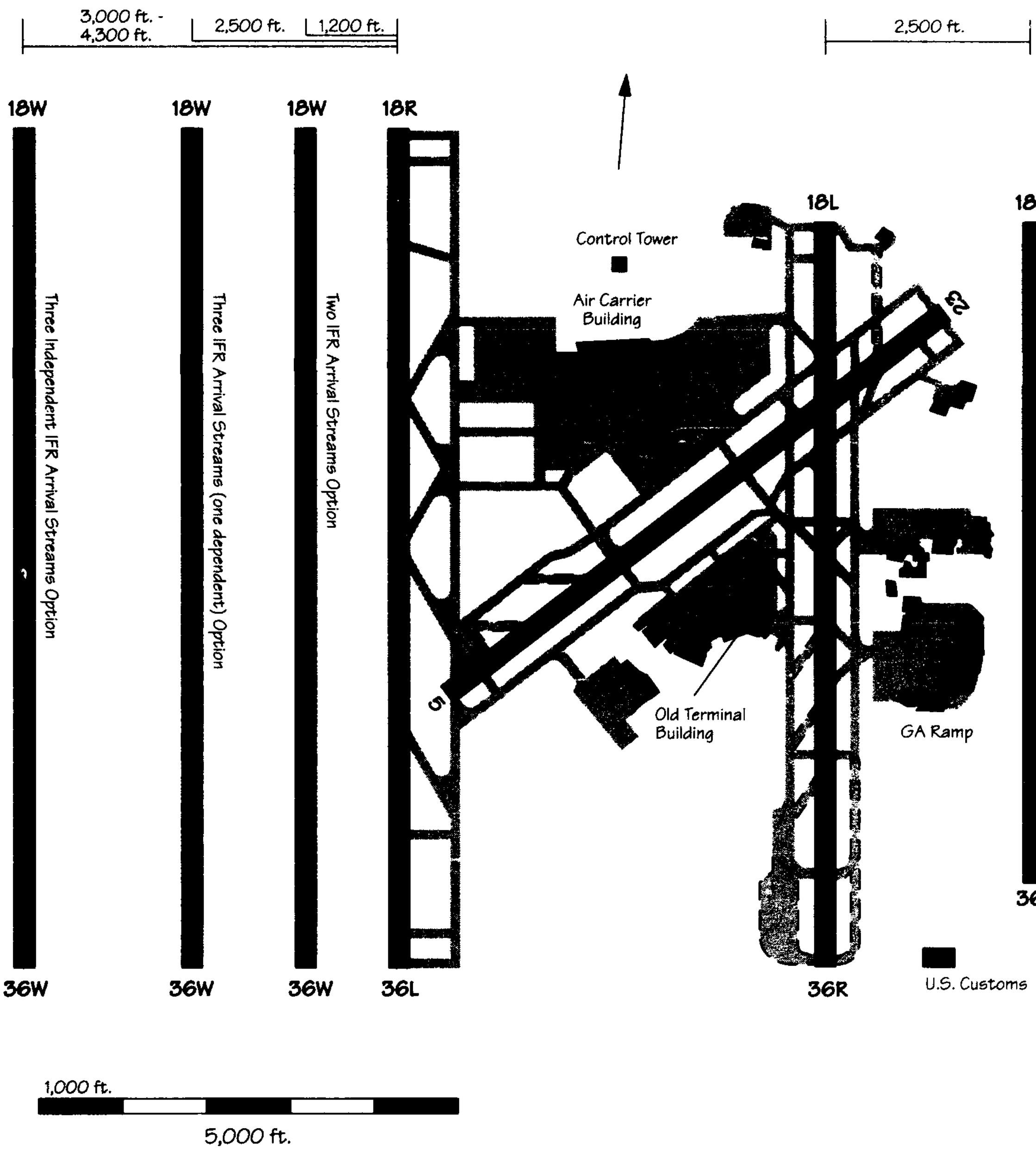
Buffalo (BUF)

There are plans to extend Runway 14/32. Construction is expected to start in 1997, with completion estimated for 1999. Construction costs are estimated at $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.



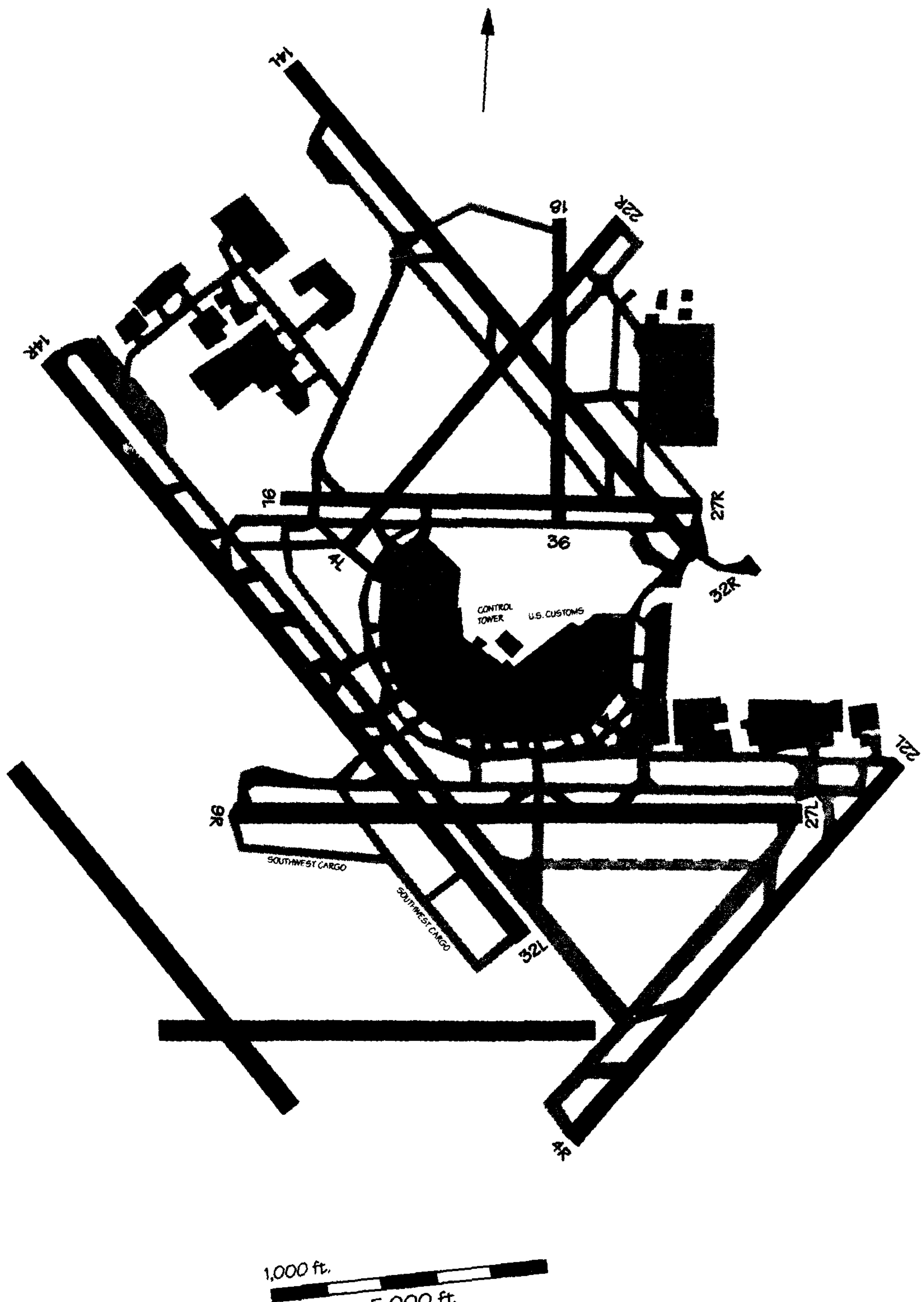
Charlotte (CLT)

Construction is expected to be completed in 1994 extending Runway 18L/36R 1,000 feet south to provide simultaneous approach capability during noise abatement hours. Plans are to open a third parallel 8,000-foot runway west of Runway 18R/36L in 1997 that would permit independent IFR arrivals. Construction should start in 1995. The Capacity Team also recommended a fourth parallel runway east of 18L/36R. Triple or quadruple IFR approaches could become available with the construction of this runway.



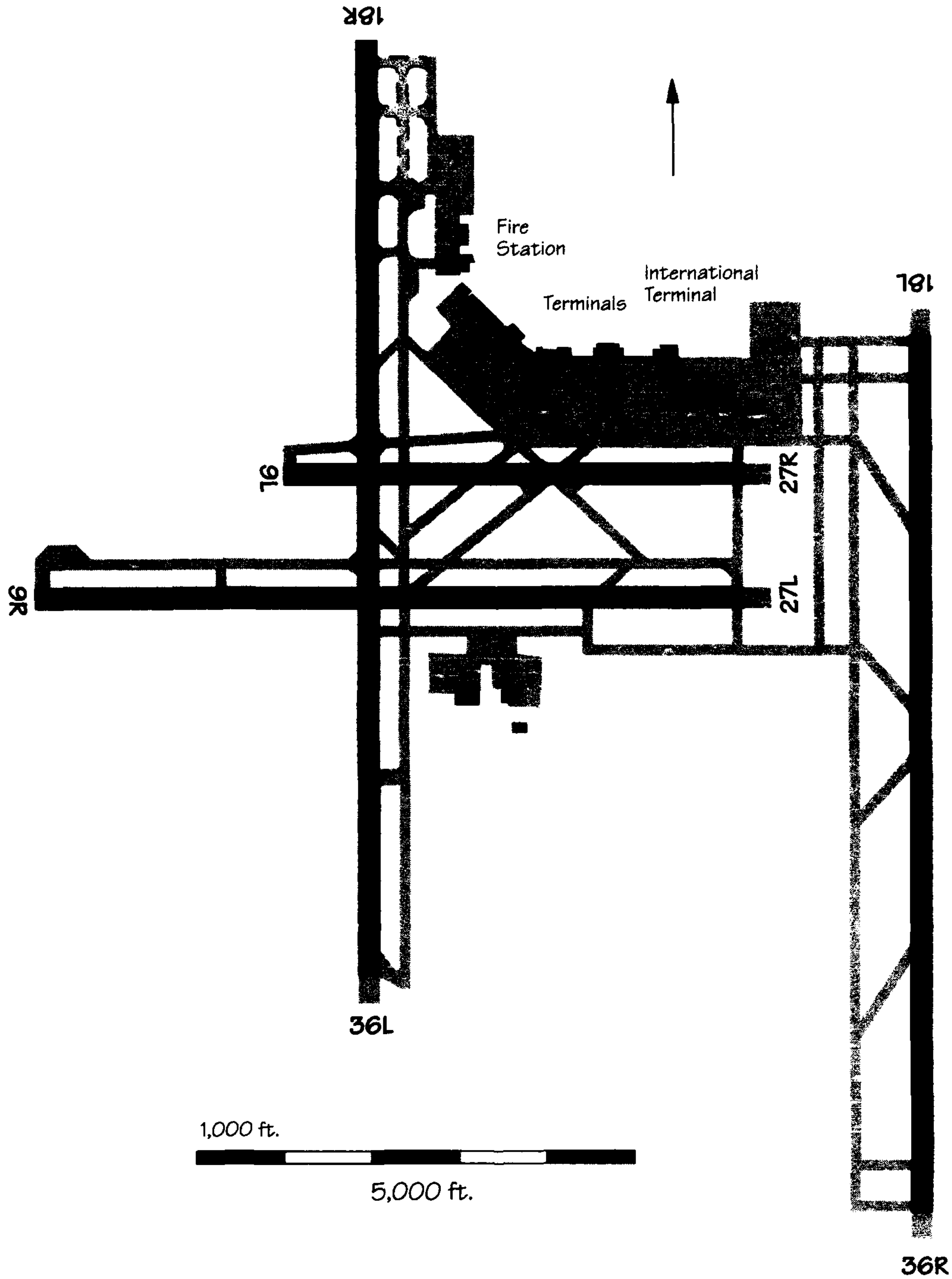
Chicago O'Hare (ORD)

New Runways 9/27 and 14/32 and extensions to Runways 14L and 22L have been recommended by the Chicago Airport Capacity Design Team.



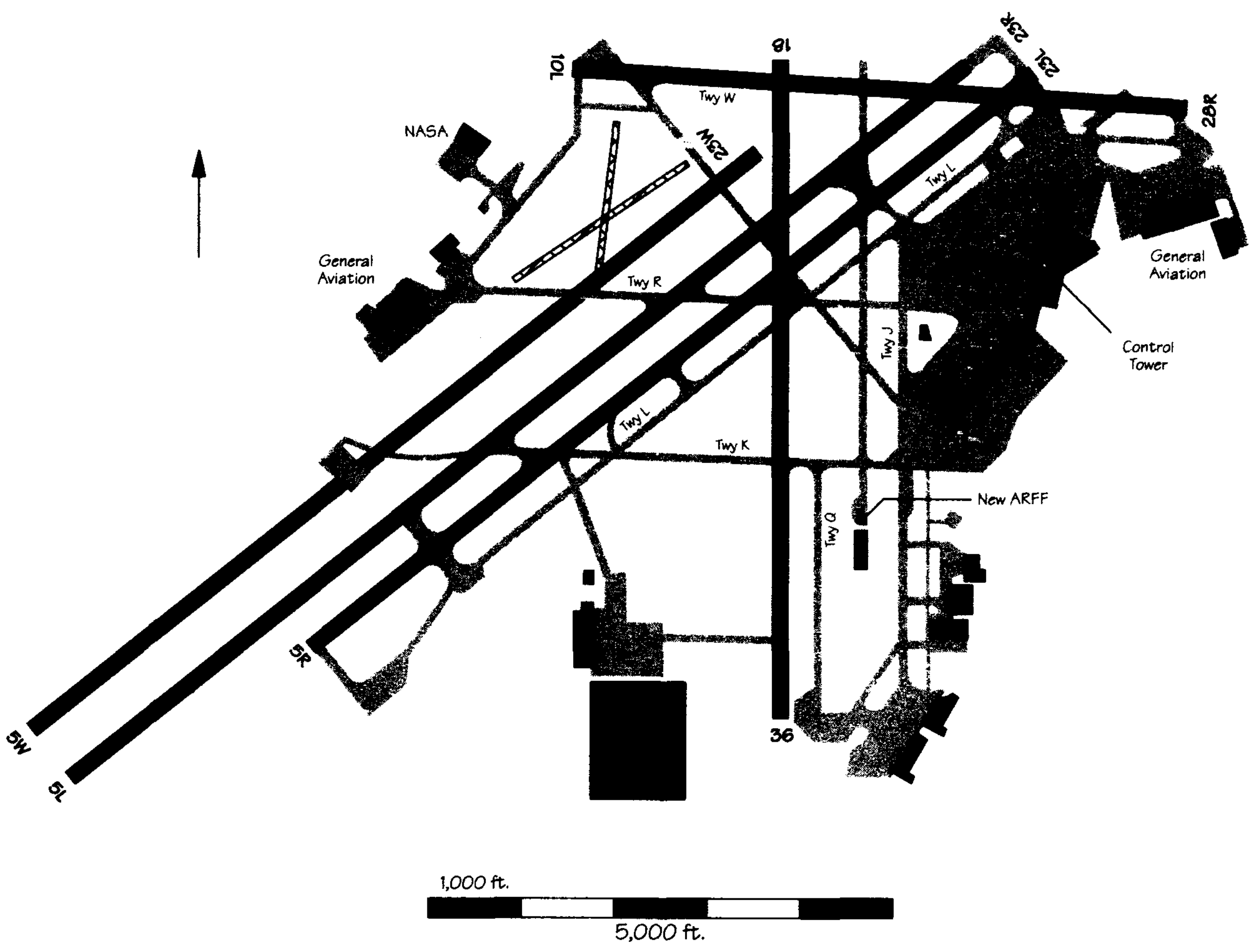
Cincinnati (CVG)

New Runway 18L/36R, parallel to and 6,200 feet from Runway 18R/36L, became operational in January 1991. This runway provides the potential for independent IFR configurations, doubling IFR arrival capacity. An extension of Runway 18R/36L has been proposed to allow all aircraft to land on Runway 18R and hold short of Runway 27L.



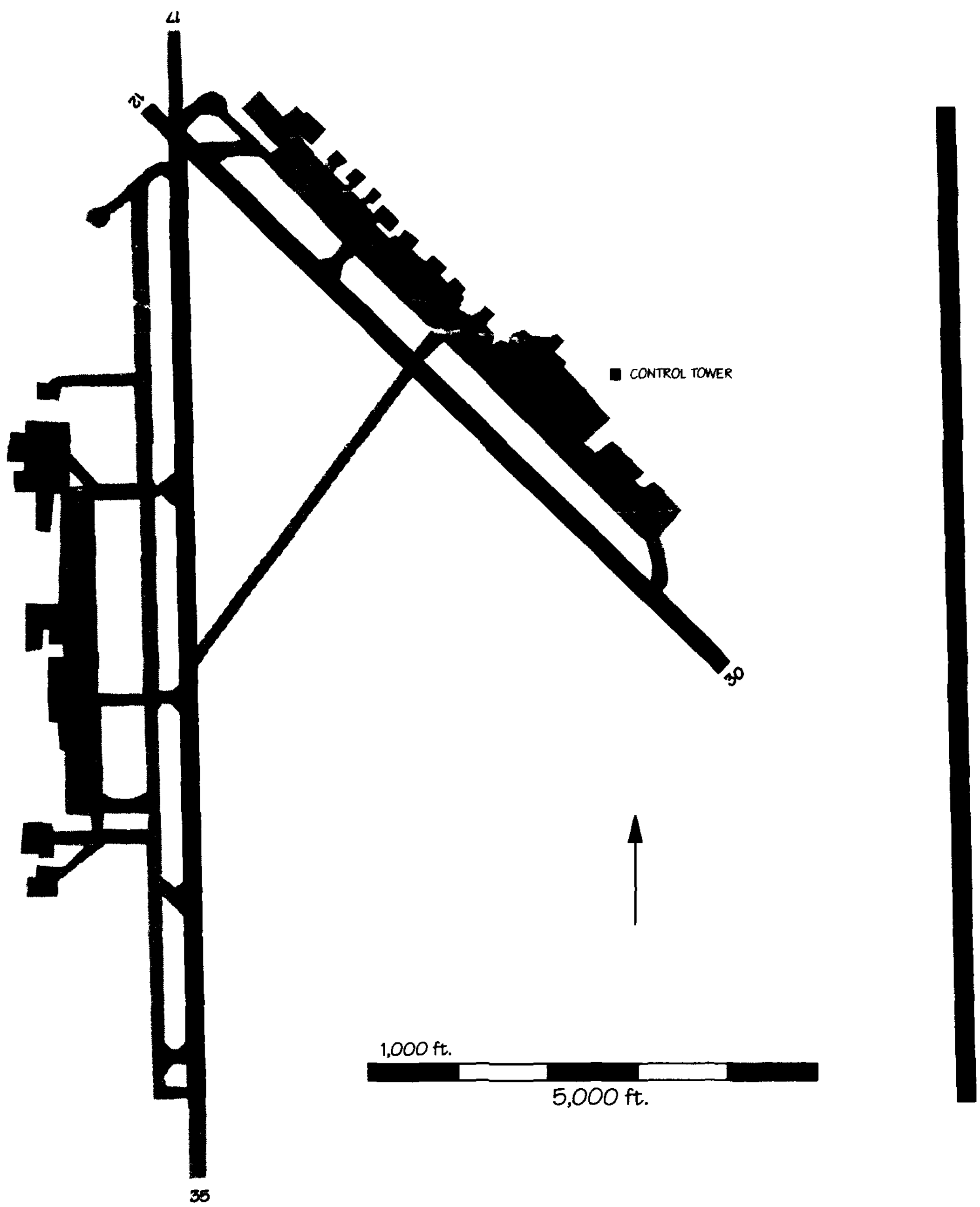
Cleveland-Hopkins (CLE)

A Master Plan Update is currently being coordinated. The preliminary Airport Layout Plan shows construction of a replacement Runway 5L/23R that would be 9,000 feet long and 150 feet wide. Construction is expected to be completed in 1998 at a cost of $42 million. Also included in the development plan is an extension of the existing Runway 5L/23R from 7,095 feet to 12,000 feet at an estimated cost of $10 million and conversion of the existing Runway 5R/23L to a parallel taxiway at a cost of $2 million. All of this work is scheduled for completion in 1998.



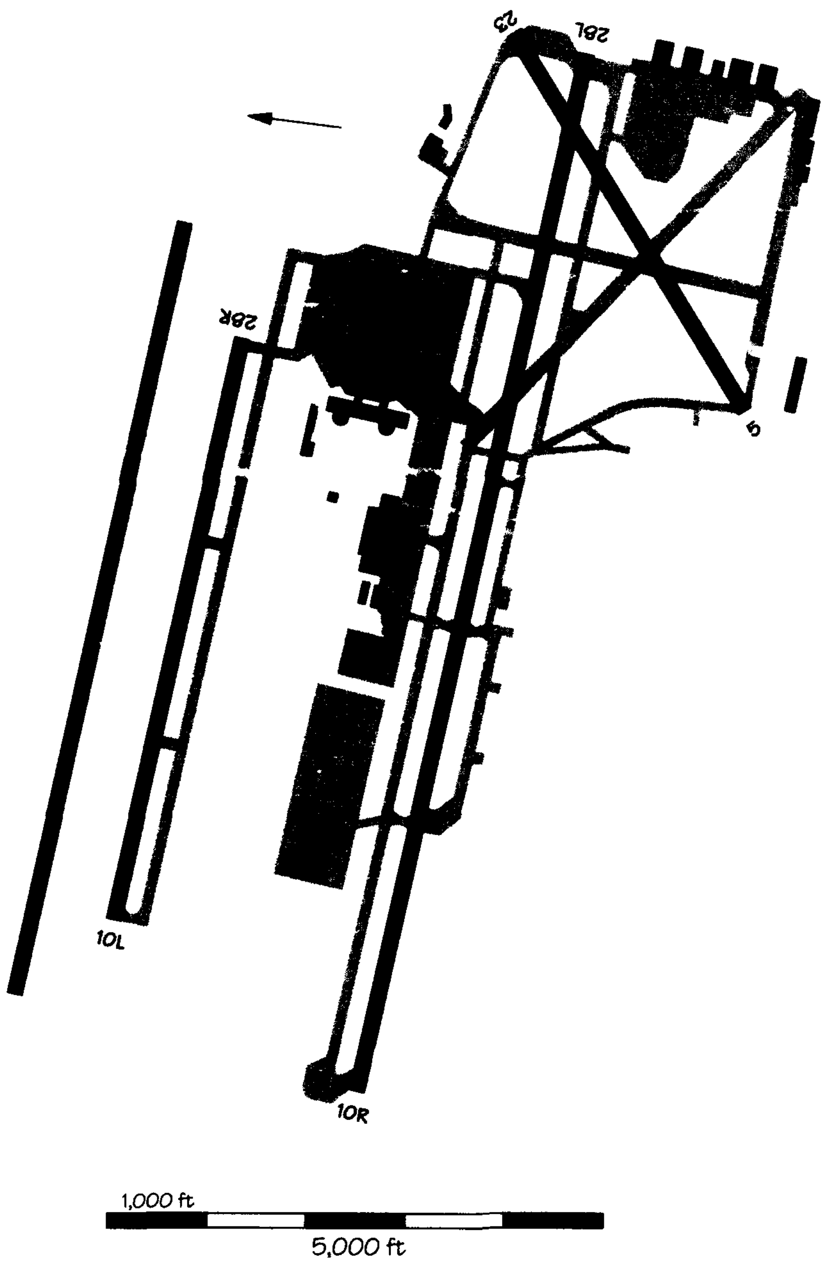
Colorado Springs (COS)

Runway 17L/35R will be constructed 8,600 feet east of existing Runway 17/35. This should permit two approach streams during IFR conditions, doubling arrival capacity. Construction began in January 1991, and the project will cost $38 million.



Columbus (CMH)

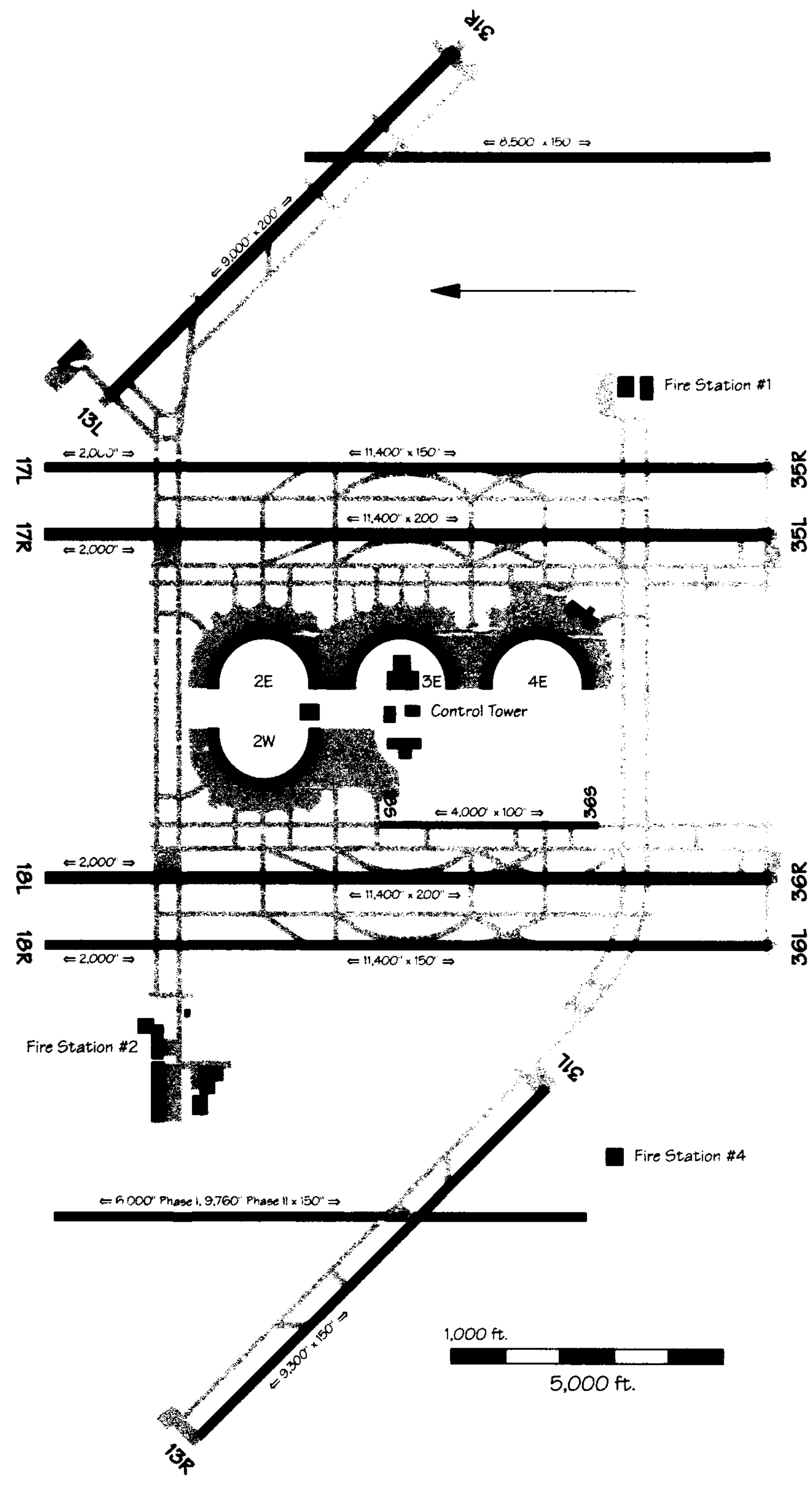
An update to the current Airport Layout Plan is being coordinated. It includes replacement of the existing Runway 10L/28R with a new 8,000-foot long and 150-foot wide runway located 600 feet north of the existing runway, which would provide a 3,400-foot separation from Runway 10R/28L. The existing Runway 10L/28R will be lengthened and converted to a taxiway. The improvements are expected to begin 1994–1995. The estimated cost is $48 million.



Dallas-Fort Worth (DFW)

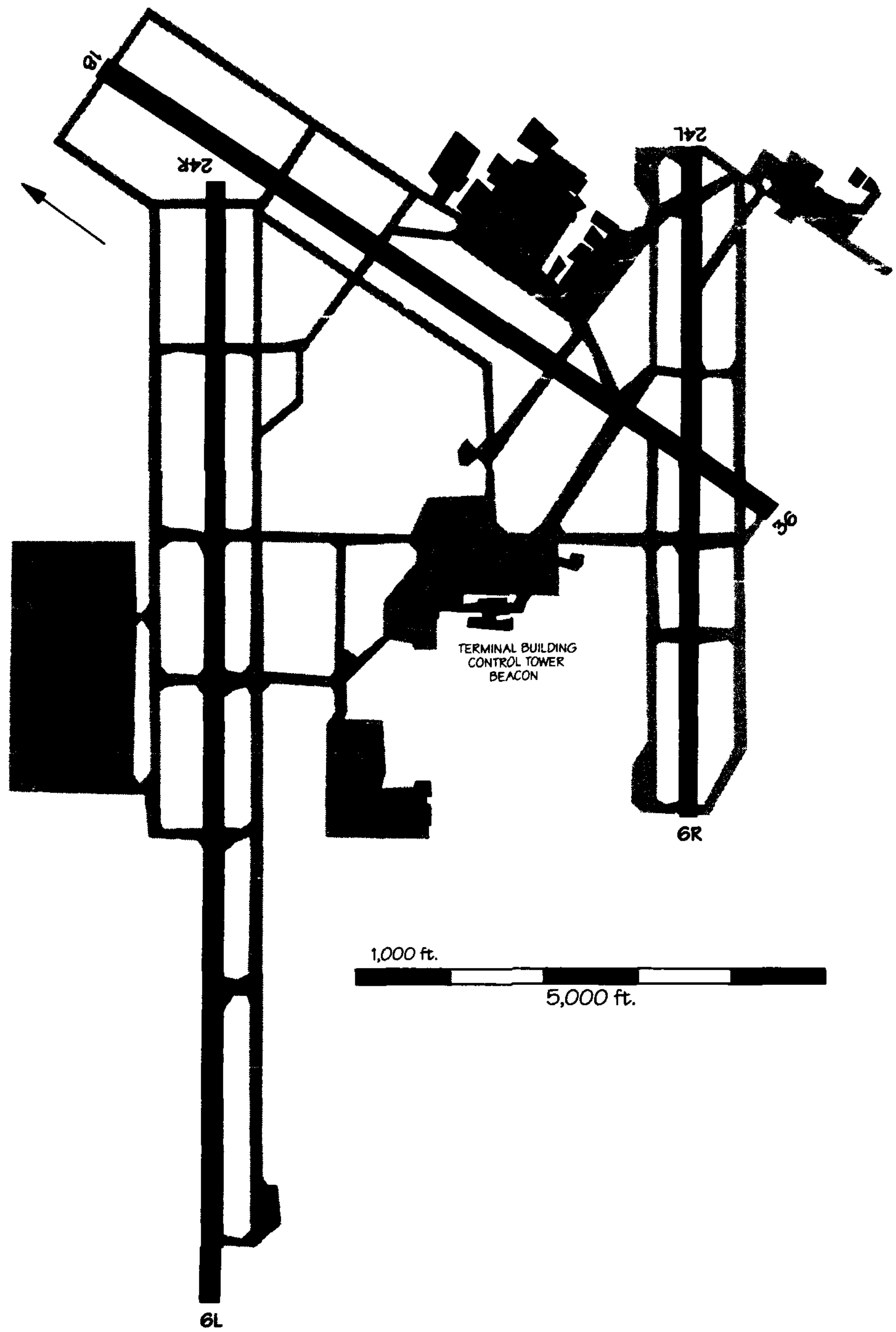
Proposed 2,000-foot extensions to all of the north/south parallel runways will provide an overall length of 13,400 feet for each. The estimated cost of each extension is $24 million. The tentative date of completion of Runway 35L is 1993, with Runway 36R scheduled to start construction in late 1993. Also planned are two more parallel runways, Runway 16L/34R and Runway 16R/34L. The east runway, Runway 16L/34R, will be extended to 8,500 feet. It will be located 5,000 feet east of and parallel to Runway 17L/35R. The estimated cost is $110 million. It is anticipated that the east runway will be operational by 1996. Construction on the west runway, Runway 16R/34L, will begin when warranted by aviation demand. It could be available as early as 1999. The estimated cost is $70 million. It will be located 5,800 feet west of Runway 18R/36L. Runway 16R/34L may be constructed in phases, with the first phase a 6,000 foot runway located north of Runway 13R/31L. The second phase extension to 9,760 feet would intersect and continue south of Runway 13R/31L. These runways could potentially permit triple or quadruple IFR arrival operations (84 and 114 hourly IFR arrivals, respectively) if the multiple approach concepts are approved.

Carswell Air Force Base (AFB), which is located in west Fort Worth, is due to close in September 1993. No decision has been made on the future use of this facility.



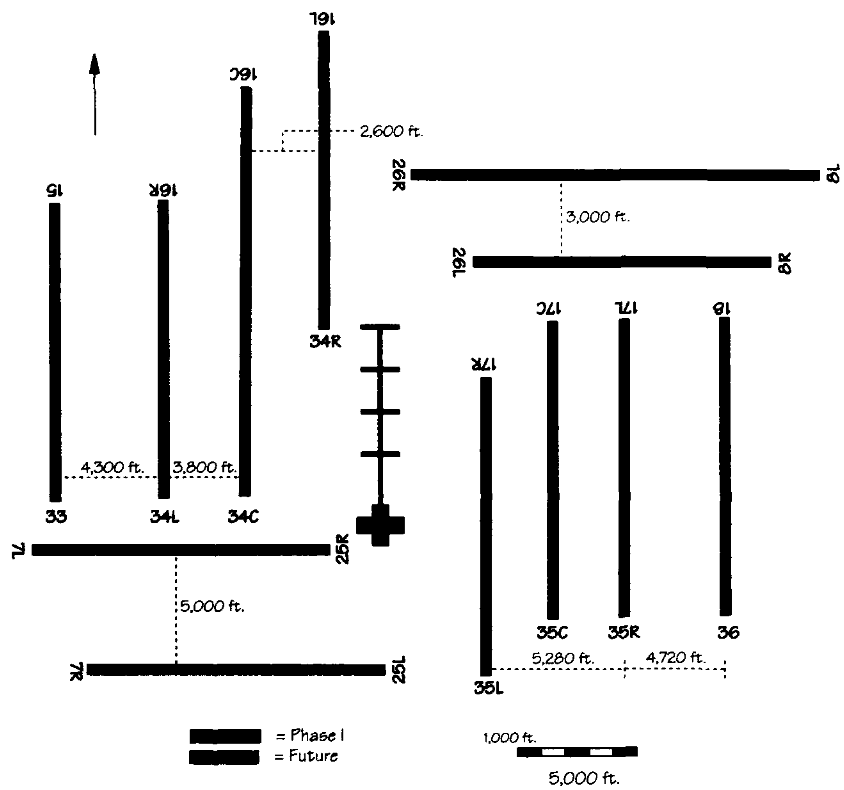
Dayton (DAY)

An extension of Runway 6L/24R to 10,900 feet has been completed. The current Airport Layout Plan shows a 600-foot extension to the southwest of Runway 6L/24R. A Master Plan Update is currently underway.



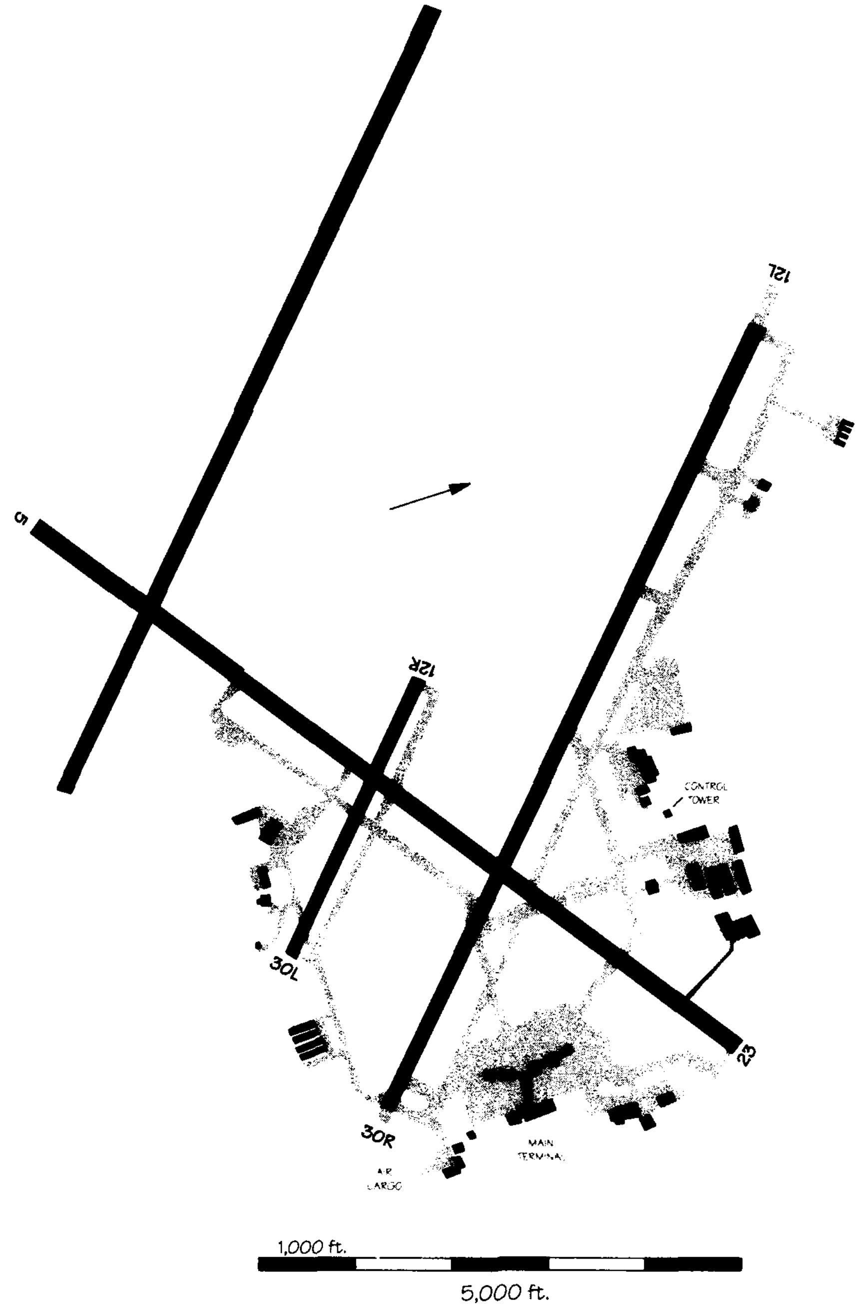
Denver International (DIA)

The initial phase of the new Denver airport will consist of five runways, with a sixth runway added a year after airport opening. The current plan involves four north-south parallels and two east-west parallels. Runway 16C/34C will initially be the farthest west of the four north-south parallels. It will be located 2,600 feet west of Runway 16L/34R and 10,200 feet west of Runway 17R/35L. Runway 17R/35L and Runway 17L/35R will be separated by 5,280 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 17R/35L and 17L/35R. Construction at the new airport began in late 1989. The total estimated cost of construction (exclusive of land acquisition and pre-1990 planning and administration costs) is 2.70 billion. The new airport is expected to be operational in late 1993 and could potentially operate independent triple or quadruple IFR approaches, if they are approved. This could increase Denver's IFR arrival capacity from 57 to 86 per hour with triples or 114 per hour with quadruples. A second, future phase proposes the construction of up to six more runways.



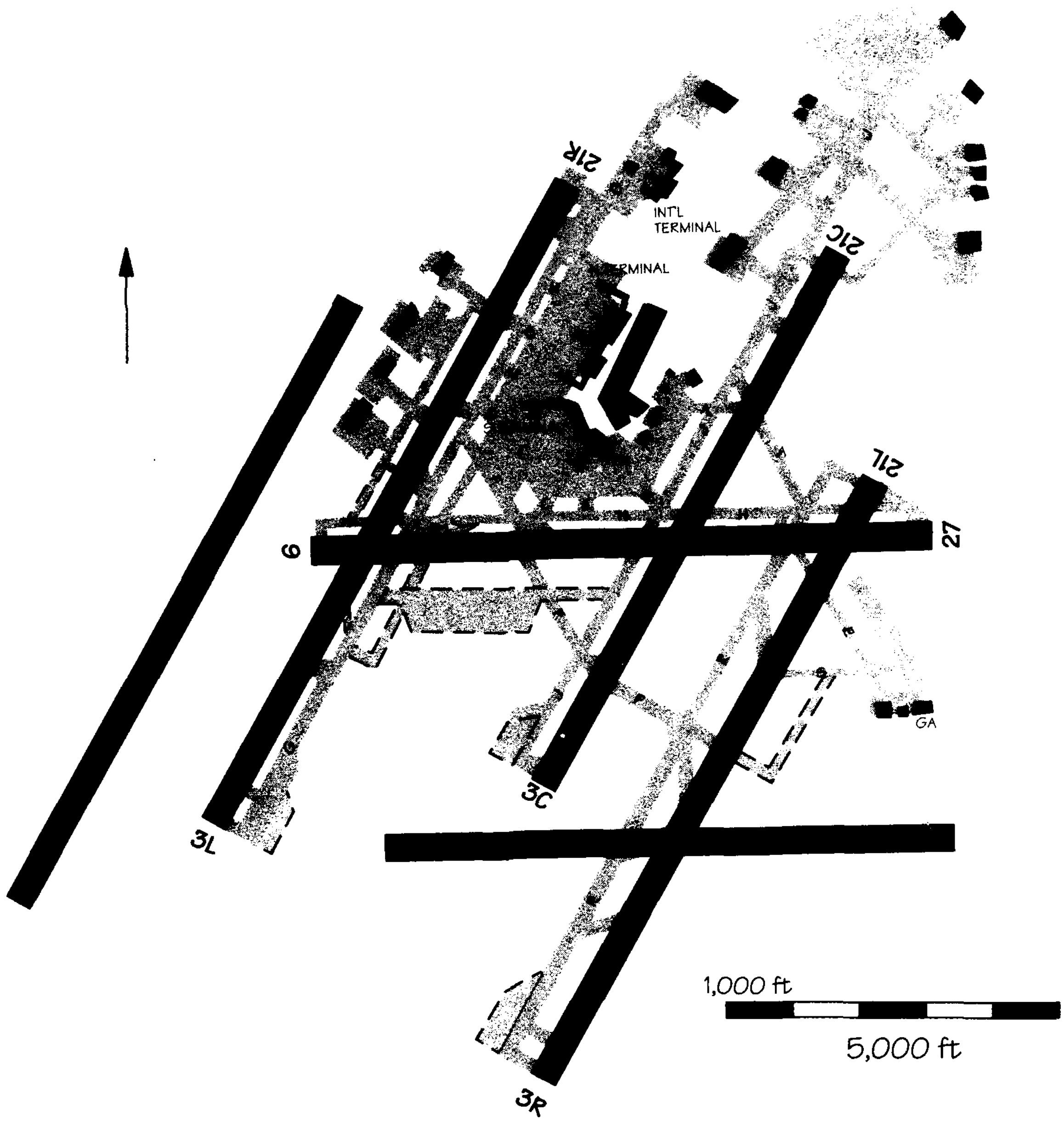
Des Moines (DSM)

An extension of the cross-wind Runway 5/23, from 6,500 to 9,000 feet, is planned to provide higher capacity to the airport and to reduce noise impacts. The estimated cost of extending the runway and upgrading the existing runway pavement to air carrier stength is $61 million. An ILS system would be installed on the Runway 23 end. Construction is expected to start in 1995. The anticipated operational date is 1998. In addition, a new 9,000 foot parallel runway at a 4,300 foot spacing to the existing air carrier Runway 13L/31R is planned for 2012. This runway would provide dual simultaneous ILS approach capability to the airport, providing a high arrival capacity in IFR conditions. Estimated cost of this parallel runway is $150 million.



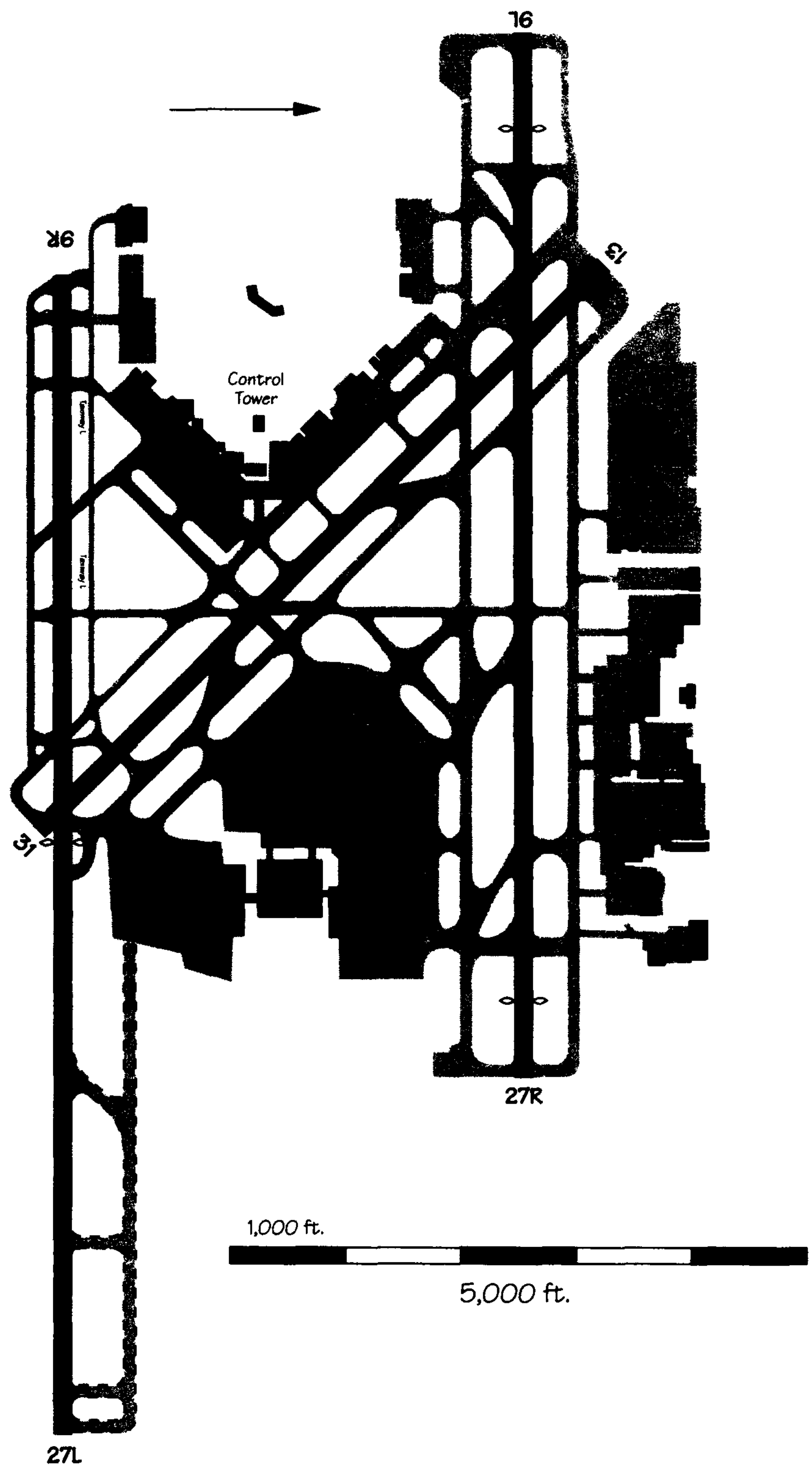
Detroit (DTW)

Runway 9R/27L is planned and will be located more than 4,300 feet from and parallel to existing Runway 9/27. The estimated cost is $85 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 began in 1991 and should be completed in late 1993. A fourth north-south parallel, Runway 4/22, 2,667 feet west of Runway 3L/21R, is also planned. Construction is expected to begin in 1994 and should be completed in 1998. The estimated cost of construction is $90 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 57 to 71. An environmental assessment was submitted in September 1989, and a record of decision was issued in March 1990 for all three projects.



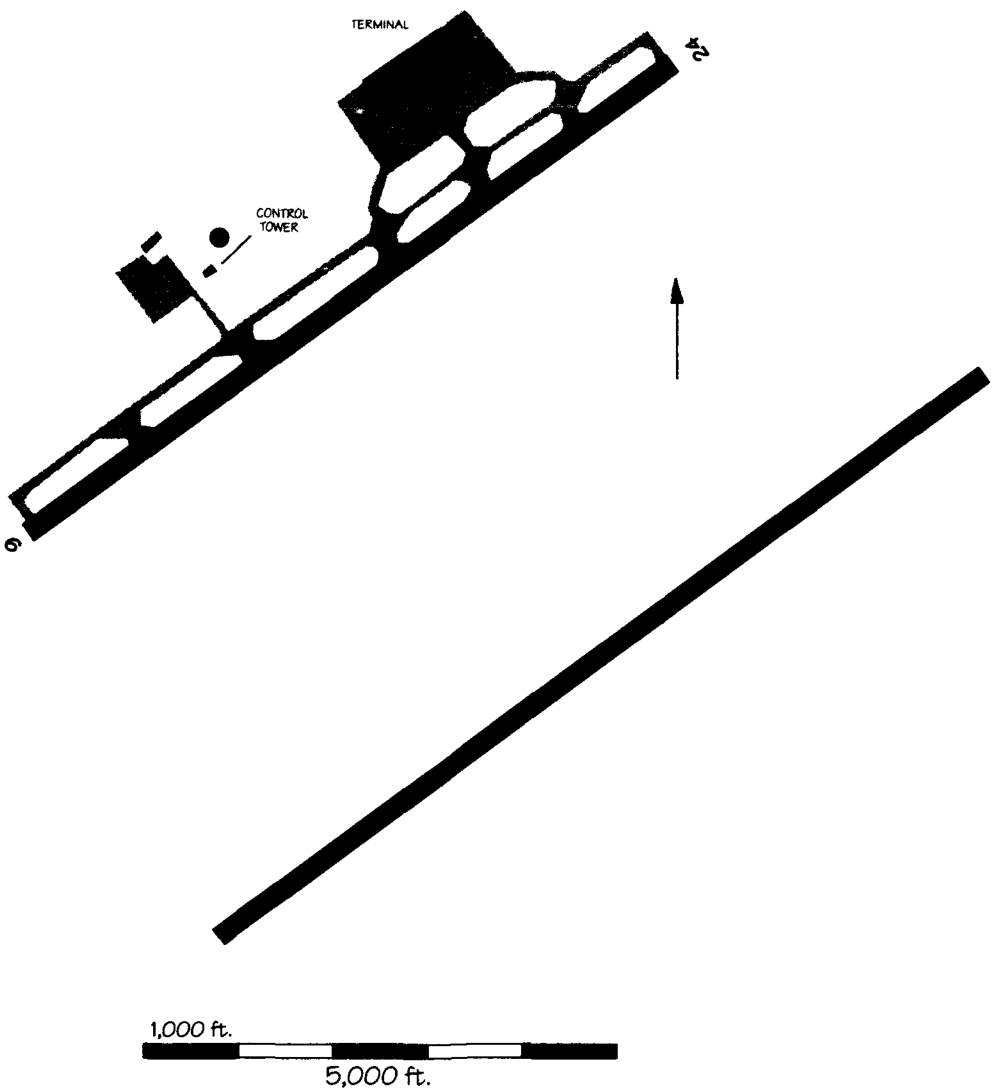
Fort Lauderdale (FLL)

An extension of the short parallel Runway 9R/27L to 6,000 or 10,000 feet long by 150 feet wide is planned to provide the airport with a second parallel air carrier runway. Construction is expected to begin in 1997. The estimated cost of construction is $96 million for the extension to 6,000 feet and $263 million for the extension to 10,000 feet. The anticipated operational date is 2000. This runway extension would permit IFR arrival capacity to increase from 29 to 57 per hour in an independent parallel operation, which would require a Precision Runway Monitor (PRM).



Fort Myers (RSW)

Planning has begun for a new 9,000 to 10,000 foot parallel runway, Runway 6R/24L, 4,300 feet or more from the existing air carrier runway. Construction is expected to begin in 1997. The new runway should be operational by 1999. The estimated cost of the project is $139 million. This new runway will support independent parallel operations, with the potential to increase IFR hourly arrival capacity from 29 to 57. Construction of an extension to Runway 6/24 from 8,400 feet to 12,000 feet is expected to begin in 1993. The estimated cost of the extension is $23 million, and the estimated operational date is 1994.

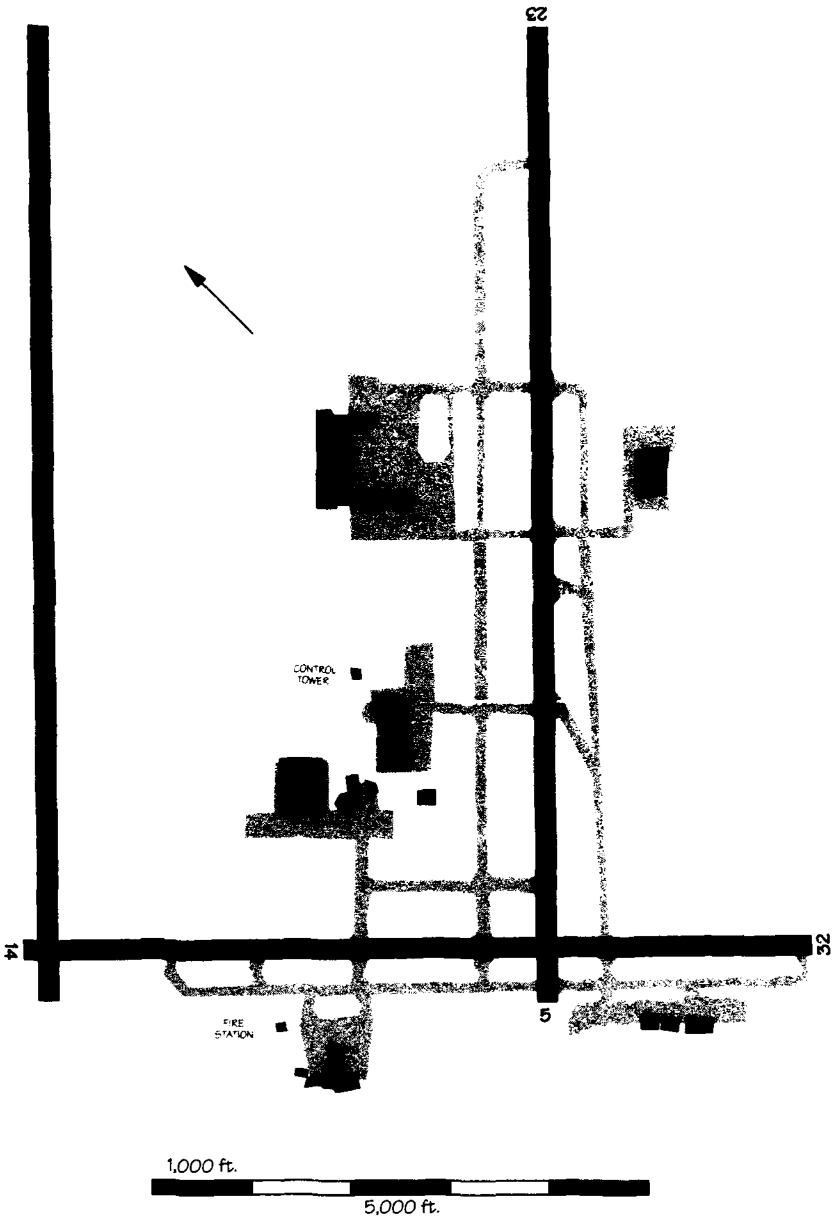


Grand Rapids (GRR)

An extension to the current Runway 8L/26R to 5,000 feet is planned for 1993. In the long-range plan, this runway will be converted into a taxiway for a new 7,000 foot runway. An extension to 8,500 feet and realignment are planned for the cross-wind Runway 18/36 (17/35). This construction is planned to start in 1994 and should be completed by 1997. The runway will provide wind coverage and reduce winter weather related delays by providing a second air carrier runway. Airport Layout Plan (ALP) and Environmental approvals for these projects were completed in January 1993.

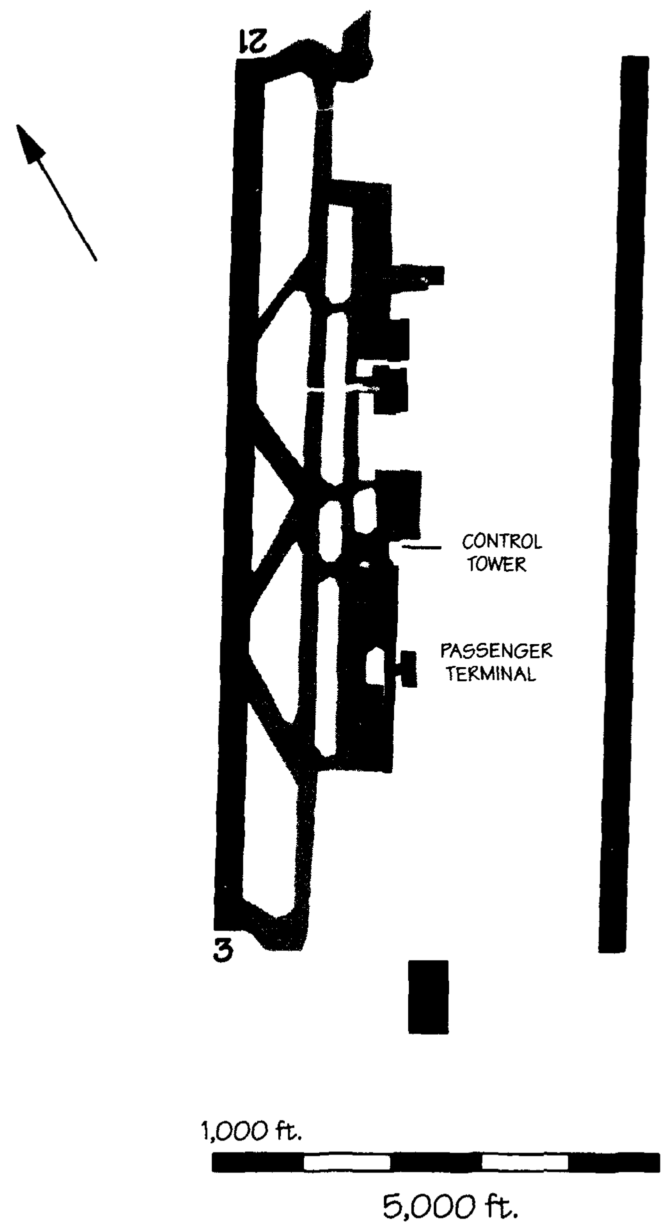
Greensboro (GSO)

A new parallel Runway 5L/23R, 5,000 feet northwest of the existing Runway 5/23 is under consideration. The new runway would permit independent parallel operations, potentially doubling hourly IFR arrival capacity from 29 to 57. The estimated cost of the 7,000-foot long parallel runway is $20 million. It is planned to be completed in 2010. In addition, a 1,200-foot extension to Runway 14/32 is under review.



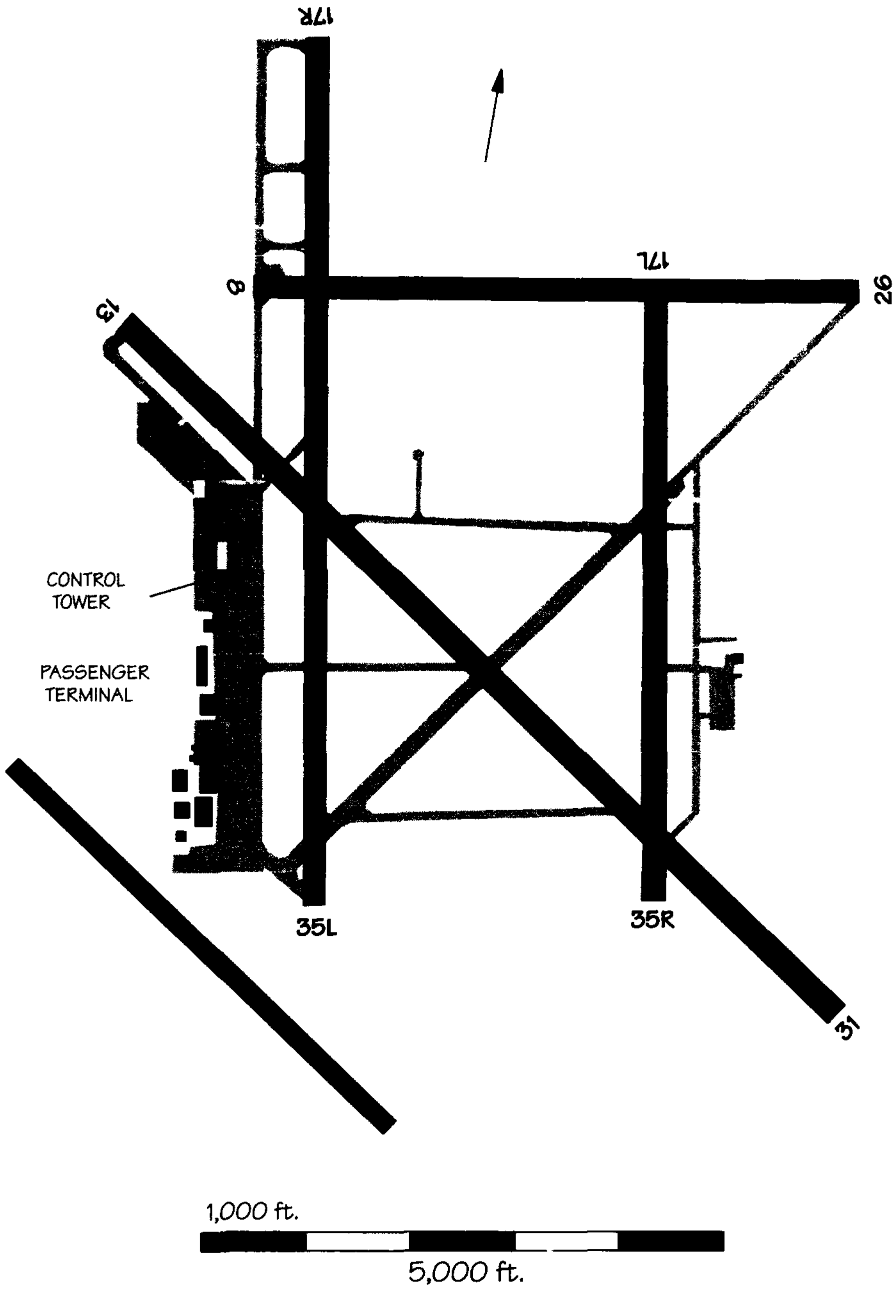
Greer Greenville-Spartanburg (GSP)

A new parallel runway, Runway 3R/21L, is anticipated in 1999 at a cost of $25 million. Presently, its planned length is 10,000 feet with a 4,300 foot separation from Runway 3/21. This would potentially double hourly IFR arrival capacity from 29 to 57. Also, an extension of Runway 3L/21R to 10,000 feet is planned. Construction is expected to be completed in 1995 at a cost of $12 million.



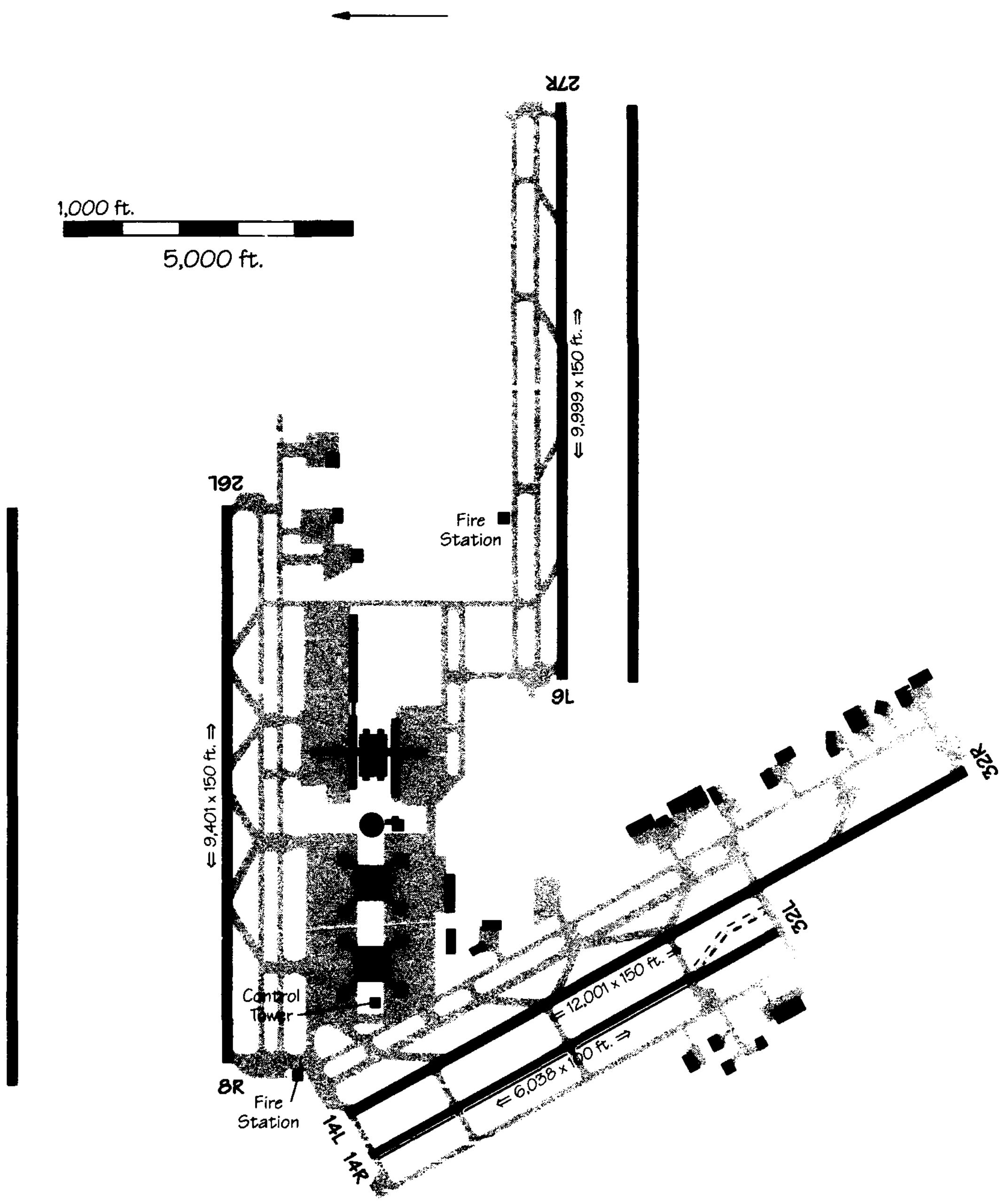
Harlingen (HRL)

An extension to Runway 13/31 and a new parallel GA runway, Runway 13L/31R, are being planned. The extension to Runway 13/31 will bring the runway length to 9,500 feet at an estimated cost of $6.7 million. Construction is anticipated to begin in 1994 and should be completed in 1995. The new GA runway, Runway 13L/31R, will be 5,000 feet long. Construction is expected to begin in 1994. Runway 13L/31R should be operational in 1995–2000 at a cost of $5 million.



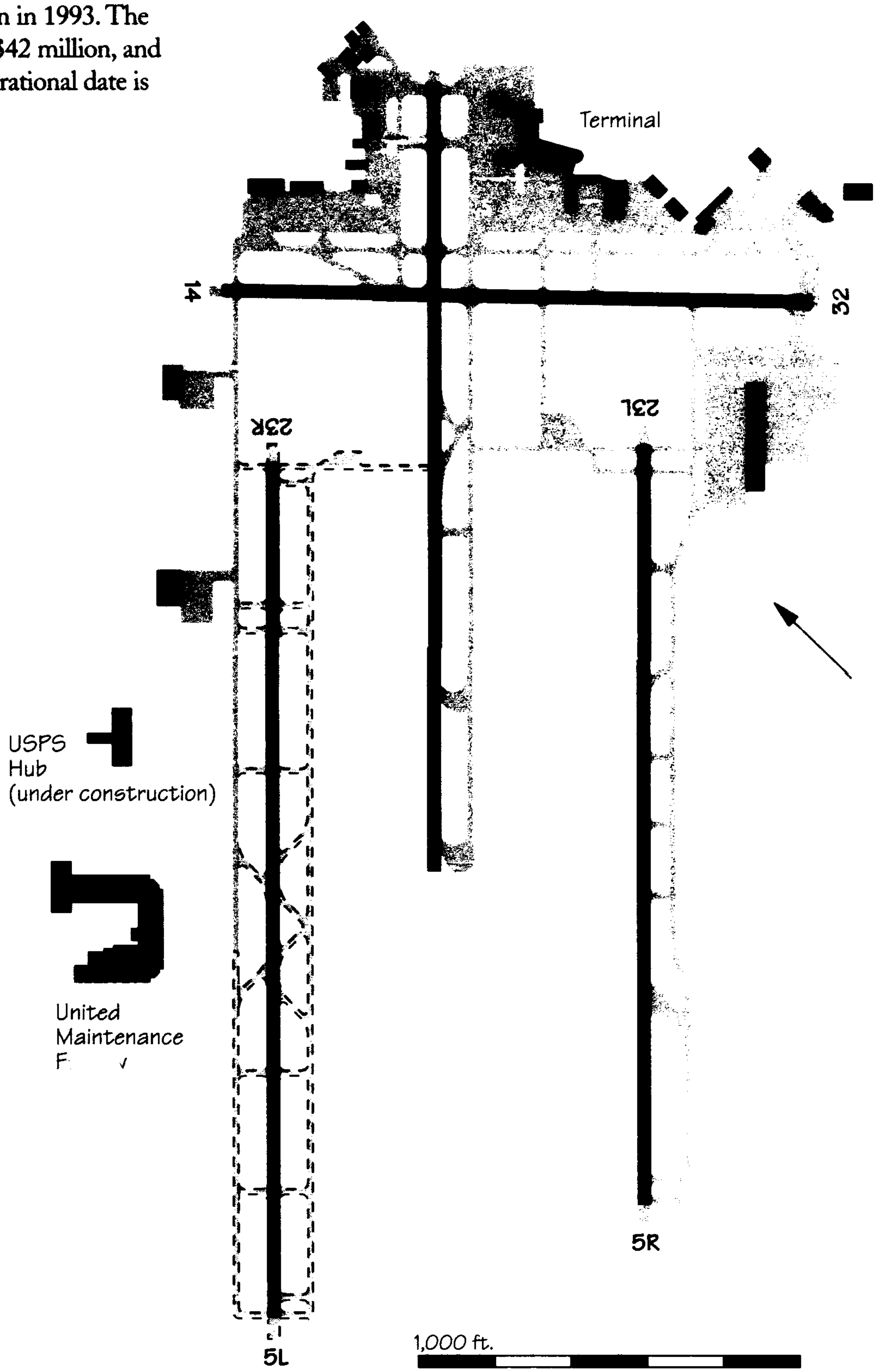
Houston (IAH)

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 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 the 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 to support triple IFR approaches, if approved, which could increase hourly IFR arrival capacity from 57 to 86. 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.



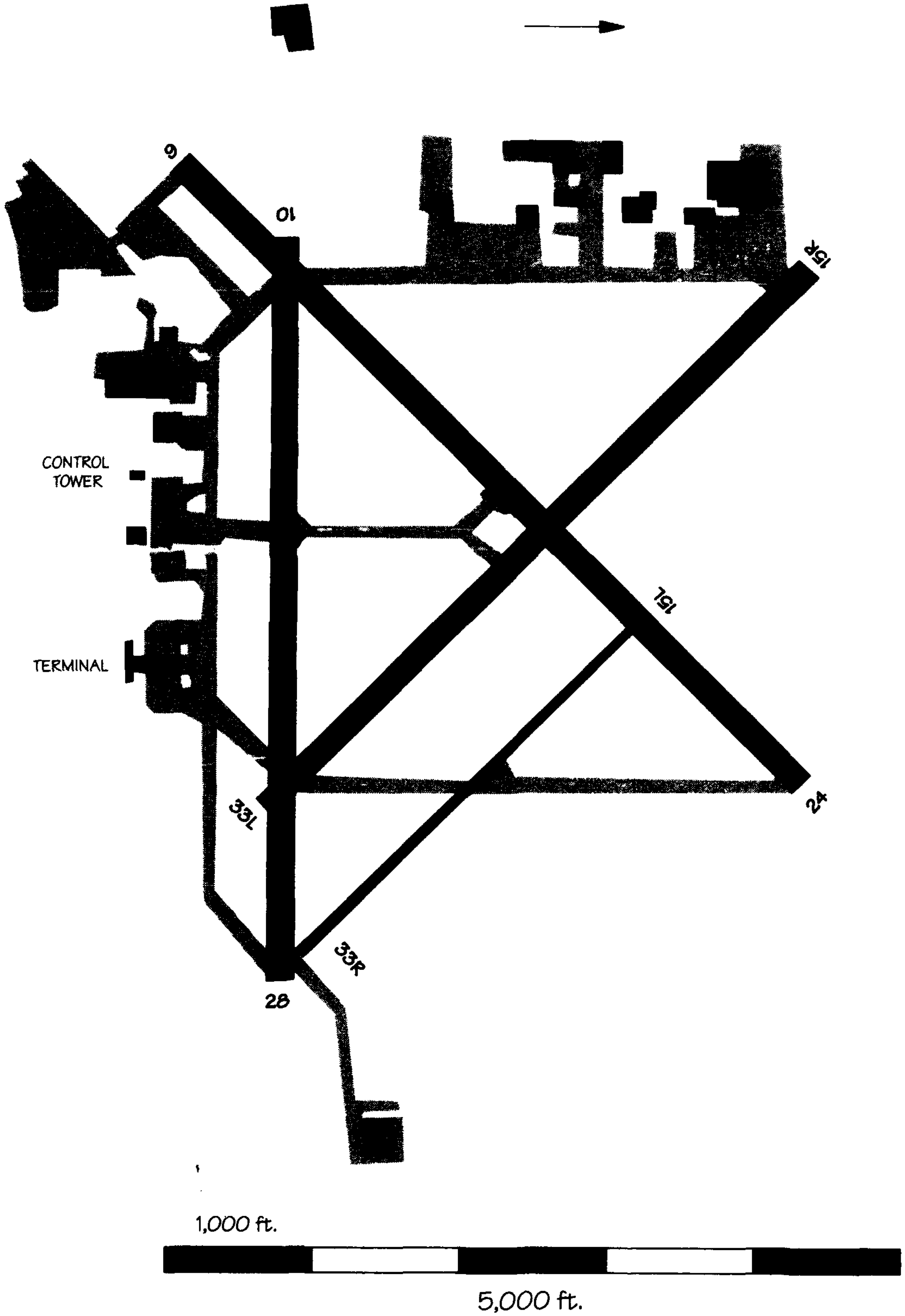
Indianapolis (IND)

Construction of a replacement for Runway 5L/23R is scheduled to begin in 1993. The estimated cost is $42 million, and the estimated operational date is 1996.



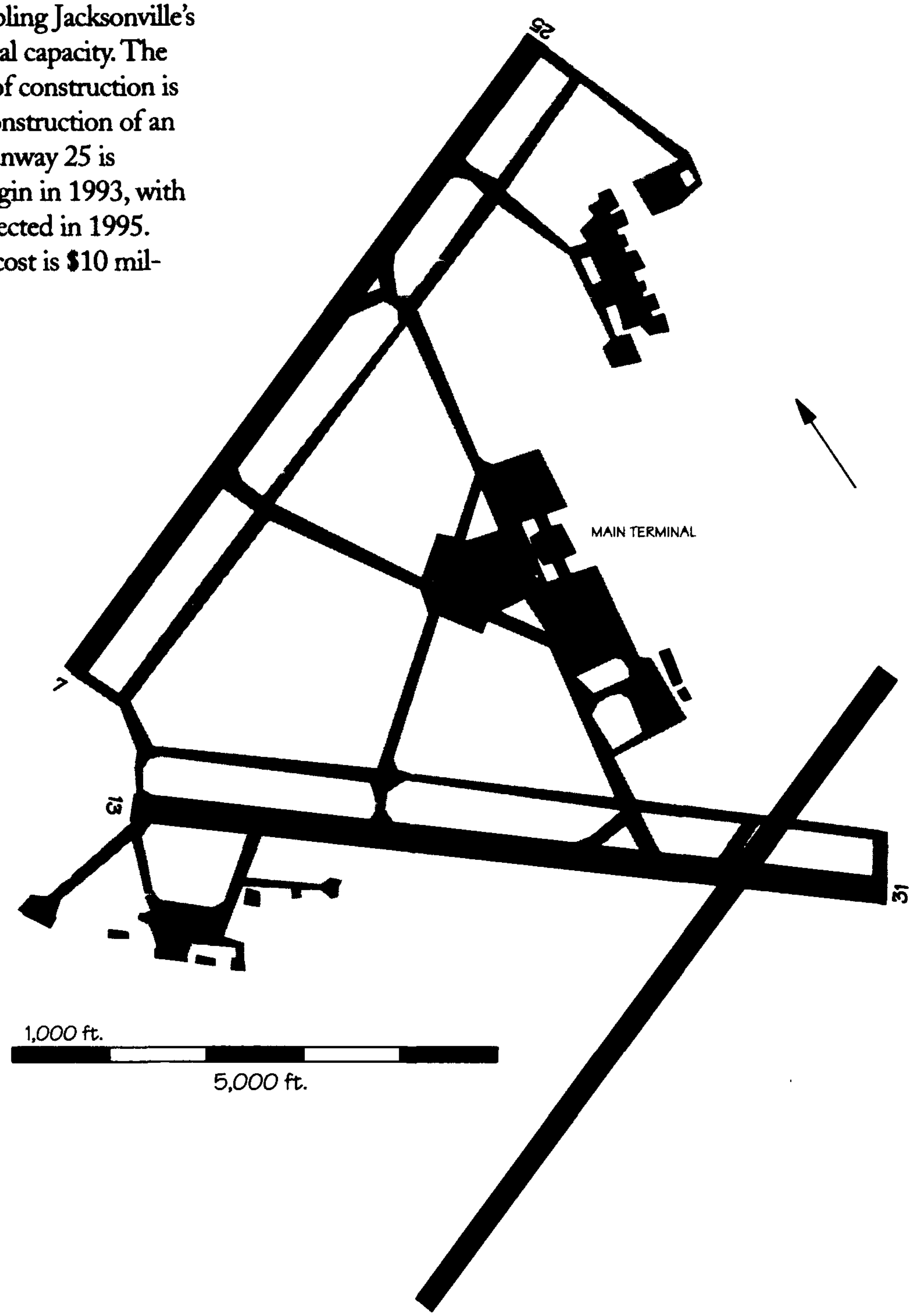
Islip (ISP)

A 1,000 foot extension to Runway 6/24 is under consideration.



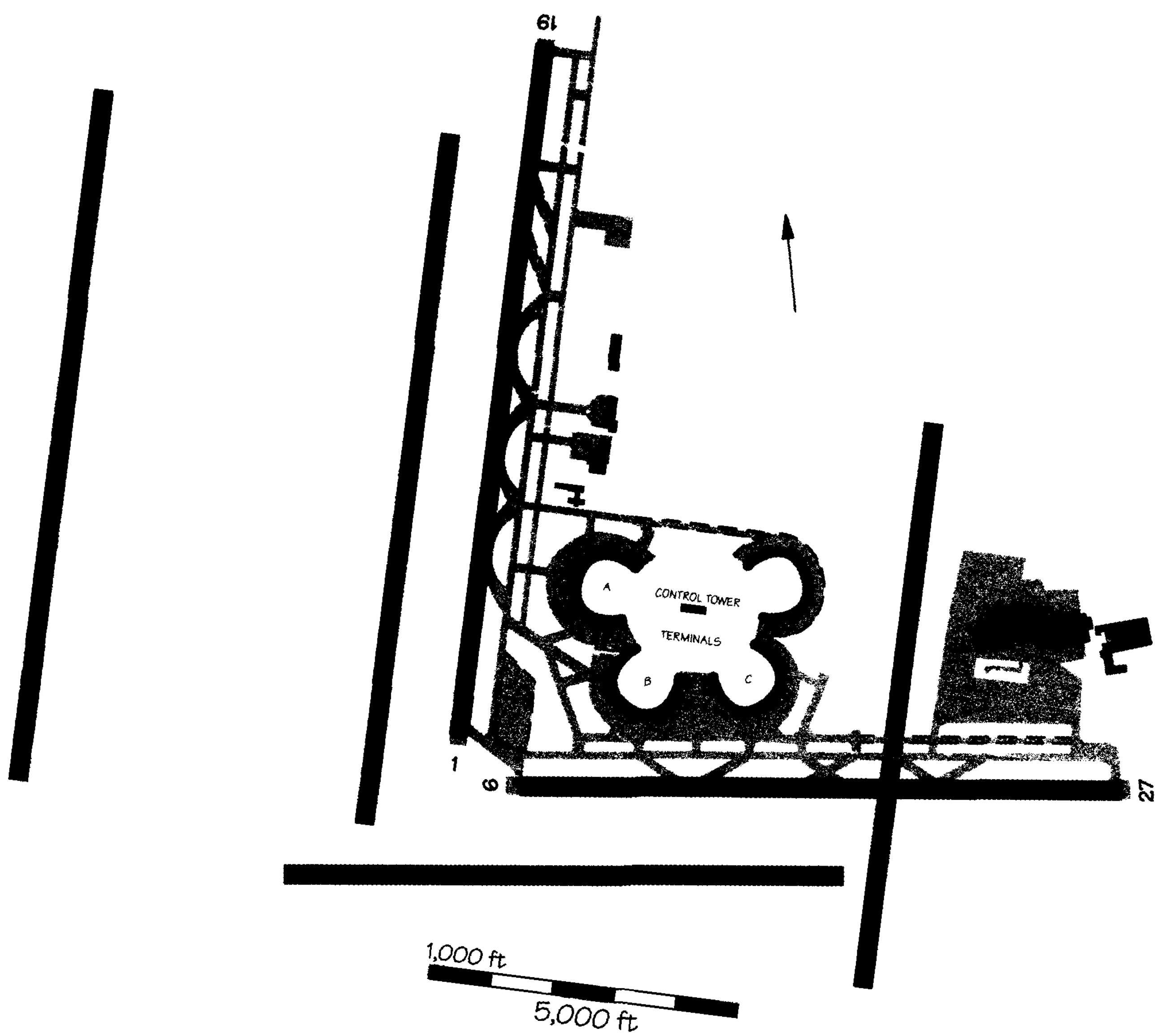
Jacksonville (JAX)

A new 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. The estimated cost of construction is $37 million. Construction of an extension to Runway 25 is scheduled to begin in 1993, with completion expected in 1995. The estimated cost is $10 million.



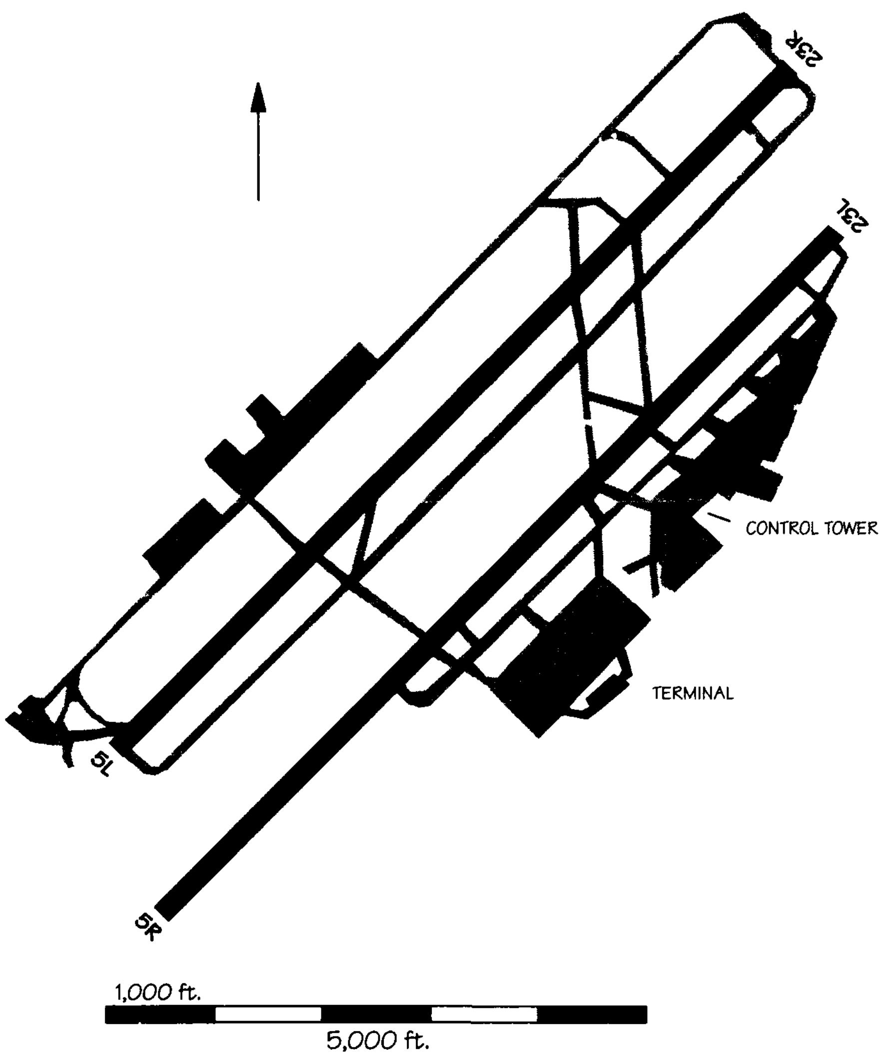
Kansas City (MCI)

A new north-south parallel Runway 1R/19L is currently under construction. Located 6,575 feet east of existing Runway 1/19, it will permit independent parallel IFR operations. The estimated cost of construction is $46.2 million. A new Runway 9R/27L is proposed 1,400 feet south of the existing Runway 9/27. Runway 18L/36R is under consideration for construction after 2000. This new runway will be 1,400 feet from, parallel to, and west of the existing Runway 1/19. 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 57 to 86.



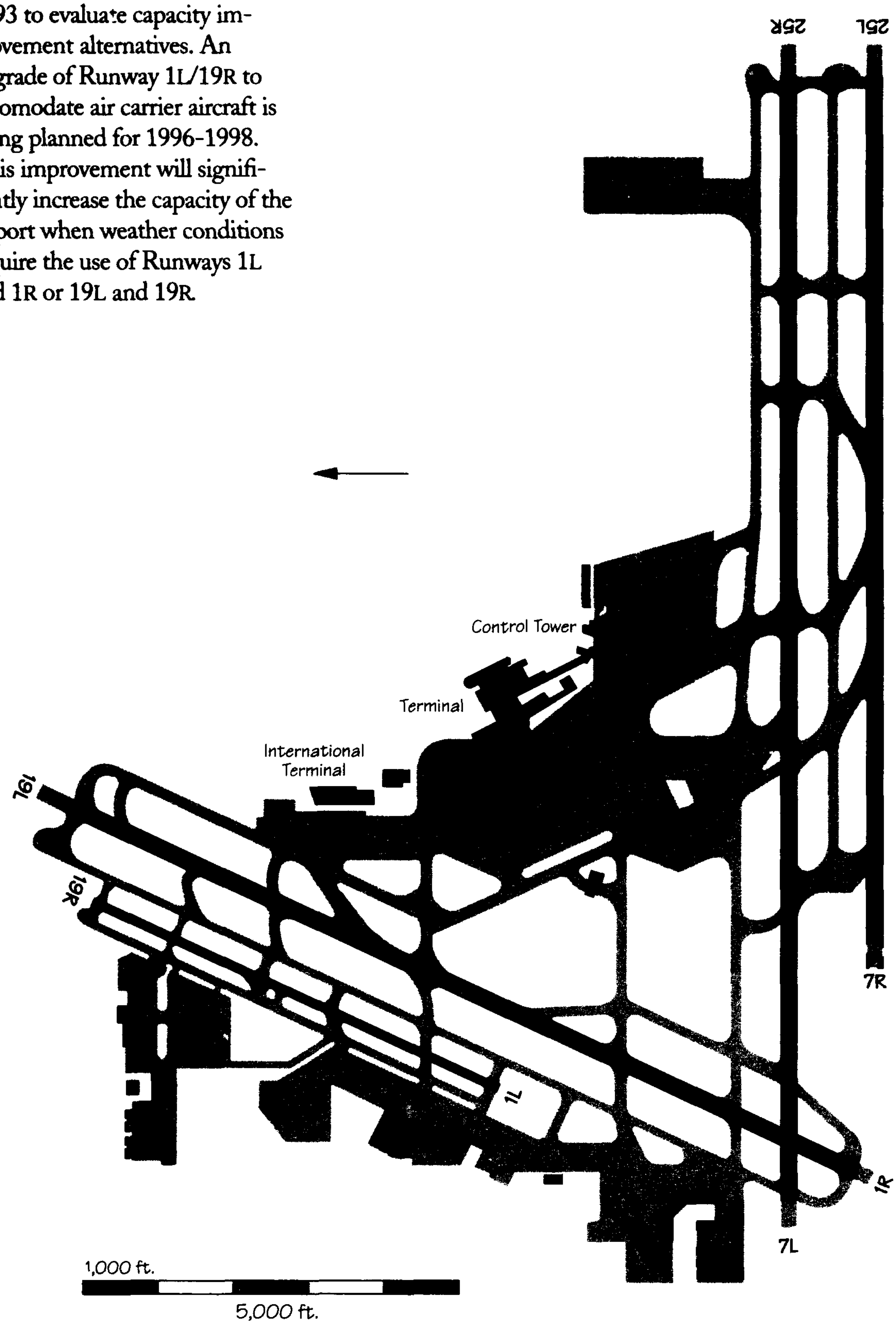
Knoxville (TYS)

A 3,000-foot extension of Runway 5R/23L to 9,000 feet is now complete and operational. Construction began in June 1989 and cost $17.4 million.



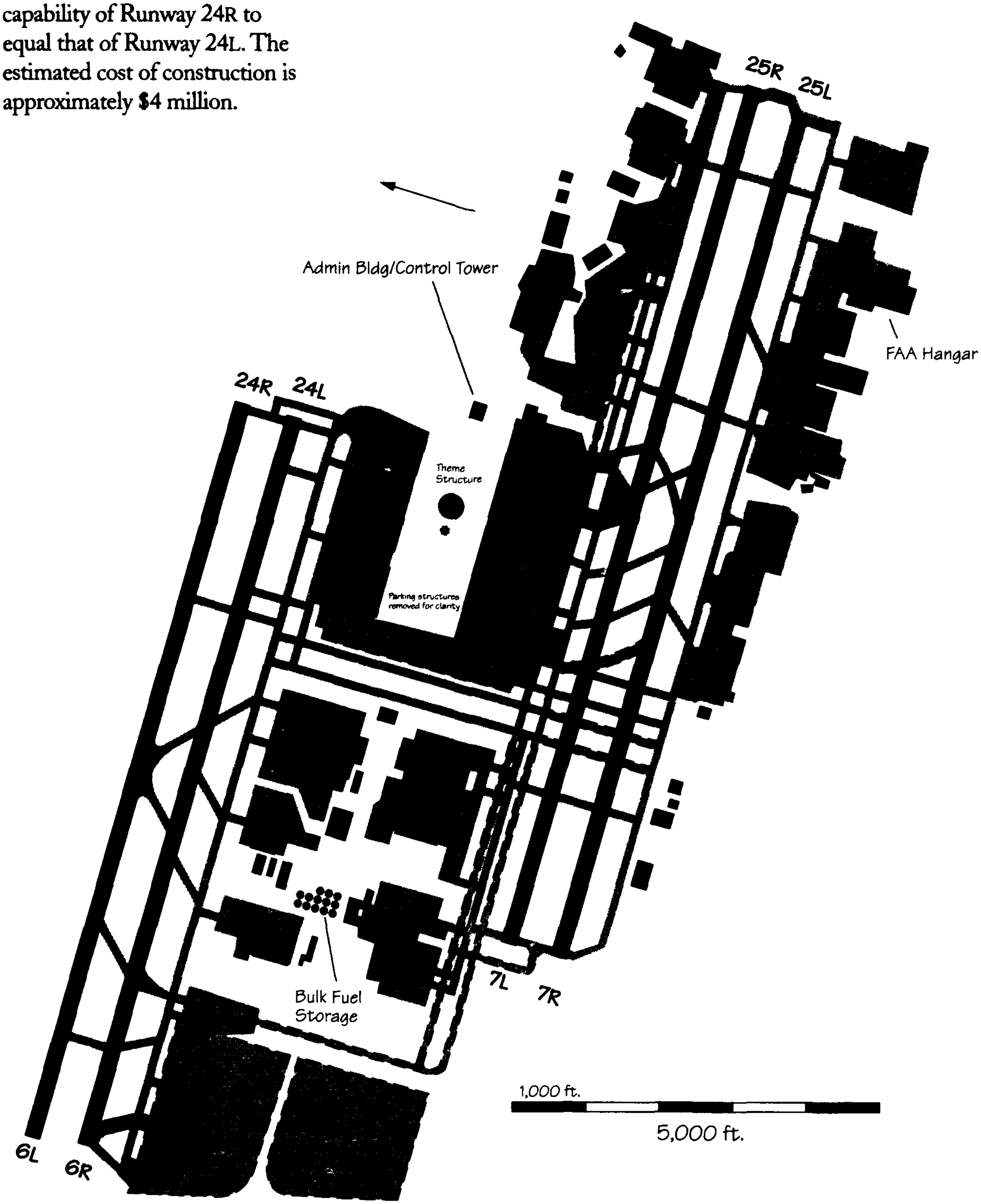
Las Vegas (LAS)

An Airport Capacity Design Team Project began in January 1993 to evaluate capacity improvement alternatives. An upgrade of Runway 1L/19R to accomodate air carrier aircraft is being planned for 1996-1998. This improvement will significantly increase the capacity of the airport when weather conditions require the use of Runways 1L and 1R or 19L and 19R.



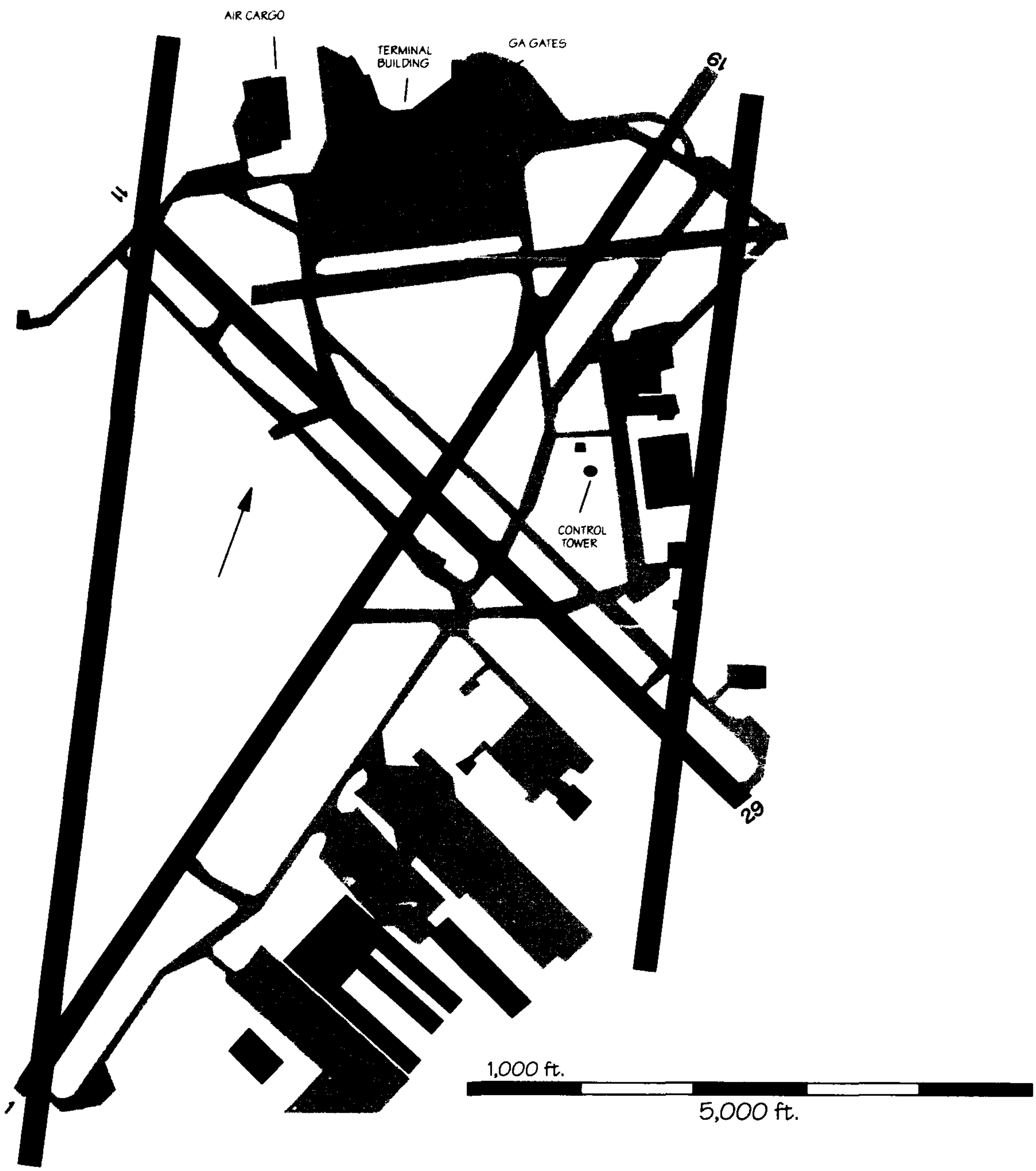
Los Angeles (LAX)

Current plans are to extend Runway 6L/24R 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.



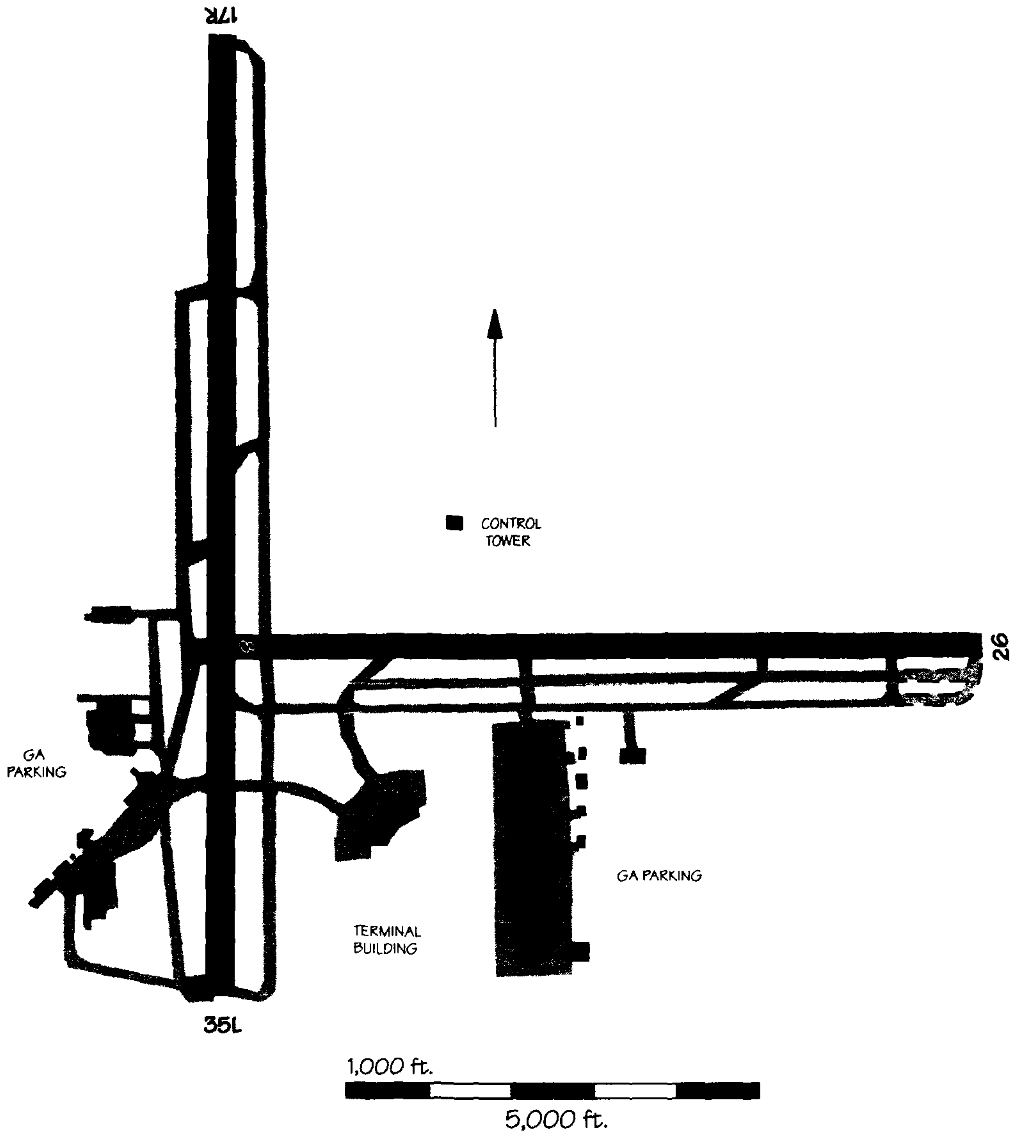
Louisville (SDF)

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 $250 million, and construction is scheduled to begin in 1993. The east runway is expected to be operational in 1997. The west runway is expected to be operational in 1996, permitting independent parallel IFR operations and increasing hourly IFR arrival capacity from 29 to 57.



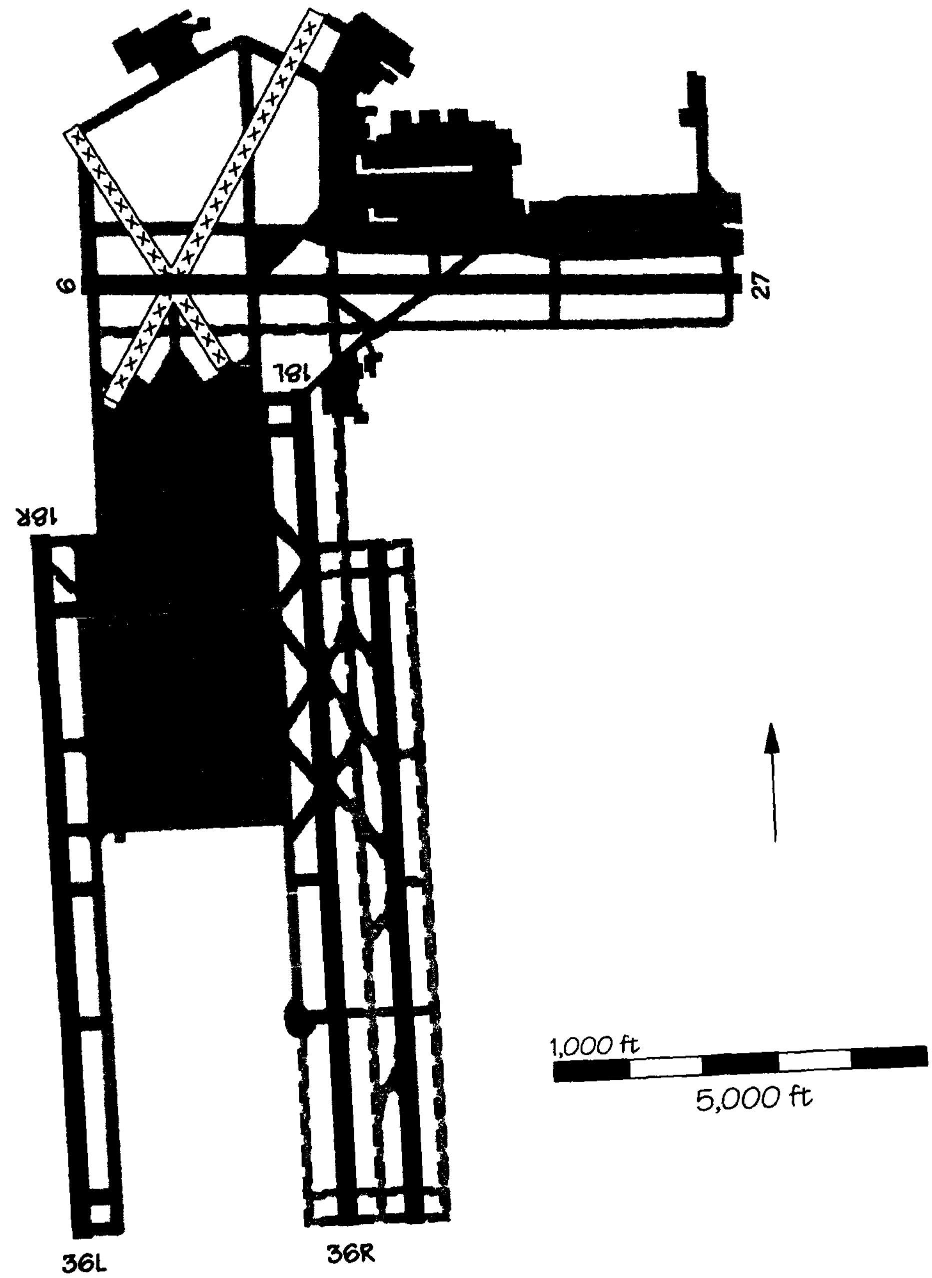
Lubbock (LBB)

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



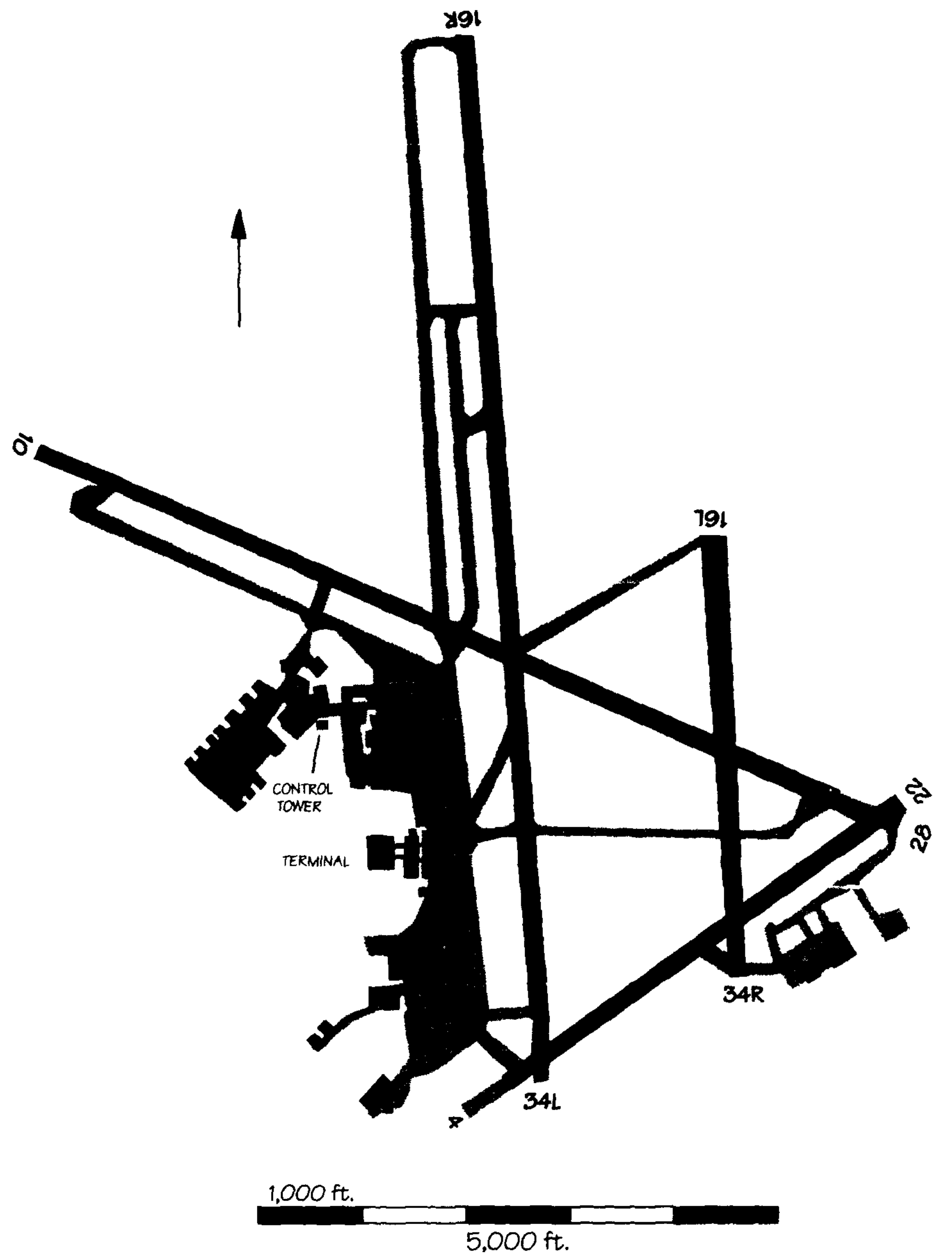
Memphis (MEM)

A new north-south runway, Runway 18E/36E, is planned, and this new runway will be parallel to the existing pair of runways. It will tentatively be located 900 feet east of Runway 18L/36R and 4,300 feet from Runway 18R/36L, thus allowing independent parallel approaches. This would double present hourly IFR arrival capacity. Construction should be completed in late 1995. The estimated cost is $105 million. An extension of Runway 36R is also planned. Construction is expected to be completed by 1997 at a cost of $10 million.



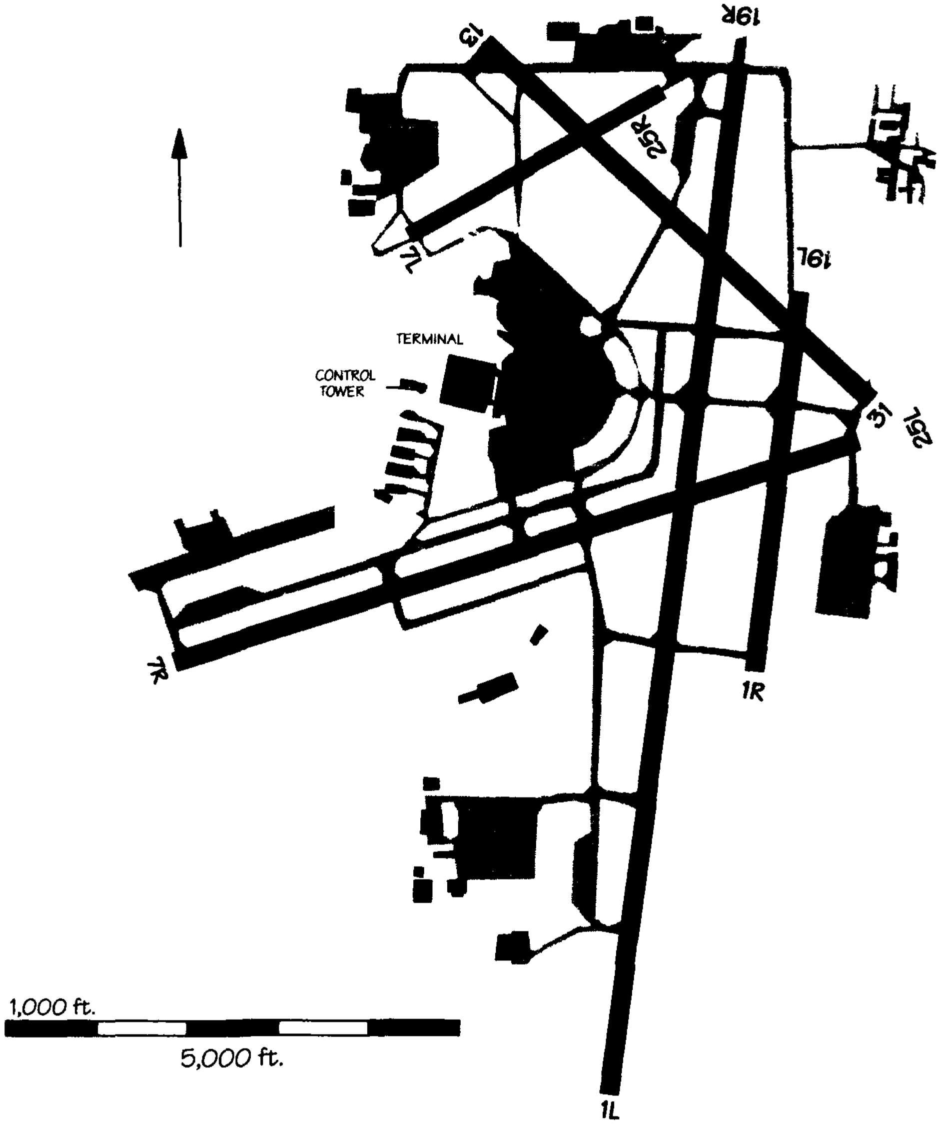
Midland (MAF)

An extension to Runway 10/28 is planned, and construction is scheduled to begin in 1994. The extension should be completed in 1995. The estimated cost of construction is $11 million.



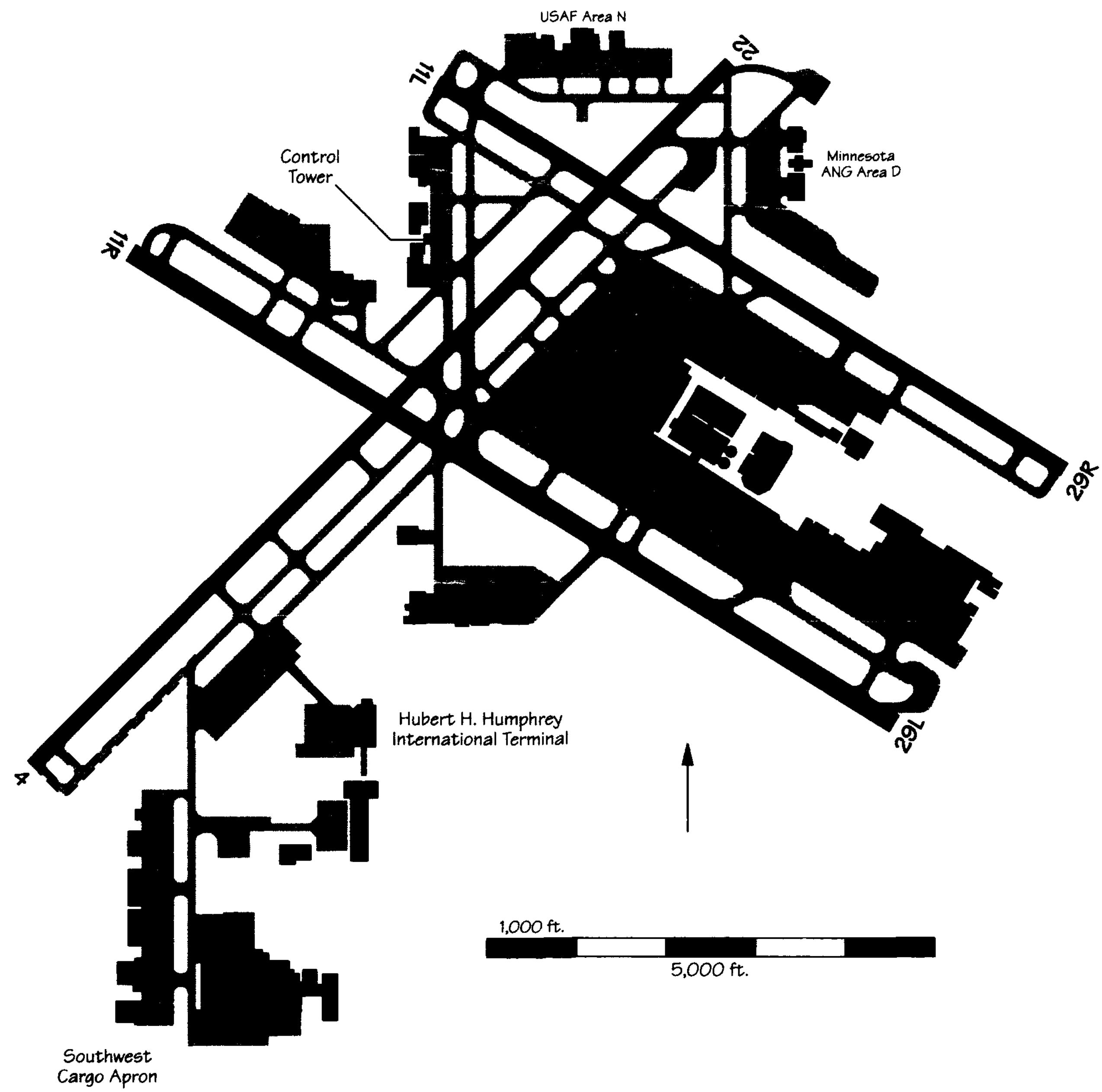
Milwaukee (MKE)

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 1994 and should be completed in August 1995 at a cost of $13 million. A new parallel Runway 7R/25L is planned in the future.



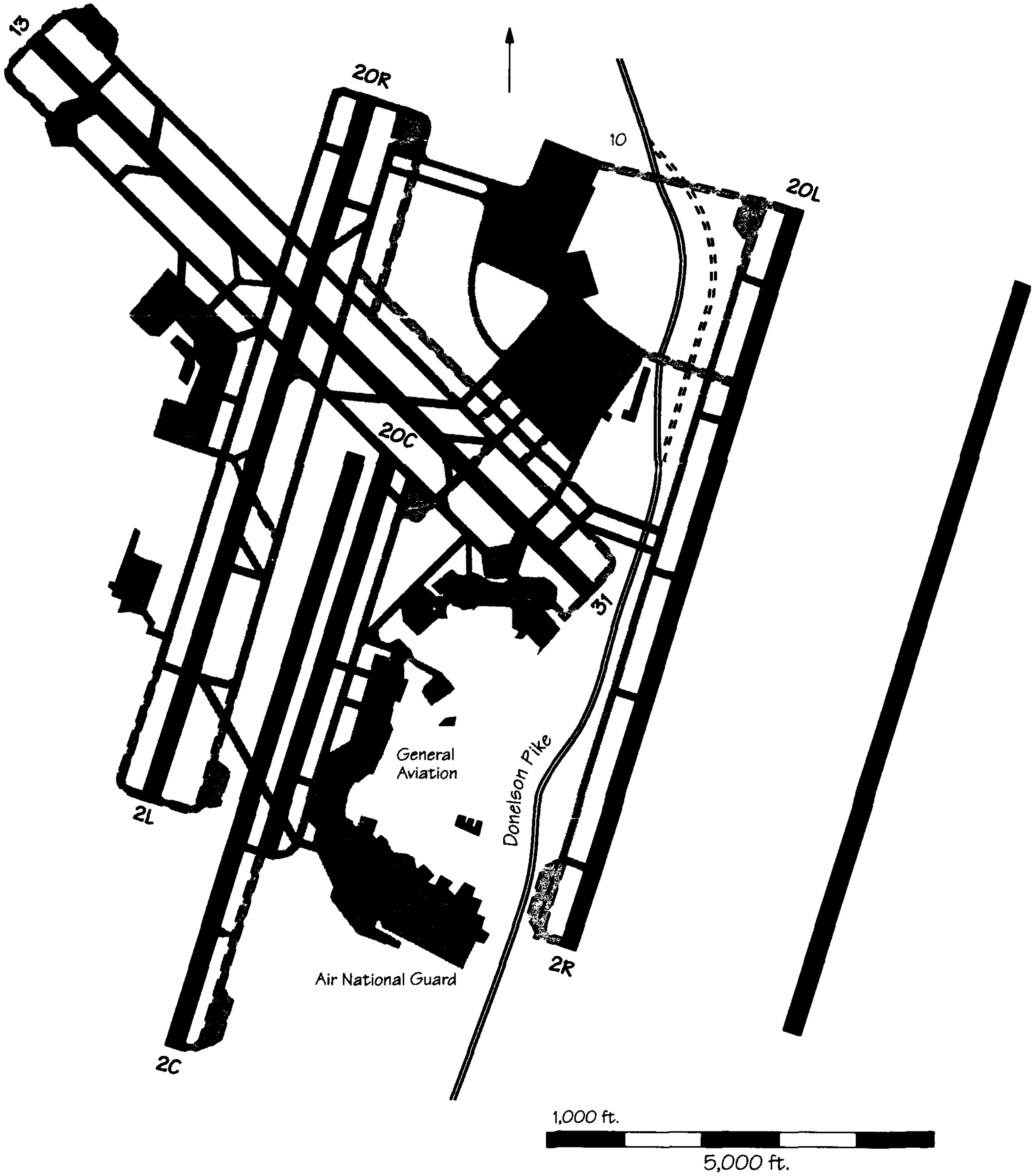
Minneapolis (MSP)

An extension of Runway 4/22 2,750 feet to the southwest is proposed, which would bring the runway length to 11,000 feet. Construction is scheduled to begin in June 1994, and the extension should be operational in late 1994. The estimated cost of construction is $15 million.



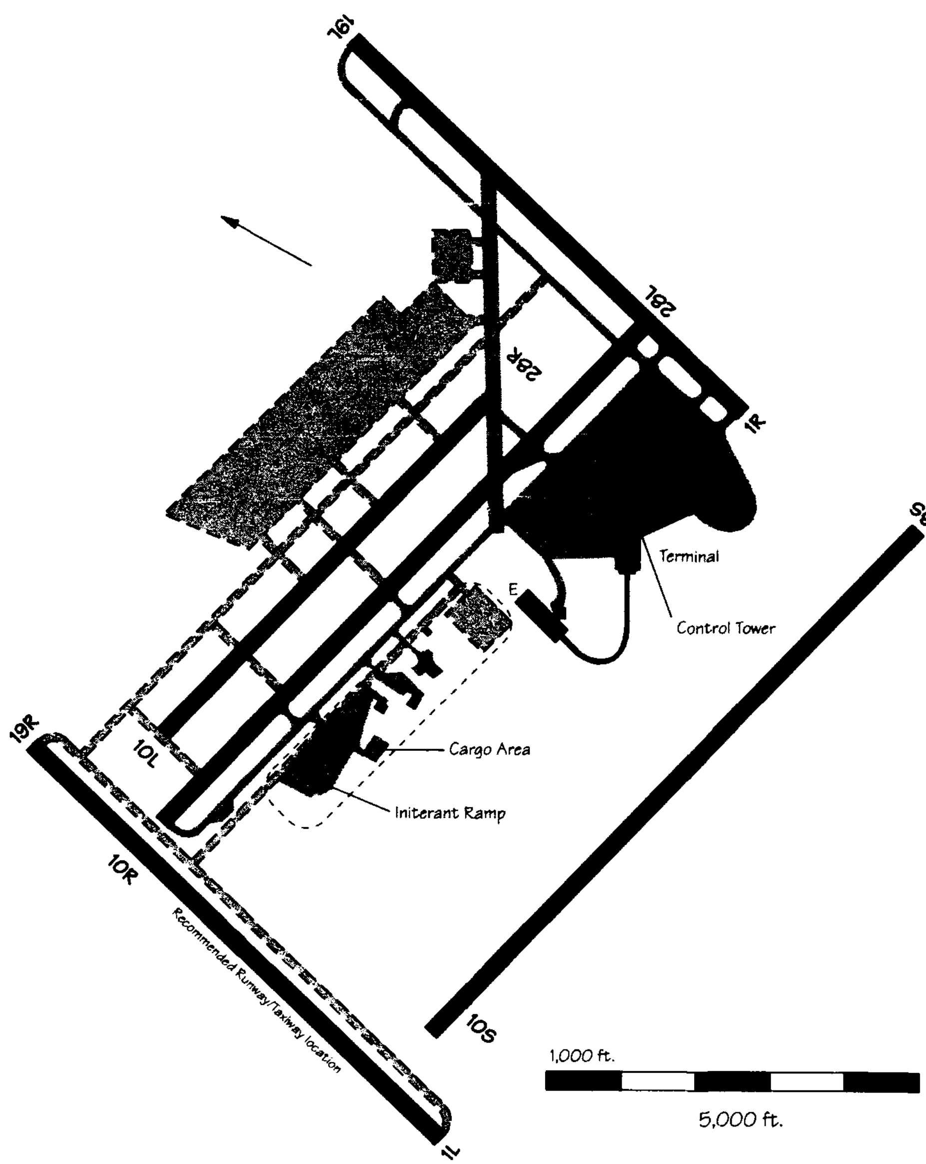
Nashville (BNA)

The relocation and extension of Runway 2C/20C is under construction. The runway should be operational in 1994, and the estimated cost of the project is $34 million. The extension of Runway 13 is also under construction and is expected to be completed in 1994. A new Runway 2E/20E is planned for the future between 1,500 and 3,000 feet from Runway 2R/20L. In addition, extensions to Runways 2R/20L and 2L/20R are planned.



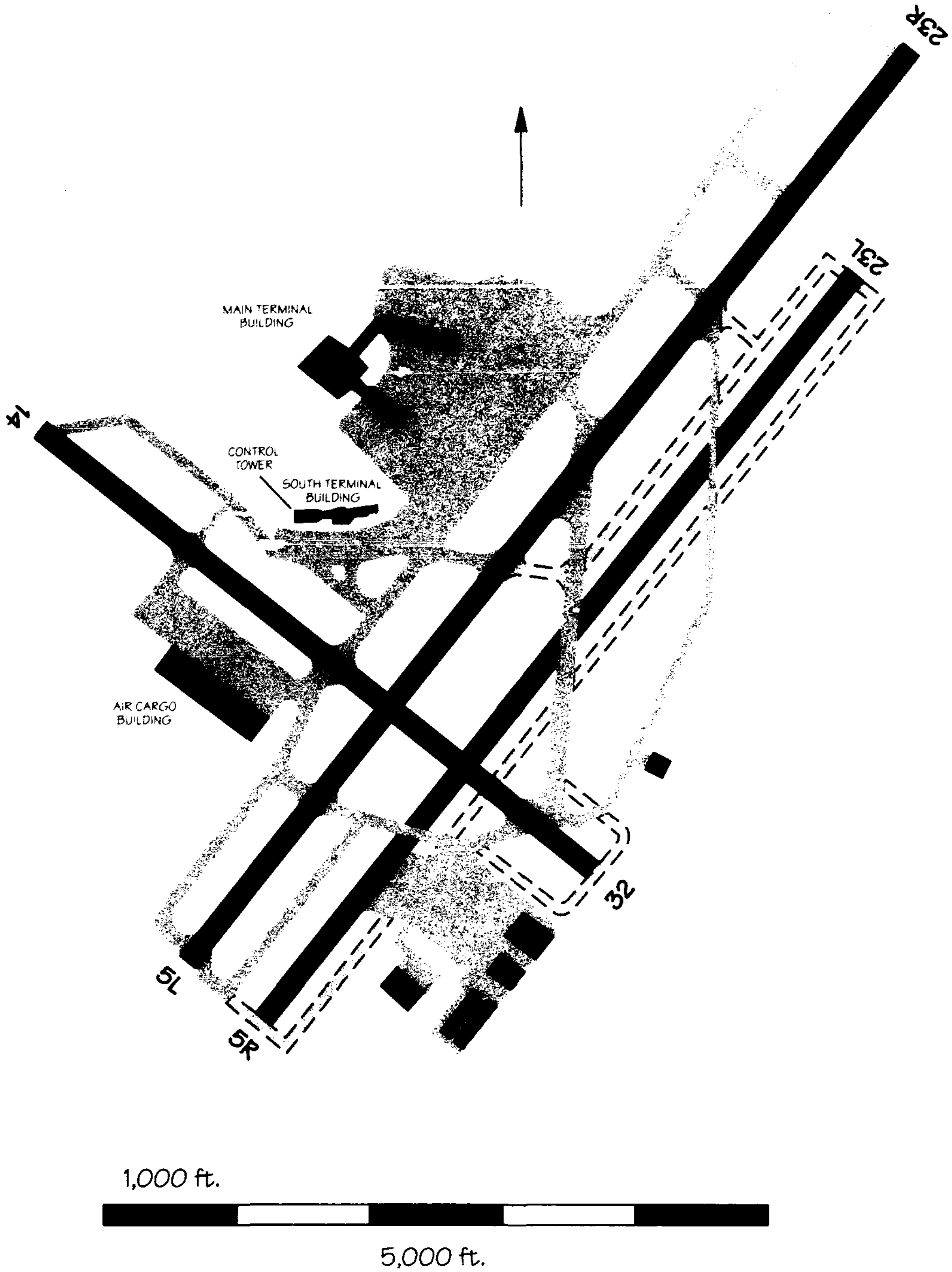
New Orleans (MSY)

A new north-south runway, Runway 1L/19R, is planned. This new runway will be parallel to the existing Runway 1/19 and will be located west of the threshold of Runway 10, approximately 11,000 feet away from Runway 1/19. This will allow independent parallel operations, doubling IFR hourly arrival capacity. Pending environmental approvals, construction could begin as early as January 1995 and be completed in 2000, at an approximate cost of $205 million. As an alternative to this north-south runway, the airport is considering the construction of an east/west parallel runway, Runway 10S/28S, 4,300 feet to the south of existing Runway 10/28, off of present airport property. The airport is also planning to construct a north parallel east/west taxiway approximately 800 feet north of and parallel to the existing Runway 10/28, which could later be converted into a 6,000-foot commuter and general aviation runway. The site preparation phase of the taxiway construction has already begun. The estimated cost of construction is $25.5 million, and the expected operational date is 1995.



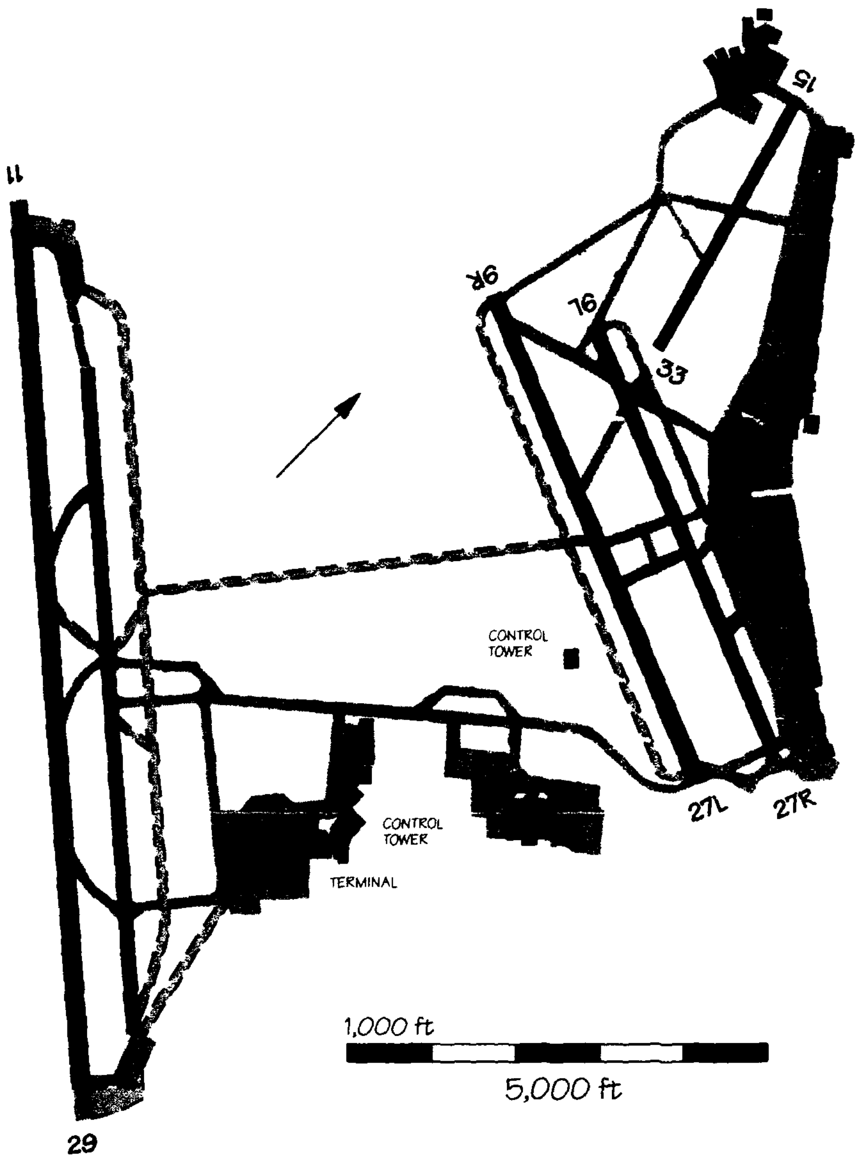
Norfolk (ORF)

A new runway, 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. Construction began 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.



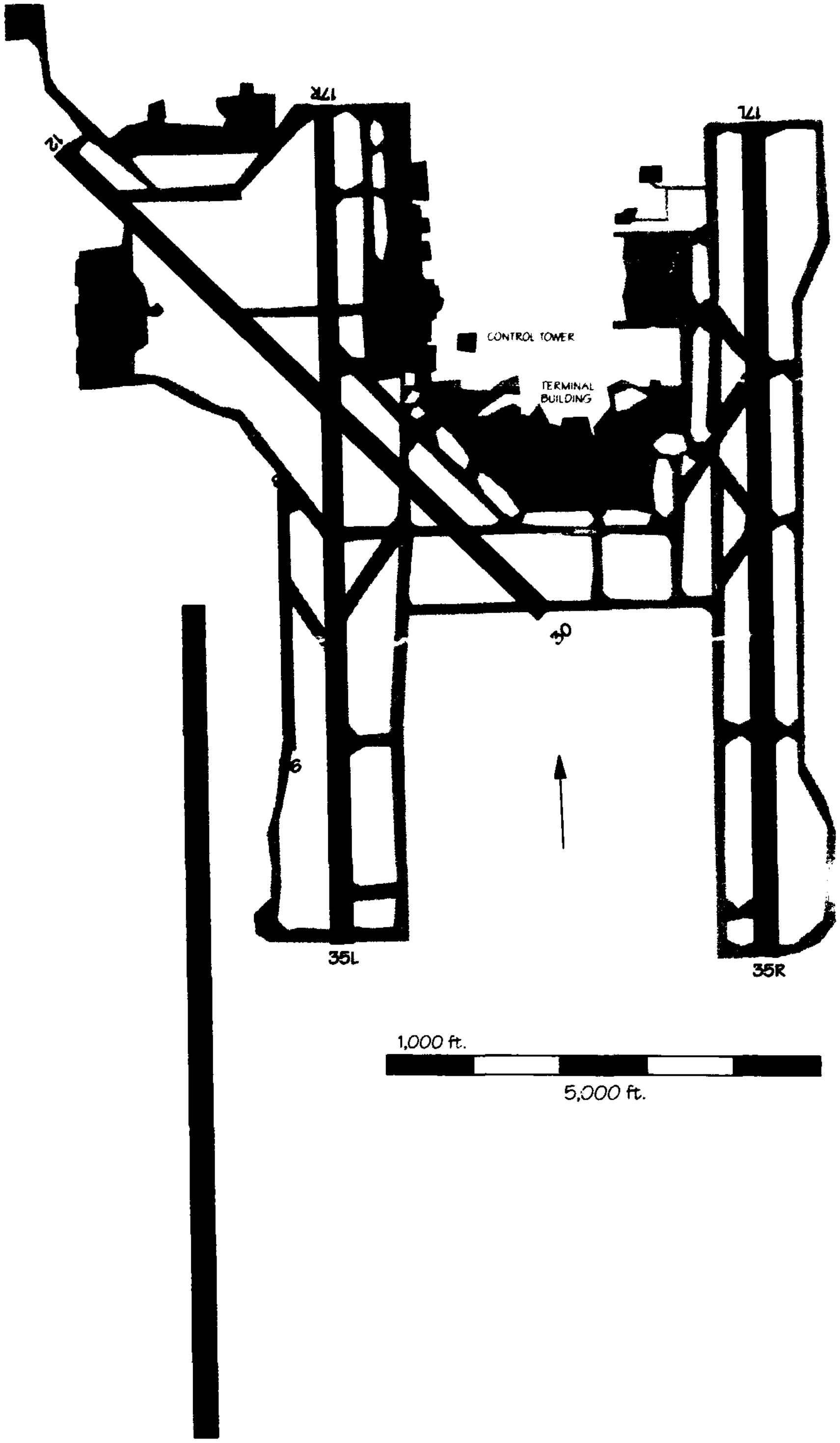
Oakland (OAK)

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



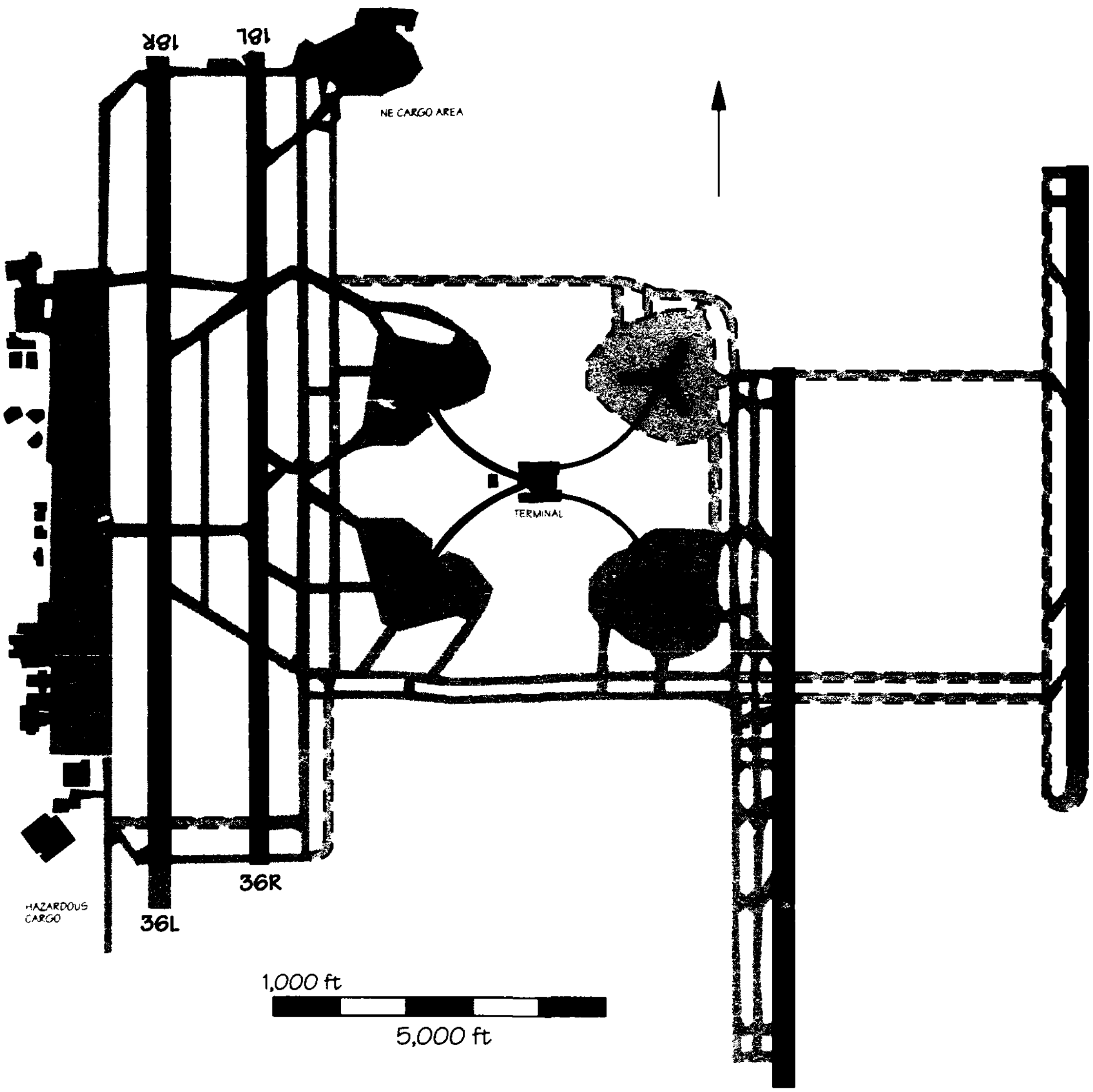
Oklahoma City (OKC)

Extensions to both north/south runways to the south 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 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.



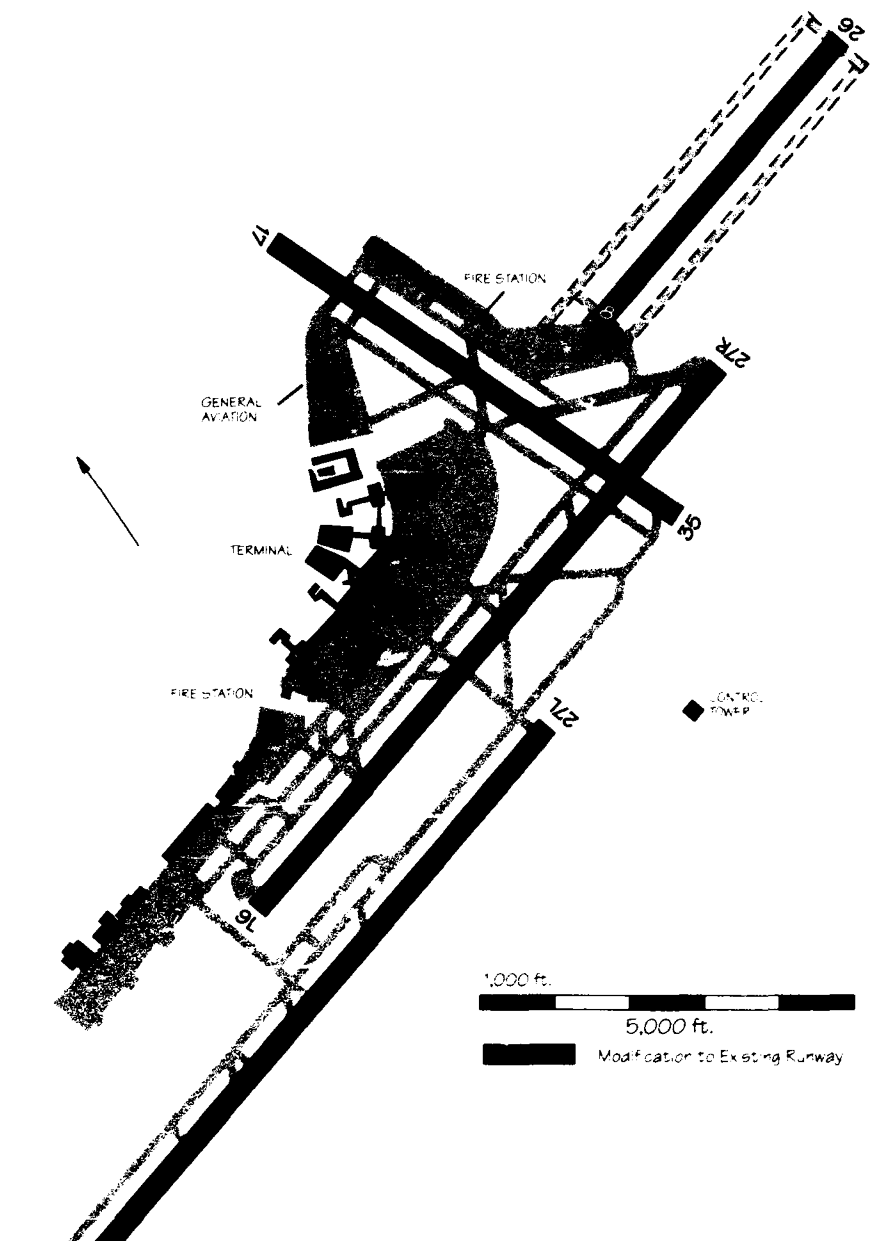
Orlando (MCO)

A fourth north-south runway, Runway 17L/35R, is expected to be operational in 1997. 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 $100 million.



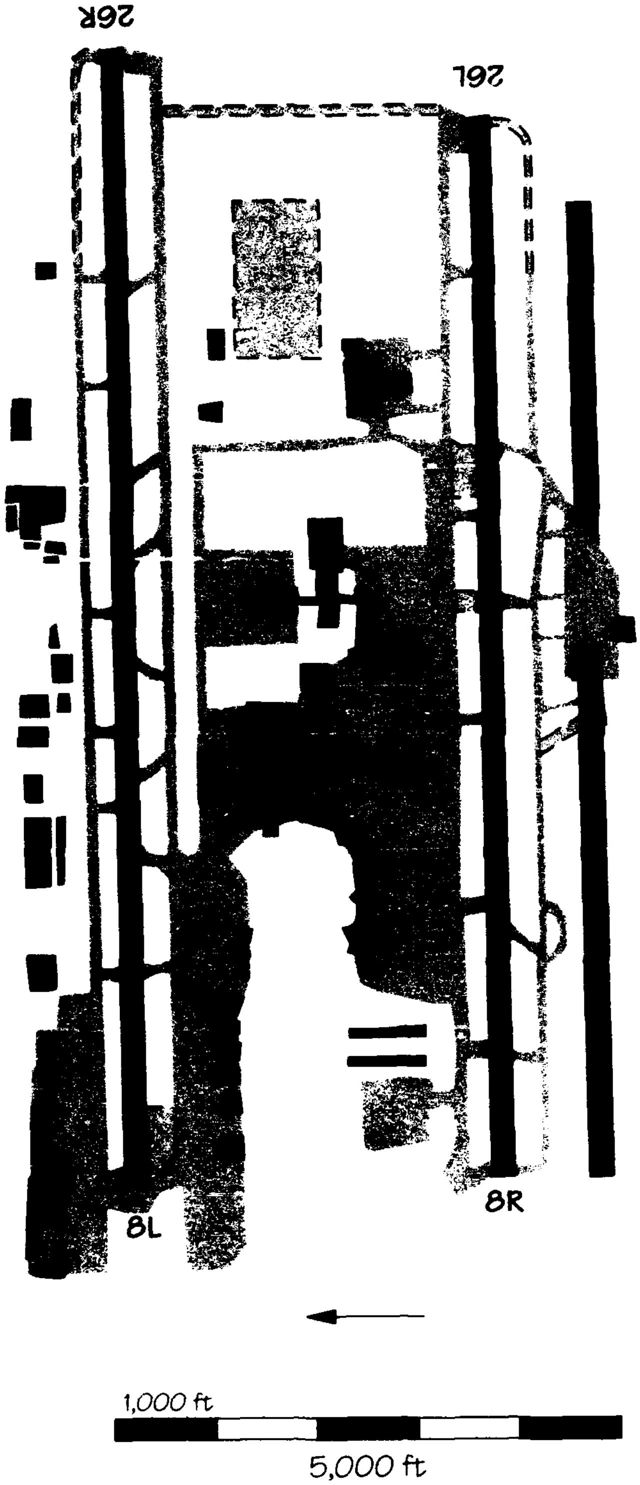
Philadelphia (PHL)

A 600-foot extension of Runway 17/35 is currently planned. In addition, the inner parallel, Runway 9L/27R, will shift 400 feet south closer to Runway 9R/27L. The extension of Runway 17/35 and relocation of Runway 9L/27R would effectively eliminate the intersection of the two runways and increase their respective capacities during most conditions of wind and weather. The relocated Runway 9L/27R is expected to be operational in January 1997 at an estimated cost of $109 million. The estimated cost of extending Runway 17/35 is $17 million. A new 5,000-foot parallel commuter runway, Runway 8/26, has been proposed and would be located 3,000 feet north of Runway 9R/27L. The estimated cost is $169 million.



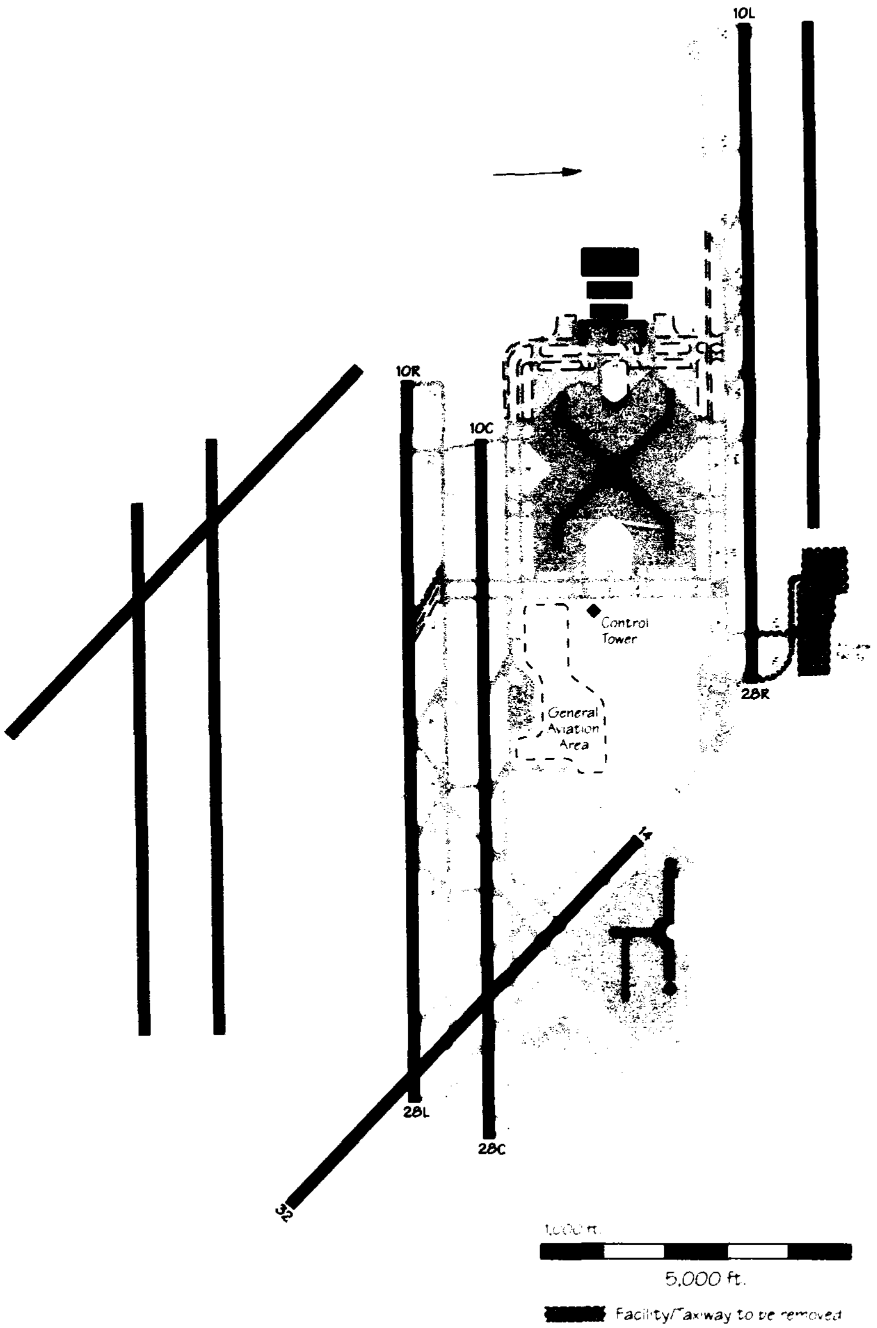
Phoenix (PHX)

A 9,500-foot third parallel runway, Runway 7/25, is proposed 800 feet south of Runway 8R/26L. The estimated cost of construction is $88 million. A final Environmental Impact Statement is scheduled for completion in FY93. The estimated operational date for 7,800 feet of Runway 7/25 is 1997; the remaining 1,700 feet of the runway is not scheduled at this time.



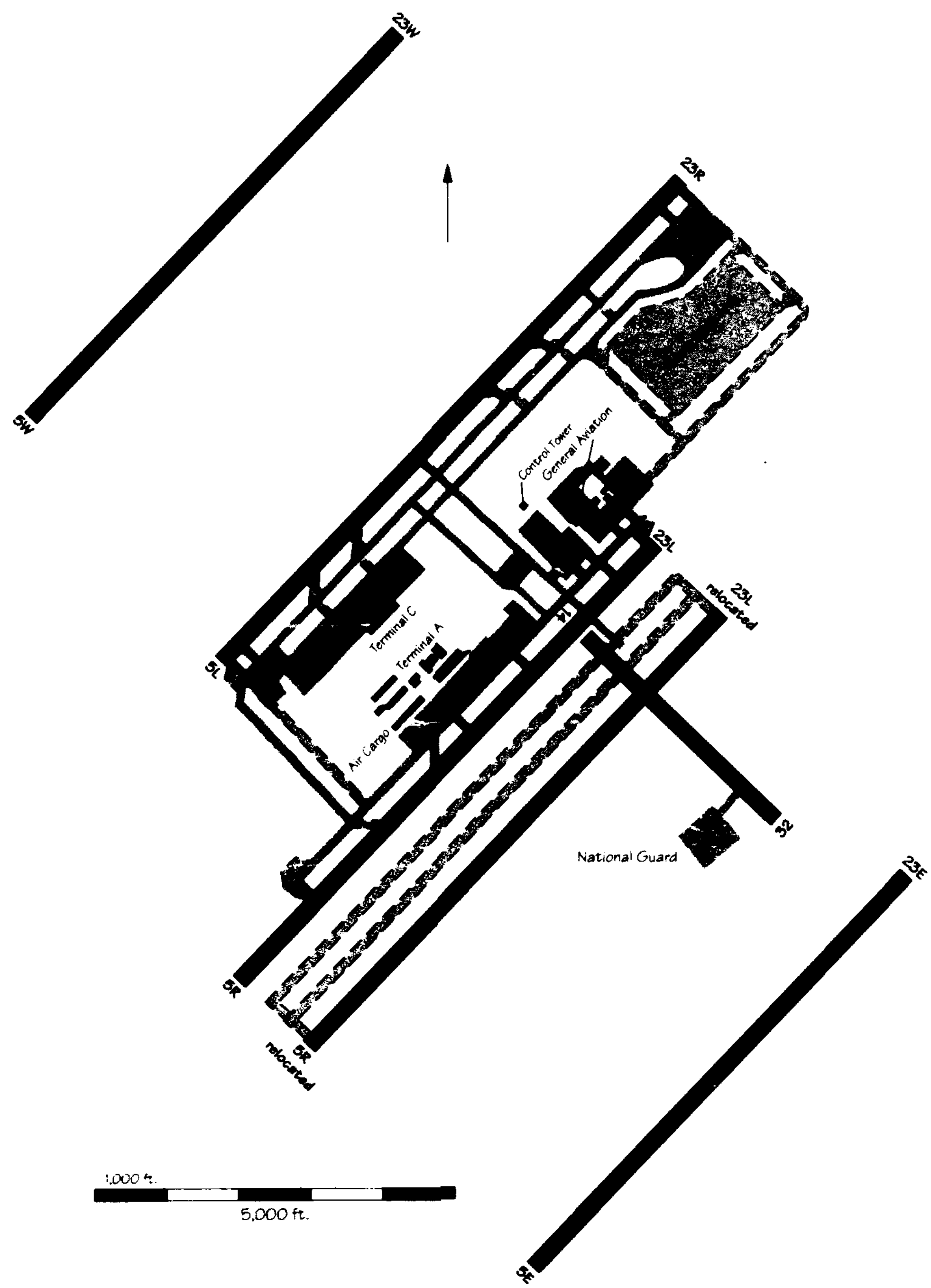
Pittsburgh (PIT)

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 1993 and be completed in 1995. It will be located 8,700 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 1996, also at an estimated cost of $100 million. Completion of the fourth parallel may permit triple independent IFR approaches.



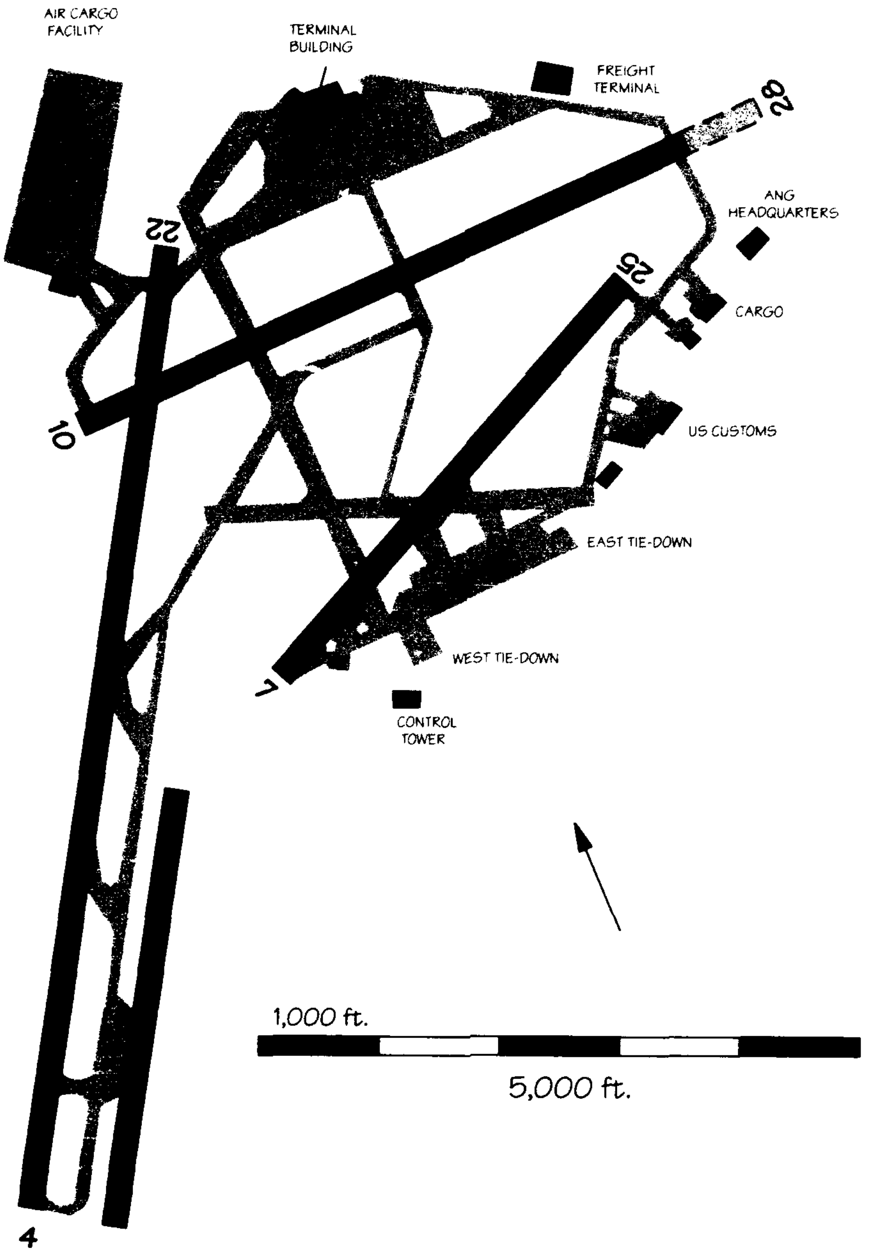
Raleigh-Durham (RDU)

The relocation of Runway 5R/23L and its associated taxiways is expected to begin in 1994. 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 of construction is $37 million. Two other runways are proposed for eventual construction. Runway 5W/23W would be located 1,000 to 4,300 feet to the northwest of Runway 5L/23R, and Runway 5E/23E would be located 1,000 to 4,300 feet to the southeast of the relocated Runway 5R/23L. The estimated cost for the construction of each of these runways is $75 million.



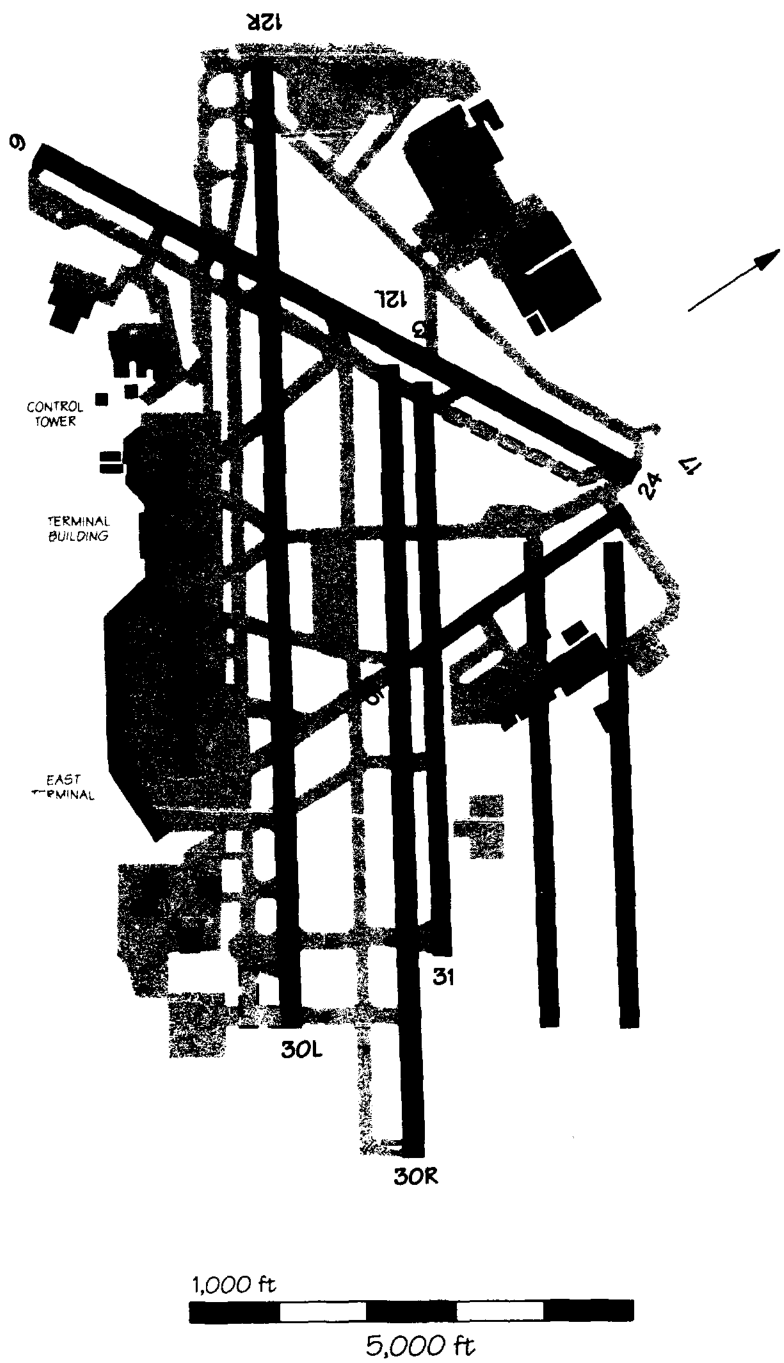
Rochester (ROC)

Construction of an extension to Runway 10/28 is expected to begin in 1995 and should be completed in 1996. 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. Construction of a new parallel Runway 4R/22L is estimated to cost $4.7 million. The new runway should be operational in 2000. Environmental assessments have not yet been started for these projects.



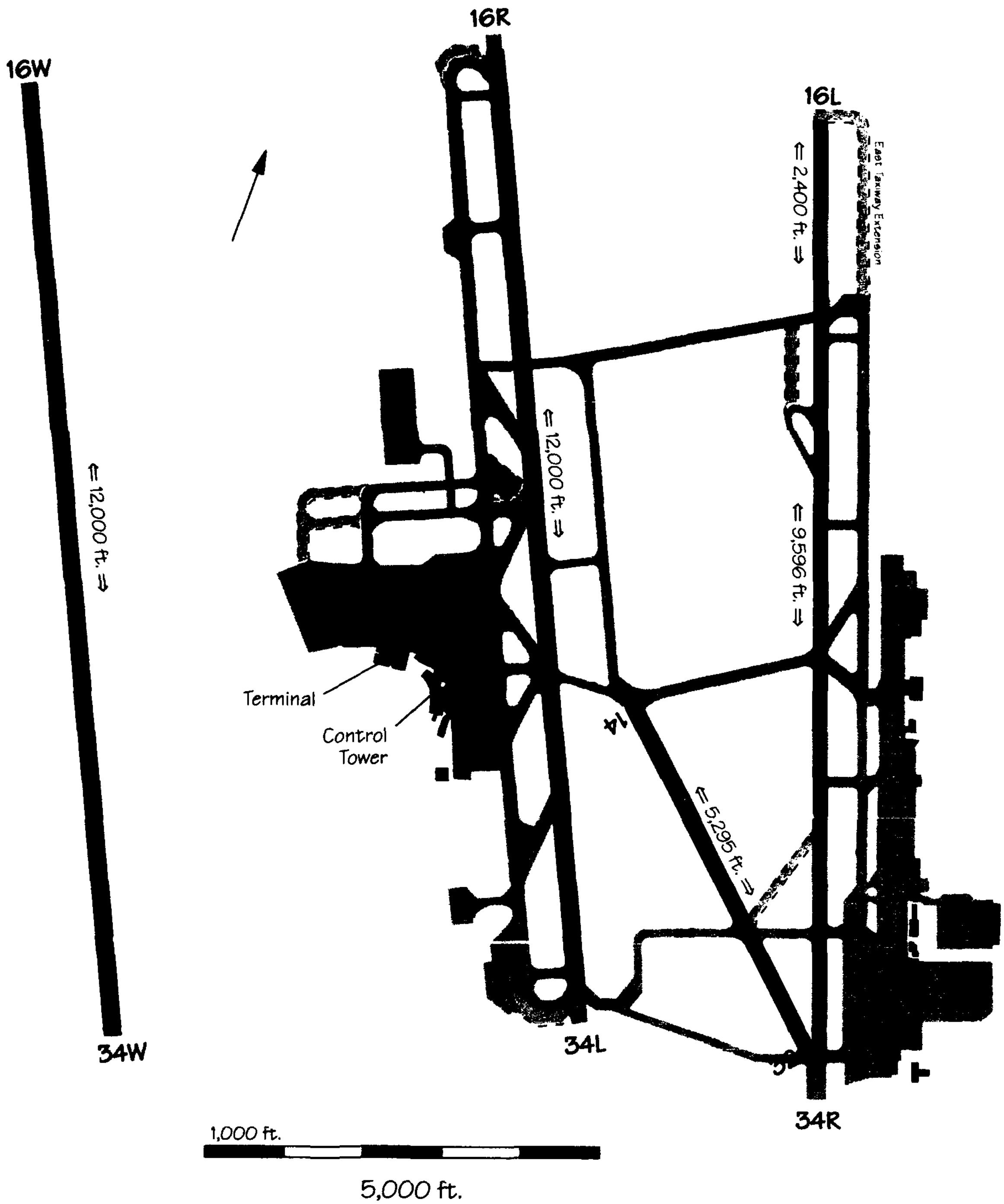
St. Louis (STL)

A new parallel Runway 12L/30R in several configurations has been recommended by the St. Louis Airport Capacity Design Team. Taxiway F has been permanently converted into a new Runway 13/31 for commuter and general aviation aircraft. A Master Plan Update is underway, and the entire airport layout may change as a result. The new plan will probably call for four parallel runways, with at least two supporting independent IFR operations.



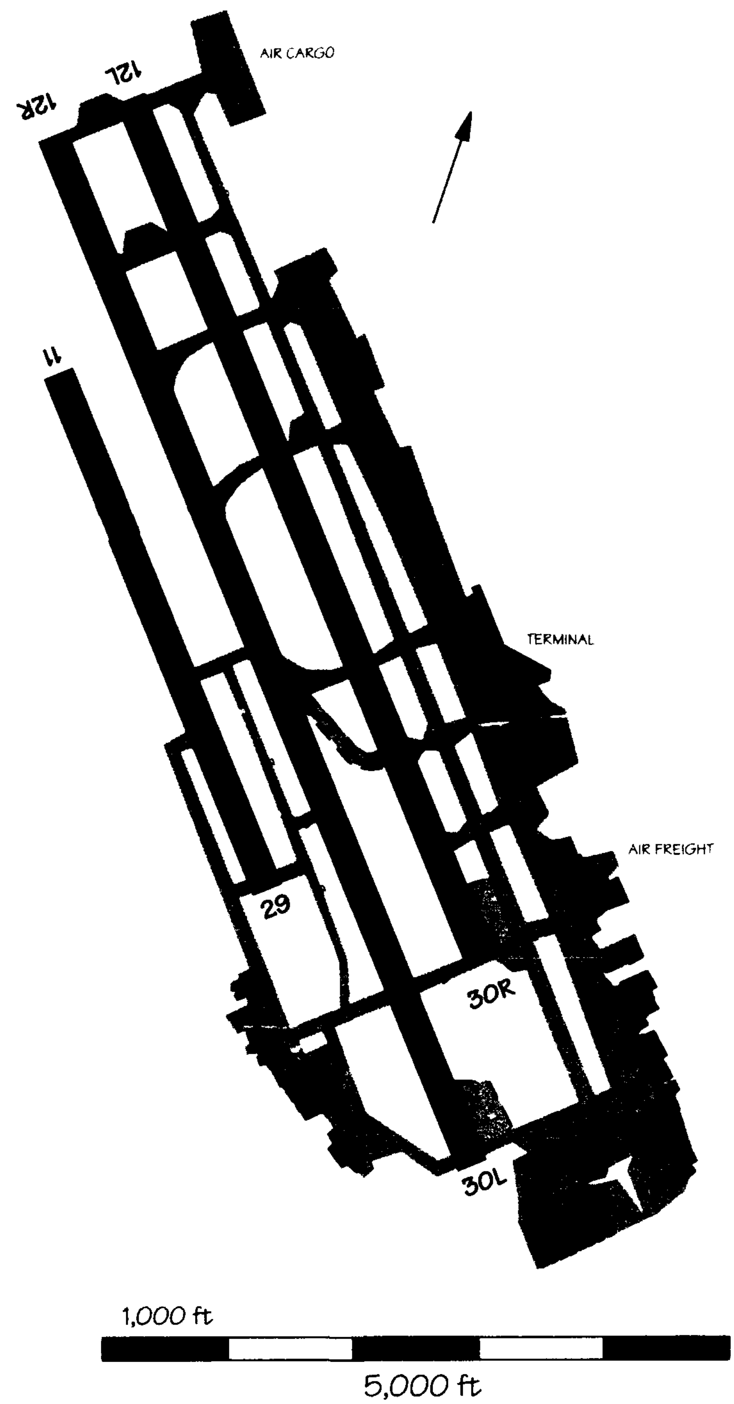
Salt Lake City (SLC)

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 1993. The estimated cost of construction is $95 million. This may permit triple IFR approach operations, if they are approved.



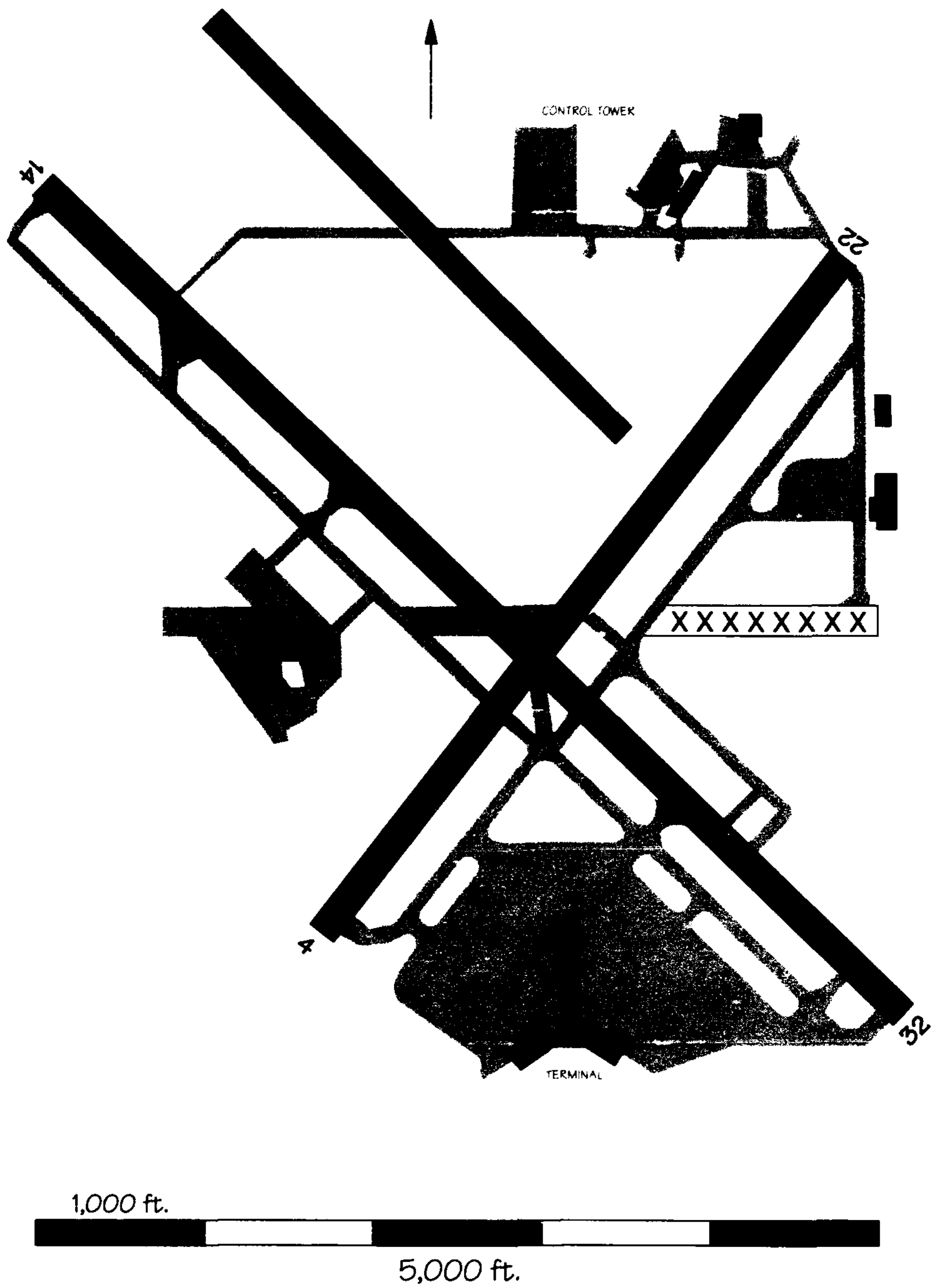
San Jose (SJC)

An extension of Runway 30R/12L is under construction at an estimated cost of $8 million and is scheduled for operation in 1993.



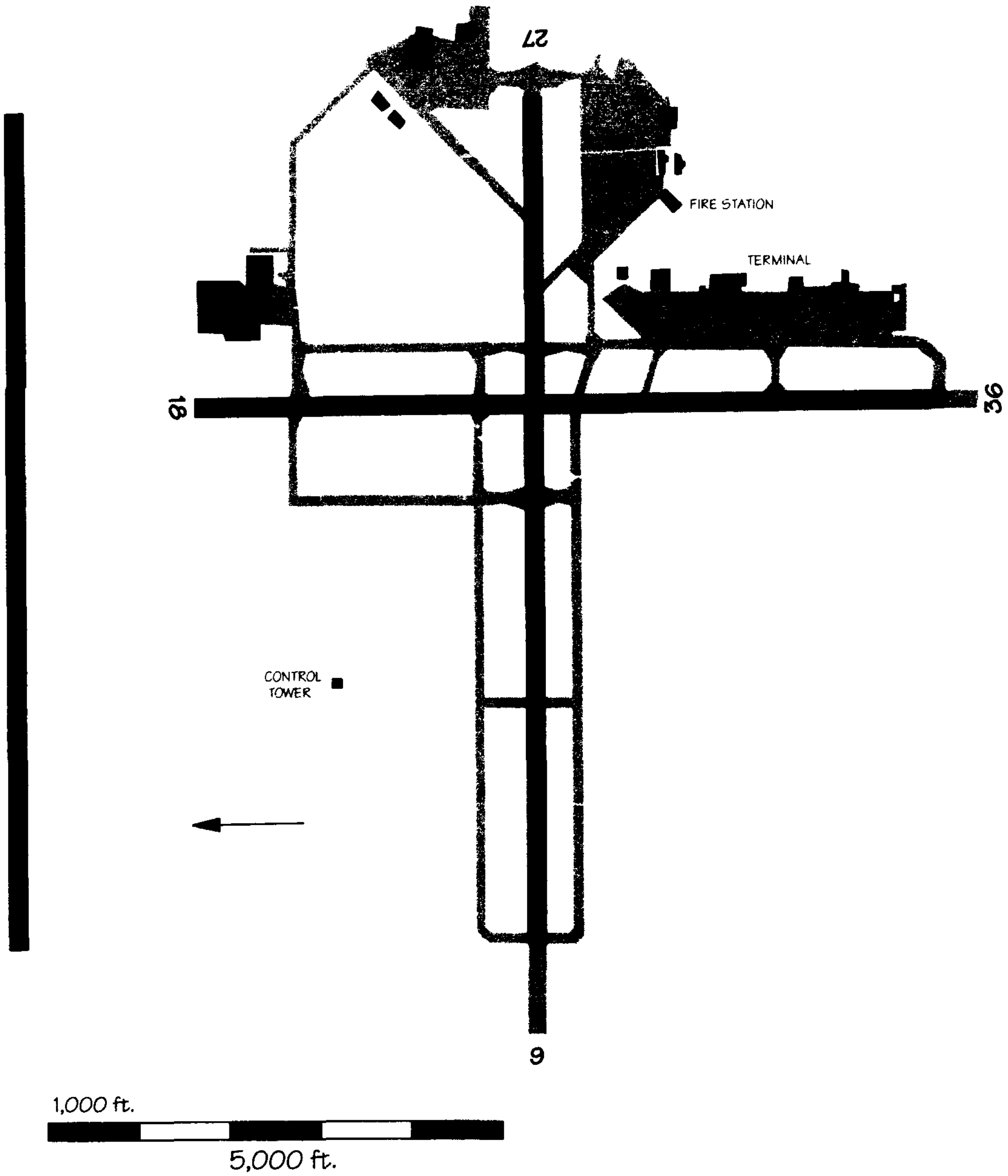
Sarasota (SRQ)

A new parallel Runway 14L/32R is being planned at an estimated cost of $10 million. It is expected to be operational by 1996. In addition, an extension of the existing Runway 14/32 is planned at a cost of $4.5 million. It is expected to be complete in 1995.



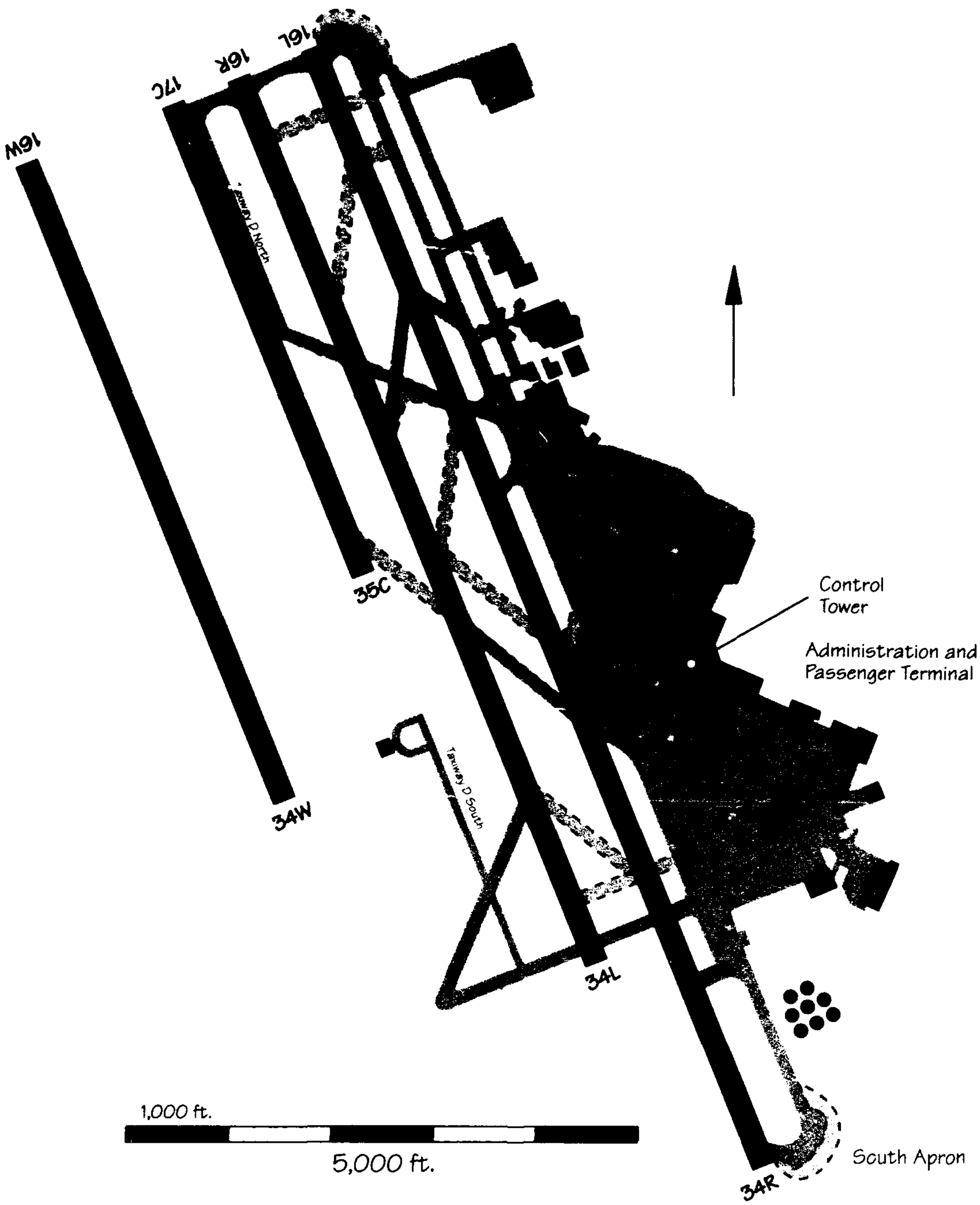
Savannah (SAV)

Three 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 parallel runway, Runway 9L/27R, is shown on the airport layout. Construction is expected to begin in 2009 and should be completed in 2010 at a cost of $20 million. Also, an extension to the existing Runway 9R/27L is planned to begin in 1996, with construction expected to be completed in 1997 at a cost of $6.5 million.



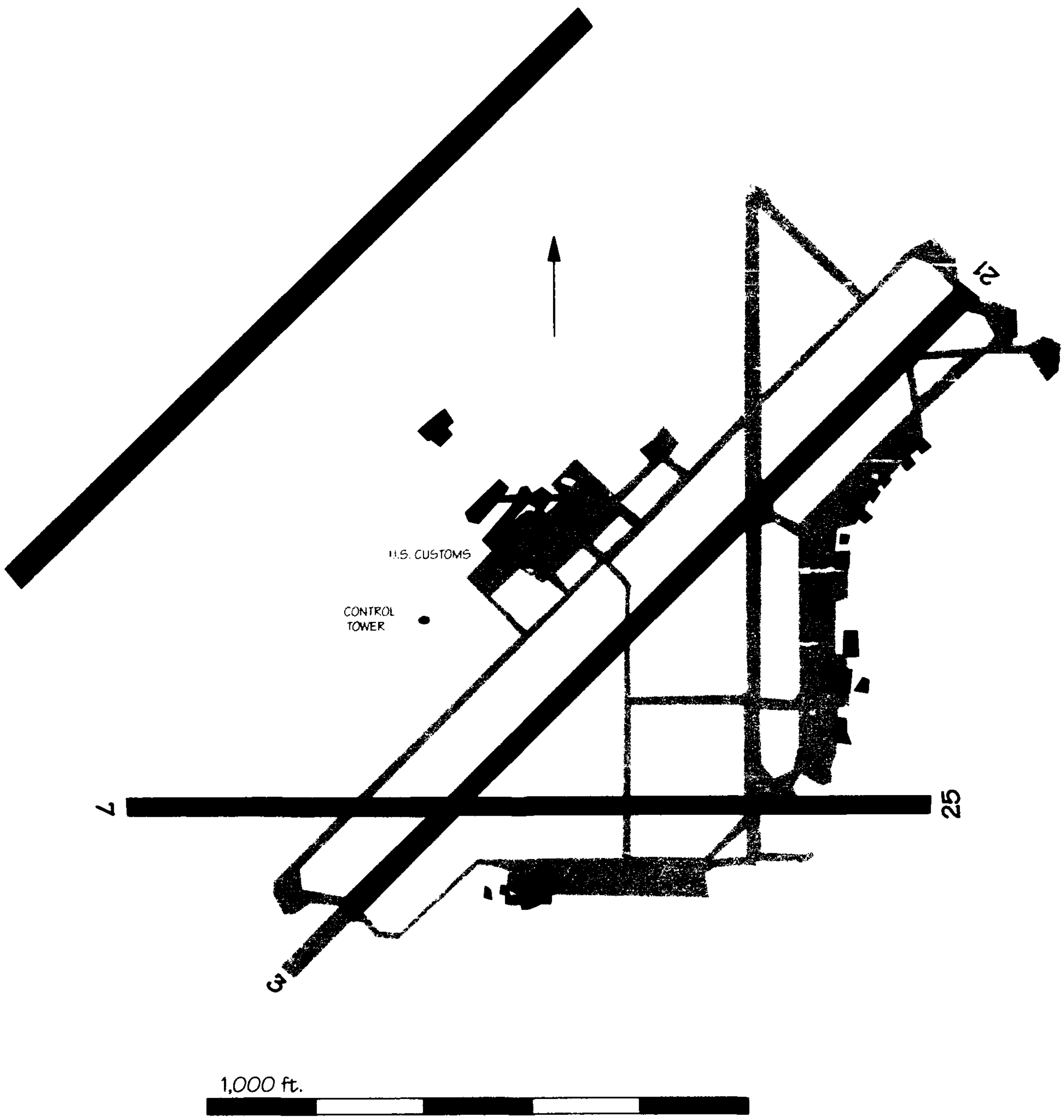
Seattle-Tacoma (SEA)

Potential airport improvements include a new 7,000-foot runway, Runway 16W/34W, to be located 2,500 feet from Runway 16L/34R, and conversion of an existing taxiway into a new parallel commuter runway for VFR use, Runway 17C/35C.



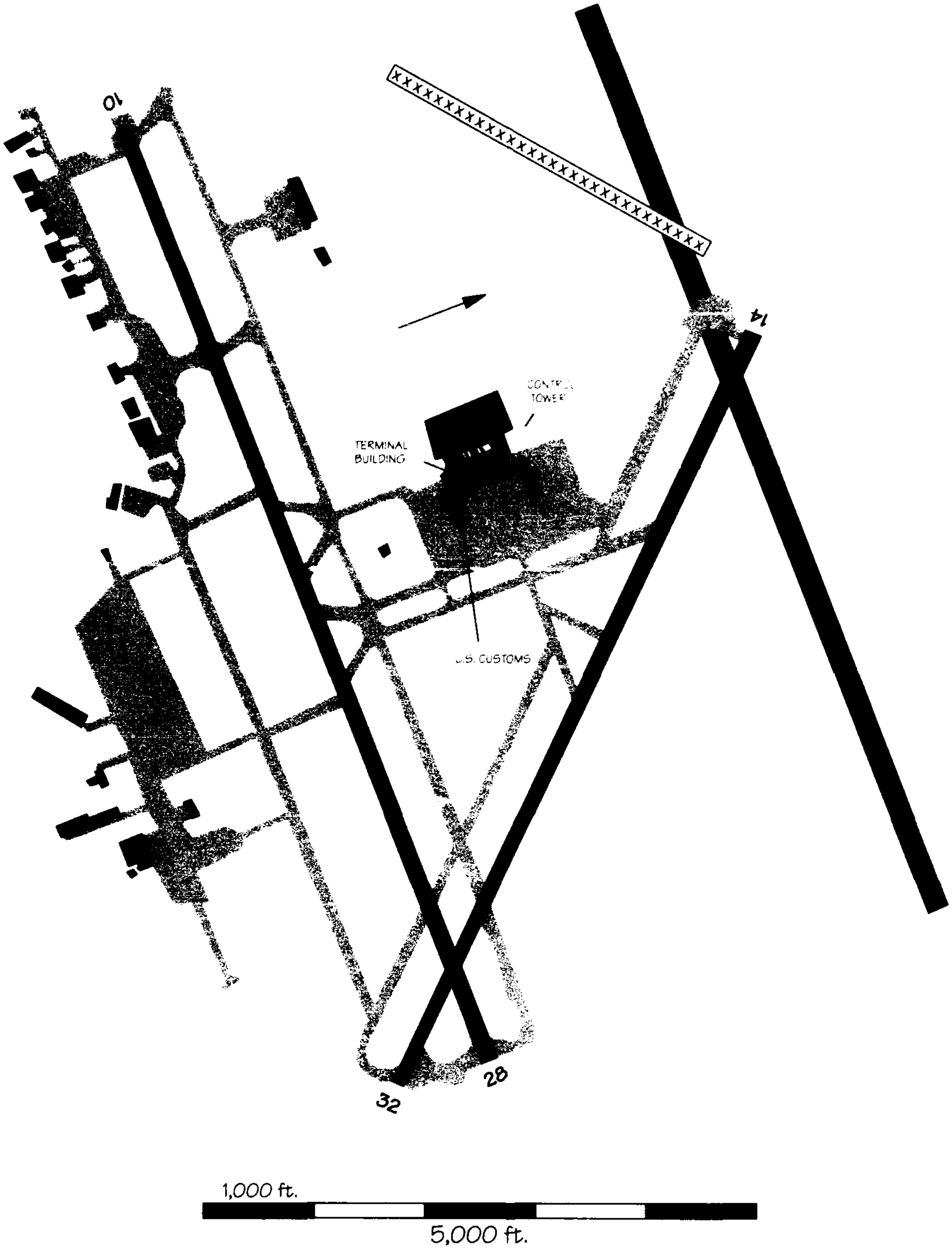
Spokane (GEG)

Future projects 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 \$50-\$75 million. Construction is expected to start in 1997 and should be completed in 2000.



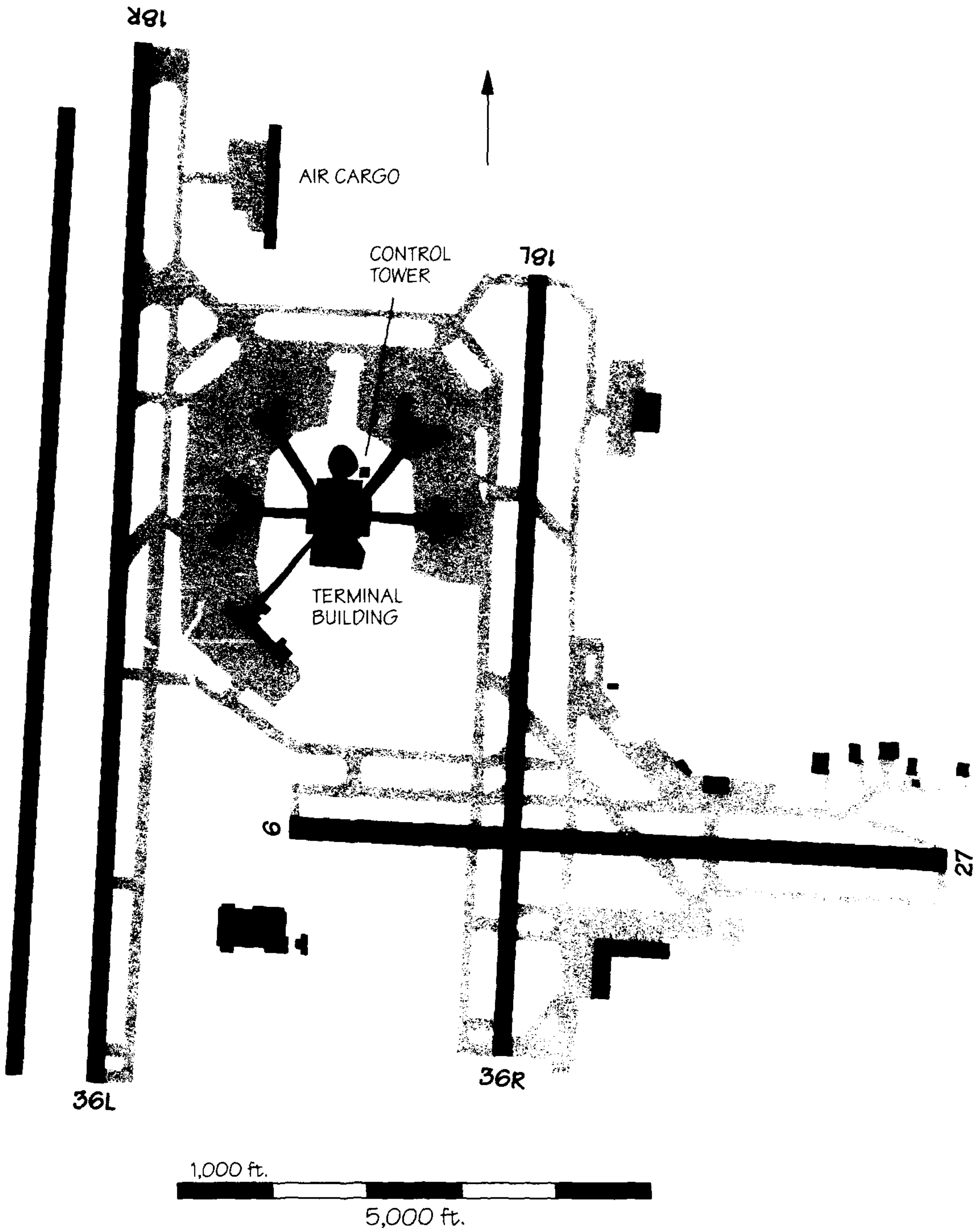
Syracuse (SYR)

There is potential for a parallel Runway 10L/28R, 9,000 feet long and separated from the existing Runway 10/28 by 3,600 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 $55 million for the first phase of the new runway, which would be 7,500 feet long, including a parallel taxiway and connections to the ramp. The final length of the runway will be 9,000 feet.



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 scheduled to start in 1995. The estimated operational date for the runway is 1997, and the estimated cost of construction is $53 million. No increase in hourly IFR arrival capacity will be provided, but VFR capacity will increase as well as IFR departure capacity.



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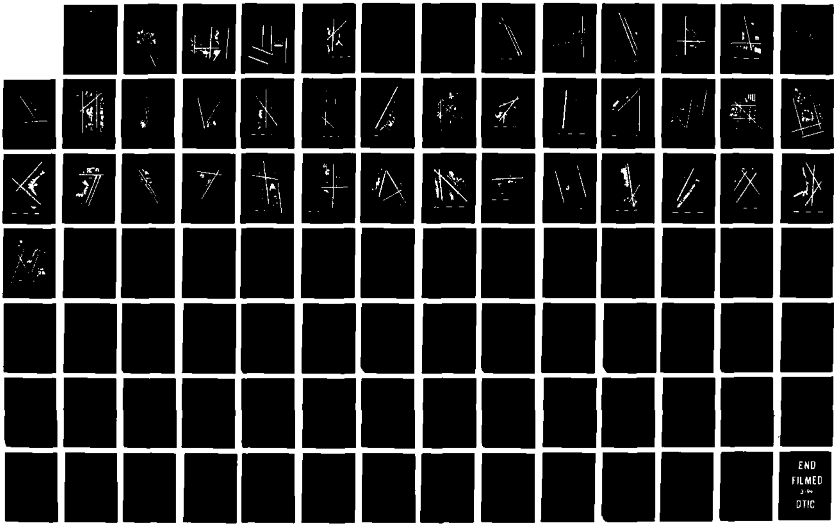

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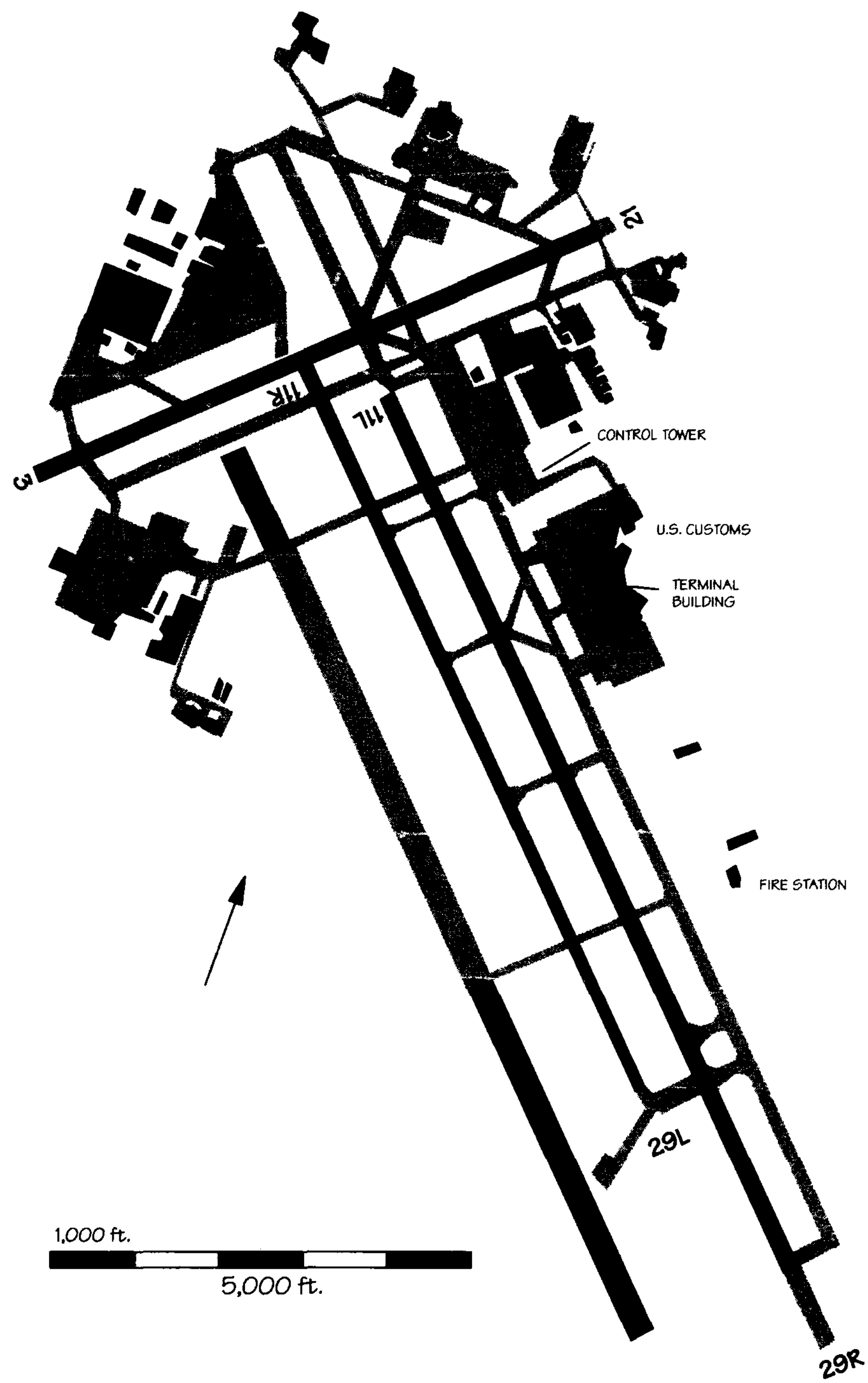
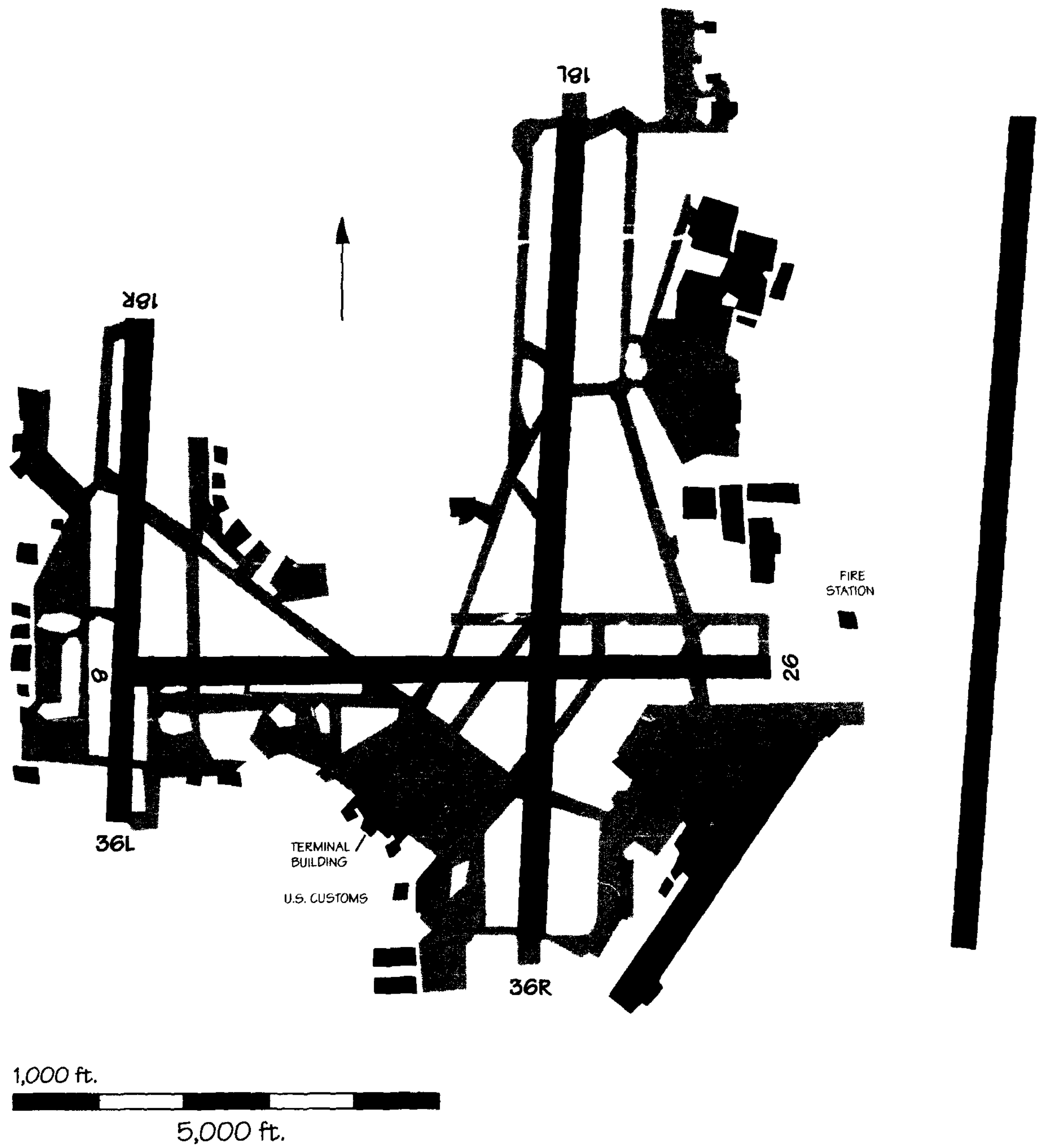
Tucson (TUS)

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 1997-1999. The cost of construction is estimated to be $143 million.



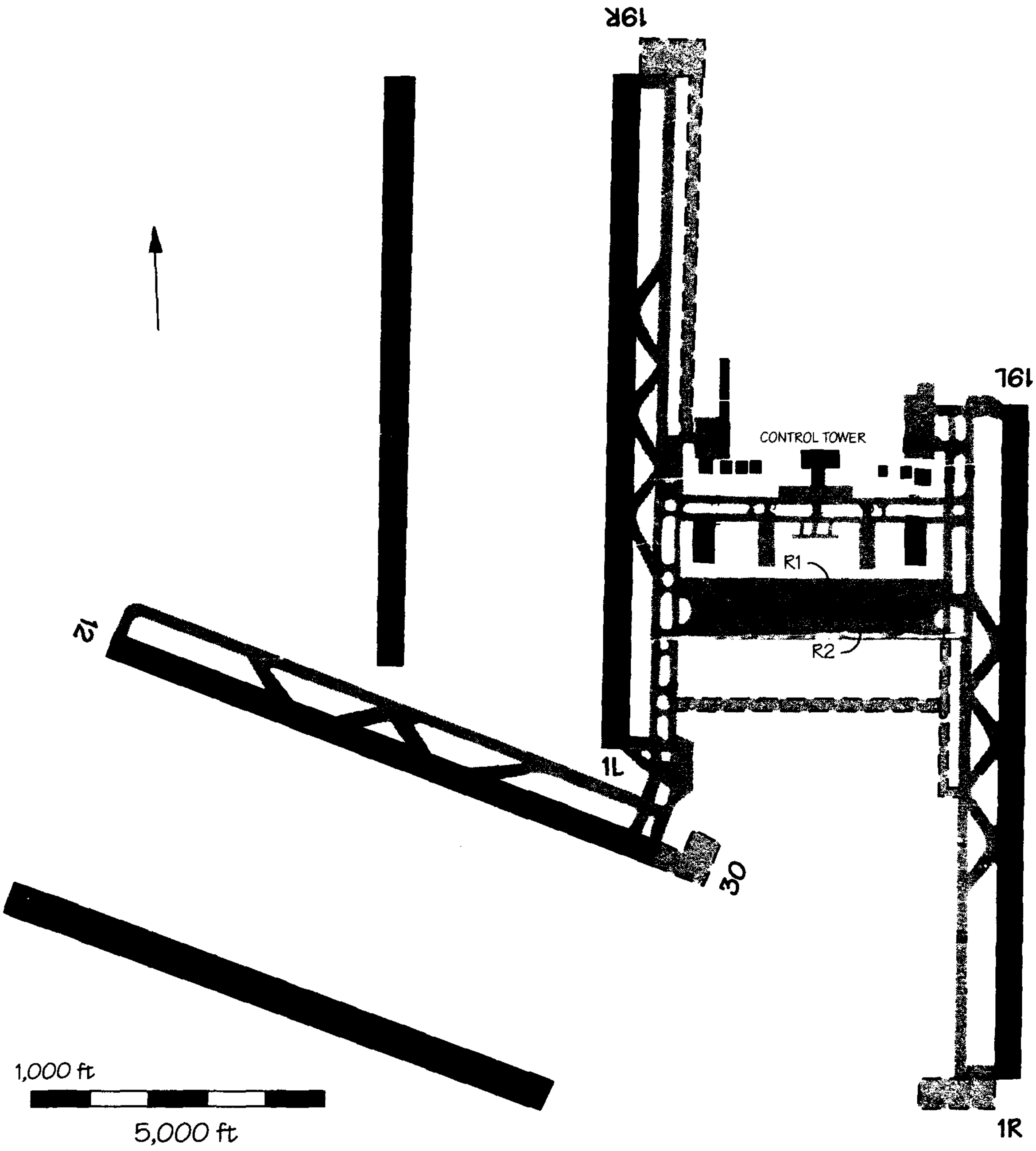
Tulsa (TUL)

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.



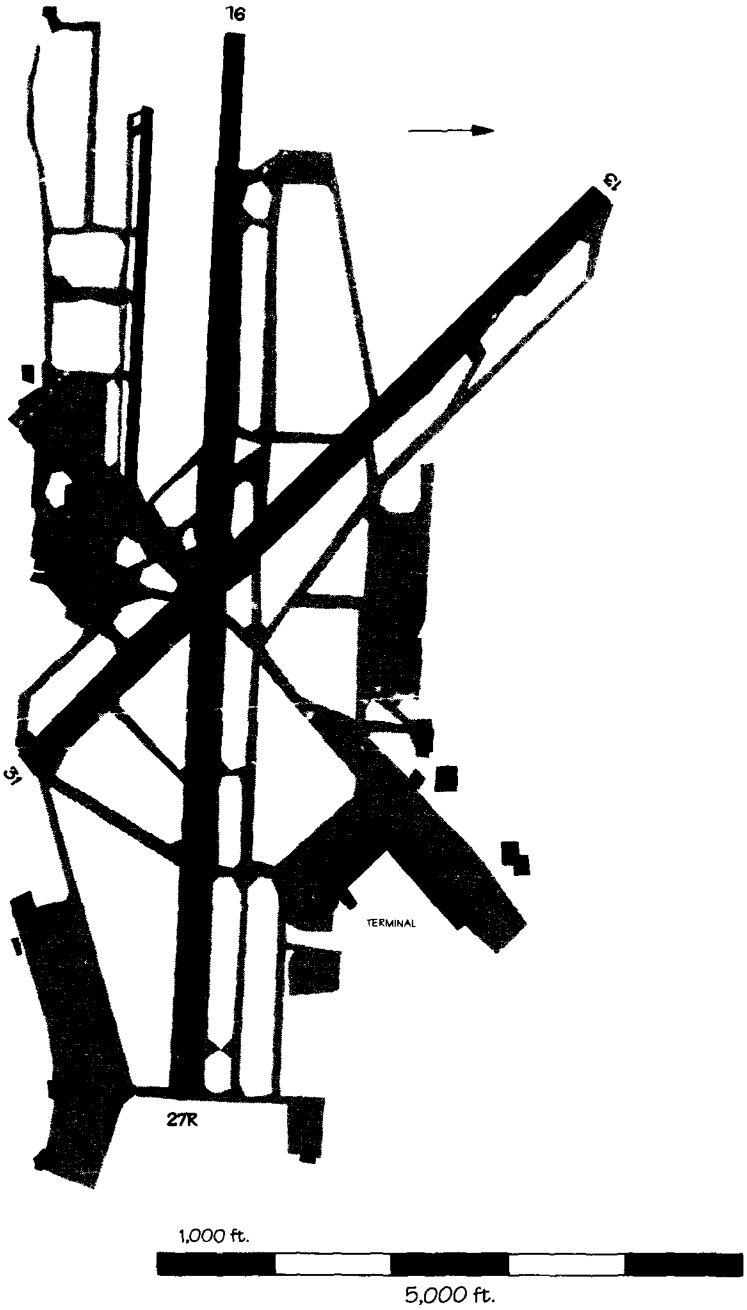
Washington (IAD)

Construction of an extension to Runway 12/30 was completed in 1992. The estimated cost of construction was $12 million. Two new parallel runways are under consideration. A north-south parallel, Runway 1W/19W, would be located 3,500 feet west of the existing parallels and north of Runway 12/30. This could provide triple independent parallel approaches, if they are 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)

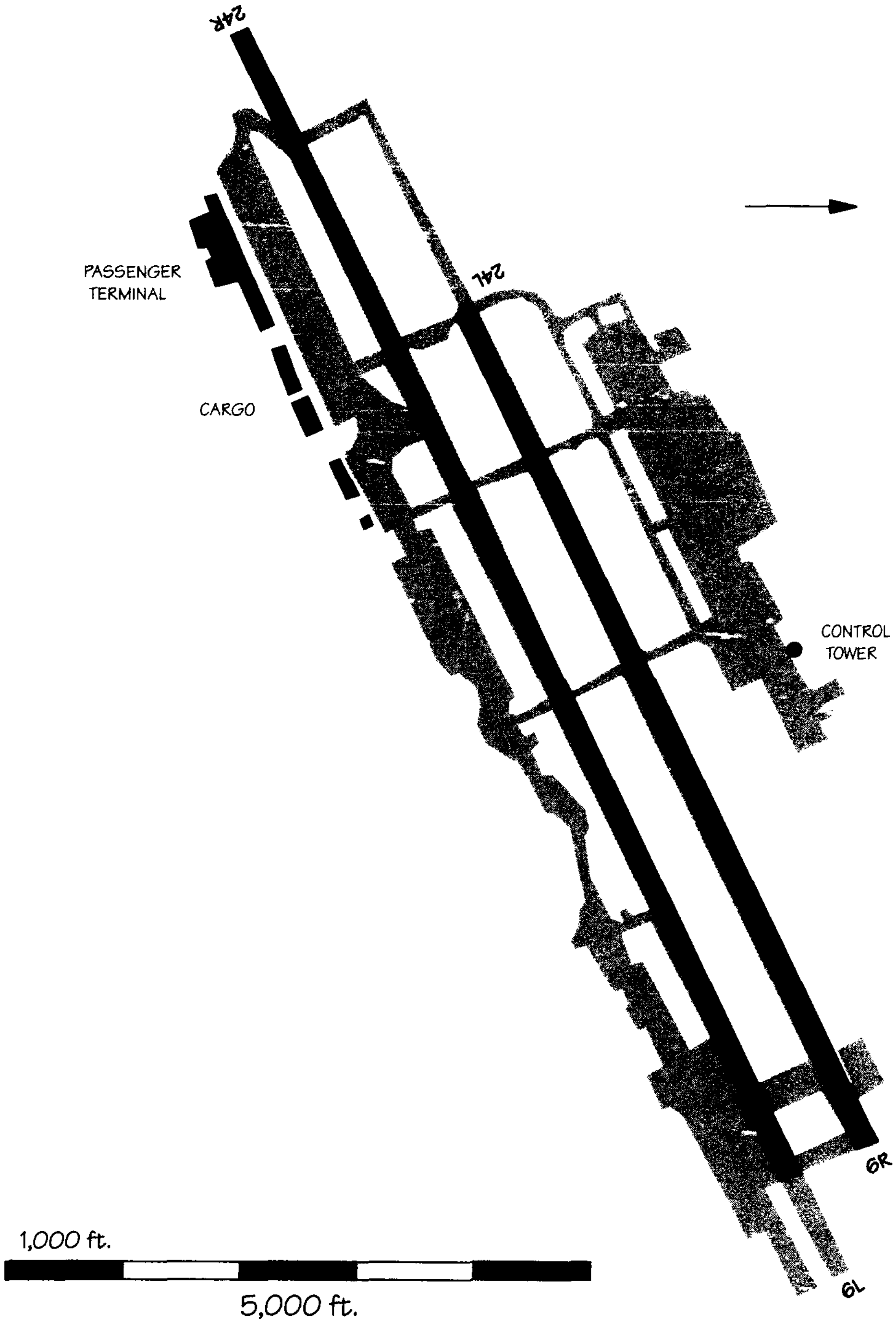
Runway 9L/27R will be extended 1,200 feet to the west and 811 feet to the east, for a total length of 10,000 feet. Construction is estimated to be completed in 1998. The total estimated project cost is $5 million. In addition, an extension of Runway 13/31 is planned to be complete in 1995 at a cost of $5 million.



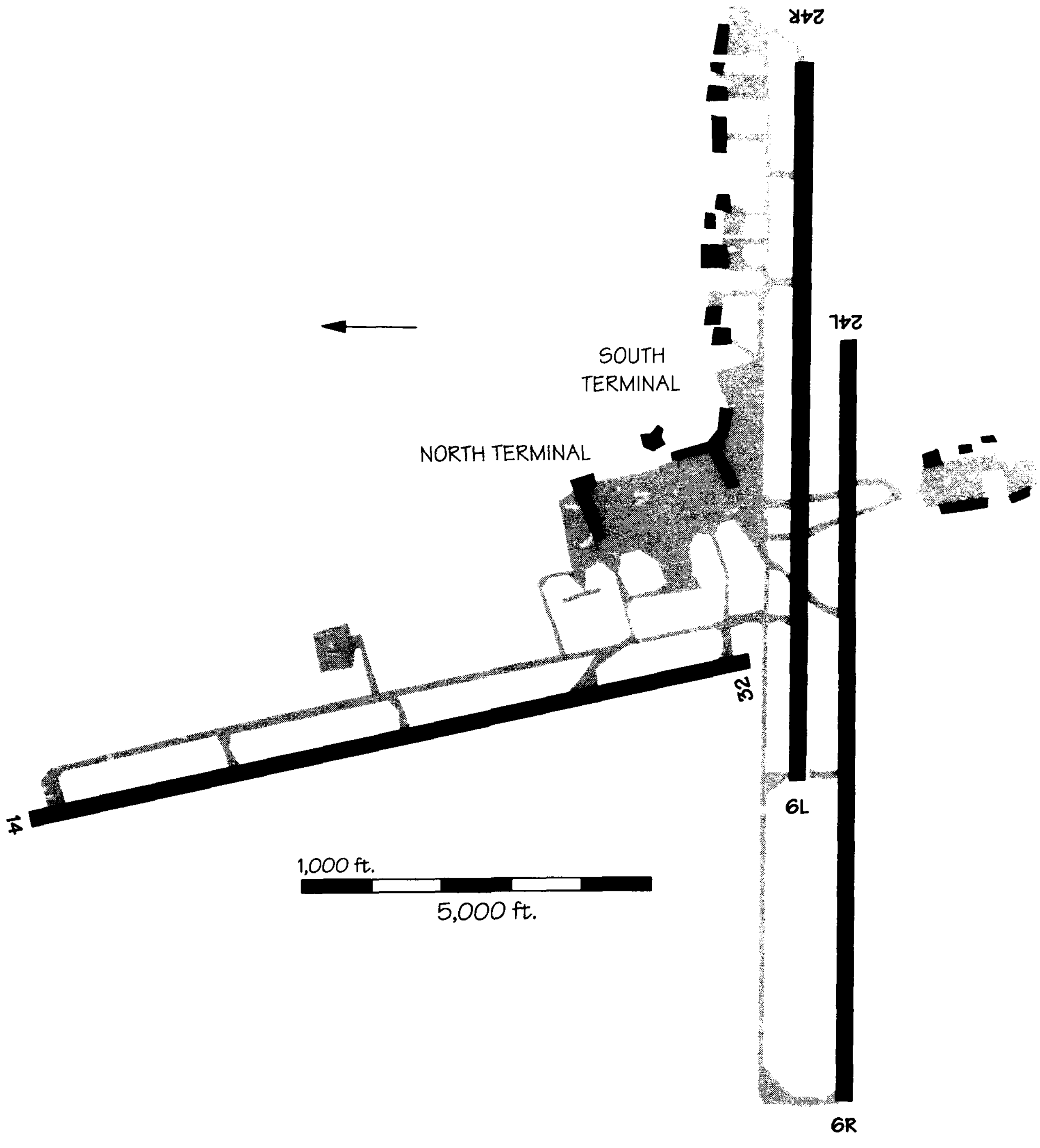
Appendix E

Layouts of the Remaining Top 100 Airports[1]

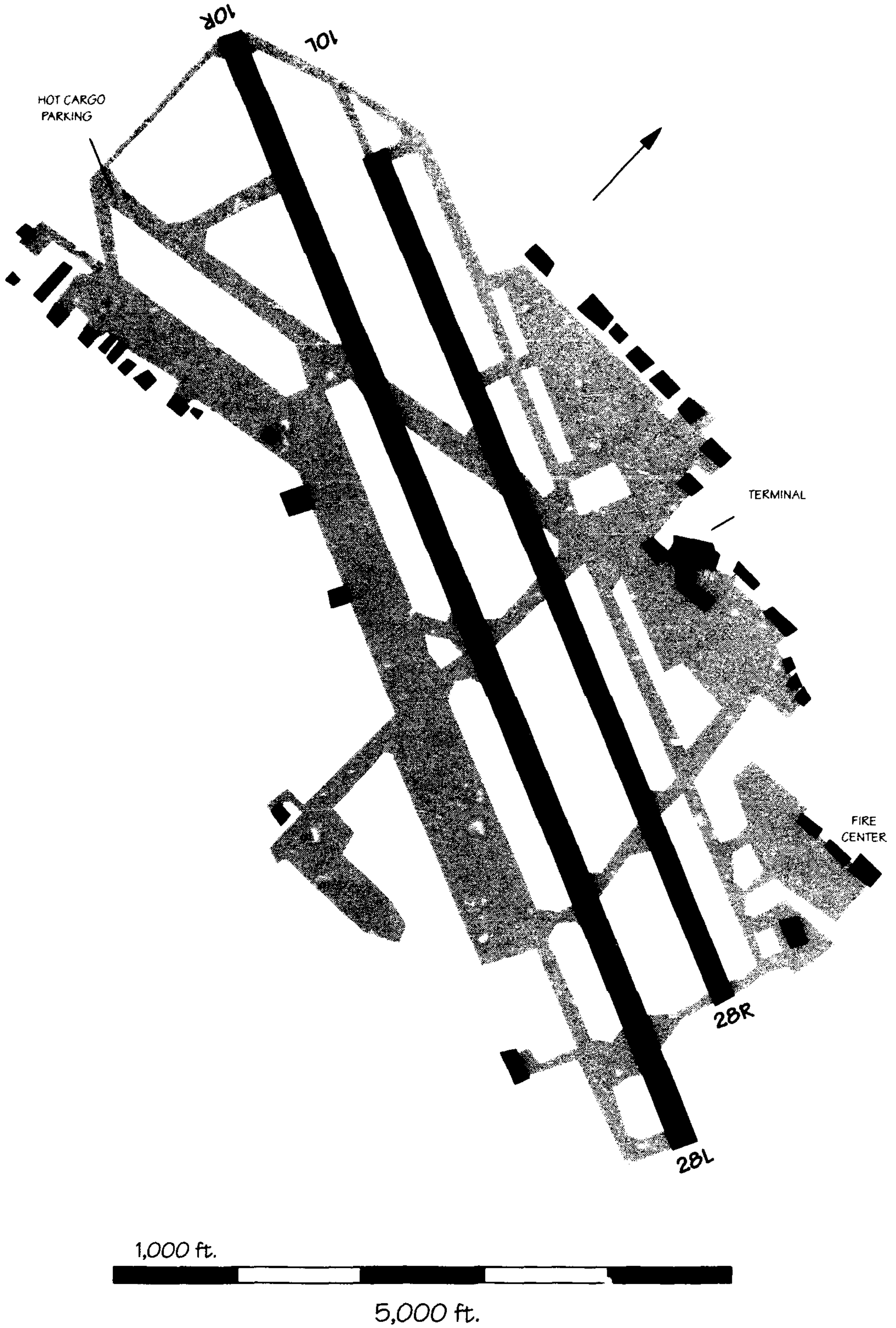
1. All 100 airports are pictured in either Appendix C, Appendix D, or Appendix E, with some duplication between appendicies. See Appendix B for a complete listing of ALPs and their locations.



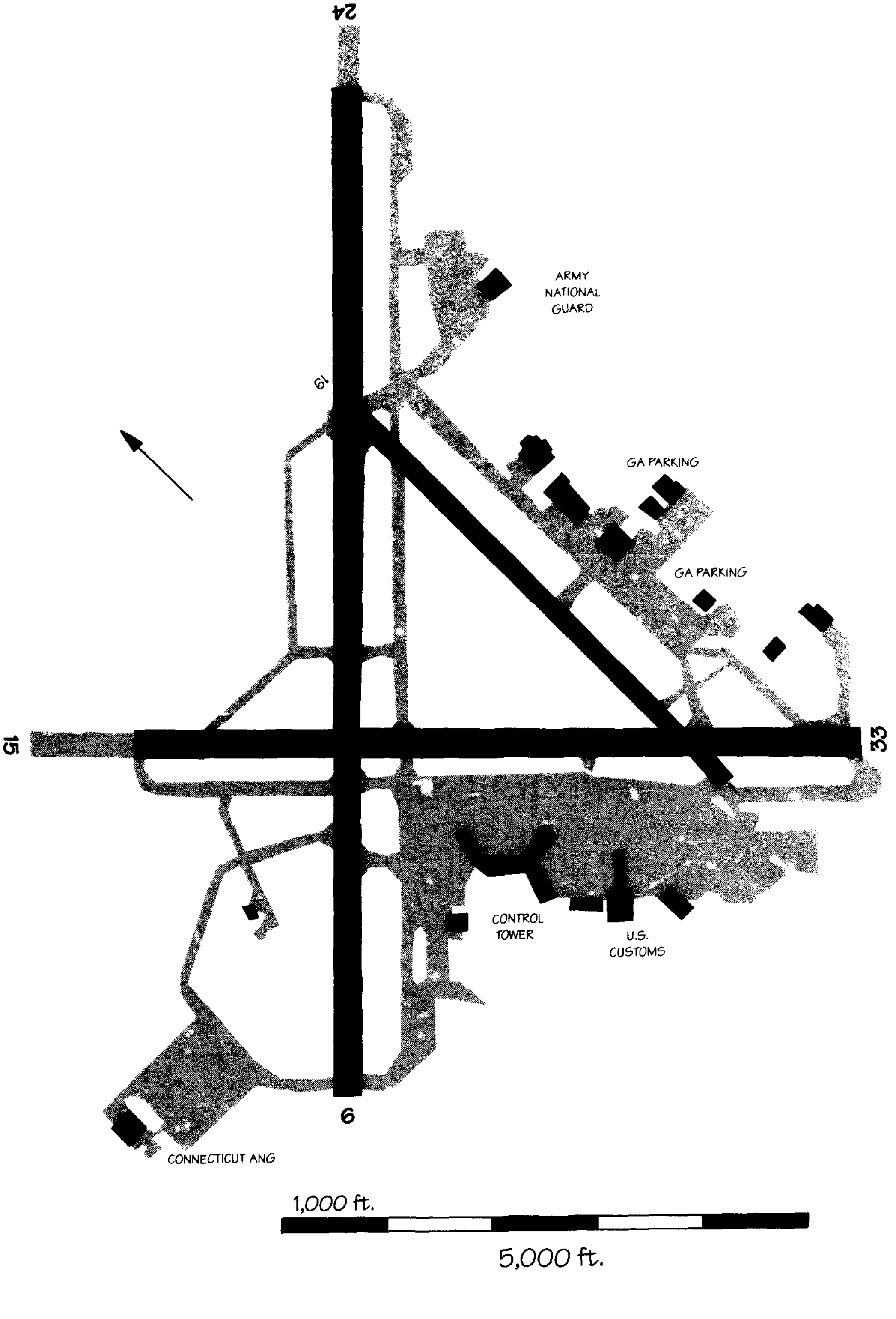
Agana Field, Guam



Anchorage International Airport

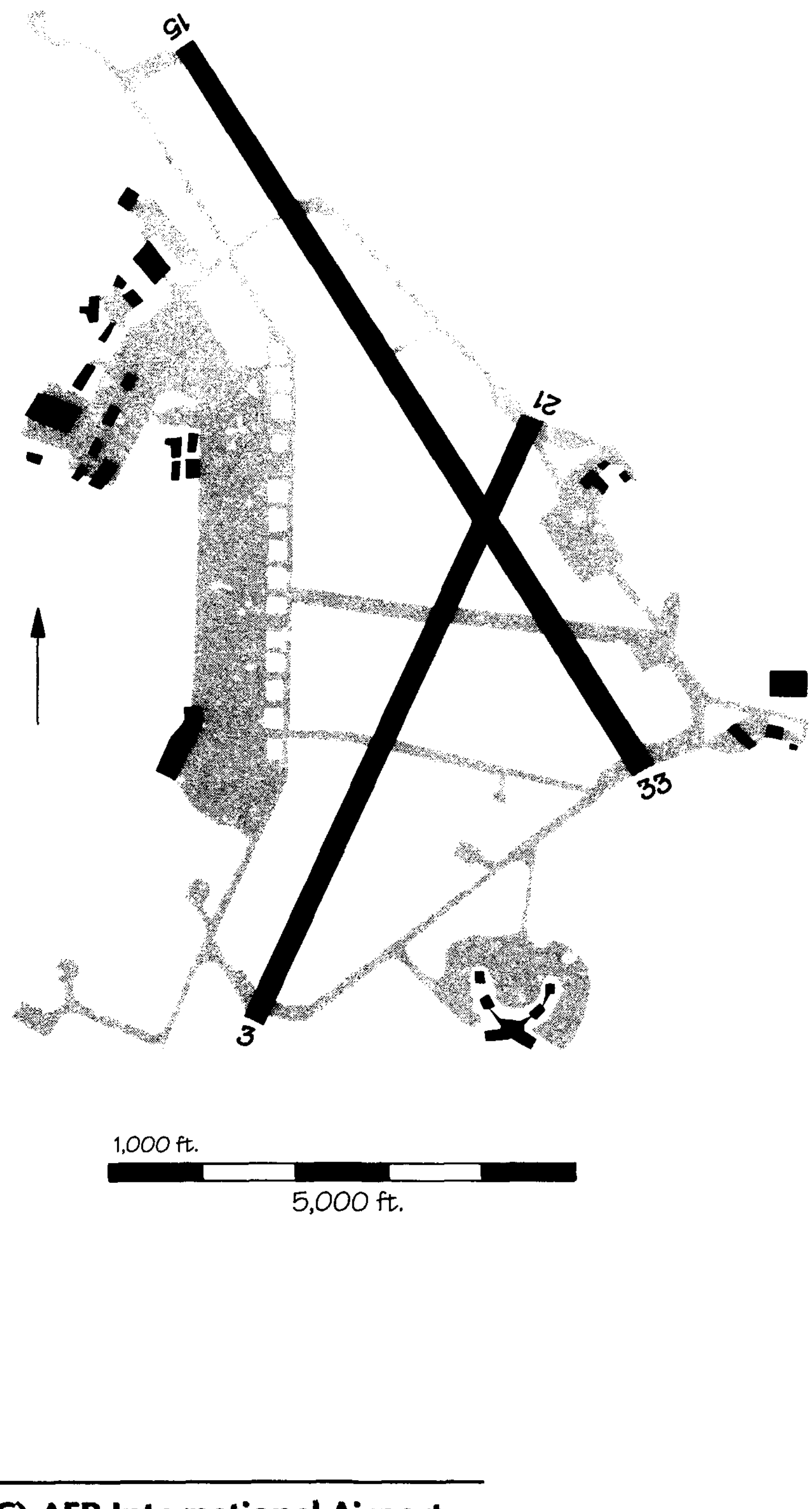


Boise Air Terminal Gowen Field

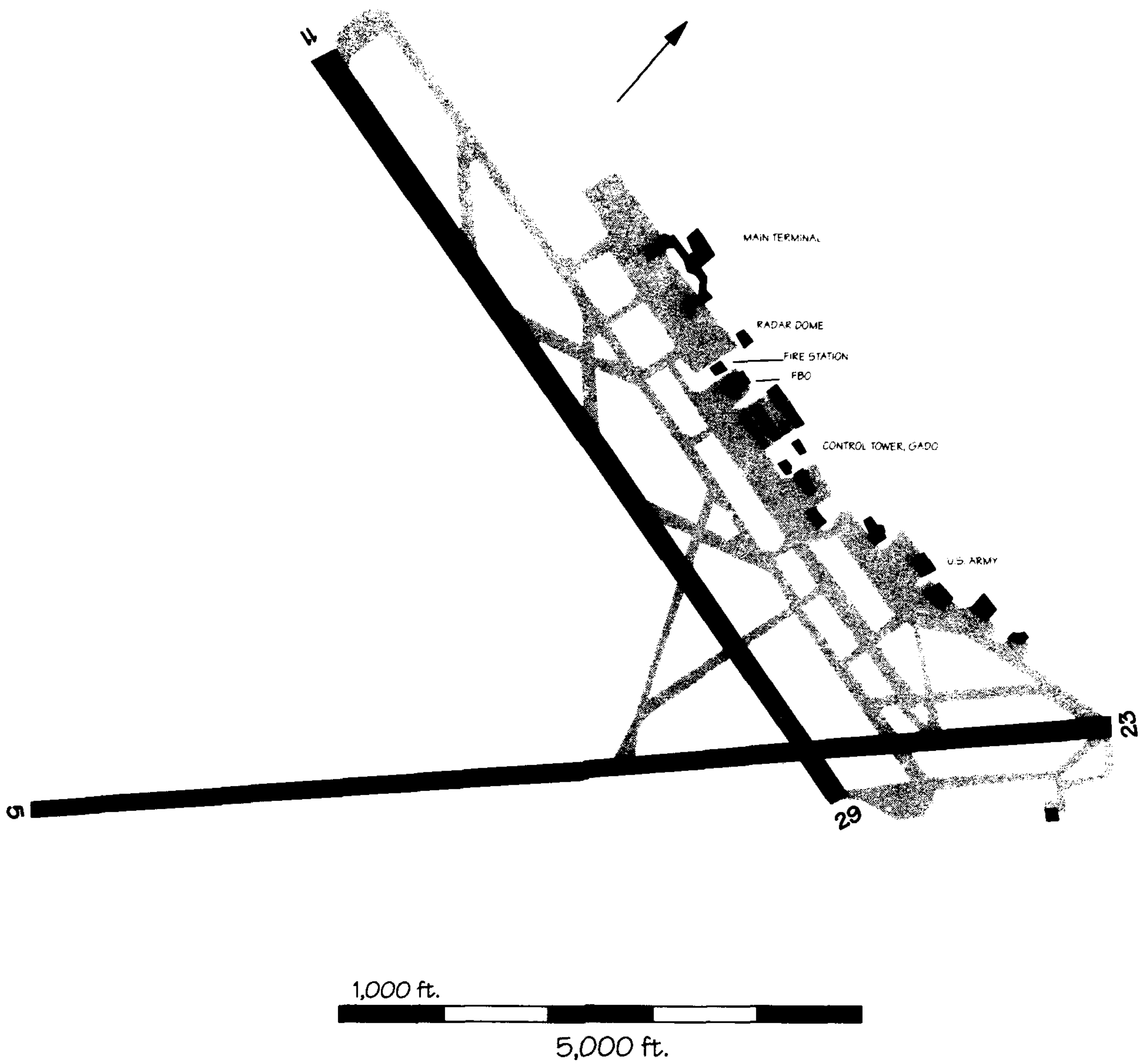


Bradley International Airport

Burbank-Glendale-Pasadena Airport

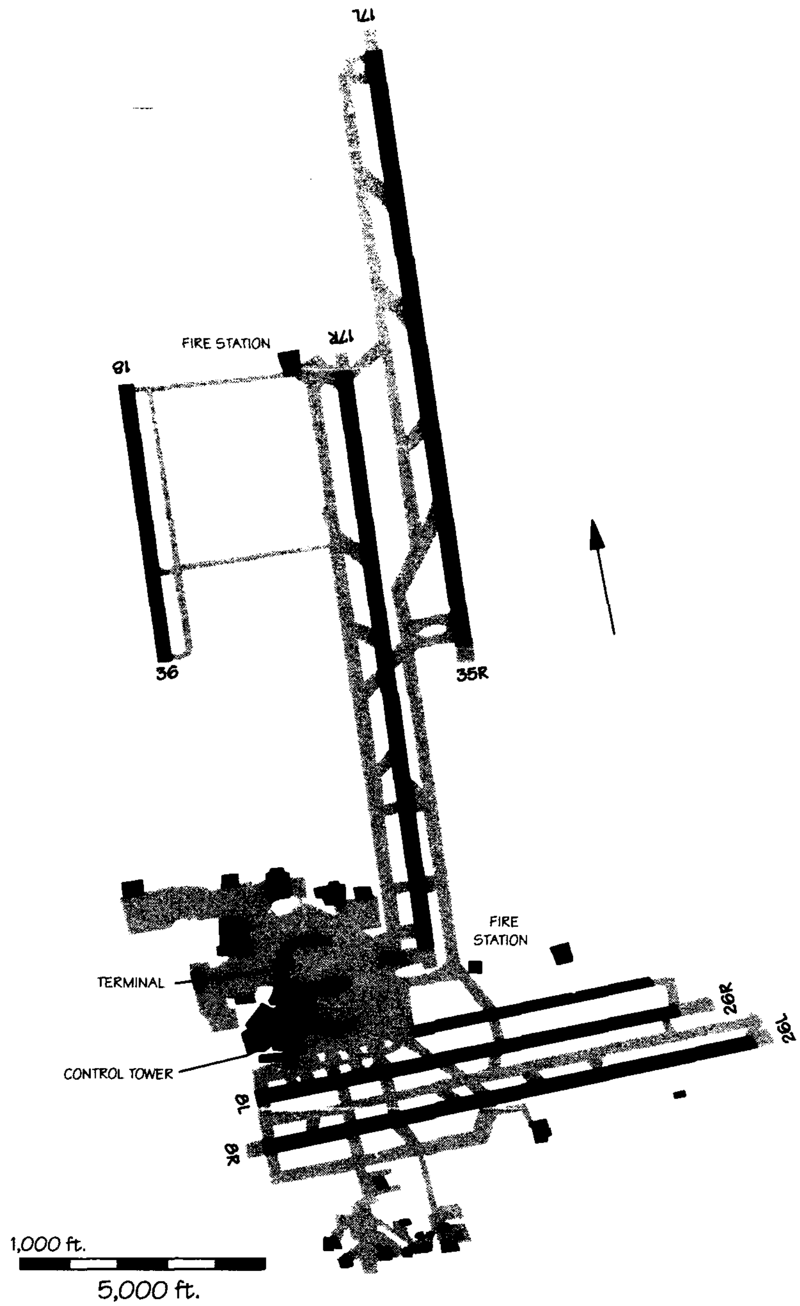


Charleston (SC) AFB International Airport

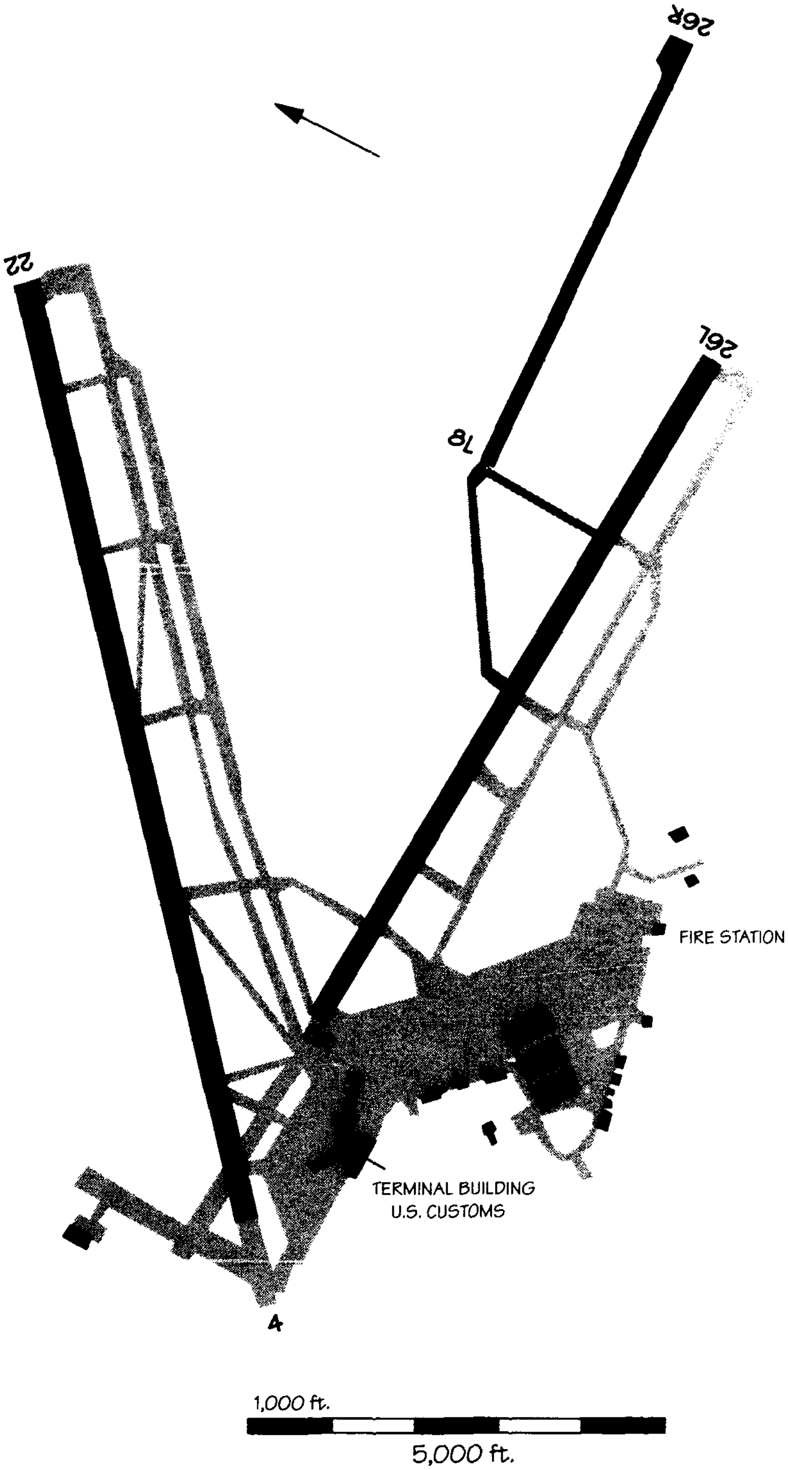


Columbia Metropolitan Airport

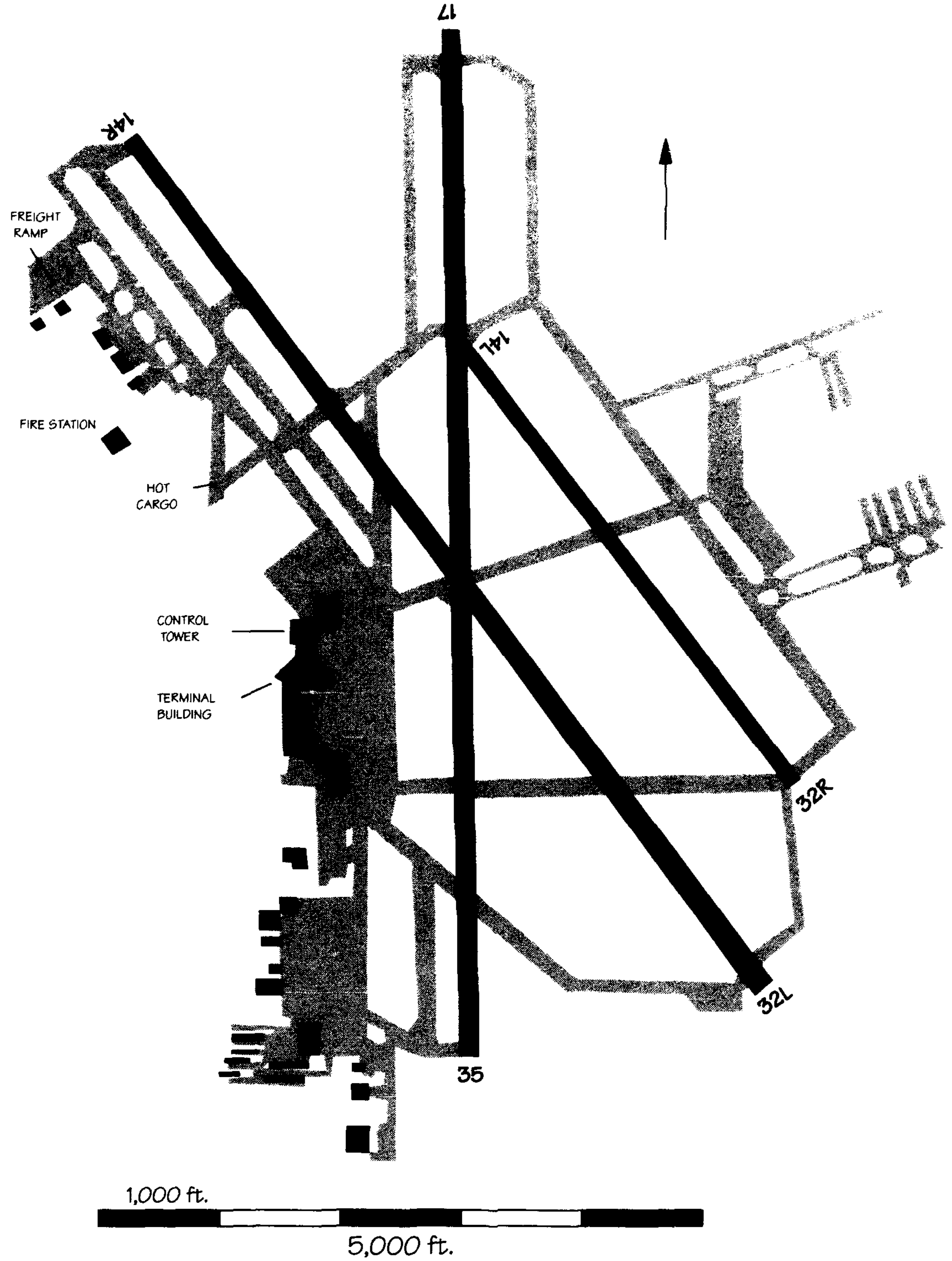
Dallas-Love Field Airport



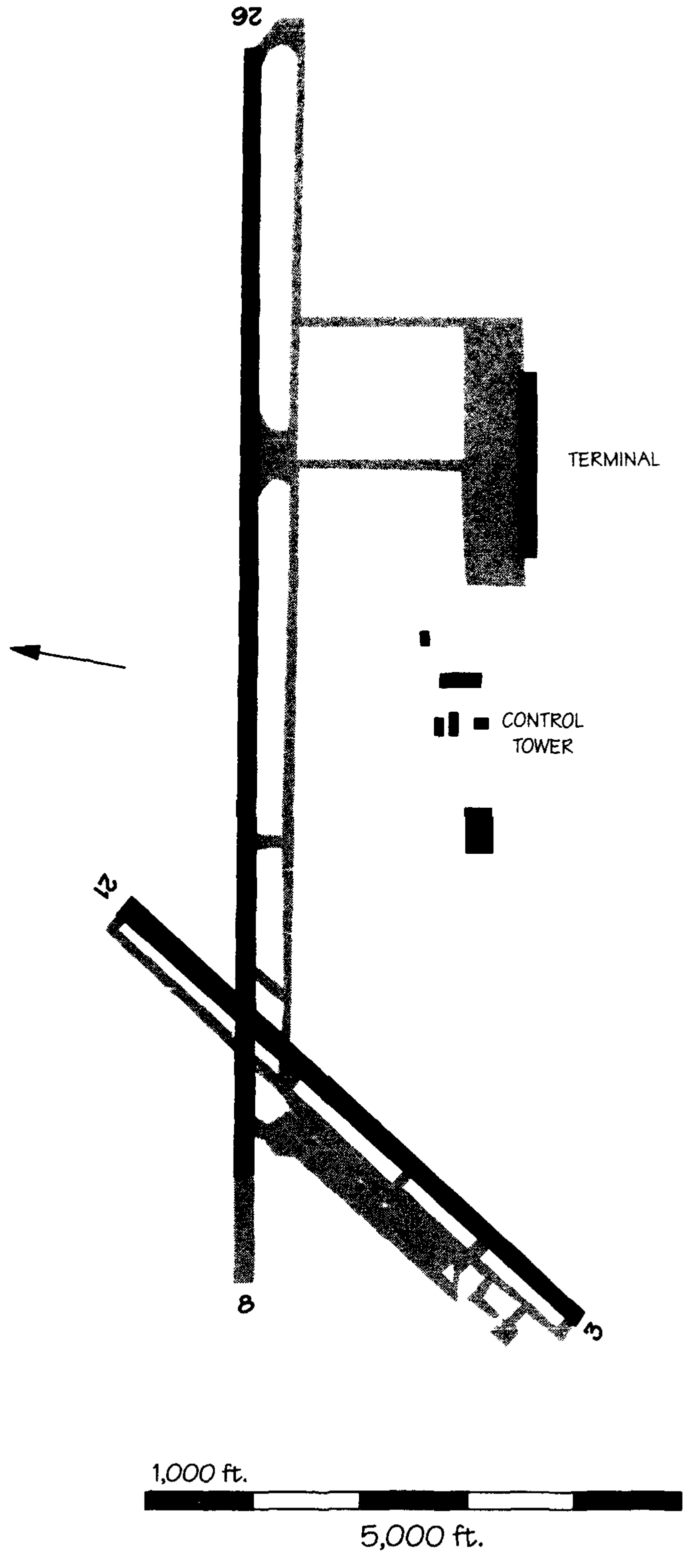
Denver Stapleton International



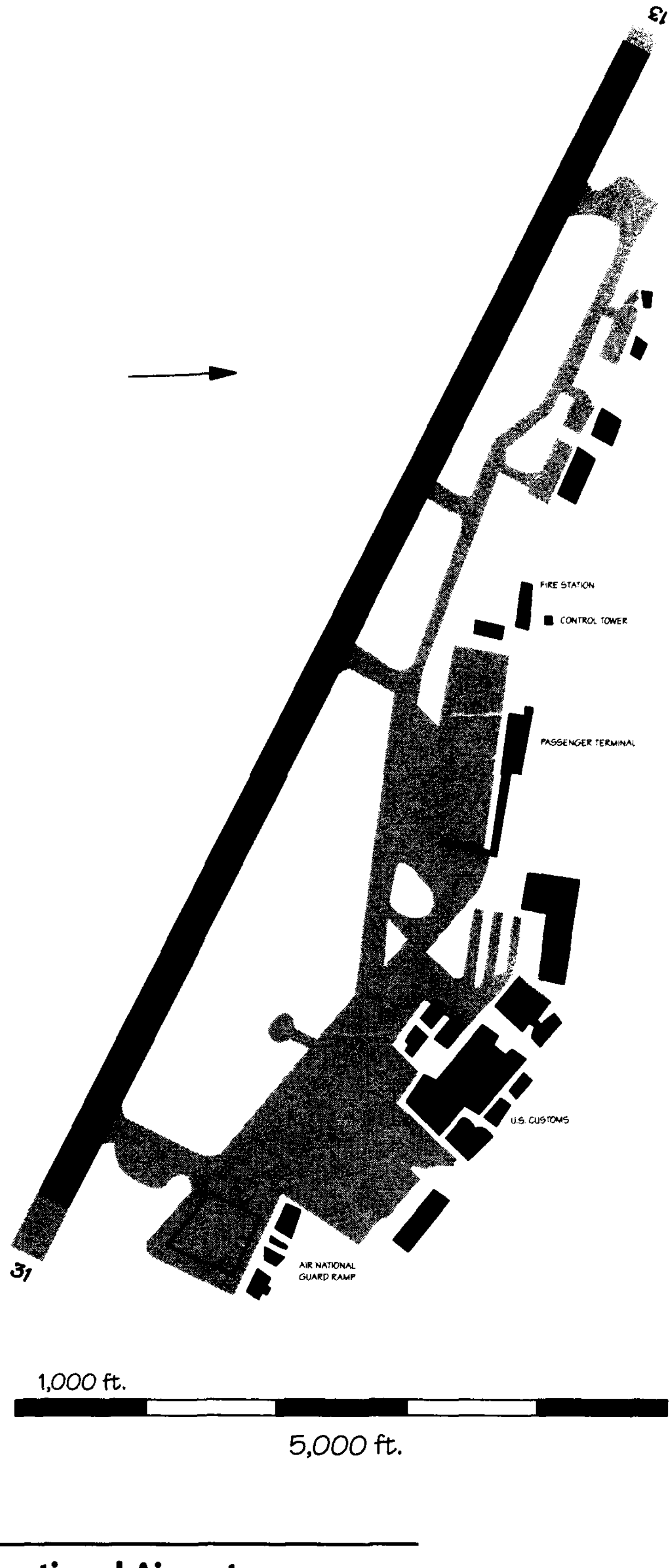
El Paso International Airport



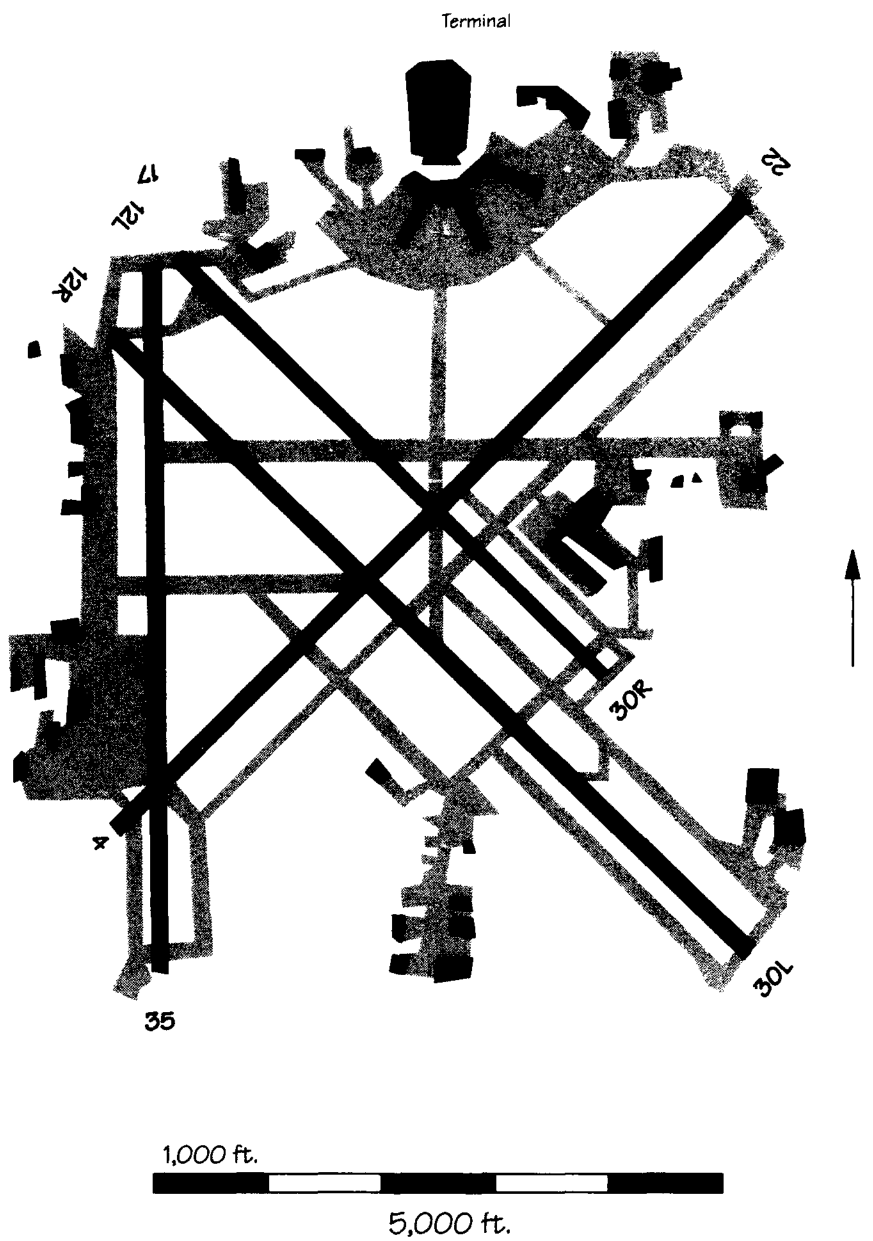
Eppley Field Airport (Omaha)



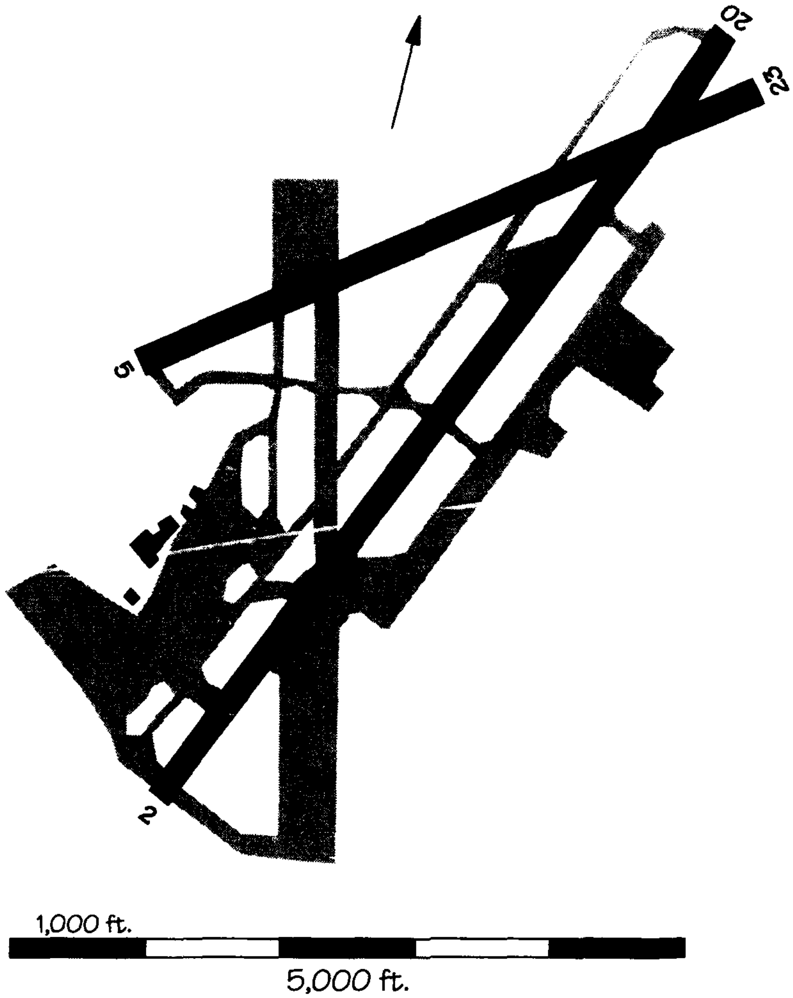
General Lyman Field Airport (Hilo)



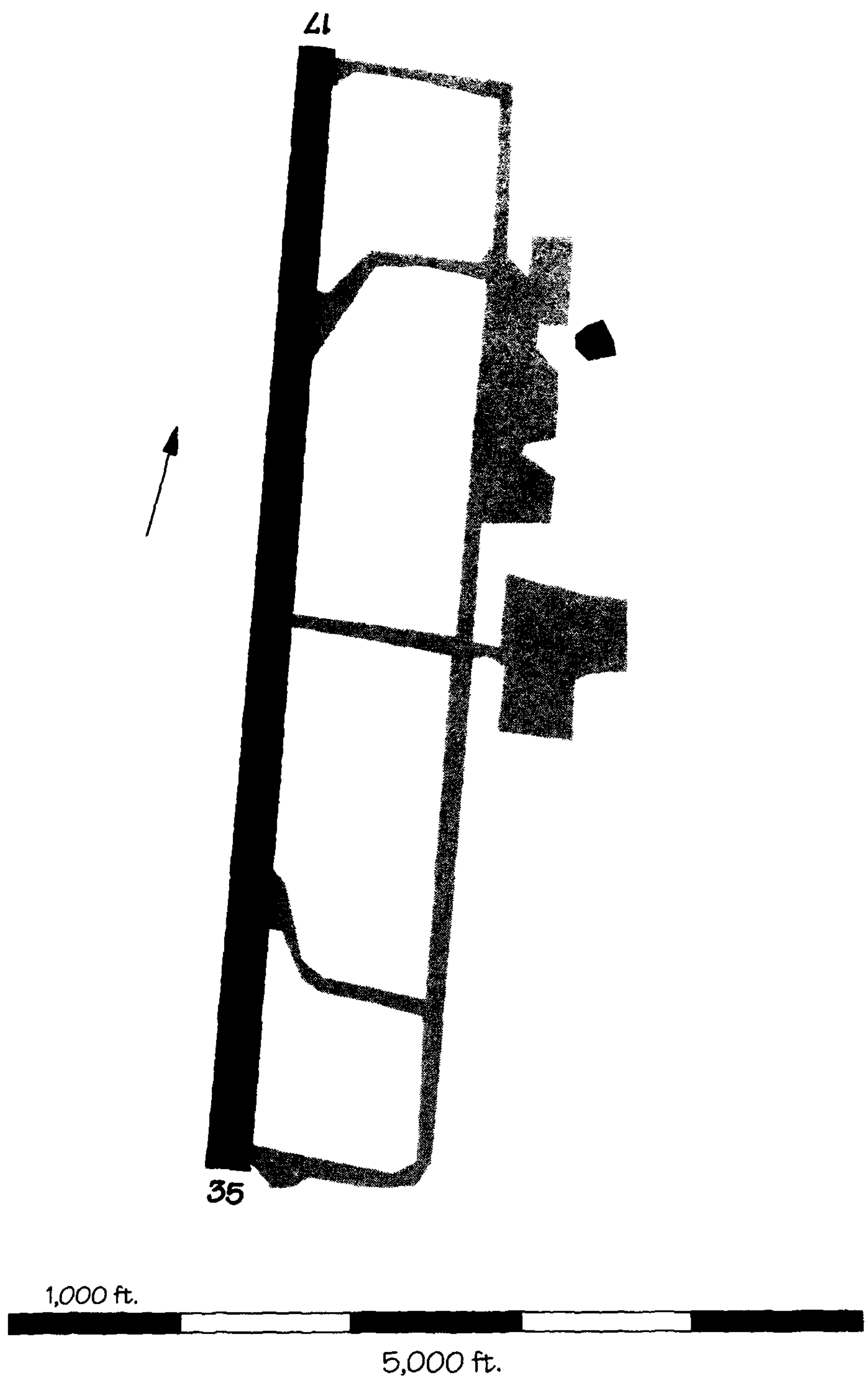
Harrisburg International Airport



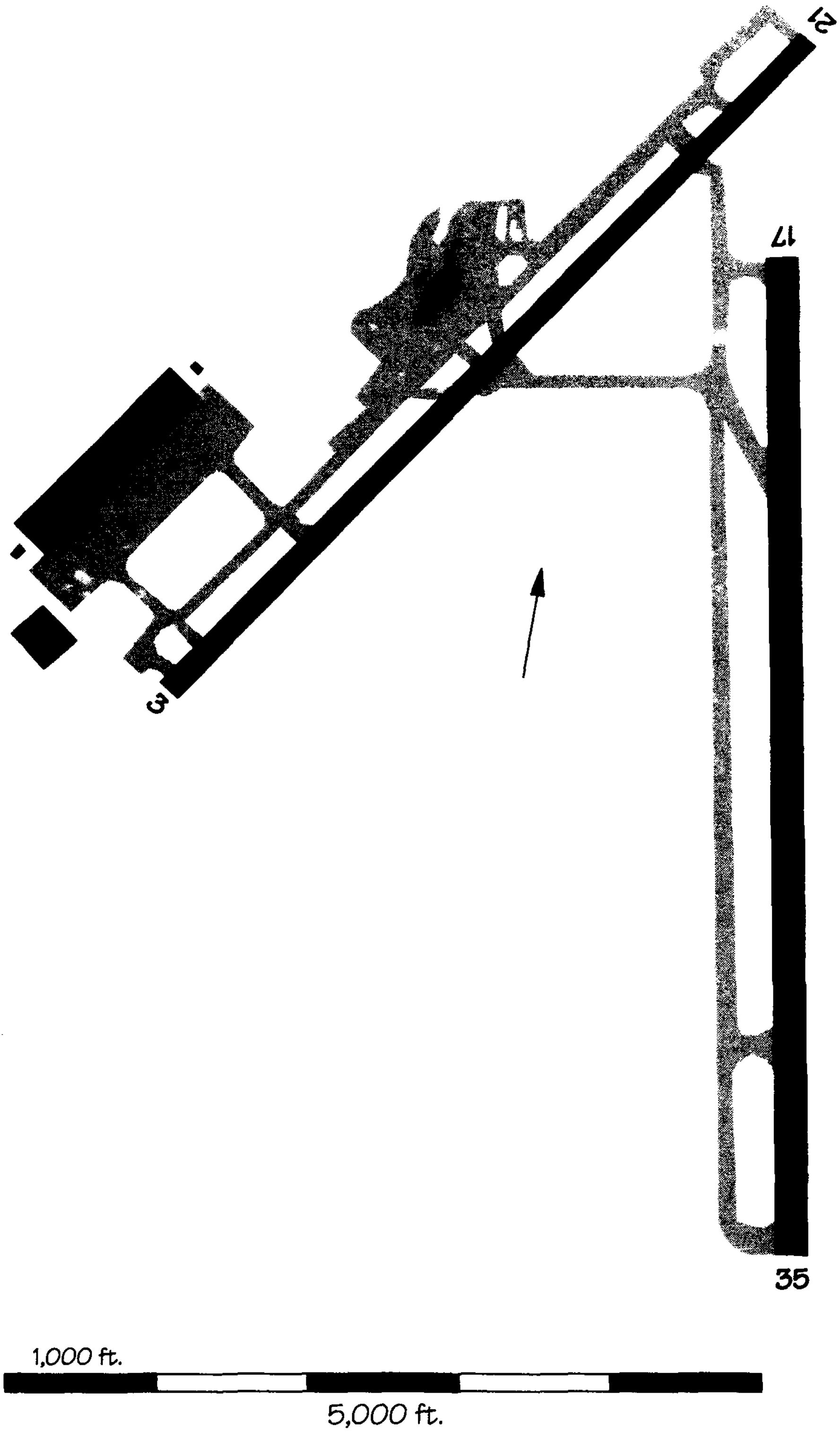
Houston Hobby



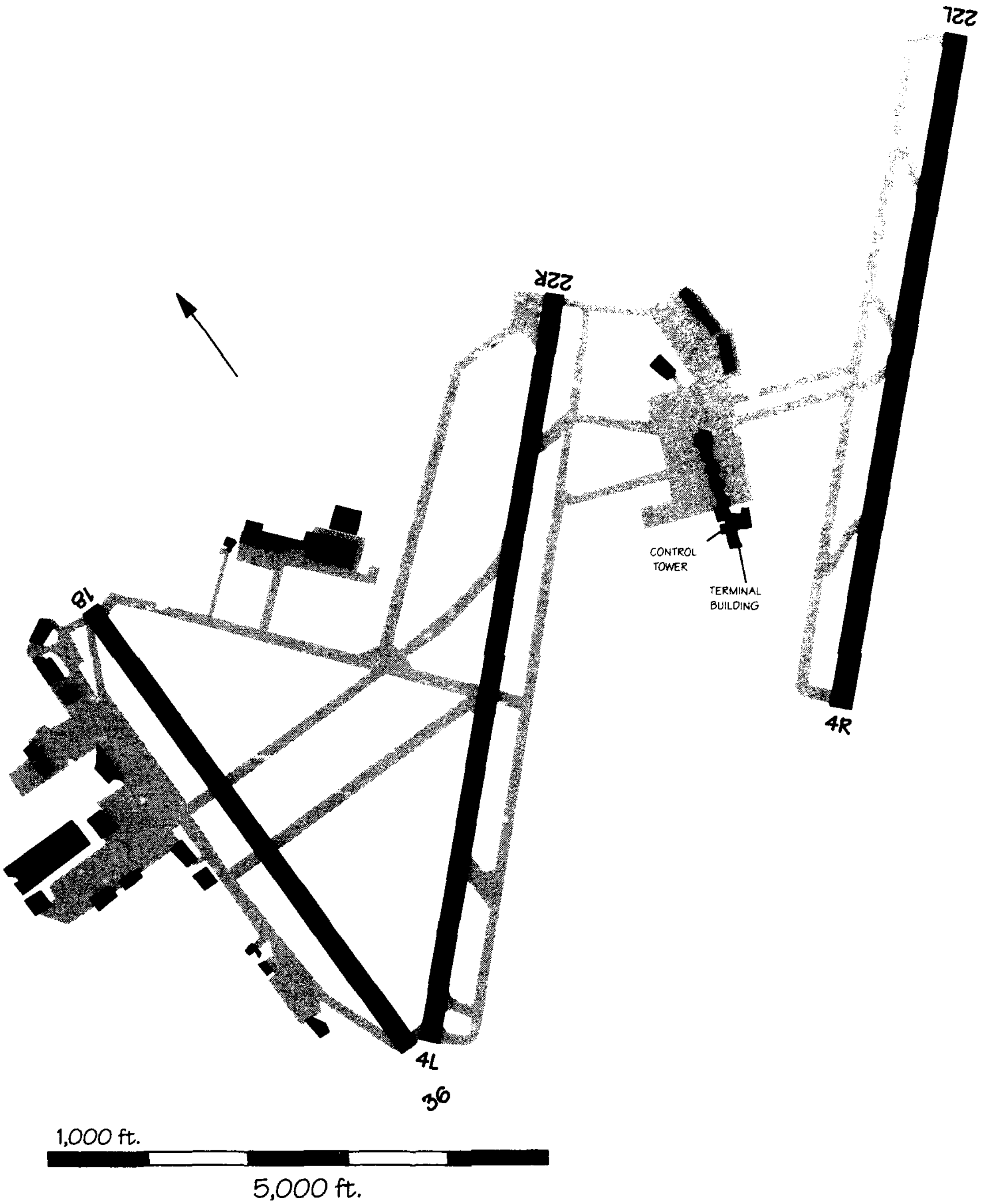
Kahului Airport



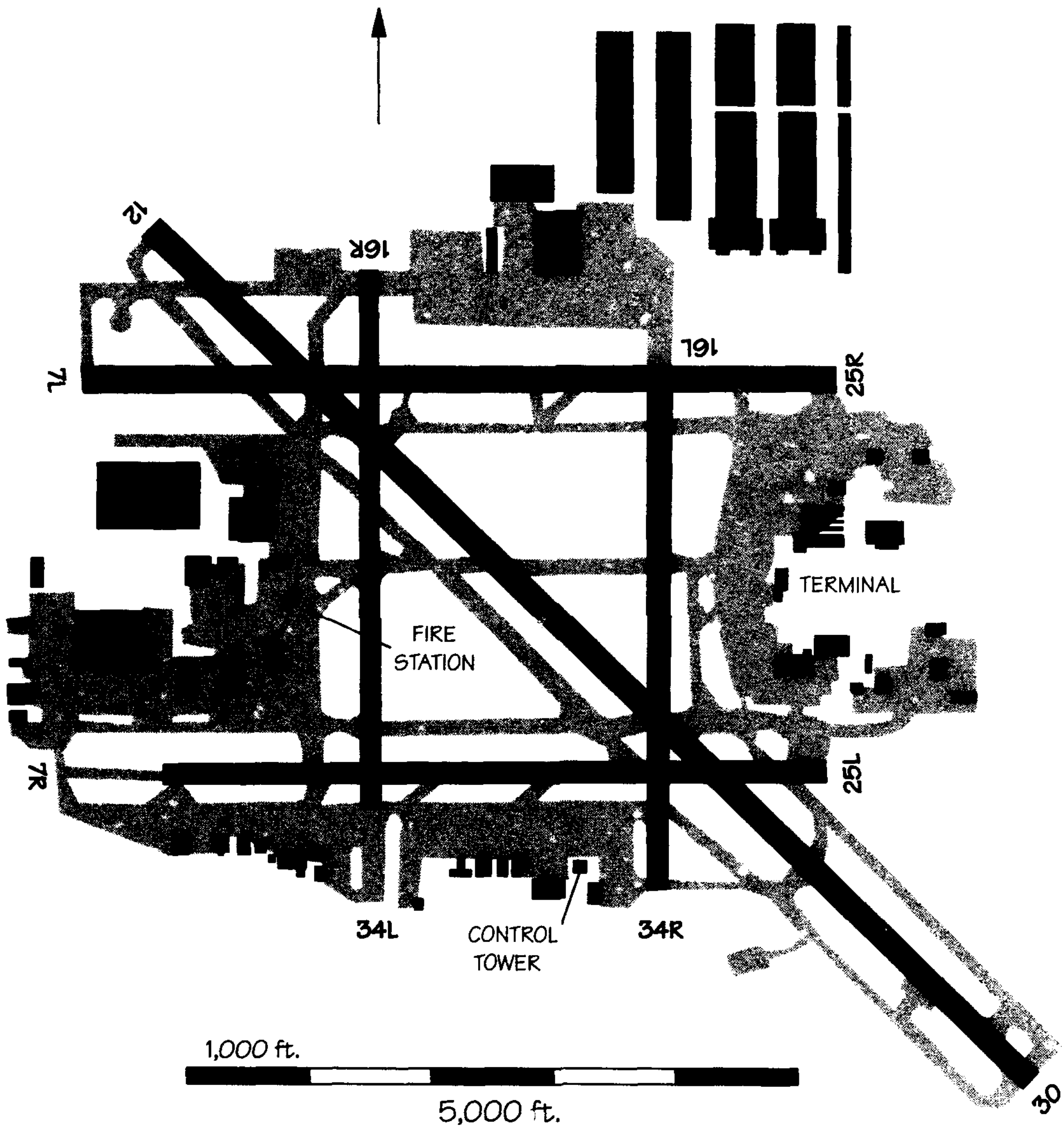
Keahole Airport (Kailua-Kona)



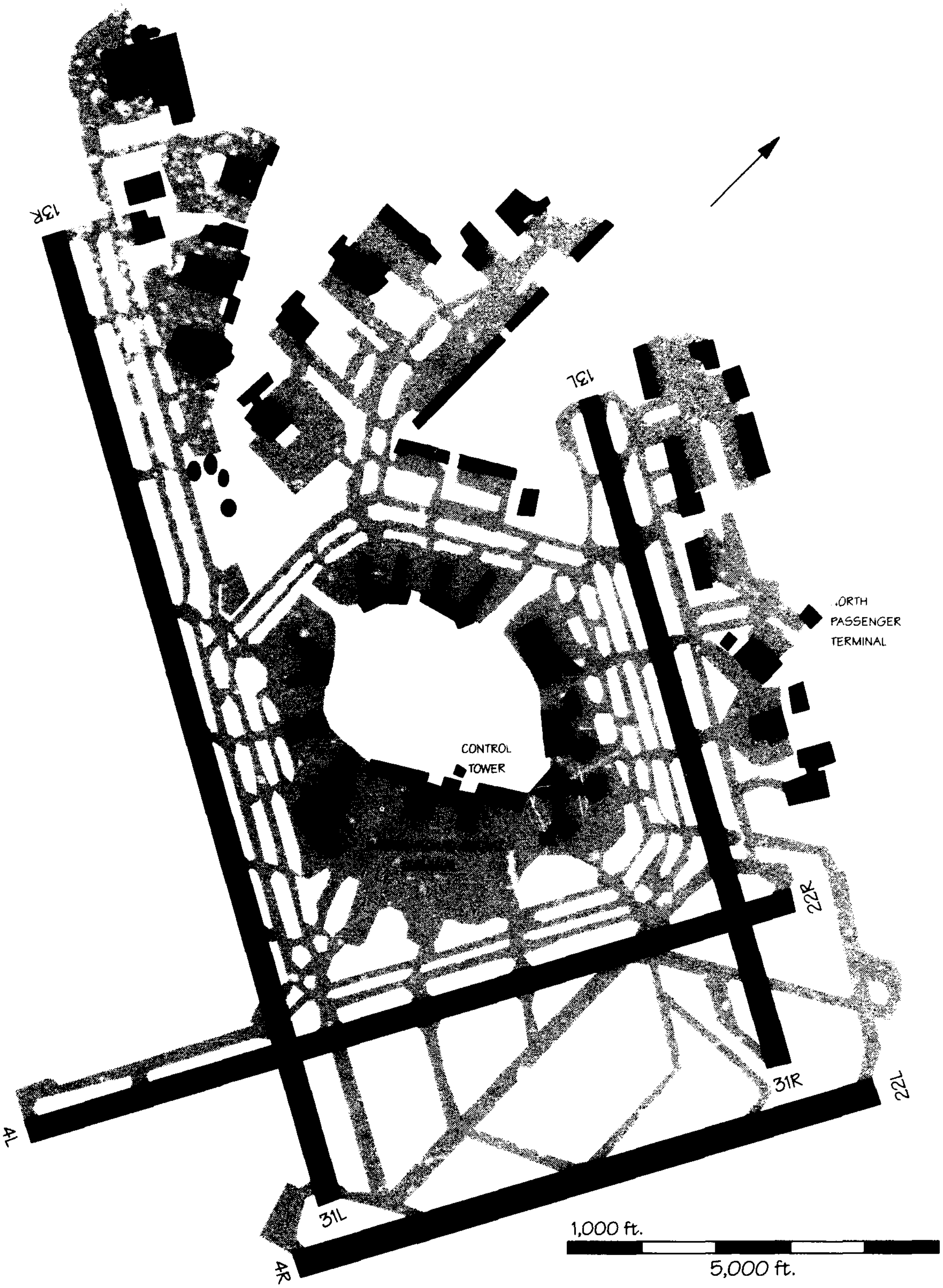
Lihue Airport



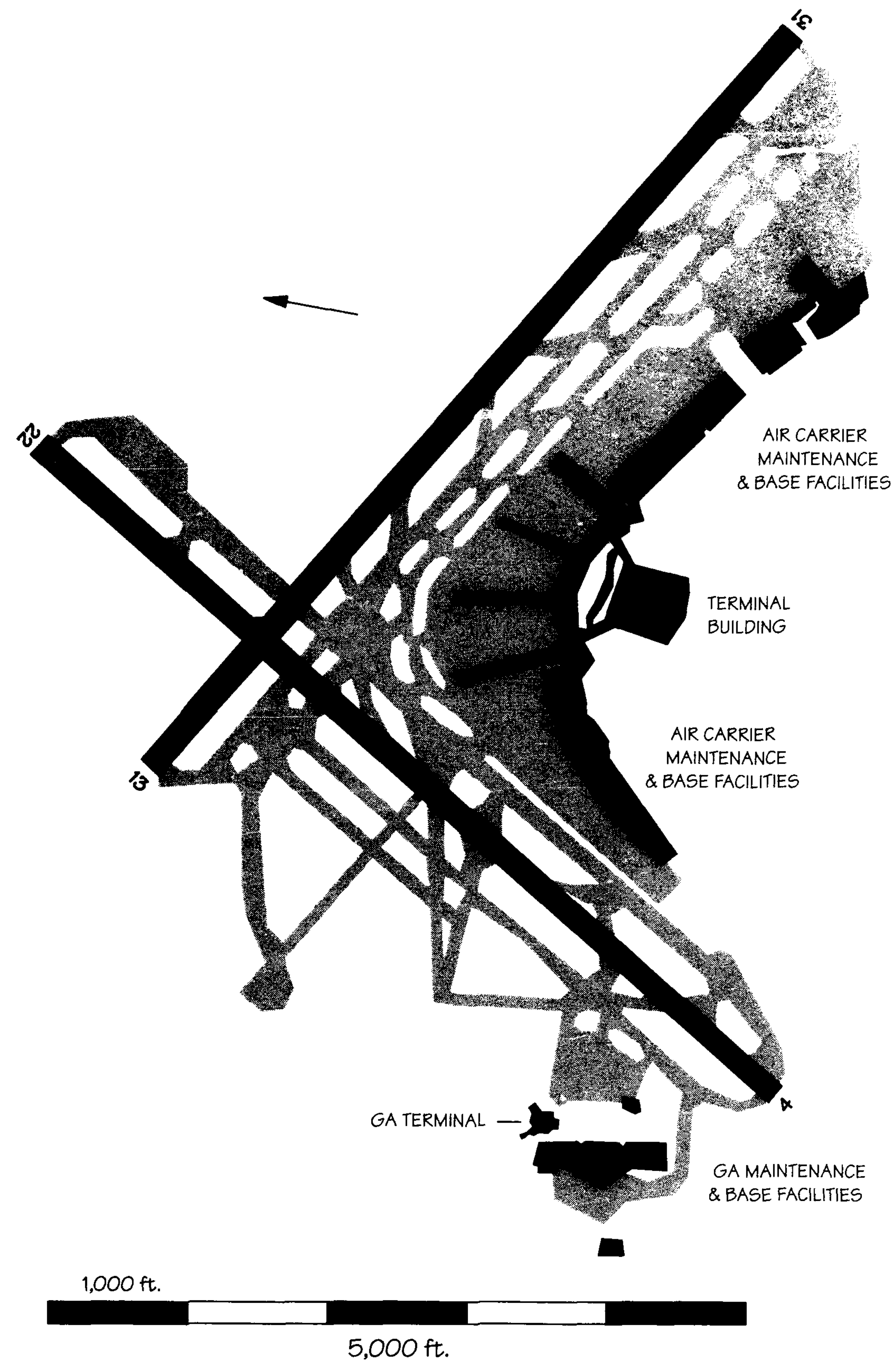
Little Rock Adams Field



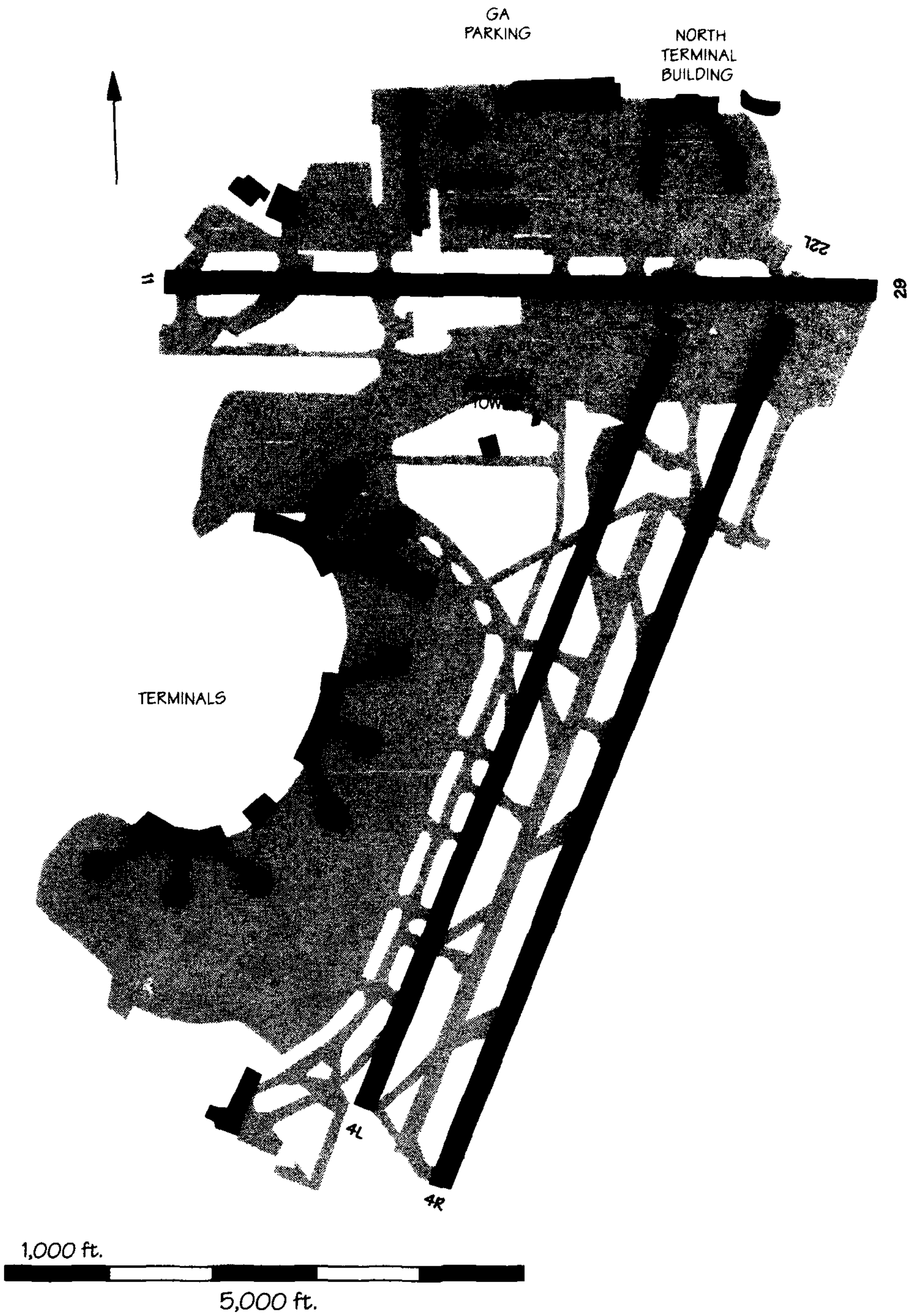
Long Beach Daugherty Field Airport



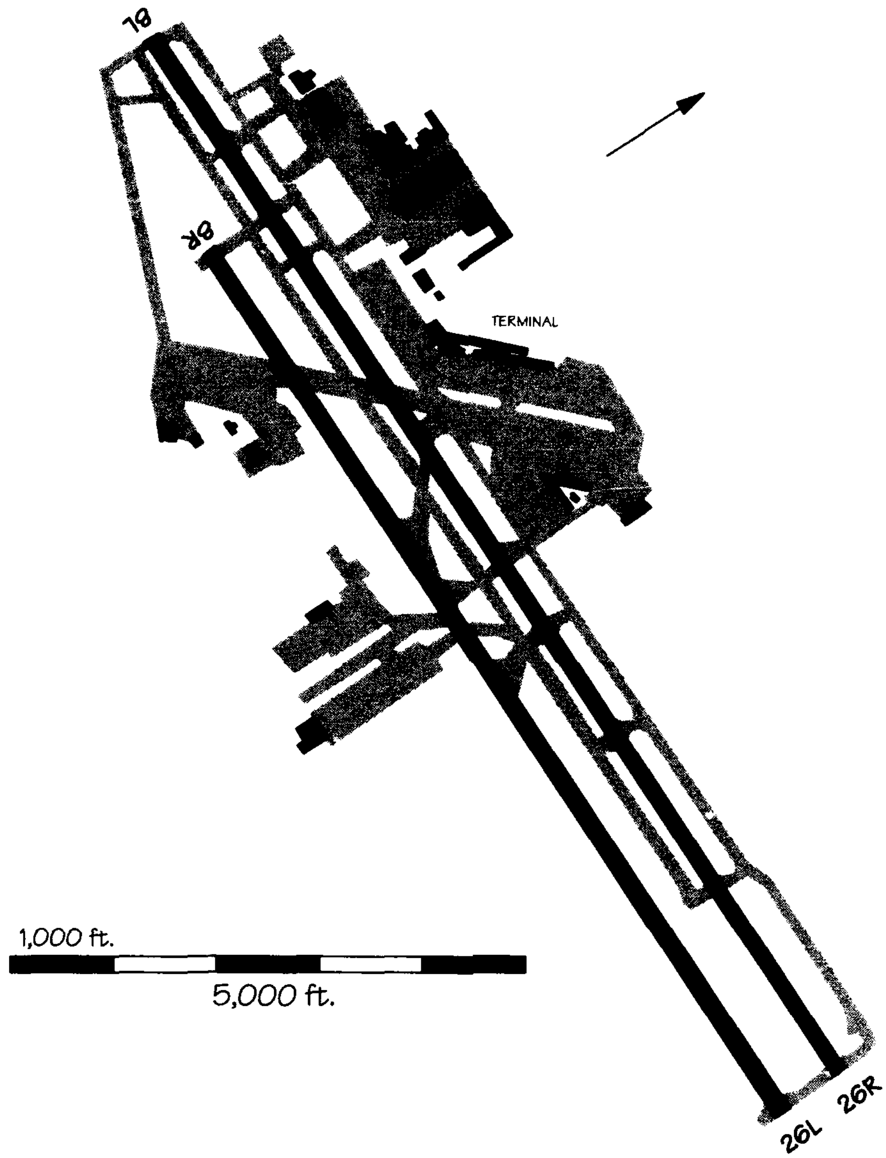
New York John F. Kennedy International Airport



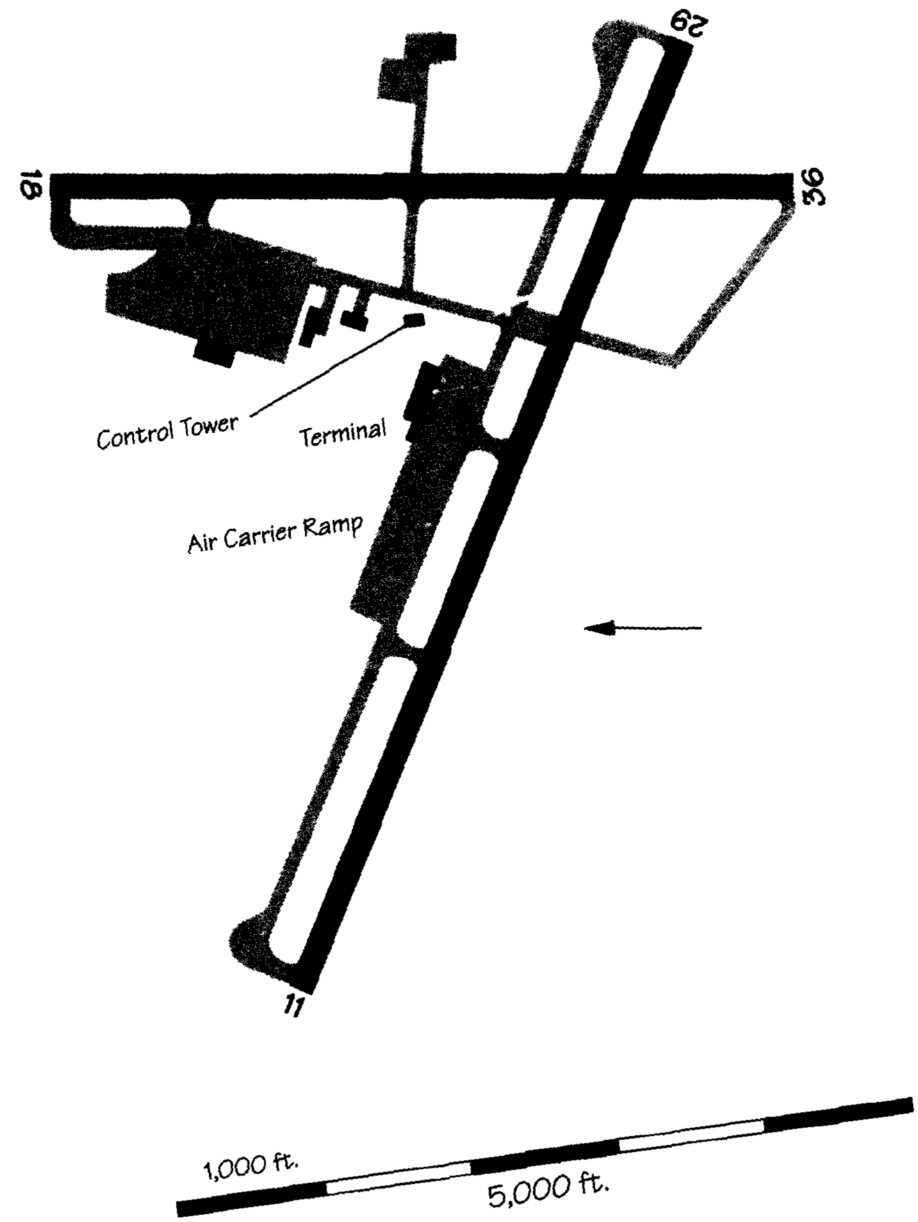
New York La Guardia Airport

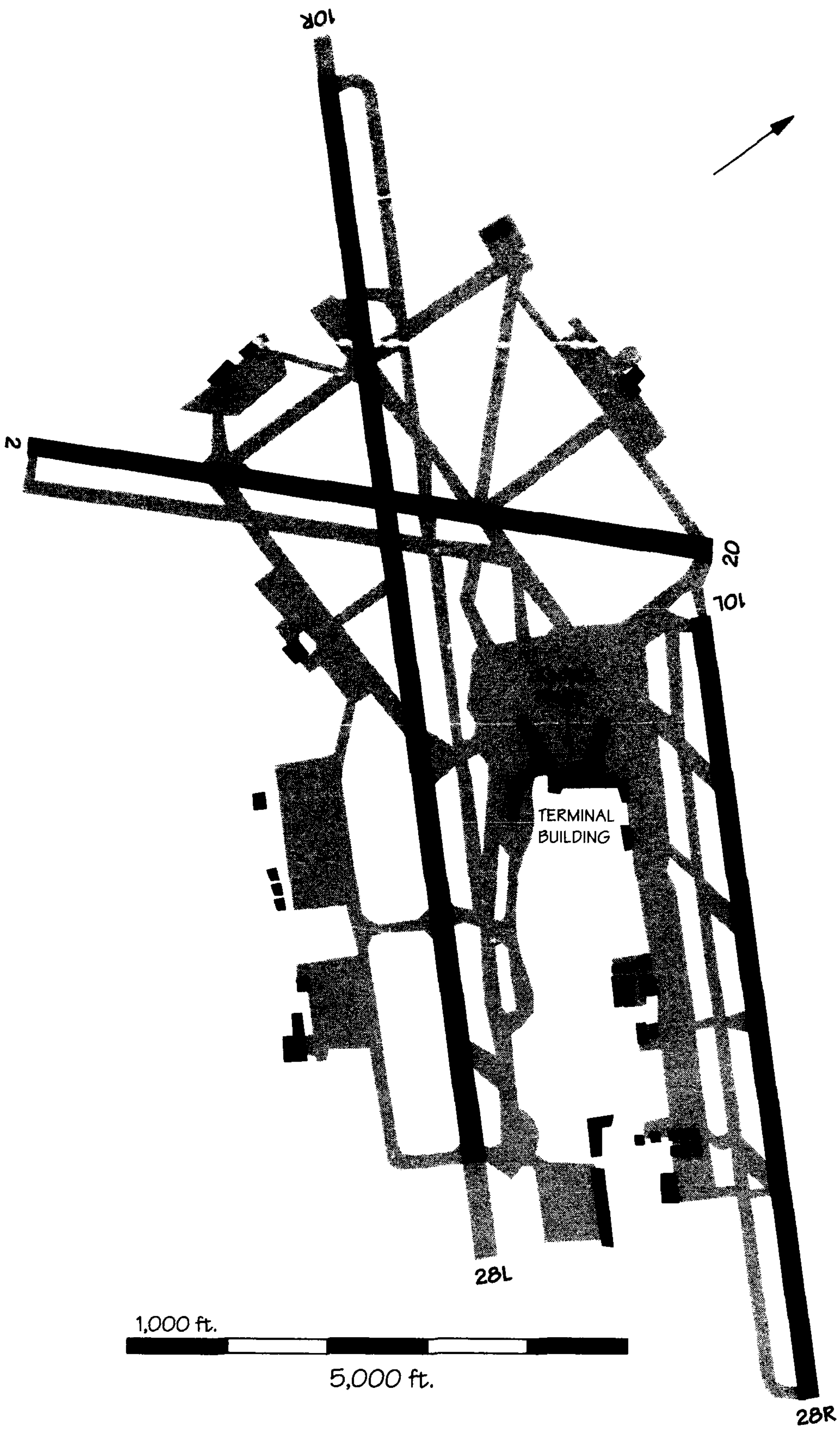


Newark International Airport

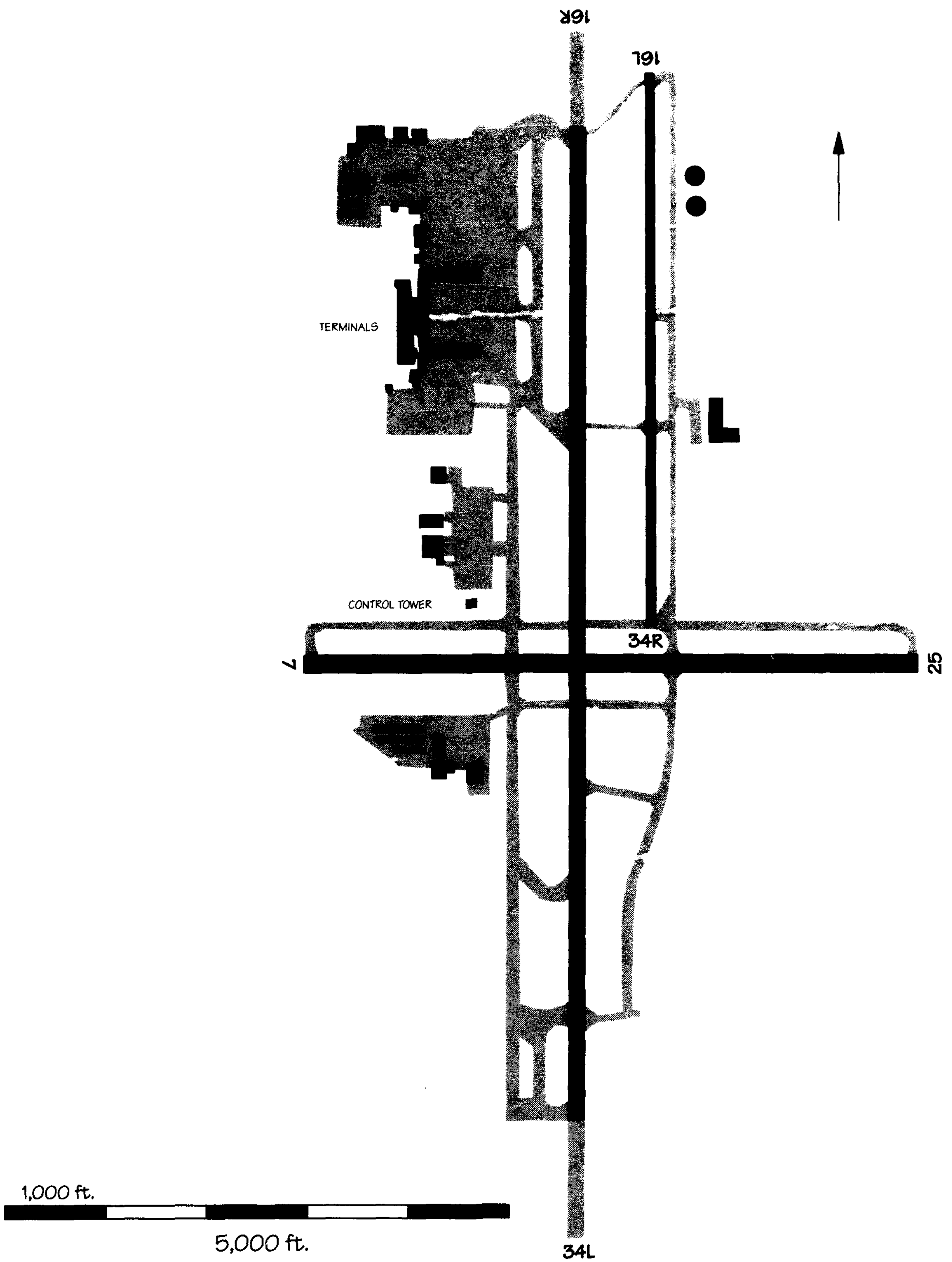


Ontario International Airport

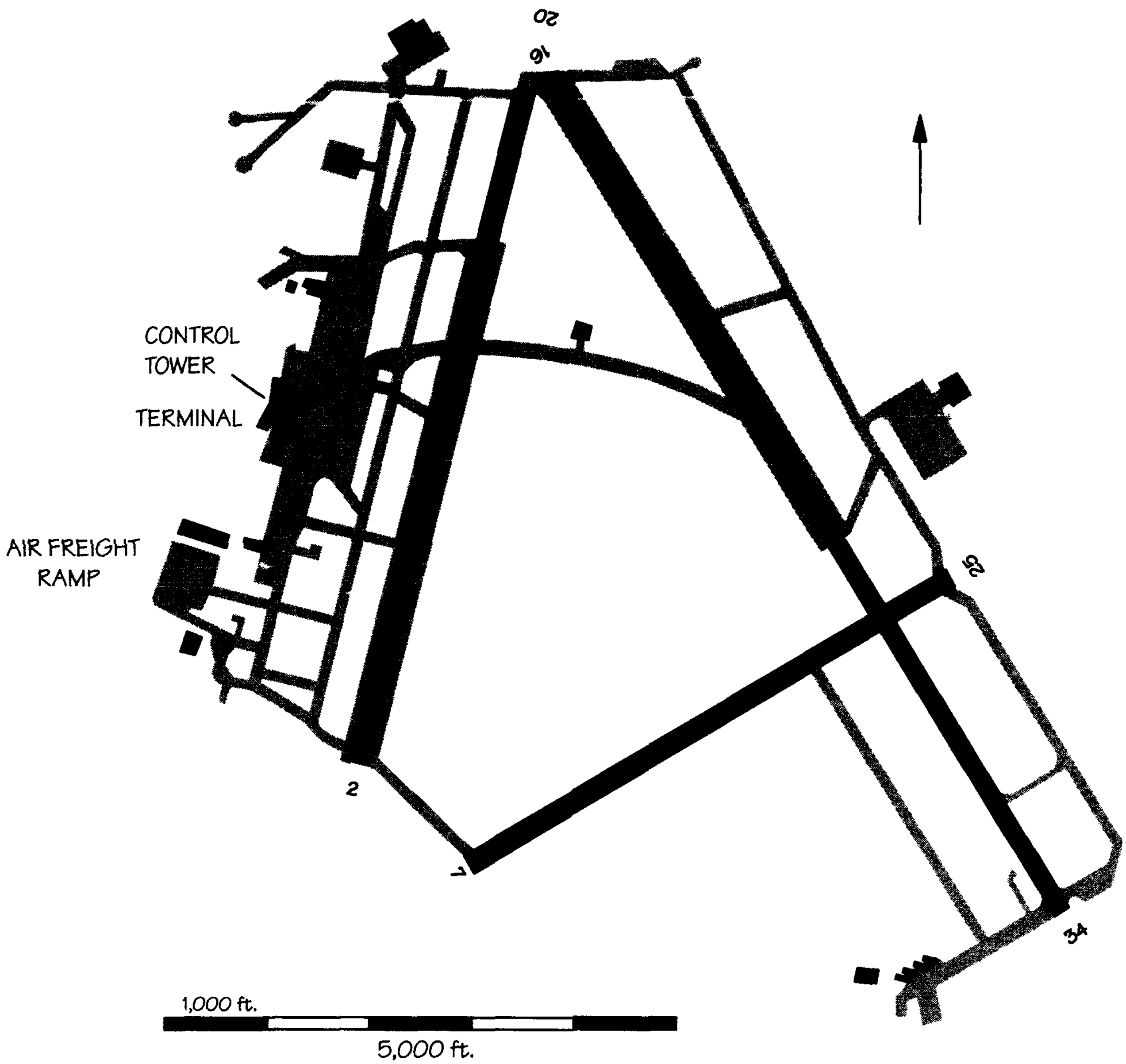

29
18
36
Control Tower
Terminal
Air Carrier Ramp
11
1,000 ft.
5,000 ft.



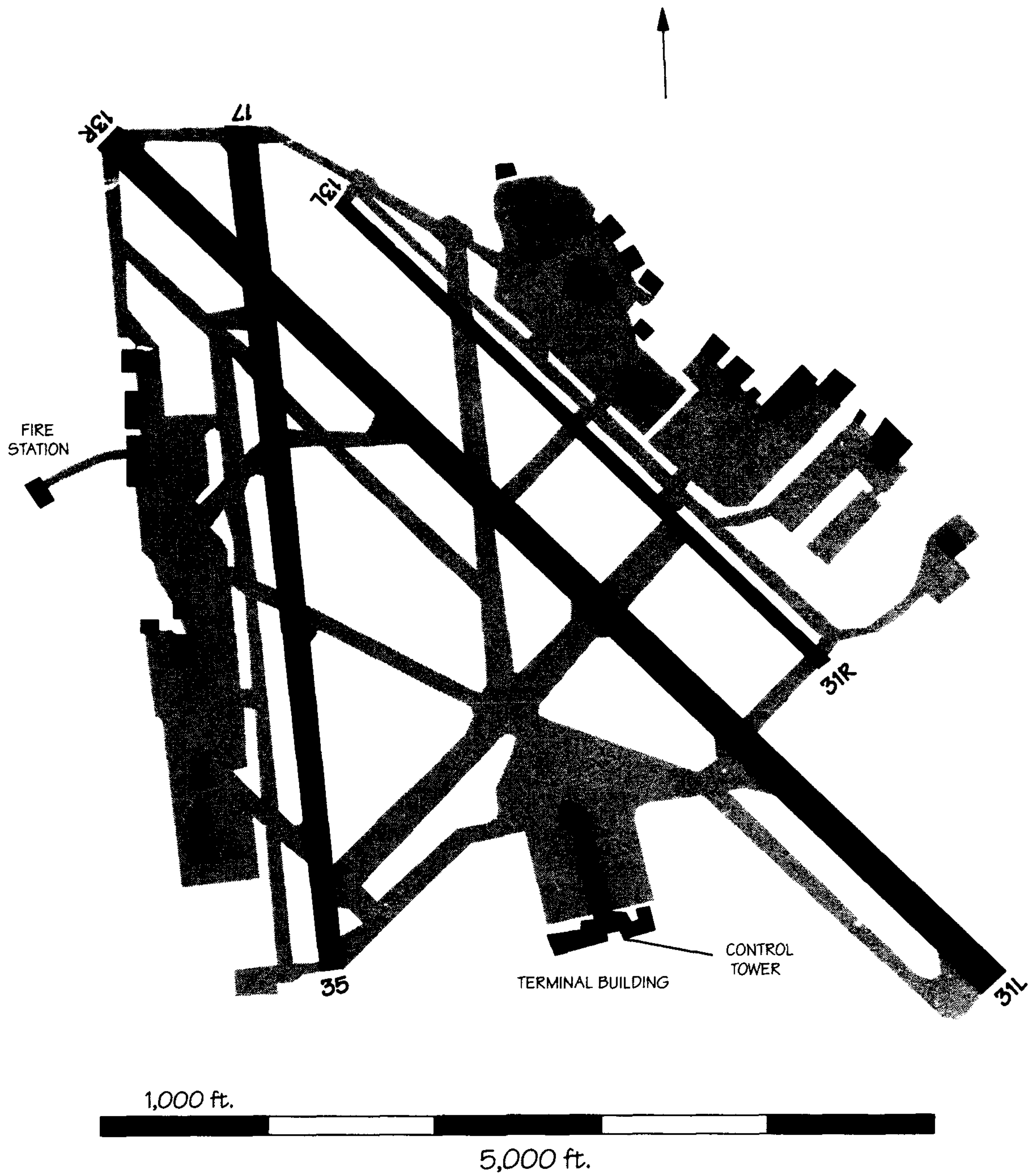
Portland, OR International Airport



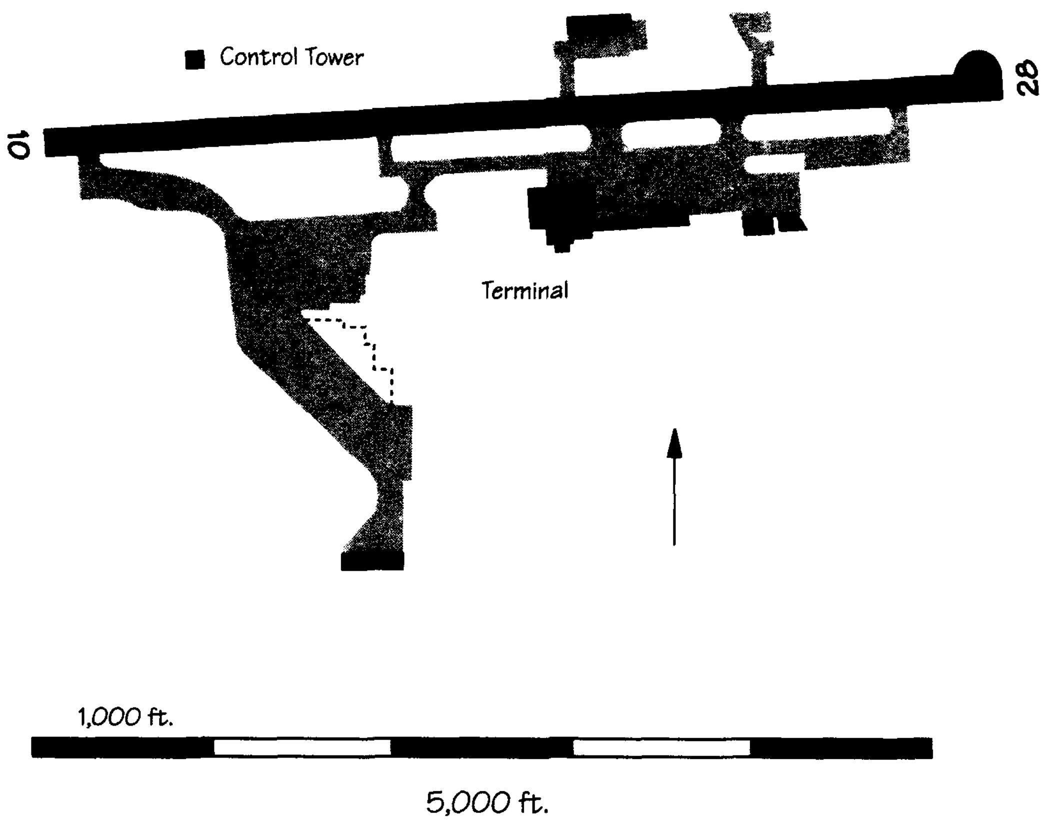
Reno Cannon International Airport



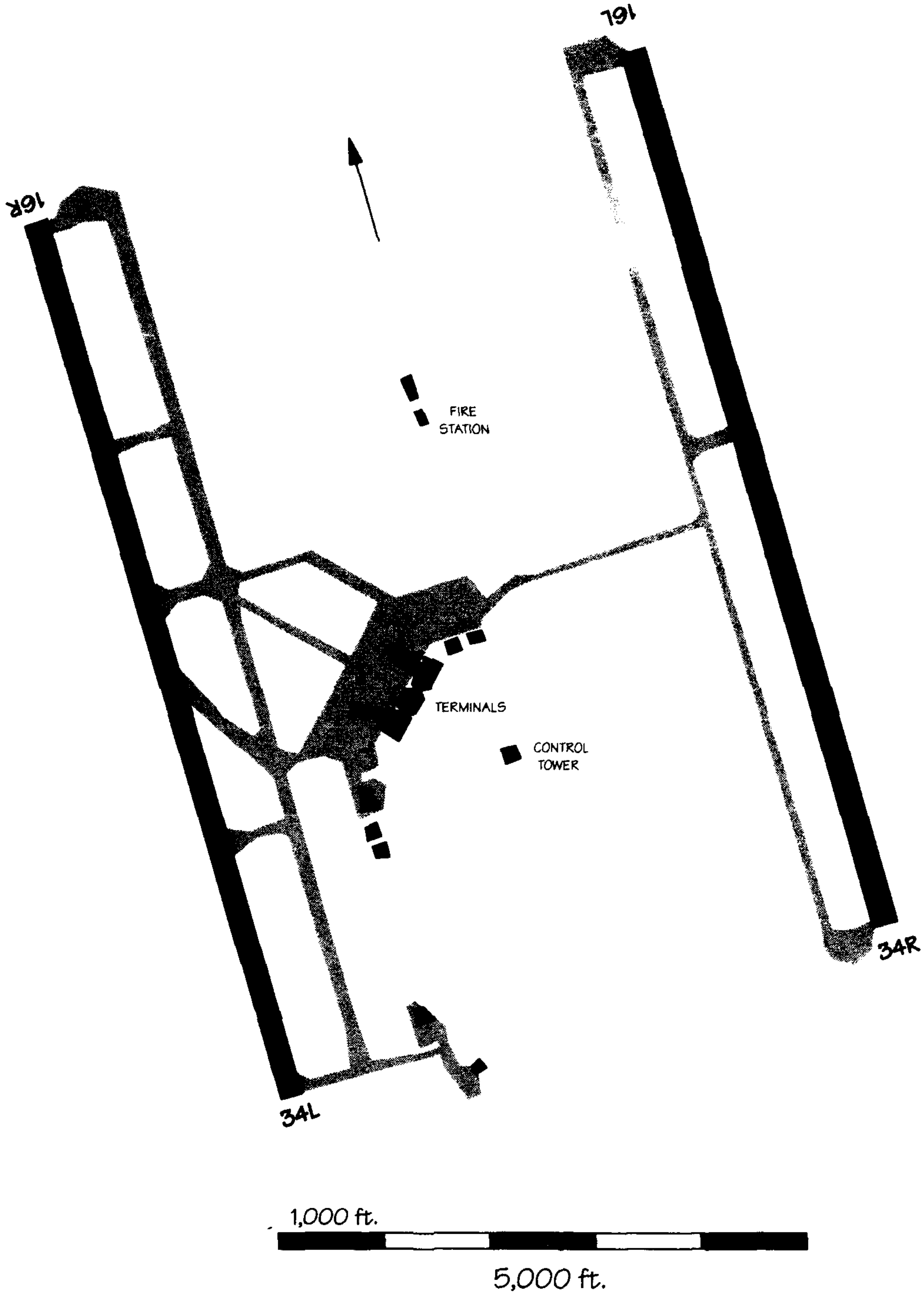
Richmond International Airport (Byrd Field)



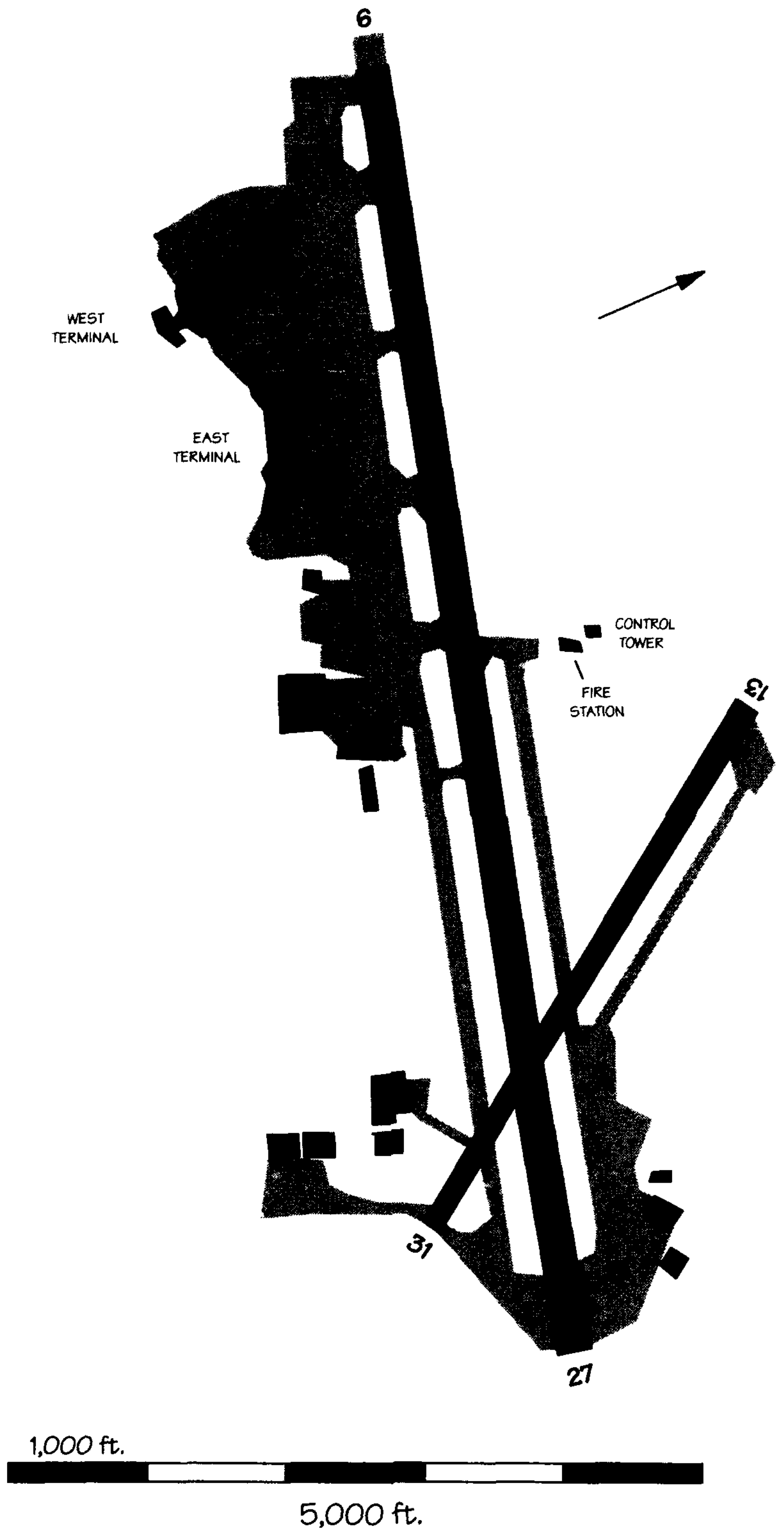
Robert Mueller Municipal Airport (Austin)



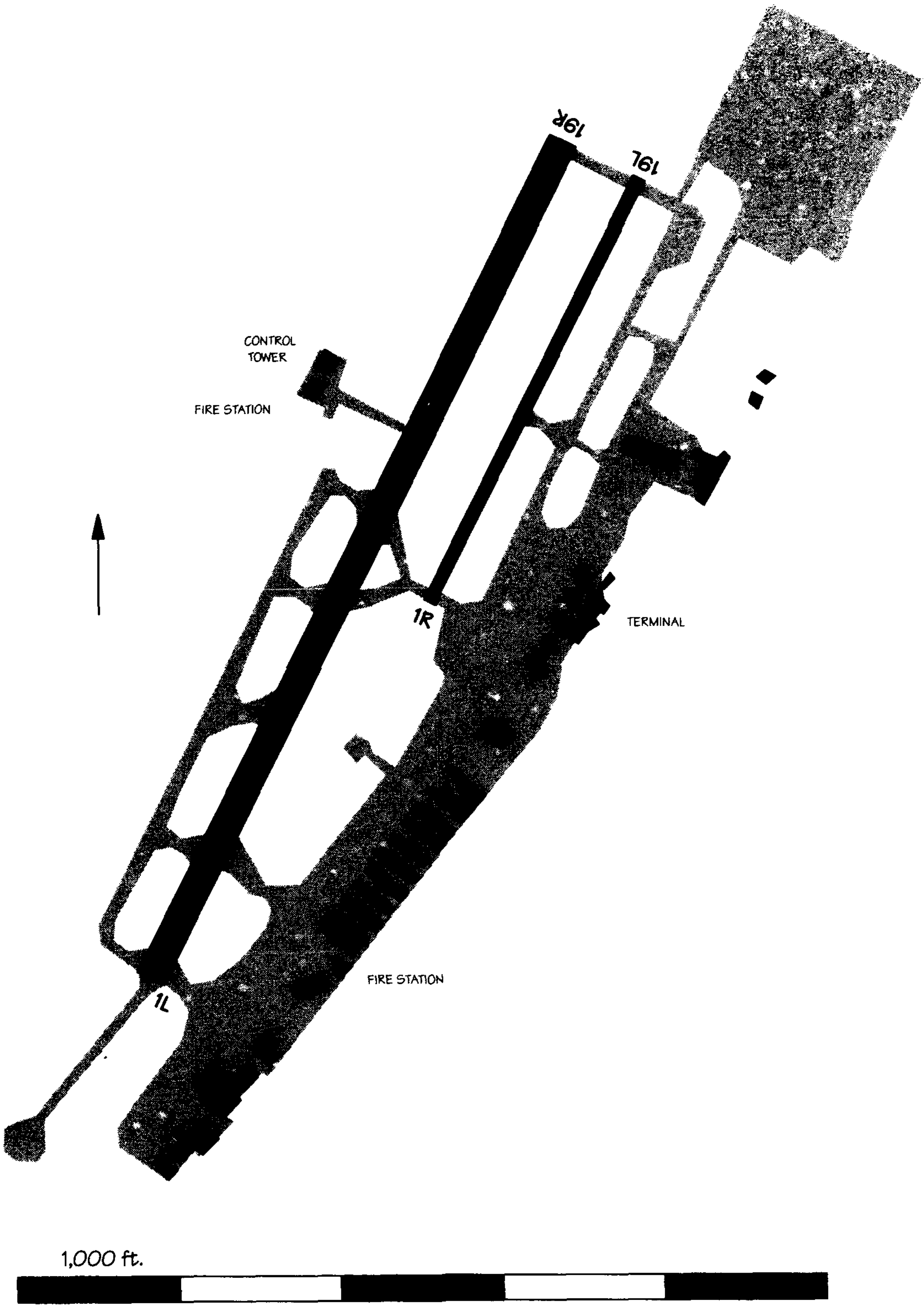
Charlotte Amalie St. Thomas



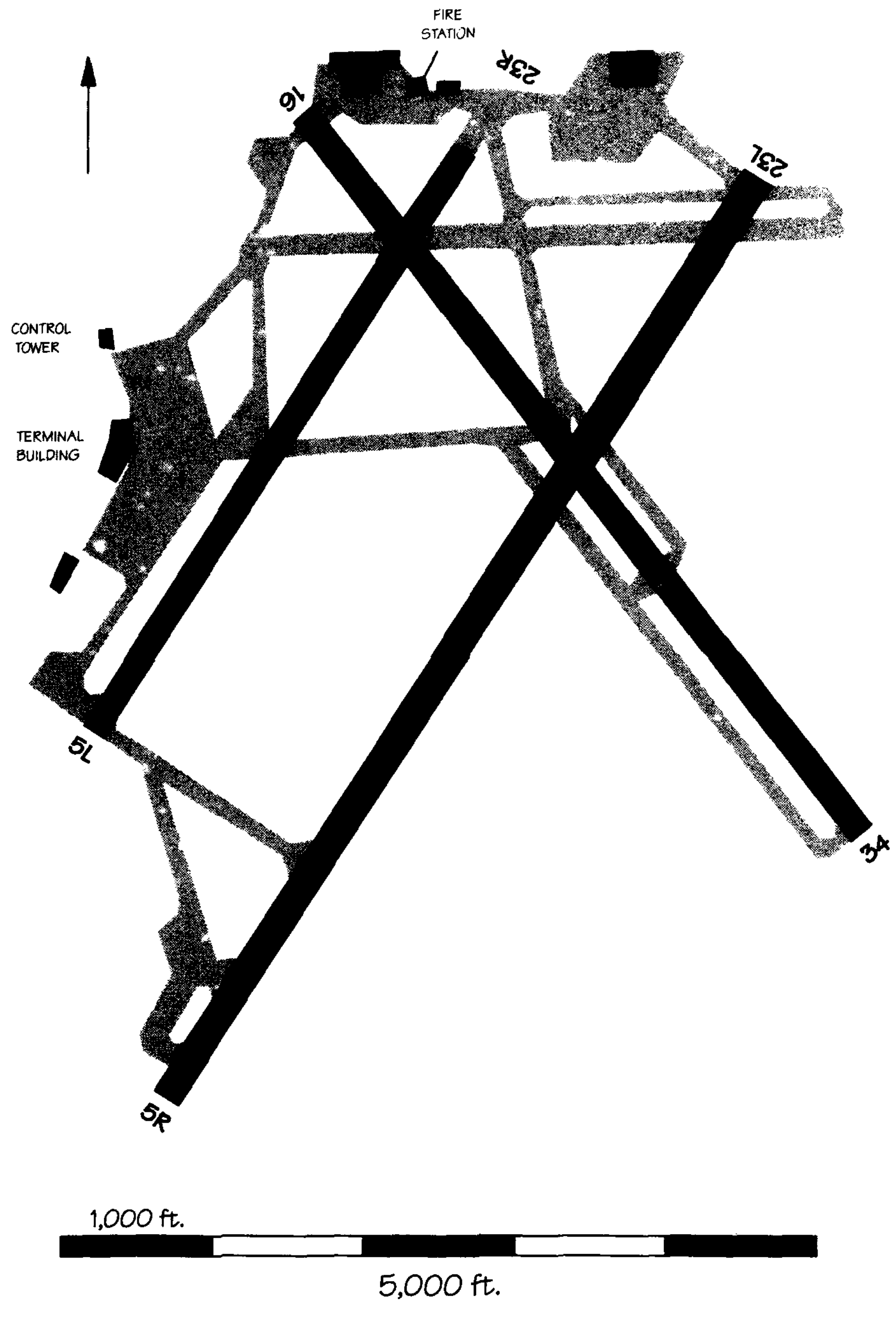
Sacramento Metropolitan Airport



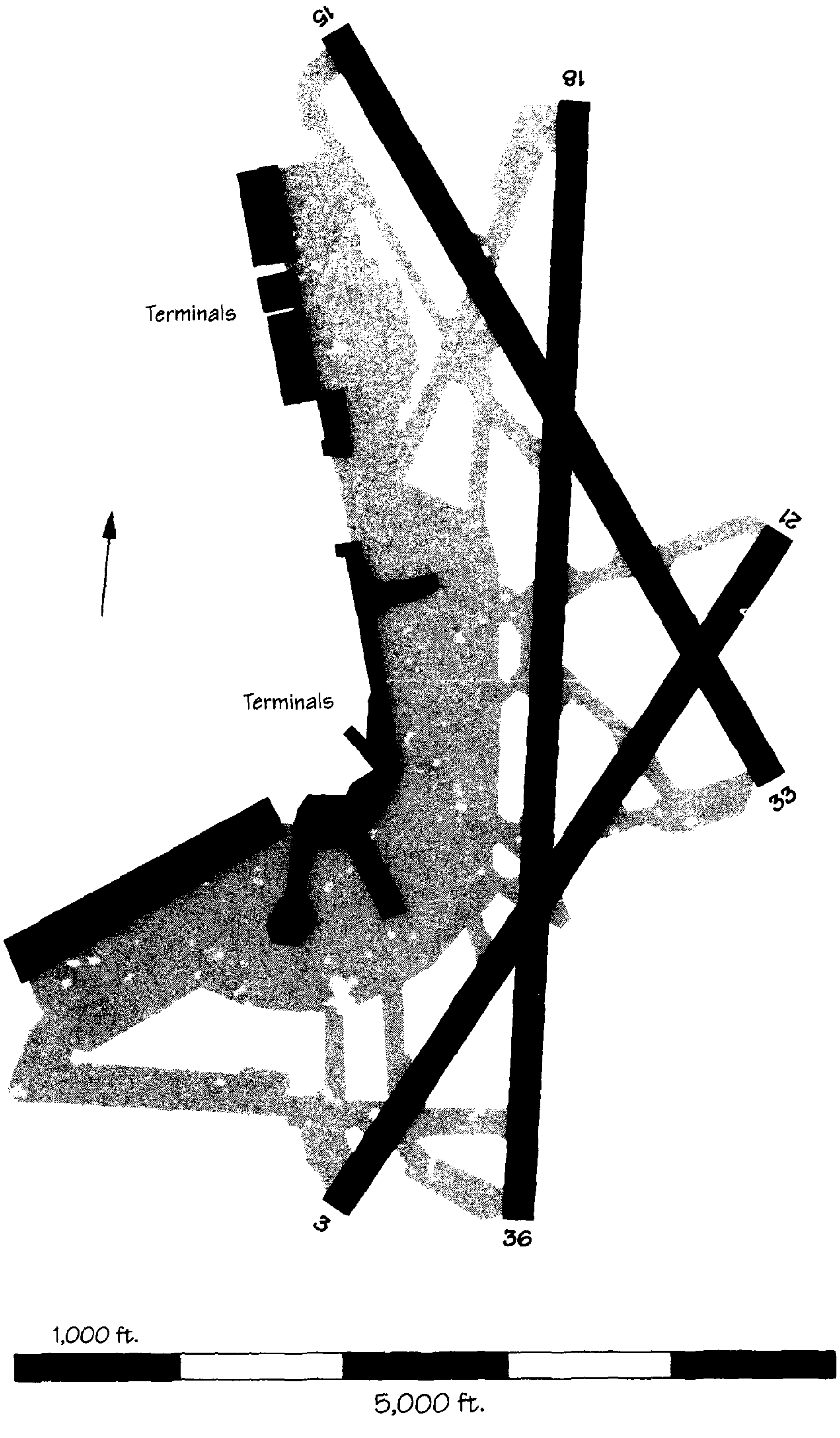
San Diego International-Lindbergh Field Airport



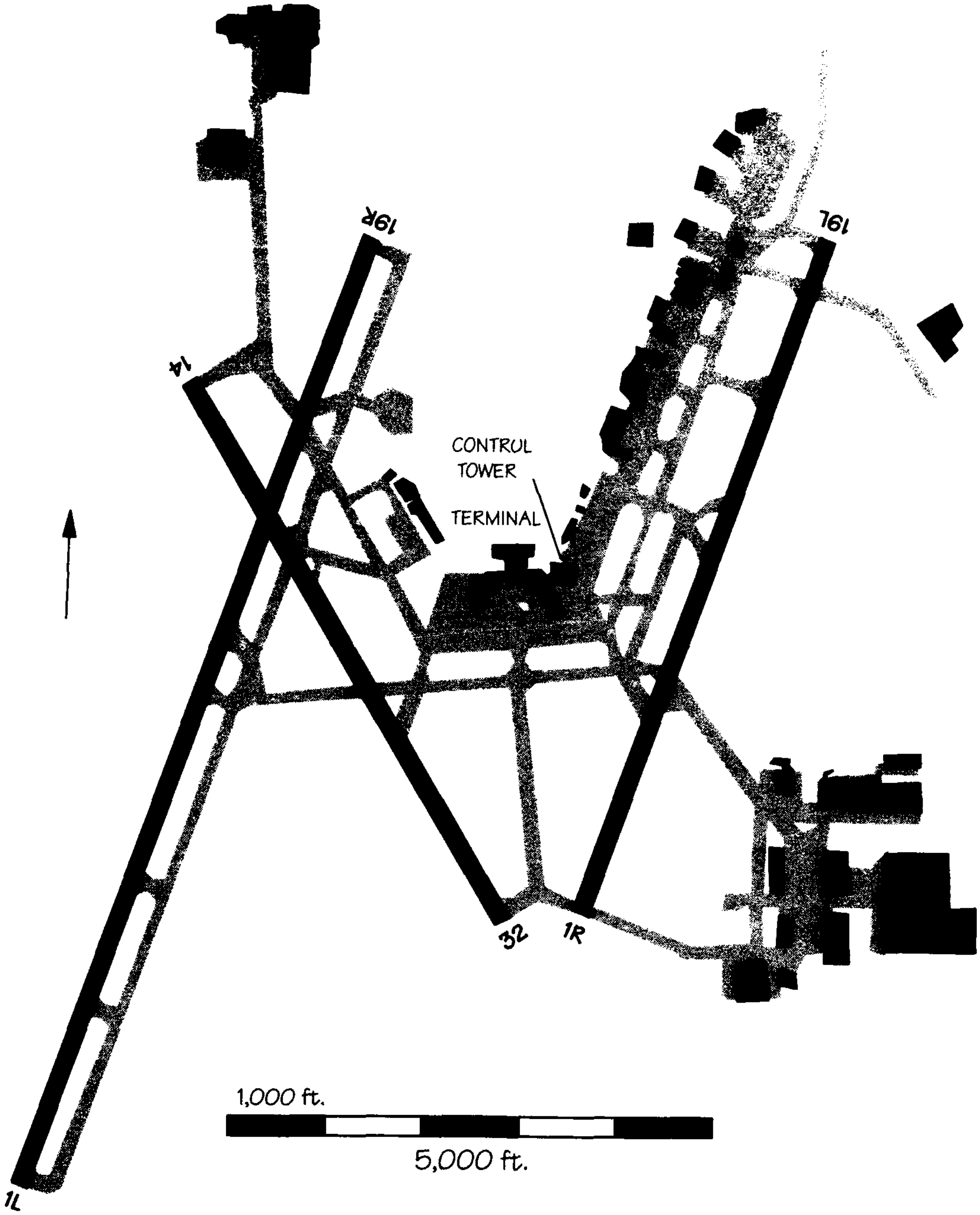
Santa Ana John Wayne, Orange County



Theodore Francis Green State Airport (Providence)



Washington National Airport



Wichita Mid-Continent Airport

Appendix F

Airport Capacity Design Teams
Potential Savings from Recommended Airfield Improvements

This appendix expands on the summary material in Table 2-4. Estimates of savings are in hours of delay and millions of 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 $85.3	104.93 $173.1	201.90 $366.4	
(2) Construct independent fourth north/south runway	3.32 $5.1	6.97 $11.5	25.46 $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 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

Lambert St. Louis 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 G

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 forecast for the 21st century.

Major FY91-92 Accomplishments

- Federal Aviation Order 7110.110 governing dependent converging instrument approaches using Converging Runway Display Aid (CRDA) was signed November 30, 1992.
- Airport Movement Area Safety System (AMASS) testing started at San Francisco International.
- Independent simultaneous approaches to parallel runways spaced between 3,400 and 4,300 feet were approved when Precision Runway Monitor (PRM) is used.
- The first Traffic Alert and Collision Avoidance System (TCAS) II equipment was certified.
- The Vertiport Design Guide and Advisory Circular was issued.
- Aircraft Situation Displays (ASD) were installed at 20 Air Route Traffic Control Centers (ARTCCs) and selected Terminal Radar Approach Control (TRACON) facilities.
- Dynamic Ocean Tracking System (DOTS) Track Generation and Traffic Display Functions were installed at Oakland, Anchorage, and New York ARTCCs.
- The Runway Incursion Plan was issued.
- ICAO guidance material for reducing vertical separation between FL290 and FL410 to 1,000 feet was completed.
- Eleven Airport Capacity Design Team Studies were completed; six are still underway. Seven Airspace Analysis Technical Reports were completed along with two Airspace Design Team Reports. Four Airspace Studies were initiated.
- Automated En Route Air Traffic Control (AERA), Traffic Management Advisor (TMA), and Traffic Management System (TMS) were integrated into the Integration and Interaction Laboratory (I-Lab).
- The first publicly available versions of SIMMOD for the workstation and PC were issued.

Complete project details, including funding and implementation dates where appropriate, are given in the following pages. Key elements of the R,E&D capacity effort 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 Capability, 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.*

G.1 Terminal Airspace Capacity Related Projects

G.1.1 Terminal Radar (ASR) Replacement Program

Responsible Division: ANR-200
Contact Person: Gerald Taylor, 202/606-4622

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 FY89 and the first leapfrog ORD was in FY90. The last leapfrog ORD is scheduled for FY94 and the last ASR-9 ORD is planned for FY95.

Products

- Replace 96 radars
- Leapfrog 56 radars

G.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 greatly over the last two years. 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

G.1.3 Simulation Model Development (SIMMOD)

Responsible Division: AOR-200
Contact Person: Steve Bradford, 202/267-8519

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. 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 FY88 and publicly released in FY89. Through FY90, 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 FY91, 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 FY92, applications work continued for both airport and airspace environments. In addition, Version 2.0 of SIMMOD was completed. This version, available for workstations, is significantly faster than that for microcomputers. This version includes better graphical output displays and automated data-acquisition capability. For example, SIMMOD generates output data that can be used directly by other FAA models, including the Integrated Noise Model used for environmental studies.

For FY93, the 3-dimensional version of SIMMOD will be completed and distributed to users. This version will significantly improve the ability of analysts and decision makers to design airspace changes by allowing full visualization of traffic iterations in all dimensions. Facilities for the display of enhanced geographical and census data will be included and will provide the analyst with deeper insight into potential noise conflicts arising from redesigning airspace for capacity improvement.

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

G.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, providing advisories designed to optimize the flow of arrival traffic and to facilitate the early implementation of these aids at busy airports.

The TATCA program consists of three projects developed in parallel to assist air traffic controllers. These projects are: the Converging Runway Display Aid (CRDA), the Center-TRACON Automation System (CTAS) and the Controller Automation Spacing Aid (CASA). CRDA provides geometric spacing aids for aircraft by means of software changes within existing ARTS terminal radar processors. A Federal Aviation Order (7110.110) governing dependent converging instrument approaches utilizing CRDA was signed November 30, 1992.

The CTAS project is now in laboratory development and consists of the following components: a comprehensive traffic planning and scheduling tool known as the Traffic Management Advisor (TMA) for the Air Route Traffic Control Center (ARTCC), a Descent Advisor (DA) for en route controllers, a turn and speed advisor for terminal controllers known as the Final Approach Spacing Tool (FAST) and an ascent trajectory synthesis tool for departing aircraft known as Expedite Departure Path (EDP).

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) and other ATC and cockpit automation capabilities.

Program Milestones

Laboratory evaluations and demonstrations of TMA have been completed. TMA is currently being evaluated and demonstrated in the Denver ARTCC. Further field evaluation for TMA and FAST will take place at the Dallas/Fort Worth Center in FY93. Laboratory development of DA and EDP is continuing.

Products

- Major CRDA milestones include:
  Begin national implementation 07/92
- Major TMA milestones include:
  Field Concept Development and Evaluation .. 08/92
  Limited National Deployment 10/94
- FAST milestones include:
  Fast Functionality in FDADS 08/92
  Field Concept Development/Evaluation 05/93
  Begin Limited National Deployment 04/95
- DA milestones include:
  Develop Prototype Software 07/93
  Deploy DA in ISSS 04/95
  Develop DA in ACCC 04/98
- EDP milestones include:
  Begin Limited National Deployment 04/96
- CASA milestones include:
  Begin Limited National Deployment 06/95
- TATCA/AAS milestones include:
  Modification to the System Level Specification for the AAS 04/94
  Integrated TATCA with ACCC 04/94

G.1.5 Airport Surface Traffic Automation (ASTA)

Responsible Division: ARD-50
Contact Person: John Heurtley, 202/646-5566

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.

The ASTA program consists of five elements: a runway status light system, a surveillance data link, aural and visual warnings, data tags, and a traffic planner.

The Runway Status Light System (RSLS) will automatically control lights that show pilots if the runway is occupied. ASTA will provide new surveillance data and interface software to enable the RSLS to function with ASDE-3 sensors, AMASS, and ARTS. For the surveillance data link, ASTA will combine surveillance information from ASDE-3 radars and Differential GPS. ASTA will provide controllers with prioritized aural and visual warnings and cautions on ARTS equipment. ASTA will also display target locations with alphanumeric data tags. ASTA will provide positive target identification for special vehicles such as fire, rescue, snow plows, etc. The ASTA project will share information with the TATCA project to create an interrelated runway incursion prevention system.

All airports that are slated to receive ASDE-3/AMASS equipment under the F&E program will also receive ASTA. For those airports not equipped with ASDE-3/AMASS, ASTA will use other potential ground movement sensors, such as the DGPS surveillance data link for detecting aircraft and vehicles.

Program Milestones

The ASTA project was started in FY89 to reduce the risk of runway incursions and improve airport capacity through increased efficiency of aircraft surface movements and better departure traffic management. In FY90, alternative capabilities for reducing runway incursions were identified. In FY93, contracts were awarded to demonstrate alternative technologies to prevent runway incursions, the third AMASS was established at Boston Logan International Airport to provide an ASTA DGPS testbed, and the RSLS was successfully demonstrated to industry at Boston Logan.

In FY94, technical performance assessments on the surveillance data link and associated ground processing functions will be completed at Boston Logan. In FY95, a detailed system specification for incorporating DGPS data with ASDE-3/AMASS and aircraft/vehicle data tags will be completed. In FY96, an RFP for developing a pre-production unit and 40 to 60 production units will be released and the following year the contract will be awarded and operational test and evaluation will take place.

G.1.6 TCAS II Applications to Improve Capacity

Responsible Division: ASC-200
Contact Person: Ken Peppard, 202/267-7375

Purpose

To identify and evaluate potential applications of the Cockpit Display of Traffic Information (CDTI) provided by the Traffic Alert and Collision Avoidance System (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 potential to increase the efficiency and capacity of the National Airspace System (NAS), reduce controller workload, and, at the same time, increase 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 has been 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 ATC simulations, using both part-task and full-task cockpit simulators and flight tests. Consideration will be given both to applications that can use the TCAS display "as is" and ones that require additional information and enhanced display capability. For each studied application, procedures will be developed with due consideration given to all relevant pilot and controller issues, such as workload and safety, and any special data and/or display requirements will be defined.

Program Milestones and Products

- Identification of near-term CDTI applications 5/93
- ATC simulations with full-task simulators 6/93
- Proposed procedures for near-term applications 12/93
- Display requirements for near-term applications 12/93
- Identification of long-term CDTI applications .. 07/94
- Flight tests 12/94
- Display and other requirements of long-term CDTI applications 06/95
- Implementation of long-term CDTI applications 01/97

G.2 Other Capacity Related Projects

G.2.1 FAA National Simulation Capability (NSC)

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

Purpose

To establish the NSC 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 NSC 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 NSC will feature rapid prototyping, configuration, modularity, flexibility, and expandability to address research, engineering, and development ATC issues and provide feedback to interacting programs. Initial NSC capabilities will be derived from the I-Lab. This base was expanded through FY92 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 FY93 to incorporate human-in-the-loop inter-operability 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 FY90, the FAA initiated the I-Lab Project. Initial development included facility preparation, commercial equipment and software procurement, and software infrastructure development. FY90 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 FY91, 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). In FY92, the I-Lab completed establishment of its initial experimentation capability including central simulation control. This extended 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 NSC planning will continue.

The NSC is expected to begin operation in FY93 using the resources of the I-Lab and the FAA's Technical Center.

Products

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

G.2.2 Dynamic Special-Use Airspace Management

Responsible Division: ARD-100
Contact Person: Barry Gamblin, 202/267-9855

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 FY89 to identify and document the current methods for the FAA/DoD coordination of military SUA. During FY90, additional discussions between FAA and DoD were conducted to determine the general development direction the agencies should pursue to enhance that coordination process. In FY91, 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.

In FY92, software/hardware enhancements were incorporated into the existing SUA Management System (SAMS) to reduce the time and workload associated with processing SUA data provided by FAA field elements.

Products

- SAMS functionality incorporated into TMS
- Direct interface to military SUA planning and coordination system
- Enhanced FAA/Military Liaison Specialist automation capabilities
- Direct interface to automated FSS's relating to SUA status

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

Responsible Division: AOR-200
Contact Person: Steven Bradford, 202/267-8519

Purpose

To maintain a long-term analysis capability through the application of modern tools of operations research and computer modeling and to aid in developing, designing, and managing 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, en route sectors, routes, navigation fixes, and flow control restrictions. The model permits the analyst to capture the effects of system performance problems, usually measured in terms of delays, as they propagate throughout the nation during the day. The representation of the national airspace system reflects the effects of instrument meteorological conditions at airports, air traffic control procedures, air carrier operating practices, and additional details.

Products

Several analyses were completed recently using the NASPAC Simulation Modeling System (SMS) to assess the implications of proposed system improvements on NAS performance. These analyses included studies of the nationwide impacts of the potential failure of an Area Control Facility under alternative facility consolidation assumptions, the implementation of Microwave Landing Systems (MLSs) at New York and Chicago, the implementation of Precision Runway Monitors (PRMs) at selected airports, the implementation of civil tiltrotor service in the Northeast corridor , the impact of rotating the arrival fix cornerposts at Chicago, the impact of the Dallas/Ft. Worth Metroplex Plan, and the impact of communications outages.

The results from these efforts have aided in assessing likely impacts and in formulating FAA positions on proposed improvements. Follow-on efforts from a subset of these analyses will investigate additional issues that have surfaced more recently or that have been identified as part of the analyses performed to date.

Program Milestones

A number of significant enhancements have been made to the SMS recently. An additional module of the SMS was developed that calculates user cost impacts based on delay data estimated by the simulation model. A new release of the NASPAC SMS, Release 3, was delivered to the FAA in June of 1992. The enhancements incorporated in Release 3 of the SMS are designed to reduce the time required to complete model applications, to make the model easier to use, and to expand the range of applications in which it can be used effectively. The principal enhancements included in Release 3 include a capacity tool to make it easier to develop the airport capacity values used as input to the model, a tool to assist analysts in developing demand estimates for new air carrier hubs or new airports, enhancements to the user interface and data file structures and tools to assist analysts in processing results produced by the model.

In FY92, several other tasks were conducted that address concerns related to aviation system capacity. Work began on efforts to improve the level of support provided to systems engineering decision making in the FAA. As part of this task, a preliminary assessment was conducted of some of the key issues facing the FAA today and of some of the metrics that can be used in the near term to address them. Another study was conducted of the NASPAC and SIMMOD simulation models to aid in ensuring that the two models can be applied in a coordinated and complementary manner.

The analyses to be performed in FY93 include studies of interest to various FAA offices. The emphasis of the work to be conducted will focus on projects that represent high priority tasks related to systems engineering decision making, in which capacity and system performance are often the major concern.

NASPAC SMS will continue to be improved in FY93. The improvements will focus on the development of a version of the model that can be applied quickly and that does not require extensive training or skill to operate. The documentation for the SMS will also be updated and augmented to include components of the system that have not been documented in detail to date.

G.2.4 Vertical Flight Program

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

Purpose

To improve the safety and efficiency of vertical flight (VF) operations and increase NAS capacity through R,E&D into air traffic rules and operational procedures; heliport/vertiport design and planning; and aircraft/aircrew certification training.

Program Milestones

The Rotorcraft Master Plan (RMP) envisions advanced VF technologies, like the tiltrotor, providing scheduled short-haul passenger and cargo service for up to 10 percent of projected domestic air travel. To accomplish this expanded use of vertical flight, the FAA is responsible for developing the appropriate infrastructure and regulations in parallel with industry's actions and commitment to develop and operate market-responsive aircraft.

The VF program is being executed through many concurrent projects and activities, which are divided into three technical sub-program areas: Air Infrastructure, Ground Infrastructure, and Aircraft/Aircrew.

The Air Infrastructure sub-program will provide R,E&D to enable reliable, all-weather operations for VF passenger and cargo aircraft. The research results will include developing both visual and instrument terminal approach and departure procedures, steeper IFR approach angles, improvements in low altitude navigation and air traffic control services, VF air route design, and noise abatement procedures.

Ground Infrastructure research will address heliport and vertiport design and planning issues, including the terminal area facilities and ground-based support systems that will be needed to implement safe, all-weather, 24-hour flight operations. Developing obstacle avoidance capabilities is a critical design-related effort. Research will include applying lessons learned from detailed accident and rotorcraft operations analyses. Simulation will be used extensively to collect data, analyze scenarios, and provide training to facilitate safe operations.

Aircraft/Aircrew research will develop minimum performance criteria for visual scenes and motion-base simulators; evaluate state-of-the-art flight performance for cockpit design technology; and develop crew and aircraft performance standards for determination of display and control integration requirements. Research will also be conducted in support of the FAA's responsibilities to certificate both conventional and advanced technology VF aircraft.

Products

- Terminal area approach procedure requirements
- ATC route standards, procedures and models
- Vertiport/heliport design standards
- Improved VF noise planning model
- VF noise abatement procedures
- Rotorcraft simulator standards
- VF aircrew training and certification requirements

Schedule

- Publish vertiport design requirements for 1996 Olympics FY94
- Produce audio visual training aids and workbooks to assist in training Expert Decision Making techniques FY94
- Publish civil tiltrotor air carrier profitability report FY94
- Identify night vision enhancement device technology applications FY95
- Publish advanced technology VF performanceand demonstration guidelines .... FY°5
- Publish results of test and analysis of a variety of heliport and vertiport design parameters, including minimum required VFR airspace for curved approaches and departures, minimum parking and maneuvering areas, marking and lighting, and rotorwash protection requirements FY96
- Conduct extensive VF noise data collection FY96
- Publish Technical Report supporting certification requirements of VF aircraft display formats FY96
- Publish national-level guidelines for joint industry/local government advanced technology VF demonstration program FY96
- Develop low noise conversion corridor criteria for tiltrotors FY97
- Publish terminal area procedures for steep-angle approach and departure FY97
- Publish simulation-based analysis of pilot performance in an obstacle-rich environment, with results being used to evaluate necessary heliport and vertiport design criteria FY97
- Publish CTR noise certification requirements FY98

G.3 En Route Capacity Related Projects

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

Responsible Division: AOR-200
Contact Person: Ken Geissinger, 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.

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 next 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

An en route 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 FY91. In FY92, it was given the capability to read airspace design data and aircraft track data available at the facilities and to accept user changes to these data interactively. This tool will be expanded to include other controller workload elements in FY93. The SDAT will be test implemented at two sites in FY93 and actual implementation will begin in FY94.

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 design evaluation tool
- National airspace design evaluation tool
- NAS equipment evaluation model
- Automated collision risk evaluation tool

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

Responsible Division: ARD-20
Contact Person: Chuck Eng, 202/267-7243

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 percent and 7 percent 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 from ODAPS, 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.

The track generation capability will be certified to ensure that generated tracks meet international separation standards required for safety. An airspace reservation system will be developed to enhance airspace utilization leading to substantially reduced airline operating cost. Integration of oceanic and domestic traffic planning capability will be implemented to allow seamless traffic management across domestic and oceanic boundaries for improved airspace use. The DOTS functionality will be integrated with the Advanced Traffic Management System (ATMS).

Program Milestones

In FY91, 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).

In FY92, a track advisory prototype system was installed in the Oakland ARTCC and testing of the prototype is continuing. Work will start soon on DOTS to ATMS integration, airspace reservation system and certifying the track generation function.

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

G.3.3 Oceanic Display and Planning System (ODAPS)

Responsible Division: ANA-150
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 and in the Initial Operational Capacity (IOC) status at New York.

Program Milestones

The contractor has resolved all high and critical priority software problems identified to date. Nineteen 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 14 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. The FAATC System Support Facility is operational to support maintenance and enhancements.

Products

Oceanic display and flight data automation for two ARTCCs

- ZOA S/W handoff to ATR-400 .... 07/91
- Last integration test complete (IOC) (ZNY) 05/92
- Last ORD complete (ZNY) 04/93

G.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, and selected high activity TRACONs.

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 capabilities 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 the John A. Volpe National Transportation Systems Center, Cambridge, Massachusetts.
- One computer program suitable for adaptation and use at 20 domestic ARTCCs and selected TRACONs.

G.3.5 LORAN-C Systems

Responsible Division: AND-30
Contact Person: Donald Stadtler, 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. 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

G.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 1994 and Step 2 for 1995.

Products

- ADS (Step 1) mod operational on Oceanic Development Facility (ODF)
- Perform Engineering/HF Trials
- Complete Data Link (Step 2) Requirements Definition
- ADS Step 1 installed at Oakland and New York
- Complete Step 2 Operational Concepts and System Specification
- ADS Data Link (Step 2) mod operational on ODF
- Complete display enhancements to Oceanic ATC
- Complete integration and validation of Step 2 mod on ODF
- Complete avionics development support standards
- ADS Data Link (Step 2) installed at Oakland and New York
- Develop international ADS standards and operational procedures (SOPS)
- Develop minimum operational performance standards (MOPS)

G.3.7 Separation Standards

Responsible Division: ARD-100
Contact Person: Gene Wong, 202/646-3475

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) determination 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 FL290 and FL410 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 FY90, the ICAO guidance material for world-wide and regional reduction of the high-altitude vertical separation standard from 2,000 to 1,000 feet was finalized.

In FY91 the ICAO guidance material amending current Pacific track longitudinal separation standards was completed, including distance, as well as time. This amendment resulted in reduced separation minimums.

In FY93, the activities associated with implementing the 1,000 foot vertical separation standard in North Atlantic airspace by 1996 will be continued. The investigation of aircraft height-keeping performance will be conducted by collecting and evaluating data from studies and engineering trials.

In FY93-94, ICAO guidance material for separation standards in the horizontal plane will continue to be developed. The four major items are area navigation (RNAV), Required Navigation Performance (RNP), Automatic Dependent Surveillance (ADS), and General Guidance on Separation Standards for Airspace Planners. The goal is to complete RNAV guidance in 1994-1995. The RNP was requested by the ICAO Future Air Navigation Systems (FANS) committee and has implications for the world-wide use of global positioning system (GPS) and establishing separation standards. The goal is to complete RNP guidance in the FY94 period. The introduction of ADS will provide near real time surveillance and communications in many areas that presently depend on pilot reports over high frequency communications. A new or modified Collision Risk Model (CRM) is being developed to establish quantitative guidance in establishing separation standards based on new technologies. These new technologies include ADS , intervention and satellite based navigation and communication. This effort is expected to be completed in 1995-1996. The final major effort is the continued work on developing general guidance on separation standards for airspace planners. This effort is expected to be completed in FY95.

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 1996. This will be the first time it will be used in flight levels above 290.

G.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 FY91 and FY92, these algorithms will be tested and refined. Migration to the ETMS is expected in FY93.

The development of the Strategy Evaluation (SE) function will begin in FY93 with migration to the ETMS anticipated in FY94.

The Automated Execution (AEX) function will be significantly more sophisticated than the previous stages. Development of this function is expected to commence in FY94, with migration to the ETMS currently scheduled for FY98.

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

G.3.9 Automated En Route Air Traffic Control (AERA)

Responsible Division: ACD-300
Contact Person: Stan Pszczolkowski, 609/484-6844

Purpose

To provide an interactive software capability for the Area Control Facility (ACF) to plan and monitor the four-dimensional flow of air traffic.

Specifically, AERA will provide the capability to: (1) permit most aircraft on IFR flight plans to fly fuel-efficient profiles, (2) increase the safety of the system by reducing the potential for operational errors, (3) increase system capacity by integrating en route metering with local and national flow control, and (4) increase controller productivity by increasing the number of aircraft and volume of airspace that a control team can safely manage.

AERA's implementation approach was changed as part of the revised strategy for incremental development of the Area Control Computer Complex (ACCC). These changes include the definition of Full AERA Services (FAS) as the combined functionality of AERA 1 and AERA 2 and the introduction of an interim operational step between the basic ACCC and FAS. This interim step, called Introductory AERA Services (IAS), was established to facilitate operational and technical transition as well as provide timely system benefits. IAS includes the original AERA 1 capabilities, some of which were modified to ensure upward compatibility to FAS, and several AERA 2 controller automation aids. IAS will be operational approximately twelve (12) months after ACCC implementation. IAS uses the ACCC's four-dimensional flight path trajectory estimation model to support the following features:

- Flight plan conflict probe ,which will predict potential violations of separation standards between aircraft and between aircraft and special use (e.g., restricted) airspace
- Sector workload analysis, which will calculate and display personnel workload measures to supervisors and specialists to assist them in balancing sector staffing levels
- Trial flight plan function, which will allow controllers to evaluate alternative clearances prior to issuing them to aircraft
- Automated reconformance ,which will adjust the calculated trajectory to reflect the aircraft's actual flight path and notify the controller of each adjustment in order to maintain system safety
- Automated replan ,which will aid the controller in granting conflict-free user requests at the earliest possible time

Approximately one year after the implementation of IAS, the remaining FAS capabilities (originally part of AERA 2) will be implemented. These extend IAS from detecting potential conflicts to providing the controller with suggested resolutions. The automation generated resolutions will avoid the predicted conflict, not cause additional conflicts and minimize the deviation from the aircraft's preferred route.

Each AERA development package will undergo a series of rigorous engineering and validation steps consisting of algorithmic development, operational suitability evaluations, computer performance functional specification generation, software design and development, and comprehensive operational test and evaluation.

Program Milestones

Functional specifications for the AERA 1 functions were completed in FY84. AERA 1 research and development was completed in early FY85. Modifications to the original AERA 1 functionality were made in FY92 to transform AERA 1 into Introductory AERA Services (IAS). IAS development, operational evaluation, and implementation will be accomplished as part of the AAS contract.

AERA 2 functional specifications were completed in FY86. Prototype laboratory evaluations were completed in FY90, and detailed algorithmic and computer/human interaction specifications were produced.

AERA 2 design and analysis began in FY90 as part of the AAS contract. In FY92, activities were adjusted to accommodate the revised approach to Full AERA Services implementation. AERA 2's automated problem resolution capability and supporting functions will continue to be designed and developed as part of the AAS contract in coordination with IAS development. This software will undergo operational evaluations in ATC laboratory simulations. After operational suitability has been demonstrated, the software will be finalized and implemented.

From December 1991 through November 1992: (1) AAS specifications were revised to reflect the new approach to Full AERA Services implementation; (2) AERA design activities under the revised implementation approach continued and algorithmic and computer-human interface risk reduction demonstrations were conducted; (3) analysis of the extendibility of the detailed ACCC design to IAS was completed, as well as preliminary extendibility analysis to FAS.

Products

- AERA will provide key en route traffic conditions and prediction data to the Traffic Managment System (TMS). The upgraded traffic management system will be integrated with AERA to keep both short- and long term traffic planning coordinated
- The AAS ACCC step has been replanned to include IAS and FAS incremental development
- Weather products provided by CWP will be used by AERA. More accurate wind data will improve AERA performance
- Aeronautical Data-Link, interfaced through AAS, will provide automated controller/pilot data and advisory interchange

G.3.10 Operational Traffic Flow Planning

Responsible Division: AOR-200
Contact Person: Mark Salanski, 202/267-7809

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, capacity 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 time and fuel 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 FY91, the High Altitude Route System (HARS) program completed development and evaluation of a test-bed prototype. In FY92, the prototype was used as the "core" of the initial operational HARS planning model for field implementation at the ATCSCC and TMUs. The HARS initial prototype optimizes track generation and traffic flow planning for major U.S. city pairs. HARS also includes an alternate flow generation function (FLOWALTS) that provides rapid analysis of alternate route and flow strategies. HARS displays live air traffic and weather over a background of sector boundaries, jet routes, fixes, and airports. HARS field prototype development and demonstration will begin in FY93, 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 FY92, a fast-time simulation model for traffic flow planning (FLOWSIM) was developed to help the FAA plan daily air traffic flow based on user schedules, aircraft performance, weather, capacity 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 began in FY92 and will demonstrate and test an initial prototype in FY93. 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 FY93. It will utilize and integrate the technologies and tools developed in the preceding projects (e.g., HARS, FLOWSIM, FLOWALTS, 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

G.3.11 ATC Automation Bridge Development: TRACON Re-code and Display Channel Complex

Responsible Division: ARD-100
Contact Person: Royce Wilkerson, 202/267-7547

Purpose

To develop design alternatives and conduct risk mitigation demonstration for the development of a TRACON replacement system and 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 FY92. Detailed designs will be completed in FY93. Risk mitigation demonstrations will be conducted in FY93.

Products

- Design alternatives for TRACON systems and en route display channel systems

G.3.12 Ground Delay Substitution Analysis

Responsible Division: AOR-100
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 was prepared in October 1992. Work is continuing to develop ground delay policies, management tools, and operational options in support of air traffic systems management.

G.3.13 Meteorologist Weather Processor (MWP)

Responsible Division: ANW-300
Contact Person: Jeanne Rush, 202/267-7800

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 supports 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 all operational sites as of November 1991.

Products

- MWP systems, including an interactive workstation for the CWSU/CFWSU and briefing terminals for air traffic supervisors and traffic management coordinators to display alphanumeric, graphic, radar, and satellite weather products.

G.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 NAS.

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 FY91, the development of the flight crew and ground-system flight procedures were developed to support the flight test activities in FY92. The first flight tests of combined radar, lidar, infrared, and windshear data communications will take place in the summer of FY92 and be completed in FY93.

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

G.3.15 Aeronautical Data Link

Responsible Division: ARD-60
Contact Person: Ron Jones, 202/267-8655

Purpose

To develop aeronautical data link communications standards associated with the Aeronautical Telecommunications Network (ATN).

To develop and implement ATC and non-ATC data link applications.

Program Milestones

Phase One of the Tower Data Link System (TDLS) providing pre-departure clearance (PDC) service was displayed at 29 airports in FY91 and at a 30th airport in FY92. A Data Link Processor (DLP) was delivered to the first operational site in FY91. The first operational use of DLP will be a DLP weather database available via Mode S, scheduled for early FY93. A prototype digital ATIS service using a tower data link system was evaluated in FY92 with deployment of the operational ATIS service in FY93. Development of DLP Build-2 enhancements to support added communications functionality for the Aeronautical Telecommunication Network (ATN) and additional data link services began in FY91 with operational deployment planned for FY96. Initial en route and terminal ATC services are being developed with implementation planned in the FY96-98 time frame.

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)

G.3.16 Satellite Navigation

Responsible Division: ARD-70
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 the NAS for en route, terminal, departure, non-precision, and precision approaches and for airport surface guidance everywhere.

Program Milestones

In FY91, Minimum Operational Performance Standards (MOPS) for GPS avionics were developed to support the use of GPS as a navigation supplement. This enabled a Technical Standards Order (TSO) to be developed during FY92 and FY93 for certification of avionics, and it enabled the Flight Standards and Aircraft Certification Services to authorized operational use of GPS in June 1993. During the remainder of FY93, requirements for augmentation to GPS to support its use as a sole-means navigation source will be developed and validated. MOPS for use of GPS and GPS hybrids were initiated in FY93 and will be completed over the next year. The MOPS will apply to GPS augmented with Global Navigation Satellite System (GLONASS), inertial systems, LORAN-C, and/or Wide-Area Integrity Broadcast with Wide-Area Differential GPS (WIB/WDGPS). An accompanying TSO will be written in FY94. A Request for Proposals (RFP) for the ground stations and communications links for WIB/WDGPS will be released in FY94. A study and verification of the feasibility of the use of GPS for Category II and III precision approaches will then proceed and is planned for completion by the end of FY95.

Products

- Performance standards for aircraft avionics
- GPS system performance specifications
- Requirements for augmenting GPS for use as sole-means navigation, non-precision, and special Category I precision approaches

G.4 Airport Capacity Related Projects

G.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 FY92, design team efforts were successfully completed in Pittsburgh, Philadelphia, San Juan, San Antonio, New Orleans, and Honolulu. Design team studies are still underway at Ft. Lauderdale, Houston, Albuquerque, Indianapolis, Minneapolis-St. Paul, Port Columbus, and Cleveland. Among the airports being considered for design team studies in 1993 are Detroit, El Paso, Tulsa, 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.

Over 500 proposals for enhancing capacity have been developed for analysis by the design teams since the program began in 1985. Completed design team studies resulted in over 120 recommendations in FY91-92. Of these, 76 were completed and another 37 were either under construction or in the environmental assessment process by the end of FY92.

Products

- Action plans incorporating the projects and programs that produce capacity improvements and delay reductions at airports under study
- Analysis of airport capacity

G.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 forecast 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 11 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 CY92, the 1993 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 Pittsburgh, Philadelphia, San Juan, San Antonio, New Orleans and Honolulu will be issued. Airspace design teams are scheduled to complete reports for 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

G.4.3 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, since 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 1993. The new system will have tall poles, new hardware and software, ice-free sensors, 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.

G.4.4 VORTAC Program

Responsible Division: ANN-300
Contact Person: Charles B. Ochoa, 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 FY82 through FY89, 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. 76 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 FY90, 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 90 VORs have been converted to Double Sideband (DSB) DVORs , 50 DVORs have been retrofitted with RMM, 35 VOTs have been established, and 76 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.

G.4.5 Microwave Landing System (MLS)

Responsible Division: AND-30
Contact Person: Don Stadtler, 202/267-5857

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.

MLS is currently the international standard replacement for the Instrument Landing System (ILS), 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 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 take advantage of its inherent advantages over ILS.

Program Milestones

A 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 focusing 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 FAA's transition plan will provide an MLS at every commissioned ILS location.

Products

- A DME/P interrogator design
- Demonstrations of the MLSs operational and economic benefits
- Modifications to TERPS and approach procedures to effectively integrate MLS into the ATC system

G.4.6 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 FY92-93.

Products

- 528 RVR systems with proper documentation

G.4.7 Airport Planning and Design

Responsible Division: ACD-100
Contact Person: Hector Daiutolo, 609/484-5283

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.

In FY91, analyses of multiple exit/taxiway/crossover designs was 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. The study was completed in FY92.

Products

- Technical reports
- Computer programs and users guides
- Design criteria and guidelines for airports
- Test methods and procedures
- Analysis methods

G.4.8 Visual NAVAID

Responsible Division: ANN-300/ANN-200
Contact Person: Charles Ochoa, 202/267-6601 and Gary Skillicorn 202/267-6675

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 FY93 and beyond time frame

G.4.9 Precision Runway Monitor (PRM) for Closely Spaced Runways

Responsible Division: ANR-300
Contact Person: Byron Johnson, 202/267-8258

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.

To develop the necessary equipment to apply PRM at airports with closely-spaced runways.

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 (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 will allow more airports to conduct simultaneous 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 for other similar applications such as runway spacings below 3,400 ft. and 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 high resolution displays that were acquired in 1989.

In FY90-91, 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 FY91. Further research and development will be required before simultaneous IFR approaches at spacings below 3,400 ft. can be approved.

Specifications have been incorporated into a limited production contract which was awarded for five E-Scan systems in March 1992.

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

G.4.10 Multiple Runway Procedures Development

Responsible Division: ARD-100
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 dual, triple and quadruple Instrument Flight Rules (IFR) parallel approaches will be developed and validated. Requirements and techniques for improved surveillance, navigation and ATC display capabilities will be developed to support these procedures.

Studies sponsored by the FAA and the aviation industry have identified technical and operational concepts with the potential to reduce airport arrival delays by better utilizing multiple runway configurations in IMC. These concepts include the use of improved and current monitoring systems for conducting simultaneous approaches to dual, triple and quadruple parallel runways. Improved monitoring technology includes precision runway monitor (PRM) systems, as well as high resolution ATC displays with controller alert aid and Airport Surveillance Radar-9 (ASR-9). Promising concepts will be validated through ATC simulations and, in some cases, full-scale demonstrations at airports.

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 procedure was site specific and was developed based on the use of current ARTS displays and ASR-9. This is being followed by the development of national standards for triple and quadruple IFR parallel approaches based on the current ARTS display and ASR-9 capabilities.

The FAA has completed demonstrations of electronically scanned and "back-to-back" antenna PRM technologies resulting in the acceptance of simultaneous approaches to parallel runways spaced as closely as 3,400 feet. This project will conduct additional analyses and simulations to investigate the application of the combined use of improved data rate PRM technology with highly accurate navigation/landing systems, such as satellite navigation system, microwave landing system, and state-of-the-art autopilot to further reduce the spacing standards of parallel runways. The results of these studies for dual parallel runways will also provide the basis for the analysis of spacing standards for closely spaced triple runways. The final phase of the multiple runway procedures development will focus on quadruple parallel runways.

Program Milestones

In FY91, simulation evaluation of simultaneous IFR approaches to triple parallel runways spaced 5,000 feet apart, using ASR and ARTS displays, was completed. Recommended national standards of ATC procedures and runway spacing were developed. Simulations of triple parallel IFR approaches to runways spaced 4,300 feet apart using ASR-9 and high-resolution color displays with automated alerts were performed in FY92. Additional simulations to investigate the feasibility of using high-resolution color displays with automated alerts and ASR-9 to reduce dual and triple parallel runway spacing standards to 4,000 feet is scheduled in FY92. Simulations of dual and triple runways spaced 3,000 feet apart, using the PRM system, were conducted in FY92. Simulation evaluation of the use of offset localizer and PRM to reduce the dual parallel runway standard to 3,000 feet will be completed in FY93. Also in FY93, studies will be initiated to conduct research in the combined use of PRM technology and advanced navigation/landing technology for possible further reduction of runway spacing standards below 3,400 feet. Advanced navigation/landing technology includes the microwave landing system, global positioning system and state-of-the-art autopilots.

Products

- Simulation analysis of ATC procedures
- Flight procedures and system requirements for simultaneous IFR approaches to triple and quadruple parallel runways
- Technical reports on simulation results

G.4.11 Airport Surface Visual Control (Lighting)

Responsible Division: ACD-100
Contact Person: Paul H. Jones, 609/484-6713

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 FY91, 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 tests
- Markings for holding aircraft in low-visibility conditions
- Hold-short lighting system
- Improved taxiway exit identifier
- Improved taxiway guidance systems

Products

- Research reports and design criteria
- Lighting standards for airports

G.4.12 Development of "Land and Hold Short" Runway Warning Lights

Responsible Division: ACD-100
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 FY91, testing of a prototype system at Boston Logan Airport was completed. A final report on the prototype system was issued September 1991.

Products

- Specifications for a pulsing, white, in-pavement lighting system arranged as a "bar" across the landing runway

G.4.13 Development of ATC-Controlled Stop-Bar Lighting System

Responsible Division: ACD-100
Contact Person: Paul H. Jones, 609/484-6713

Purpose

To test, and evaluate prototype ICAO-modified-standard stop-bars installed at the intersections of taxiways with runways at JFK Airport.

To obtain operational, maintenance, controller workload, and human factors experience in use of stop-bars to prevent runway incursions in all visibility conditions.

To develop specifications for a standard FAA stop-bar system.

To obtain operational, maintenance and controller workload experience in the use of stop-bars to support Surface Movement Guidance and Control (SMGC) requirements for low-visibility operations.

Program Milestones

Operational testing of stop-bars at JFK was begun in FY91 and was completed in FY92. A final report on the use of stop-bars that will provide airport operators with information on system requirements and air traffic personnel with operating procedures for the use of stop-bars will be issued.

Products

- Report on the operational, maintenance and controller workload experience in the use of stop-bars for control of runway access at JFK during all visibility conditions
- Specifications for a FAA stop-bar system
- Report on the operational, maintenance and controller workload experience in the use of stop-bars for control of runway access at Seattle-Tacoma International Airport in support of SMGC low visibility operations

G.4.14 Evaluation of Airfield "Smart Power"

Responsible Division: ACD-100
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 was completed in FY91. Testing of the system was completed in FY92. The final report (completed in February 1992) provides data to the FAA Office of Airport Standards for use in developing standards for the use of "smart power" technology.

Products

- Final report identifying potential U.S. applications of Airfield "Smart Power" Technology, evaluating the effectiveness of the applications, and evaluating the compatibility of such a system with existing and proposed U.S. equipment

G.4.15 Airport Pavement Technology

Responsible Division: ARD-200
Contact Person: Aston McLaughlin, 202/267-8694

Purpose

To reduce the costs of pavement expenditures through a systematic research program covering three areas: pavement design and evaluation, materials and construction methods, and repairs and maintenance techniques.

Airport pavement design techniques have evolved from highway design theory developed in the 1920's and extrapolated in the 1940's and 1950's for application to aviation. While this has worked reasonably well in the past, it will not accommodate the changes associated with the new generation of aircraft now on the drawing boards.

Research in pavement design and evaluation will focus on the development of a universal pavement design method that can be applied to both flexible and rigid pavements. Efforts will concentrate first on the completion and validation of the layered-elastic design method and second on more rigorous design methods, such as mechanistic analysis, to accurately model material properties. In addition, research will be conducted to develop criteria and methods for design, evaluation, performance, and serviceability of pavements at airports in cold regions.

Research efforts in pavement materials and construction will include developing methods to specify and use new or improved materials as substitutes for conventional materials; identifying factors affecting the durability of airport pavements; developing criteria for efficient use of new construction devices, materials, and techniques, to include evaluating coal-tar mixes, roller-compacted concrete, and geotextiles and grid type materials.

Research in the area of pavement maintenance and repairs will include determining probable causes of significant distress and life-cycle costs in pavements and developing criteria and guidance for using seal-coating materials effectively to enhance pavement longevity.

Program Milestones

In FY92, efforts were initiated to validate the layered elastic theory as a part of the development of a universal pavement design methodology. A major test program was initiated to develop a sensors and instrumentation system for a long-term, comprehensive investigation of structural and environmental parameters affecting pavement performance. Studies on joint efficiency, load transfer, seal-coating procedures, and non-destructive testing were completed. A laboratory validation effort on a predictive design and analysis methodology and work on a mechanistic design methodology continued. Work on using segmented concrete in apron areas was initiated.

In FY93, the sensors and instrumentation system will be fabricated and installed at a major airport at selected locations in the runways and taxiways. Validation of the layered elastic theory for pavement design will continue. Computer software development will be initiated to graphically represent stresses and deformation using the predictive design and analysis methodology. In addition, studies will be initiated on advanced nighttime construction methods, lime-sulfate reaction, durability of asphalt mixes, and improved shoulder designs.

In FY94, the pavement design method using layered elastic theory will be fully developed, validated, and ready for application. Work on the mechanistic design method will be accelerated to develop the universal pavement design methodology. Work will continue on collecting and analyzing data that relates pavement performance with FAA design and construction standards. Criteria and methods for design, evaluation, performance, and serviceability of pavements at airports in cold regions will be completed.

Products

- Technical data for pavement design and design life, evaluation, materials, construction, maintenance, and repair
- Software and user guidelines for pavement design and analysis
- Test methods and non-destructive testing methodology

G.4.16 Wake Vortex Research

Responsible Division: ARD-200
Contact Person: Cliff Hay, 202/267-3021

Purpose

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.

To evaluate current and advanced sensor technology and develop wake vortex detection and avoidance system for automated wake-adaptive separation.

Program Milestones

In FY93, a report was published on wake vortex signatures of B757 and B767 aircraft. Analyses of data from past experiments are continuing. A report on helicopter wake vortices is near completion. Plans were completed to visit Europe this summer for a technical information exchange conference on wake vortex research.

Products

- New aircraft wake vortex separation criteria.
- Runway spacing criteria, starting with heavy-behind-heavy.
- Time-based separation criteria for departures to support terminal air traffic control automation.
- Automated wake-adaptive separation systems.

G.4.17 Visual Guidance System Simulation Capability

Responsible Division: ACD-100
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

Determination of the present FAA B-727 simulator visual system capabilities and actual low-visibility parameters was conducted in FY92. The criteria for improved lighting in the B-727 simulator visual system will be defined and validated and desk top PC software will be investigated for use in performing lighting research in FY93.

Products

- Definition of requirements for hardware and software development for a visual flight simulator

Appendix H

List of Abbreviations

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 .... Airfield Delay Simulation Model
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
ASCP .... Aviation System Capacity Plan
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
CTMA .... Center Traffic Management Advisor
CTR .... Civil Tilt Rotor

CVFP .... Charted Visual Flight Procedures
CW .... Continous Wave
CWSU .... Center Weather Service Unit
CY .... Calendar Year
DA .... Descent Advisor
DH .... Decision Height
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
EDP .... Expedite Departure Path
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
FAF .... Final Approach Fix
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
FMA .... Final Monitor Aid
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
GRADE .... Graphical Airspace Design Environment
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
MAP .... Missed Approach Point
MCF .... Metroplex Control Facility
MIT .... Miles In-Trail
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
NM .... Nautical Mile
NPIAS .... National Plan of Integrated Airport Systems
NSC .... National Simulation Capability
NTP .... National Transportation Policy
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
SAR .... System Analysis Recording
SCAG .... Southern California Airspace User's Group
SDAT .... Sector Design Analysis Tool
SDRS .... Standardized Delay Reporting System
SE .... Strategy Evaluation
SID .... Standard Instrument Departure
SIMMOD .... Airport and Airspace Simulation Model
SM .... Statute Miles
SMGC .... Surface Movement Guidance and Control
SMS .... Simulations Modeling System
SOIR .... Simultaneous Operations on Intersecting Runways
SOIWR .... Simultaneous Operations on Intersecting Wet Runways
STAR .... Standard Terminal Arrival Route
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 .... Volpe Transportation Systems Center
TSO .... Technical Standards Order
TTMA .... TRACON Traffic Management Advisor
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

Appendix I

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