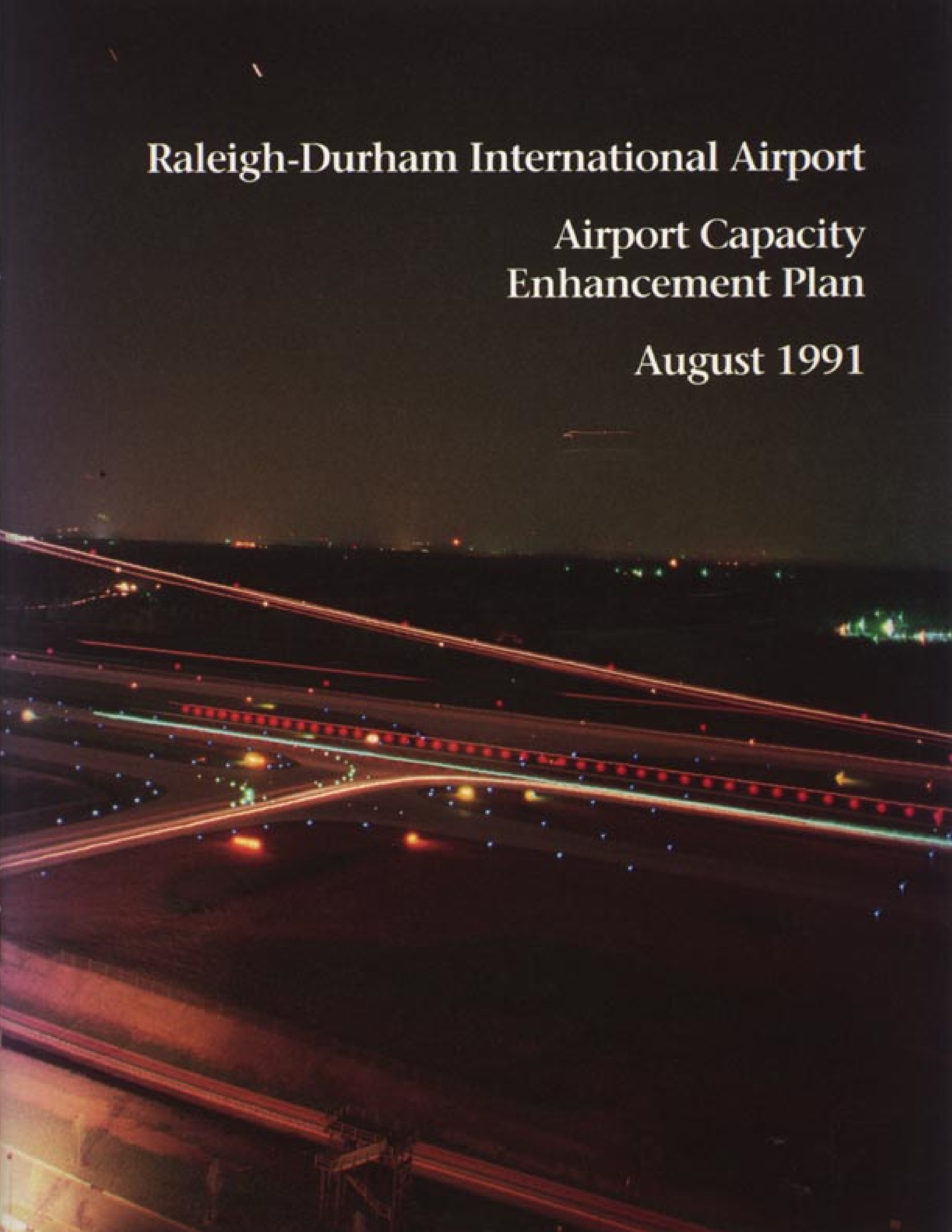
Raleigh-Durham International Airport

Airport Capacity Enhancement Plan

August 1991



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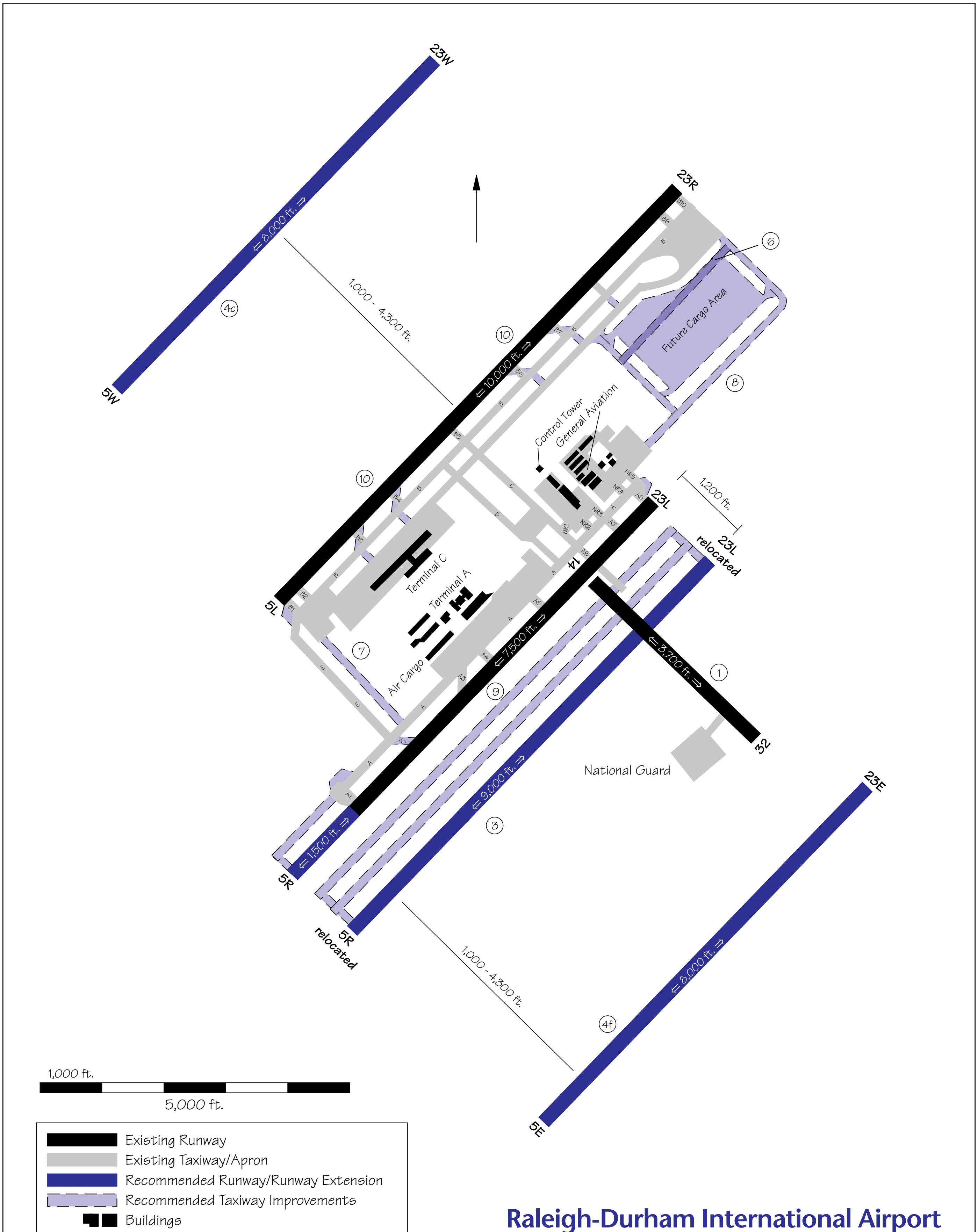
August 1991

Prepared jointly by the U.S. Department of Transportation, Federal Aviation Administration, Raleigh-Durham Airport Authority, and the airlines and general aviation serving Raleigh-Durham

Figure 1 Raleigh-Durham International Airport



Raleigh-Durham International Airport

Figure 2 Recommended Capacity Enhancement Alternatives and Annual Delay Savings*

Options	Baseline	Future 1	Future 2
	Estimated Annual Delay Savings** (in 000s of hours and millions of 1990 dollars)		
Airfield Improvements			
3. Relocate Runway 5R/23L 1,200 ft. southeast and extend to 9,000 ft. in length.	0.9/$1.0	8.4/$9.4	27.8/$31.0
4. Construct new 8,000 ft. third parallel runway:			
5W/23W			
4a. 1,000 to 2,400 ft. from 5L/23R.	3.4/$3.8	30.7/$34.2	428.1/$477.4
4b. 2,500 ft. from 5L/23R.		+	
4c. 3,000 to 4,300 ft. from 5L/23R.		+	
5E/23E			
4d. 1,000 to 2,400 ft. from relocated 5R/23L.	3.0/$3.4	30.1/$33.6	423.3/$472.0
4e. 2,500 ft. from relocated 5R/23L.	3.5/$3.9	33.2/$37.0	454.3/$506.6
4f. 3,000 to 4,300 ft. from relocated 5R/23L.	3.6/$4.0	33.8/$37.7	457.7/$510.3
5. Construct fourth parallel Runway 5E/23E (assumes 5W/23W in place).			
5a. Triple independent/dependent arrivals.	1.8/$1.9	6.8/$7.6	32.5/$36.1
5b. Triple independent arrivals.	2.4/$2.5	10.5/$11.7	66.8/$74.4
7. Construct dual parallel taxiway near feeder Taxiway E.		+	
8. Construct taxiway from new cargo complex to Runway 5R/23L.		+	
9. Construct full-length dual parallel taxiways for Runway 5R.		+	
10. Construct angle exits on Runway 5L/23R.	0.4/$0.5	2.2/$2.5	—
11. Expand holding and sequencing pads and bypass taxiways on Runway 5R/23L and all future runways.		+	
Facilities and Equipment Improvements			
13. Install CAT II/III ILS on existing and future runways.	0.4-1.4/ $0.4-$1.6	1.2-2.0/ $1.3-$2.2	1.5-2.6/ $1.7-$2.9
14. Install runway visual range (RVR) on Runway 23L and future runways.		+	
15. Install wake vortex advisory system.	0.4/$0.4	3.8/$4.3	11.4/$12.7
16. Install airport surface detection equipment (ASDE).		+	
Operational Improvements			
17. Implement staggered approaches with 1.5 NM separation.	0.6/$0.7	—	—
18. Implement independent approaches to existing runways (Precision Runway Monitor (PRM)).	—	8.4/$9.4	27.8/$31.0
19. Implement 2.5 NM spacing between similar class, non-heavy aircraft arrivals in IMC.	0.3/$0.3	4.8/$5.3	22.3/$24.9
20. Establish a terminal control area (TCA).		+	
21. Study noise abatement procedures.		+	
22. Conduct an airspace capacity design project and restructure terminal and en route airspace.	14.3/$15.9	—	260.0/$290.0

* Figure 7 lists all the alternatives considered by the Capacity Team.
** The savings benefits of these alternatives are not necessarily additive.
\+ These improvements were not simulated. Therefore, no dollar figures are available. There is a description of and justification for each of these items in Section 2 — Capacity Enhancement Alternatives.

Summary

The Federal Aviation Administration (FAA), airport operators, and aviation industry groups have initiated Airport Capacity Design Teams at various major air carrier airports throughout the United States to identify and evaluate alternative means to enhance existing airport and airspace capacity to handle future demand. A Capacity Team for Raleigh-Durham International Airport (RDU) was formed in 1989.

Unprecedented growth at RDU has made it one of the fastest growing airports in the country. Activity at the airport has increased from 1,075,000 passenger enplanements in 1983 to 4,650,000 in 1990, a 333 percent increase. In 1990, the airport handled 283,000 aircraft operations (take-offs and landings). These traffic volumes placed the airport 34th in operations and 36th in passenger enplanements among U.S. airports.

The primary objective of the Capacity Team at RDU was to identify and assess various actions which, if implemented, would increase RDU's capacity, improve operational efficiency, and reduce aircraft delays. The purpose of the process was to determine the technical merits of each alternative action and its impact on capacity. Additional studies will be needed to assess environmental, socioeconomic, or political issues associated with these actions.

Alternatives identified by the Capacity Team were tested using computer models developed by the FAA to quantify the benefits provided. Different levels of activity were chosen to represent growth in aircraft operations in order to compare the merits of each action. These annual activity levels are referred to throughout this report as:

Baseline – 300,000 operations;
Future 1 – 450,000 operations;
Future 2 – 600,000 operations.

If no improvements are made at RDU (the "Do Nothing" scenario), the annual delay cost will increase from $24.6 million at the Baseline level of operations to $856.6 million by Future 2.

The major recommendations resulting from the RDU study include:

	Future 2 Annual Delay Savings Hours	Millions of 1990 $
• Install Precision Runway Monitor (PRM)	27,821	$31.0
• Restructure terminal and en route airspace	260,019	$290.0
• Relocate and extend Runway 5R/23L	27,821	$31.0
• Construct parallel runway (5W/23W)	428,121	$477.4
• Construct fourth parallel runway (5E/23E) (triple IFR arrivals)	66,800	$74.4

Figure 3 Airport Delay Curves — Flow Rate Versus Average Delay, Existing Two-Runway Case

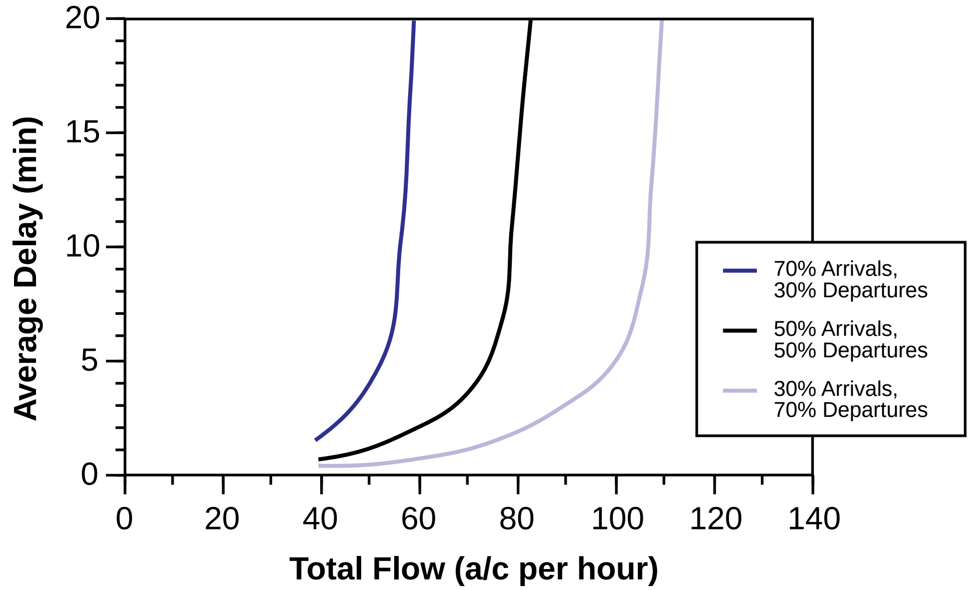


Figure 4 Profile of Daily Demand — Hourly Distribution

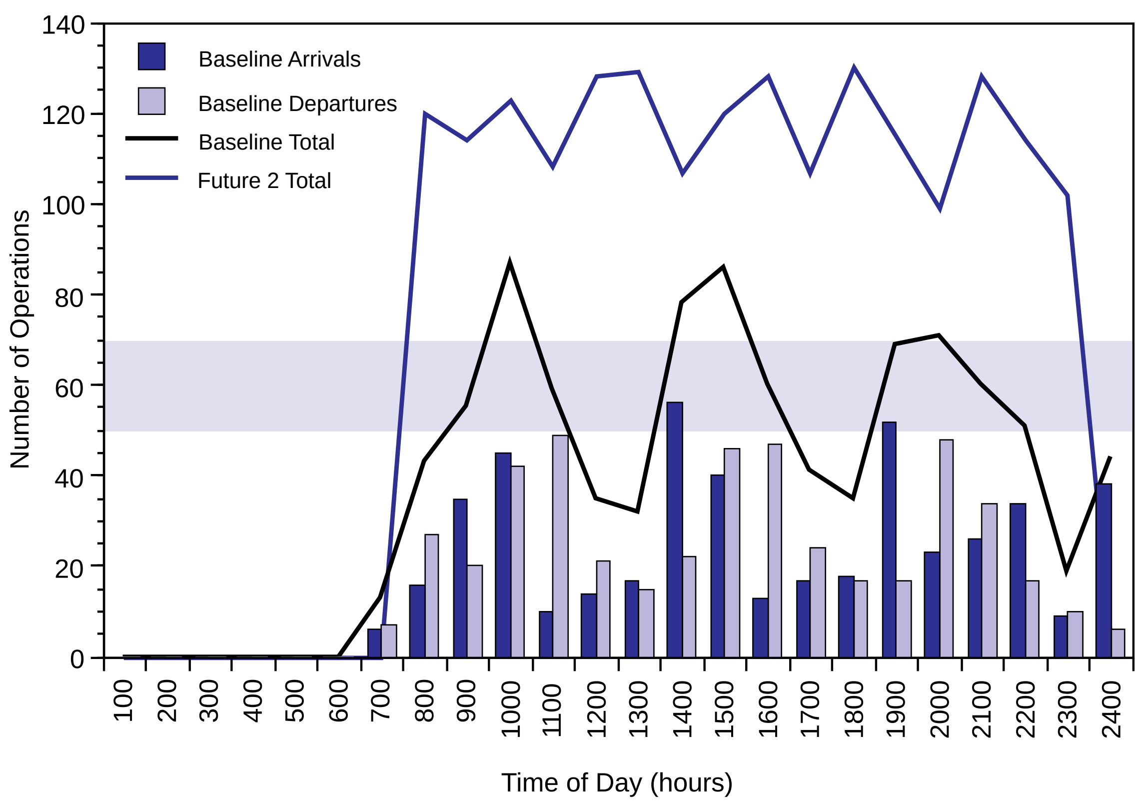


Figure 5 Delay Costs Versus Savings Benefits of Major Capacity Enhancement Alternatives

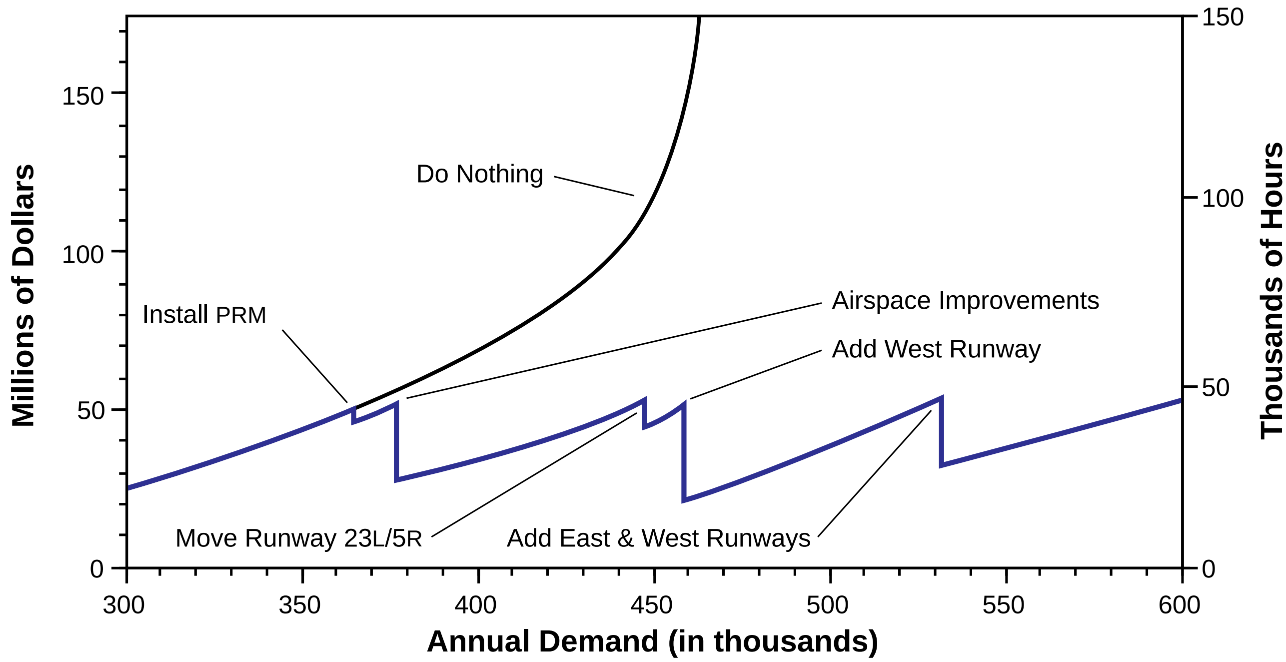


Figure 3 illustrates the capacity and delay curve for the current airfield configuration at RDU under instrument flight rules (IFR) conditions. It shows that aircraft delays will begin to escalate rapidly as hourly demand exceeds 50 to 70 operations per hour. Figure 4 shows that, while hourly demand exceeds 50 to 70 operations during certain hours of the day at Baseline demand levels, 50 to 70 operations per hour is frequently exceeded at the demand levels forecast for Future 2.

Figure 5 illustrates one possible scenario for implementing the major recommendations resulting from the Capacity Team study. The "Do Nothing" curve on the chart represents the delay cost implications of growth forecast for Raleigh-Durham International Airport if there are no improvements made in airfield capacity. The remaining curves depict the potential savings that could be realized by implementing the selected delay reduction enhancements recommended by the Capacity Team.

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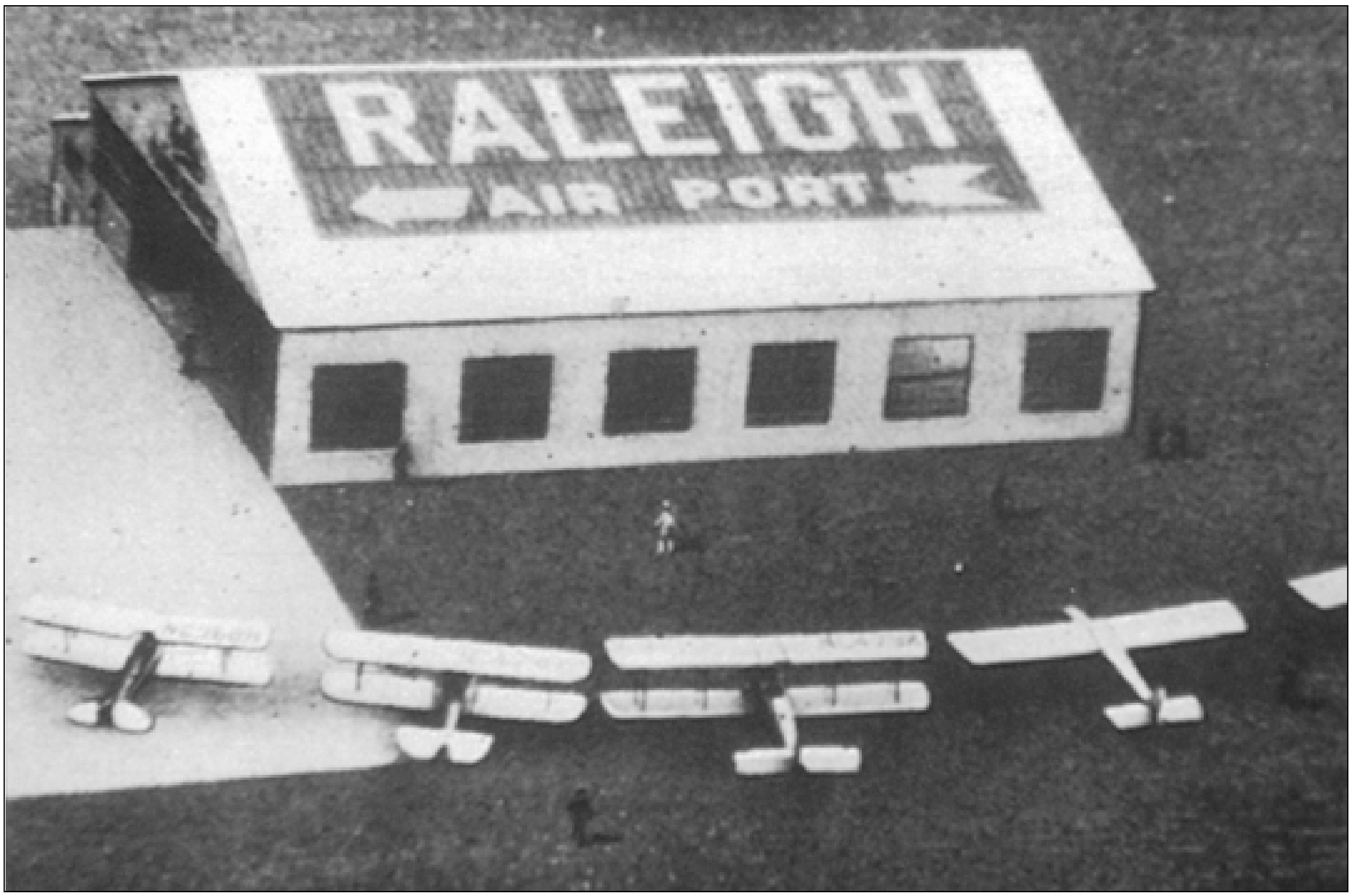
RALEIGH
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Section 1

Introduction

Background

The challenge for the air transportation industry in the nineties is to enhance existing airport and airspace capacity and to develop new facilities to handle future demand. The national air transportation system is being called on to handle unprecedented growth and ever increasing activities. 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.

To begin to meet this challenge, the FAA, along with airport operators and aviation industry groups throughout the country, have initiated joint industry and government Capacity Teams to study airport capacity enhancement at the major air carrier airports in the U.S. The objectives of these studies are to identify various alternatives for increasing capacity and to evaluate their potential to reduce delays.

In the past decade, Raleigh-Durham International Airport (RDU) has been one of the nation's fastest growing airports. Enplanements at RDU rose from 1,075,000 in 1983 to 4,650,000 in 1990, a 333 percent increase. RDU's total aircraft operations reached 283,000 in 1990, ranking it as the 36th busiest airport in the U.S.

This report has established benchmarks for development based upon traffic levels and not upon any definitive time schedule, since growth parameters often vary within generalized time frames. As a result, this report should retain its validity until the highest traffic level is attained regardless of the actual dates paralleling the development.

A *Baseline* benchmark was established based on an annual traffic level of 300,000 aircraft operations (takeoffs and landings). Two future traffic levels, *Future 1* and *Future 2*, were established at 450,000 and 600,000 annual aircraft operations respectively, based on Capacity Team consensus of potential traffic growth at Raleigh-Durham. If no improvements are made at RDU, annual delay levels and delay costs are expected to increase from an estimated 22,103 hours and $24.6 million at the Baseline activity level to nearly 768,207 hours and $856.0 million by the Future 2 demand level.

The improvements recommended by the Capacity Team are delineated in Figure 2 and described in some detail in Section 2 — Capacity Enhancement Alternatives.

Objectives

The major goal of the Capacity Team was to identify and evaluate proposals to increase airport capacity, improve airport efficiency, and reduce aircraft delays. In achieving this objective, the Capacity Team:

- Assessed the current airport capacity and the causes of delay associated with the airfield, the immediate airspace, and the apron and gate-area operations.
- Evaluated capacity and delay benefits of alternative air traffic control (ATC) procedures, navigational improvements, airfield development, and operational improvements.
- Examined the relationship between air traffic demand and delay, so that it could be used as an aid in establishing acceptable air traffic movement levels.

Scope

The Capacity Team limited its analyses to aircraft activity within the terminal area airspace and on the airfield. They considered the technical and operational feasibility of the proposed airfield improvements, but did not address environmental, socioeconomic, or political issues regarding airport development. These issues need to be addressed in future airport system planning studies, and the data generated by the Capacity Team can be used in such studies.

Methodology

The Capacity Team proceeded along a formal sequence of events, with periodic meetings for review and coordination. The FAA Technical Center's Aviation Capacity Branch provided expertise in airport simulation modeling. Other Capacity Team members contributed suggested improvement options, data, text, and capital cost estimates.

Proposed improvements were analyzed in relation to current and future demands with the help of two computer models, the Runway Delay Simulation Model (RDSIM) and the Airport and Airspace Simulation Model (SIMMOD). Appendix B briefly explains these models.

The simulation models considered air traffic control procedures, airfield improvements, and traffic demands. Alternative airfield configurations were prepared from present and proposed airport layout plans. Each configuration was evaluated to assess the benefit of projected improvements. Air traffic control procedures and system improvements determined the aircraft separations to be used for the simulations under both visual flight rules (VFR) and instrument flight rules (IFR).

Air traffic demand levels were derived from *Official Airline Guide* data, historical data, and Capacity Team and other forecasts. Aircraft volume, mix, and peaking characteristics were considered for each of the three different demand forecast levels (Baseline, Future 1, and Future 2). From this, annual delay estimates were determined based on implementing various improvements. These estimates took into account historic variations in runway configuration, weather, and demand. The annual delay estimates for each configuration were then compared to identify delay reductions resulting from the improvements.

Following the evaluation, the Capacity Team developed a plan of "Recommended Alternatives" for consideration, which is shown in Figure 2.

Figure 6 demonstrates the impact of delays at Raleigh-Durham International Airport. The chart shows how delay will continue to grow at a substantial rate as demand increases if there are no improvements in airfield capacity, i.e., the "Do Nothing" scenario. The chart also shows that the greatest savings in delay costs would be provided by:

- Installing a Precision Runway Monitor (PRM).
- Restructuring terminal and en route airspace.
- Relocating and extending Runway 5R/23L.
- Construction of a new third parallel Runway 5W/23W.
- Construction of a new fourth parallel Runway 5E/23E.

Figure 6 Airport Delay Costs — Capacity Enhancement Alternatives

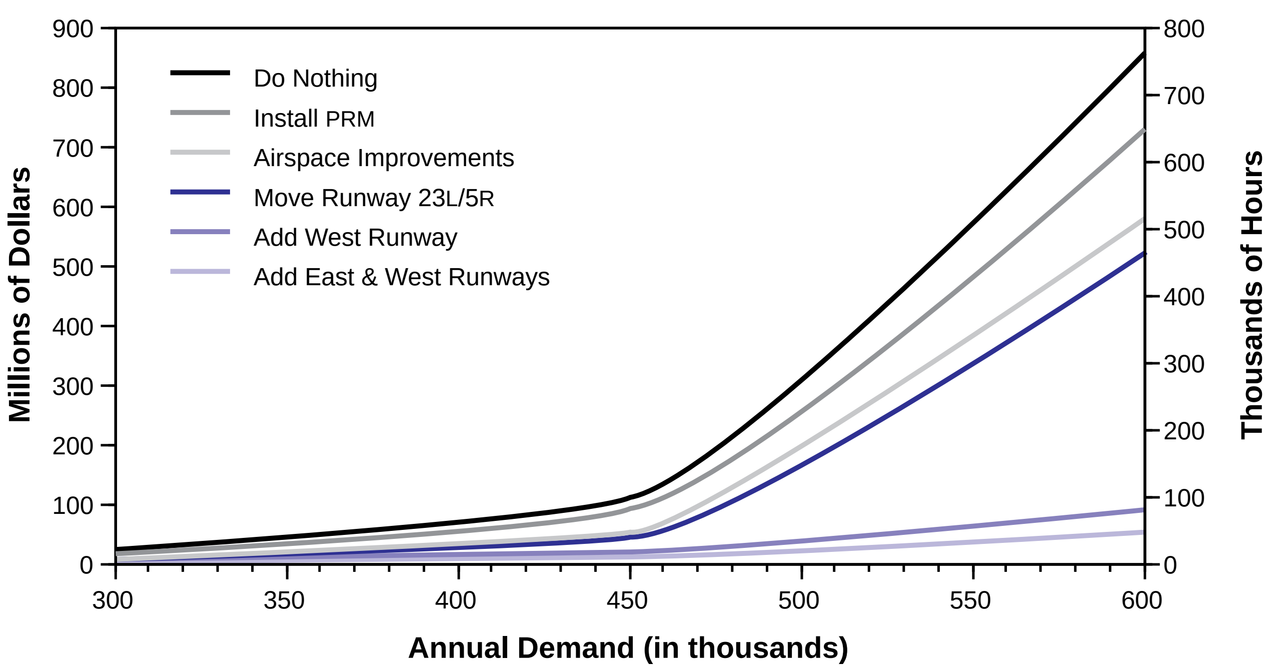


Figure 7 Capacity Enhancement Alternatives Considered

OptionsAction	Time Frame	
Airfield Improvements		
1. Develop Runway 14/32 as an independent GA runway (not intersecting).	Completed	—
2. Extend existing Runway 5R/23L 1,500 ft. to the southwest to 9,000 ft.	Not Recommended	—
3. Relocate Runway 5R/23L 1,200 ft. southeast and extend to 9,000 ft.	Recommended	Baseline
4. Construct new 8,000 ft. parallel runway:	Recommended	Future 1
5W/23W		
4a. 1,000 to 2,400 ft. from 5L/23R.	—	—
4b. 2,500 ft. from 5L/23R.	—	—
4c. 3,000 to 4,300 ft. from 5L/23R.	—	—
5E/23E		
4d. 1,000 to 2,400 ft. from relocated 5R/23L.	—	—
4e. 2,500 ft. from relocated 5R/23L.	—	—
4f. 3,000 to 4,300 ft.from relocated 5R/23L.	—	—
4g. General aviation/commuter runway.	Not Recommended	—
5. Construct fourth parallel Runway 5E/23E (assumes 5W/23W in place).	Recommended	Future 2
6. Construct new air cargo taxiway.	Under Construction	Baseline
7. Construct dual parallel taxiway near feeder Taxiway E.	Recommended	Baseline
8. Construct taxiway from new cargo complex to Runway 5R/23L.	Recommended	Baseline
9. Construct full-length dual parallel taxiways for Runway 5R.	Recommended	Baseline
10. Construct angle exits on Runway 5L/23R.	Recommended	Baseline
11. Expand holding pads and bypass taxiways on Runway 5R/23L and all future runways.	Recommended	Baseline, Future 1&2
Facilities and Equipment Improvements		
12. Install approach lights on Runway 5L.	Under Construction	Baseline
13. Install CAT II/III ILS on existing and future runways.	Recommended	Baseline, Future 1&2
14. Install runway visual range (RVR) on Runway 23L and future runways.	Recommended	Baseline, Future 1&2
15. Install wake vortex advisory system.	Recommended	Baseline
16. Install airport surface detection equipment (ASDE).	Recommended	Baseline
Operational Improvements		
17. Implement staggered approaches with 1.5 NM separation.	Recommended	Baseline
18. Implement independent approaches to existing runways (Precision Runway Monitor (PRM)).	Recommended	Baseline
19. Implement 2.5 NM spacing between similar class, non-heavy aircraft arrivals in IMC.	Recommended	Baseline
20. Establish a terminal control area (TCA).	Recommended	Future 1
21. Study noise abatement procedures.	Study*	—
22. Conduct an airspace capacity design project and restructure terminal and en route airspace.	Recommended	Baseline
23. Distribute traffic uniformly with the hour.	Not Recommended	—

* The term "Study" suggests either that a specific study be conducted on the particular subject or that it become part of a larger planning effort. This proposal requires further investigation at a level of detail that is beyond the scope of this effort.

Section 2

Capacity Enhancement Alternatives

Figure 1 shows the current layout of the airport, plus the airfield improvements considered by the Capacity Team.

Figure 2 presents the alternatives recommended by the Capacity Team and the delay savings benefits* for the recommended alternatives that were assessed by model simulations. The savings benefits of the improvements are not necessarily additive.

Figure 6 lists the various capacity enhancement alternatives that were considered by the Capacity Team and the recommended action and suggested demand level for each improvement using the activity levels Baseline, Future 1, and Future 2, which correspond to annual aircraft operations of 300,000, 450,000 and 600,000 respectively.

The capacity enhancement alternatives are categorized and discussed under the following headings:

- Airfield Improvements.
- Facilities and Equipment Improvements.
- Operational Improvements.

* The savings benefits of these alternatives are stated considering no en route airspace restrictions beyond the optimum allowable aircraft spacing.

Airfield Improvements

1. Develop Runway 14/32 as an independent general aviation (GA) runway (not intersecting).

Under this project, Runway 14/32 was modified so that it no longer intersects with Runway 5R/23L. This modification decreased the length of Runway 14/32 from 4,500 feet to 3,700 feet. Non-intersecting converging runways can be used for independent streams of arriving aircraft under VFR conditions. The project is complete.

2. Extend existing Runway 5R/23L 1,500 feet to the southwest to 9,000 feet.

This project would extend the existing Runway 5R/23L and its associated taxiway 1,500 feet for a total length of 9,000 feet. The additional length would allow Runway 5R/23L to accommodate certain long-haul or heavy-jet operations that are now accommodated only by Runway 5L/23R. The extension not only would provide air traffic control with more flexibility in sequencing arrivals and departures, but also would prove beneficial to users in reduced fuel burn and reduced operating time. The Capacity Team did not recommend this runway, because the benefits are significantly less than for alternative 3.

Estimated 1990 construction cost is $28 million.

3. Relocate Runway 5R/23L 1,200 feet southeast and extend to 9,000 feet.

Under this project, Runway 5R/23L and its associated taxiways would be relocated 1,200 feet to the southeast and extended 1,500 feet to a total length of 9,000 feet. This relocation and extension would allow certain aircraft operations that are now accommodated only by Runway 5L/23R to be accommodated by Runway 5R/23L. Runway 5R/23L cannot accommodate a full length dual parallel taxiway system on the terminal side.

The relocation would also allow Category II/III ILS operations. There are currently obstacles in the missed approach surfaces for Category II/III approaches to the existing Runway 5R/23L.

Relocation of Runway 5R/23L to the southeast would significantly increase the area available for expansion of Terminal A and its aircraft parking apron. This relocation would also permit construction of a full length dual parallel taxiway system.

Finally, relocation of Runway 5R/23L would allow for two independent VFR and IFR arrival streams and promote optimal airfield development.

Estimated 1990 construction cost is $75 million.

Annual savings at the current (Baseline) activity level will be 877 hours or $1.0 million, and, at Future 2 activity levels, 27,821 hours or $31.0 million.

4. Construct new 8,000 foot parallel runway:

5W/23W

The following are three mutually exclusive options for a new northwest parallel Runway 5W/23W.

4a. 1,000 to 2,400 feet from Runway 5L/23R.

If the new runway were constructed 1,000 to 2,400 feet to the northwest of Runway 5L/23R, it would allow for three VFR arrival streams and two IFR arrival streams and a dedicated IFR departure runway, depending on the final location of the new runway to the southeast of 5R/23L.

Estimated 1990 construction cost is $75 million.

Annual savings at the current (Baseline) activity level will be 3,364 hours or $3.8 million, and, at Future 2 activity levels, 428,121 hours or $477.4 million.

4b. 2,500 feet from Runway 5L/23R.

If the new runway were constructed 2,500 feet to the northwest of Runway 5L/23R, it would allow for three VFR arrival streams and three IFR arrival streams, one of which would be dependent.

Estimated 1990 construction cost is $75 million.

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

If the new runway were constructed 3,000 to 4,300 feet to the northwest of Runway 5L/23R, it could potentially support three VFR arrival streams and three IFR arrival streams. The exact lateral separation needed to permit closely spaced independent IFR arrivals is under evaluation by the FAA. Currently, this requires 4,300 feet between runway centerlines. A developmental program known as the Precision Runway Monitor (PRM) has demonstrated the potential for reducing parallel runway spacing (see Alternative 18).

Estimated 1990 construction cost is $75 million.

5E/23E

The following are three mutually exclusive options for a new southeast parallel Runway 5E/23E.

4d. 1,000 to 2,400 feet from relocated 5R/23L.

Construction of the new runway 1,000 to 2,400 feet to the southeast of Runway 5R/23L would allow for three VFR arrival streams and two IFR arrival streams, with a dedicated IFR departure runway.

Estimated 1990 construction cost is $75 million.

Annual savings at the current (Baseline) activity level will be 3,037 hours or $3.4 million, and, at Future 2 activity levels, 423,339 hours or $472.0 million.

4e. 2,500 feet from relocated 5R/23L.

If the new runway were constructed 2,500 feet to the southeast of Runway 5R/23L, it would increase runway capacity by allowing for three VFR arrival streams and three IFR arrival streams, one of which would be dependent.

Estimated 1990 construction cost is $75 million.

Annual savings at the current (Baseline) activity level will be 3,477 hours or $3.9 million, and, at Future 2 activity levels, 454,344 hours or $506.6 million.

4f. 3,000 to 4,300 feet from relocated 5R/23L.

If the new runway were constructed 3,000 to 4,300 feet to the southeast of Runway 5R/23L, it could potentially support three VFR arrival streams and three IFR arrival streams. The exact lateral separation needed to permit closely spaced independent IFR arrivals is under evaluation by the FAA. Currently, this requires 4,300 feet between runway centerlines. A developmental program known as the Precision Runway Monitor (PRM) has demonstrated the potential for reducing parallel runway spacing (see Alternative 18).

This alternative provides for maximum delay reduction; however, construction of this new runway is complicated by environmental matters primarily related to noise and the proximity of state park lands.

Estimated 1990 construction cost is $75 million.

Annual savings at the current (Baseline) activity level will be 3,616 hours or $4.0 million, and, at Future 2 activity levels, 457,658 hours or $510.3 million.

4g. General aviation/commuter runway.

If a new general aviation/commuter runway were constructed 2,500 feet to the southeast of Runway 5R/23L, it would allow for three VFR arrival streams and three IFR arrival streams, one of which would be dependent.

Estimated 1990 construction cost is $45 million.

Annual savings at the current (Baseline) activity level will be 3,222 hours or $3.6 million, and, at Future 2 activity levels, 252,346 hours or $281.4 million.

Construction of this general aviation/commuter runway is not recommended because the benefits are significantly less than for a longer runway.

6. Construct new air-cargo taxiway.

This project will provide a more direct route for cargo aircraft to and from the cargo ramp area, shorten taxi travel times, and reduce interference among aircraft going to and from the cargo ramp and aircraft taxiing for take-off from Runway 23R. The project is now under construction, with an estimated completion in late 1991.

7. Construct dual parallel taxiway near feeder Taxiway E.

This project would provide a direct route to Runway 5R from Terminal C while simultaneously providing an alternative route to Runway 5L from Terminals A and B. Additionally, this project would provide a direct route to Terminal C for aircraft exiting Runway 23L while simultaneously providing an alternative route, in the opposite direction, to Runway 23L from Terminal C.

The availability of these routes would result in reduced congestion at the southwest corner of Terminal C, since aircraft taxiing to Runway 23L would not be required to use Taxiways D and C; increased staging capacity and reduced congestion at the approach end of Runway 5L; and dual taxiing capability during mixed arrival and departure pushes.

Estimated 1990 construction cost is $25 million.

8. Construct taxiway from new cargo complex to Runway 5R/23L.

This taxiway would provide a more direct route for cargo aircraft to and from the new cargo complex and Runway 23L and reduce taxi travel times. Additionally, this taxiway would act as a feeder taxiway and reduce taxiway/ramp congestion.

Estimated 1990 construction cost is $10 million.

9. Construct full-length dual parallel taxiways for Runway 5R.

Completion of this project would reduce taxi interference and delays by allowing two-way traffic for arriving and departing aircraft to taxi to and from the terminals and the runways.Because of space constraints, this project could only be accomplished if existing Runway 5R/23L is relocated to the southeast (alternative 3).

Estimated 1990 construction cost (excluding cost of alternative 3) is $15 million.

10. Construct angle exits on Runway 5L/23R.

This project would reduce runway occupancy times and improve runway capacity, since air traffic controllers would be able to use a 2.5 nautical mile (NM) radar separation on final approach rather than the 3.0 NM separation that is now used.

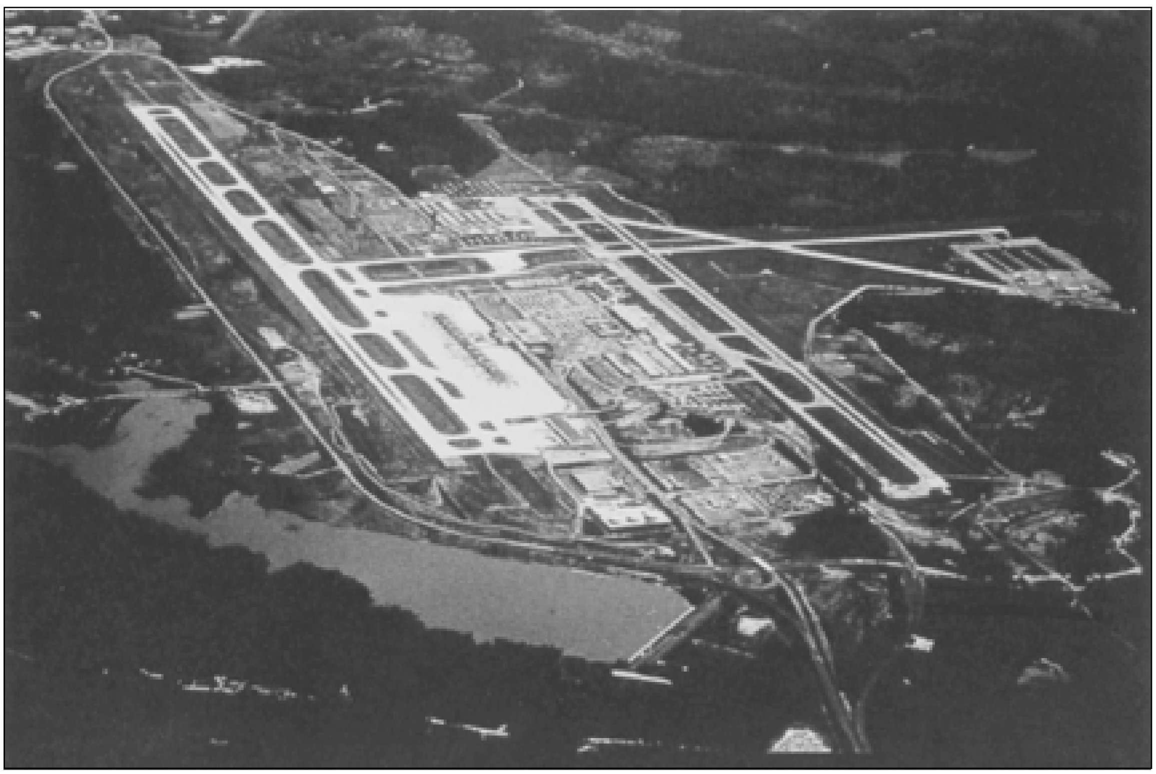
Estimated 1990 construction cost is $3.5 million.

Annual savings at the current (Baseline) activity level will be 431 hours or $0.5 million, and, at Future 1 activity levels, 2,225 hours or $2.5 million.

11. Expand holding and sequencing pads and bypass taxiways on Runway 5R/23L and all future runways.

As air carrier activity at the airport increases, air traffic flow control may require more aircraft to hold at the runway thresholds before takeoff because of departure fix restrictions. To reduce delays, it will be necessary to expand the staging areas at the ends of the runways to improve the ability of departing aircraft to bypass those aircraft waiting for departure clearance. In addition, the holding pads would provide holding areas for arriving aircraft awaiting gates.

Estimated 1990 construction cost (for Runway 5R/23L) is $5 million.



Jerry Markatos

Facilities and Equipment Improvements

12. Install approach lights (MALSR) on Runway 5L.

Installing a medium intensity approach light system with runway alignment indicator lights (MALSR) on Runway 5L would reduce the visibility minimums for the runway and thereby help to maintain capacity during instrument meteorological conditions. Installation of this facility is in progress.

Estimated 1990 construction cost is $1 million.

13. Install CAT II /III ILS on existing and future runways.

Of the six runways at RDU, four currently have ILS. Runways 5R, 5L, and 23L are equipped with CAT I ILS. Runway 23R has a CAT II ILS installed. Obstructions to missed approach surfaces preclude upgrading ILS on Runways 5R, 5L, and 23L.

The installation of enhanced ILS, such as CAT II or III, has obvious merit for RDU. Long-term weather analysis indicates that RDU has weather conditions requiring instrument approaches approximately 11 percent of the time. Weather requiring CAT II ILS occurs about 2 percent of the time; CAT III, about 0.5 percent of the time. At RDU's high demand levels, this can result in significant numbers of potential landings that cannot be made due to poor weather.

For example, RDU is subject to dense fog conditions from daybreak to mid-morning on 20 to 25 days per year. During this period, there are about 80 scheduled airline landings. Even at the Baseline demand level, the potential exists for significant delays or overflights by some 1,600 to 2,000 airline operations per year. Add other reduced visibility conditions, such as rain and snow, and the potential for airline delays is easily doubled.

Annual savings at the current (Baseline) activity level range from 360 to 1,440 hours or $0.4 to $1.6 million, and, at Future 1 activity levels, from 1,170 to 1,980 hours or $1.3 to $2.2 million, and, at Future 2 activity levels, from 1,485 to 2,640 hours or $1.7 to $2.9 million.

14. Install runway visual range (RVR) on Runway 23L and future runways.

Meteorological visibility is often observed and reported at a point distant from the runway. Runway visual range (RVR) is measured along the runway itself and provides the pilot with the distance he can expect to see down the runway. From an operations viewpoint, RVR is far superior to other measurements of meteorological visibility. RVRs would lower the approach and departure minimums and enhance RDU's all-weather capacity and reduce delays.

15. Install wake vortex advisory system.

Since the turbulence created by heavy aircraft at landing and take-off speeds (wake vortices) can be hazardous to trailing aircraft, the FAA has established minimum separations to eliminate the hazards of wake vortices. Installation of a wake vortex advisory system would allow for improved separation. Implementation of this system would reduce delays by 11,362 hours and save $12.7 million in aircraft operating costs annually for the existing airfield configuration at Future 2 traffic volumes.

16. Install airport surface detection equipment (ASDE).

Monitoring ground traffic flow during poor weather conditions is difficult and restricts the flow of ground traffic. ASDE is a short-range, high-resolution radar designed to support air traffic controllers in the monitoring and control of ground traffic.

The installation of ASDE would improve airport ground operations significantly during poor visibility conditions. ASDE would eliminate the need to rely totally on pilot position reports when aircraft are not visible from the tower. In addition to the obvious safety benefits, it would reduce congestion and delays in the movement of ground traffic.

Operational Improvements

17. Implement staggered approaches with 1.5 NM separation in instrument meteorological conditions (IMC).

Currently, the standard allowing for dual streams with runways separated by 2,500 to 4,300 feet requires a stagger of 2.0 nautical miles (NM) between adjacent streams. Improving the stagger during final approaches to 1.5 NM would reduce the in-trail spacing between successive arrivals. Improved arrival acceptance rates increase runway capacity for both arrivals and departures.

Annual savings at the current (Baseline) activity level will be 597 hours or $0.7 million.

18. Implement independent approaches to existing runways (Precision Runway Monitor (PRM)).

The addition of the equipment and procedures necessary to permit independent parallel approaches in all weather conditions to the existing runway configurations would provide a great capacity benefit at RDU. Current FAA criteria require 4,300 foot separation between parallel runway centerlines in order to conduct simultaneous instrument approaches during periods of poor visibility. At RDU, the runway-to-runway centerline separation is 3,500 feet.

A developmental program known as the Precision Runway Monitor (PRM), now on-site at RDU, has demonstrated the potential for reducing parallel runway spacing. This program relies upon improved radar surveillance with higher update rates and a new air traffic controller display system. RDU could achieve immediate delay reduction benefit with the operational implementation of PRM.

Additionally, preliminary analysis indicates that triple independent arrival operations under instrument meteorological conditions (IMC) may be feasible with the installation of PRM equipment. This concept merits attention in future planning efforts.

Annual savings at the Future 1 activity level will be 8,400 hours or $9.4 million, and, at Future 2 activity levels, 27,821 hours or $31.0 million.

19. Implement 2.5 NM spacing in Instrument Meteorological Conditions (IMC) between similar class, non-heavy aircraft arrivals.

Existing procedures require that arriving aircraft be separated by 3 NM or more. Improving separation minimums to 2.5 NM will increase runway capacity. Most of the savings occur at the highest demand levels during IFR conditions, but, if the runway exits are not visible from the tower, the 2.5 NM separation cannot be applied.

Annual savings at the current (Baseline) activity level will be 310 hours or $0.3 million, and, at Future 1 activity levels, 4,700 hours or $5.3 million.

20. Establish a terminal control area (TCA).

Establishing a TCA in the Raleigh-Durham Terminal Airspace would bring all aircraft operating with that airspace under positive control. A TCA allows the controller to adjust the volume and flow of traffic and provides a more positive control of all traffic situations.

21. Study noise abatement procedures.

If all aircraft presently operating at RDU were allowed to operate free of noise restrictions, there would be a reduction in annual delays. Currently, about 36 percent of the fleet of aircraft serving RDU meet Stage III noise requirements, with even higher percentages forecast for Future 1 and 2 activity levels. If Stage III aircraft were allowed to follow relaxed noise abatement procedures now, the savings would be somewhat less, but still significant. In addition, relaxed noise abatement procedures for Stage III aircraft may encourage the airlines to use more Stage III aircraft in their fleets serving RDU.

22. Conduct an airspace capacity design project and restructure terminal and en route airspace.

As a part of this Capacity Enhancement study, the Capacity Team evaluated the elimination of airspace restrictions that are beyond optimal aircraft spacing. The results of this evaluation are shown in Figure 2. Annual savings at the current (Baseline) activity level from removing all airspace restrictions would be 14,290 hours or $15.9 million, and, at Future 2 activity levels, 260,019 hours or $290.0 million.

The Capacity Team highly recommends a complete analysis of all of the en route and terminal airspace that interconnects with RDU. This analysis should include concepts of airspace restructuring that offer the potential for improving arrival and departure air route capacity in conjunction with airport improvements. New technology and operating concepts need to be reviewed in an effort to improve flow-control procedures and reduce miles-in-trail restrictions.

When the en route airspace capacity design project is completed, an appropriate restructuring of terminal-area and en route airspace should be implemented to ensure the entire air traffic control system is capable of using the increased airport capacity.

23. Distribute traffic uniformly within the hour.

A more even distribution of airline flights during peak periods would promote a more orderly flow of traffic near the terminal and on the taxiway system.

However, RDU is an integral part of the hub-and-spoke operation, and uniform distribution of traffic is not consistent with such an operation. Hubbing creates efficiencies that cannot be measured in a delay study of this type. This system of operations provides frequent service between city-pairs that could not support frequent direct service. Frequent flights provide an economic benefit to consumers, in particular the business flyer. Although annual savings at the current (Baseline) activity level would be 2,462 hours or $2.7 million, at Future 1 activity levels, 22,865 hours or $25.5 million, and, at Future 2 activity levels, 3,344 hours or $3.7 million, in order to properly evaluate the overall impact of hubbing and the redistribution of scheduled operations, the entire system must be studied, not any one individual airport.

The technical analysis concluded that, at Future 2 demand levels without airfield improvements, redistributing traffic uniformly over the hour has limited benefit.

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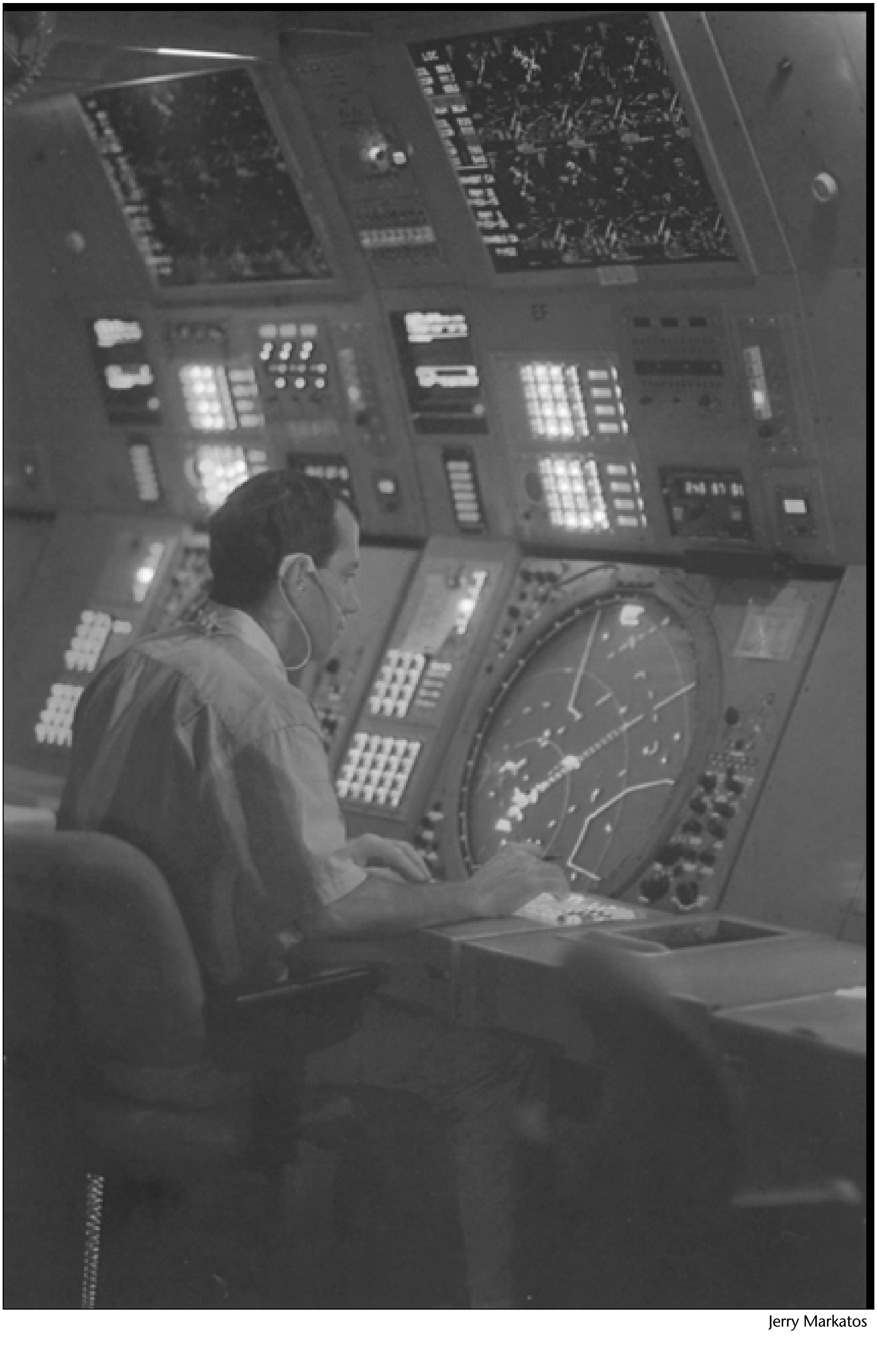
Section 3

Summary of Technical Studies



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Overview

The Raleigh-Durham Capacity Team evaluated the efficiency of the existing airfield and the proposed future configuration. Figure 8 illustrates airfield weather conditions, and Figure 9, runway utilization. The potential benefits of various improvements were determined by examining airfield capacity, airfield demand, and average aircraft delays.

The Capacity Team used the Runway Delay Simulation Model (RDSIM) to determine aircraft delays during peak periods. Delays were calculated for current and future conditions.

Daily operations corresponding to an average day in the peak month were used for each of the forecast periods. Daily delays were annualized to measure the potential economic benefits of the proposed improvements. The annualized delays provide a basis for comparing the benefits of the proposed changes. The benefits associated with various runway use strategies were also identified.

The fleet mix at Raleigh-Durham International Airport (RDU) has an average direct operating cost of $1,115 per hour. This figure represents the costs for operating the aircraft and includes such items as fuel, maintenance, and crew costs, but it does not consider lost passenger time, disruption to airline schedules, or any other intangible factors.

The cost of a particular improvement was measured against its annual delay savings. This comparison indicates which improvement will be the most effective.

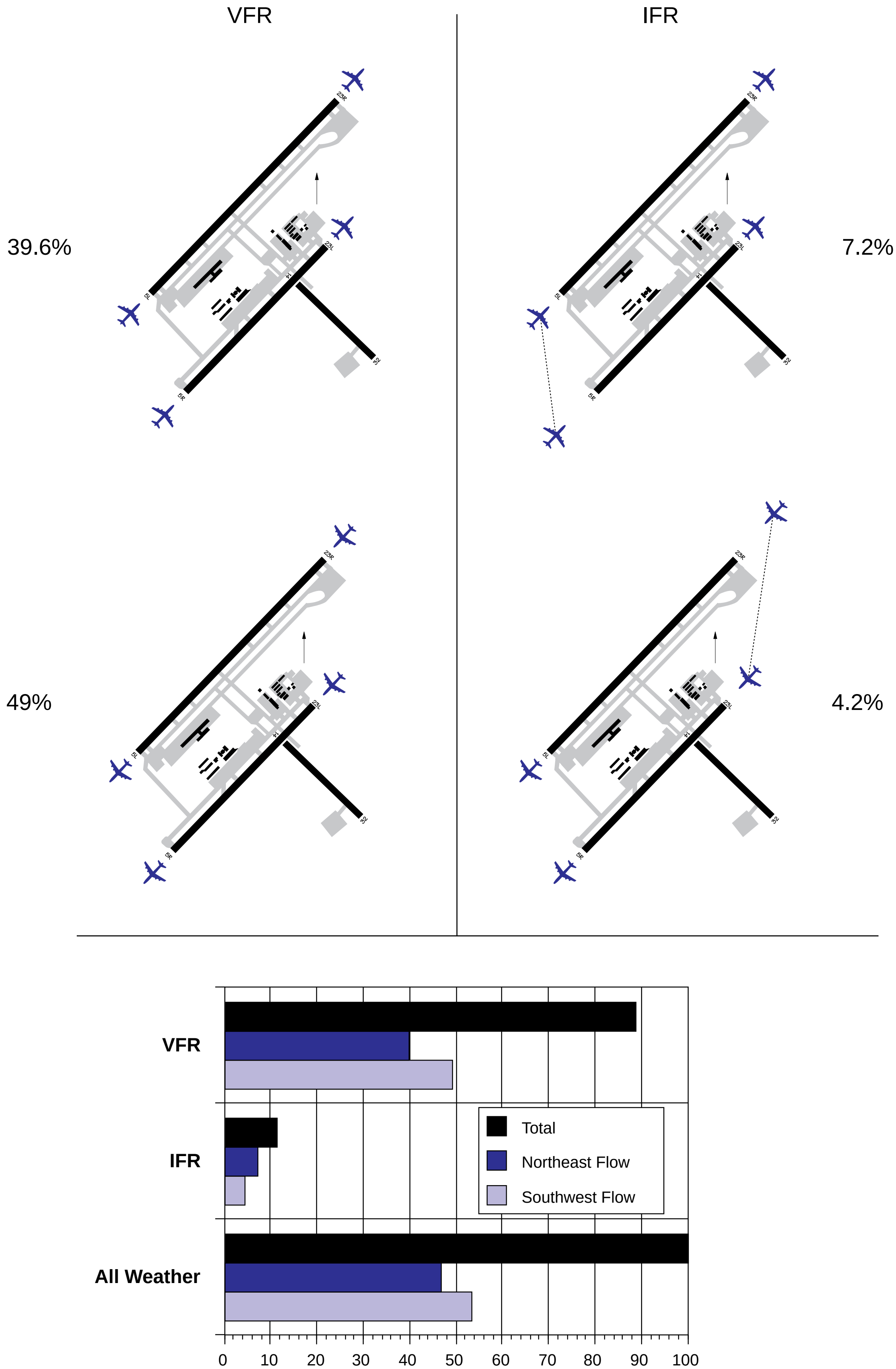
For expected increases in demand, a combination of improvements can be implemented to allow airfield capacity to increase while aircraft delays are minimized.

Figure 8 Airfield Weather

	Ceiling/Visibility	Occurrence (%)
VFR	2,100 feet or above/5 SM or above	88.6
IFR	below 2,100 feet/below 5 SM	11.4

VFR — Visual Flight Rules
IFR — Instrument Flight Rules
SM — statute miles

Figure 9 Existing Runway Utilization (percentage use)



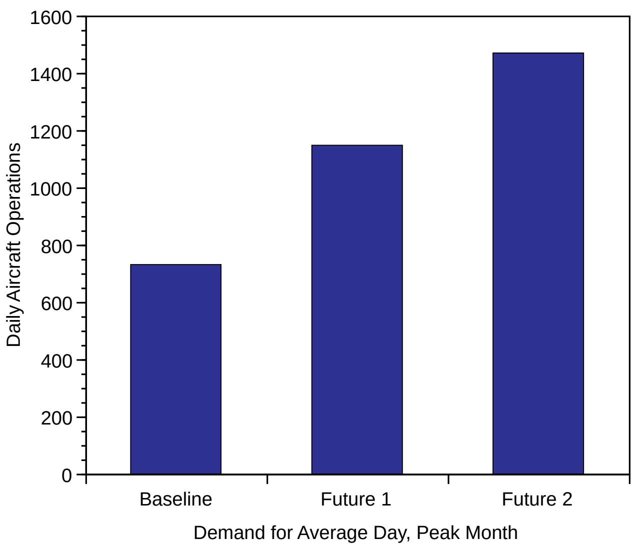
Airfield Capacity

The RDU Capacity Team defined airfield capacity to be the maximum number of aircraft operations (landings or takeoffs) that can take place in a given time. The following conditions were considered:

- Level of delay
- Airspace constraints
- Ceiling and visibility conditions
- Runway layout and use
- Aircraft mix
- Percent arrival demand

Figure 10 illustrates the average-day, peak-month arrival and departure demand levels for RDU for each of the three annual activity levels used in the study, Baseline, Future 1, and Future 2.

Figure 10 Airfield Demand Levels



Annual		24-Hour Day (Average Day, Peak Month)	Peak Hour
Baseline	300,000	938	87
Future 1	450,000	1,406	102
Future 2	600,000	1,875	130

Figure 11 presents the airport delay curves for RDU under the current two air carrier runway configuration. The curves were developed for various runway configurations, under Instrument Flight Rules (IFR) conditions, with a 30/70, 50/50, and 70/30 split of arrivals and departures. These curves are based on the assumption that arrival and departure demand is randomly distributed within the hour. Other patterns of demand can alter the demand/delay relationship.

The curves in Figure 11 illustrate the relationship between airfield capacity, stated in the number of operations per hour, and the average delay per aircraft. They show that, as the number of aircraft operations per hour increases, the average delay per operation increases exponentially.

Figure 12 illustrates the hourly profile of daily demand for the Baseline activity level of 300,000 aircraft operations per year. It also includes a curve that depicts the profile of daily operations for the Future 2 activity level of 600,000 aircraft operations per year.

Comparing the information in Figures 11 and 12 shows that

- aircraft delays will begin to escalate rapidly as hourly demand exceeds 50 to 70 operations per hour, and,
- while hourly demand exceeds 50 to 70 operations during certain hours of the day at Baseline demand levels, 50 to 70 operations per hour is frequently exceeded at the demand levels forecast for Future 2.

Figure 11 Airport Delay Curve — Flow Rate Versus Average Delay, Existing Two-Runway Case

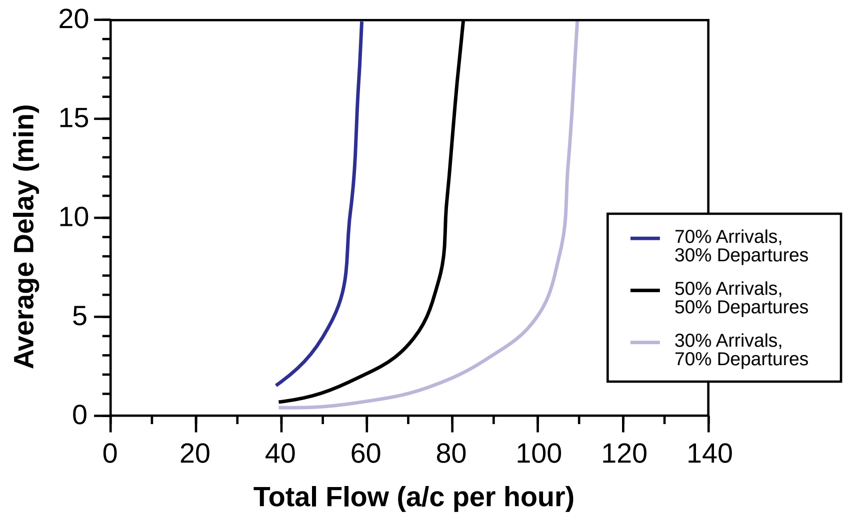


Figure 12 Profile of Daily Demand — Hourly Distribution

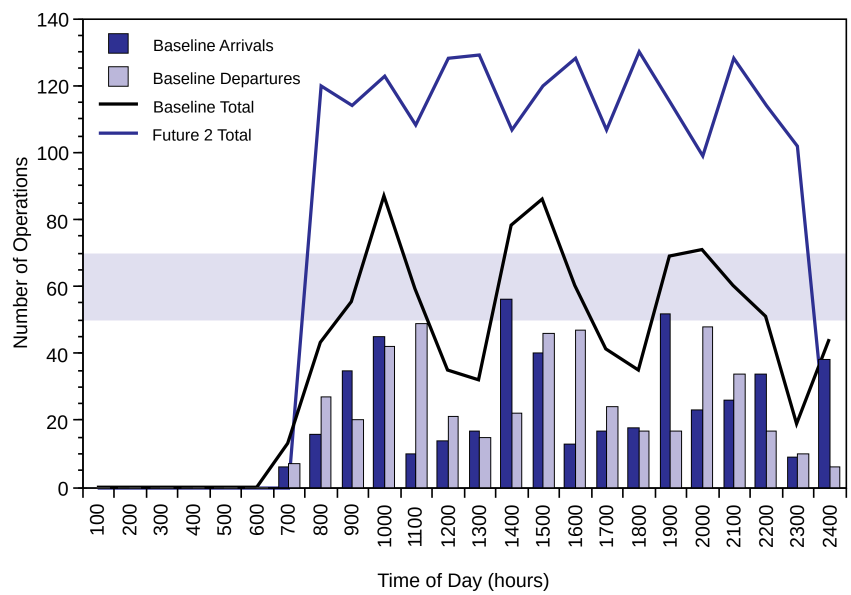


Figure 13 presents additional airport delay curves under both VFR and IFR conditions. Like Figure 11, they illustrate the relationship between airfield capacity and the average delay per aircraft. They show that, with the addition of a third and fourth parallel runway, airfield capacity increases.

Figure 13 Additional Airport Delay Curves — Flow Rate Versus Average Delay, VFR and IFR

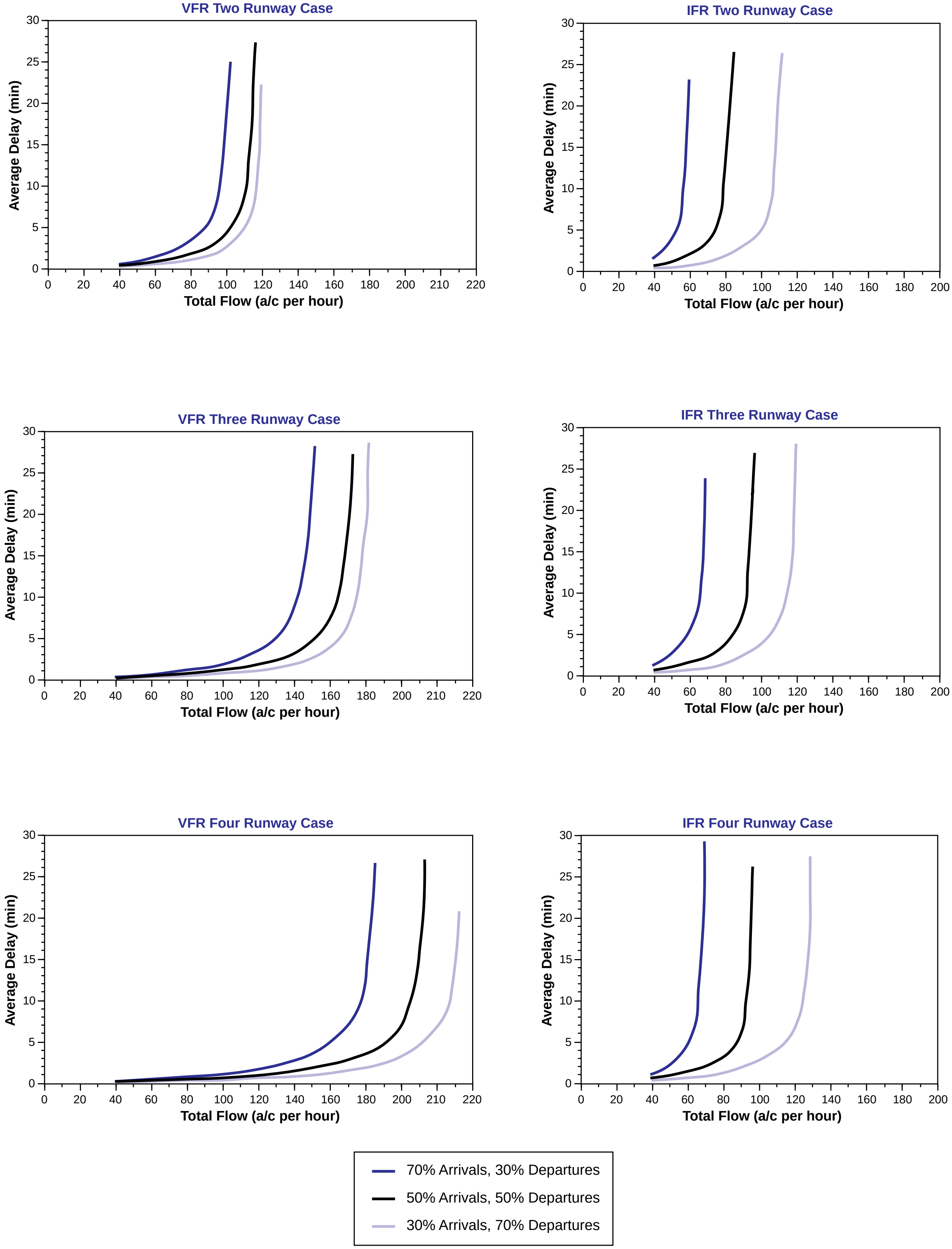
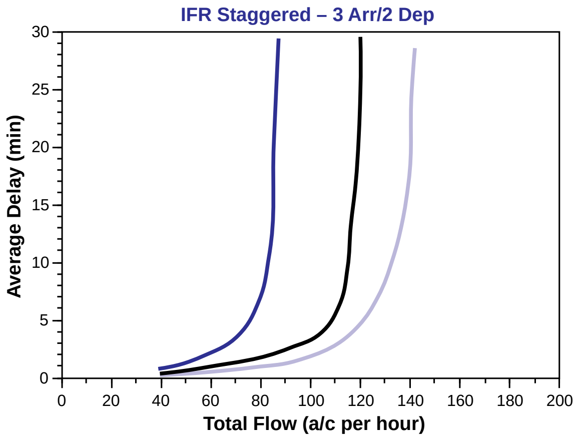
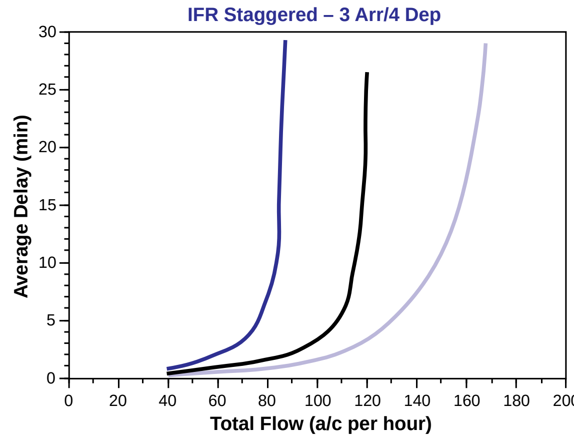
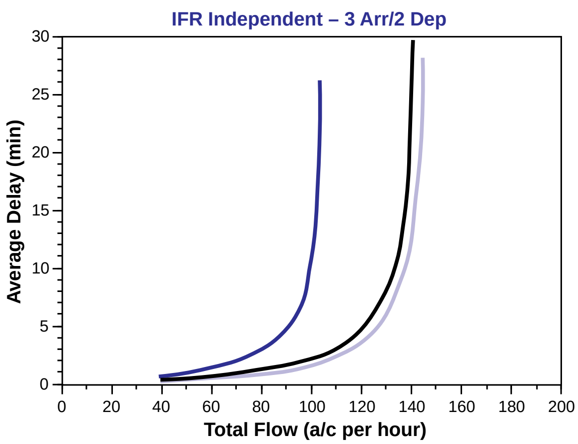
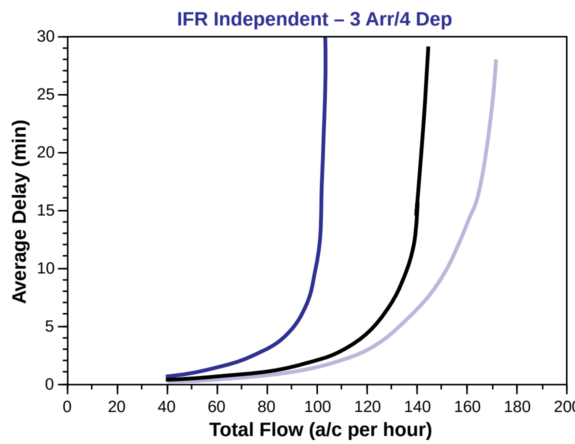


Figure 13 Additional Airport Delay Curves (continued) — Flow Rate Versus Average Delay, VFR and IFR









70% Arrivals, 30% Departures
50% Arrivals, 50% Departures
30% Arrivals, 70% Departures

Aircraft Delays

Aircraft delay is defined as the time above the unimpeded travel time for an aircraft to move from its origin to its destination. Aircraft delay results from interference from other aircraft in the system competing for the use of the same facilities.

The major factors influencing aircraft delays are:

- Weather
- Airfield and ATC System Demand
- Airfield physical characteristics
- Air traffic control procedures
- Aircraft operational characteristics

Average delay in minutes per operation was generated by the Airport and Airspace Simulation Model (SIMMOD). A description of this model is included in Appendix B.

Under the "Do Nothing" situation, if there are no improvements in airfield capacity, the annual delay cost could increase as follows:

Annual Delay Costs

	Hours	Millions of 1989 $
Baseline	22,100	$24.6
Future 1	98,200	$109.5
Future 2	768,200	$856.6

Figure 14 shows annual delay information plotted as average delay per operation as a function of future demand. If no improvements are made in airport capacity, the average delay per operation of 4.4 minutes in Baseline will increase to 76.8 minutes per operation by Future 2.

Figure 15, with an expanded scale, indicates that, with the future demand pattern and with airspace improvements, the airport in its present configuration could support 410,000 operations per year with an average delay per operation of four minutes. Relocating Runway 5R/23L , in addition, would allow the airport to support 430,000 yearly operations at the four minute average delay level. The addition of a third parallel runway to the west will increase the annual capacity to 500,000 operations, and the addition of a fourth parallel runway to the east will further increase annual capacity to 570,000 operations.

Figure 16 indicates that without improving airspace, the addition of a west runway would allow the airport to support 335,000 operations per year with an average delay per operation of four minutes. The addition of both an east and a west parallel runway would support 445,000 annual operations.

Figure 14 Operations Costs — Average Delay Per Operation

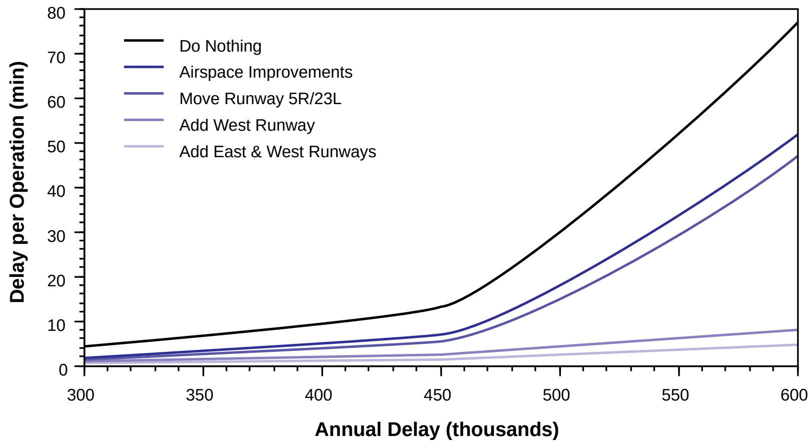


Figure 15 Operations Costs — Average Delay Per Operation (Expanded Scale)

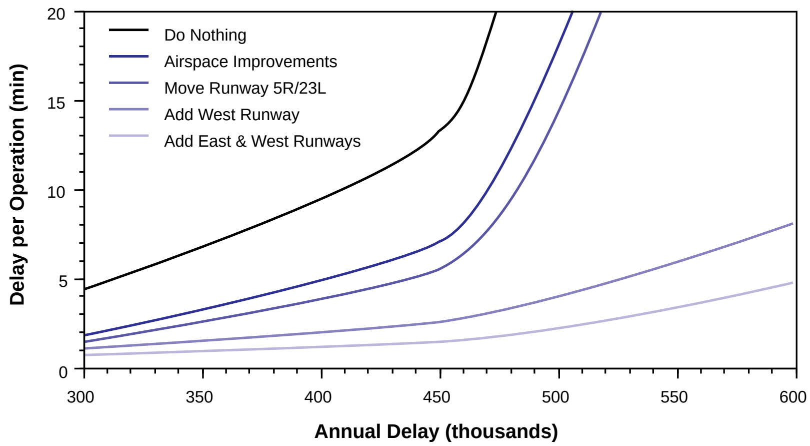
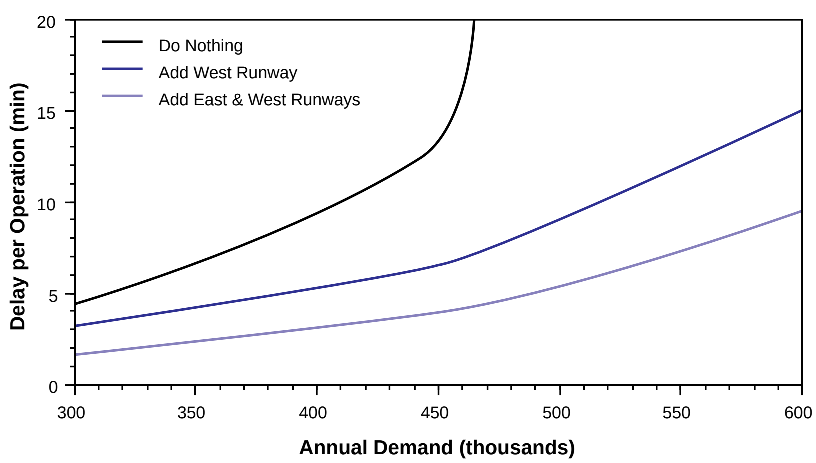
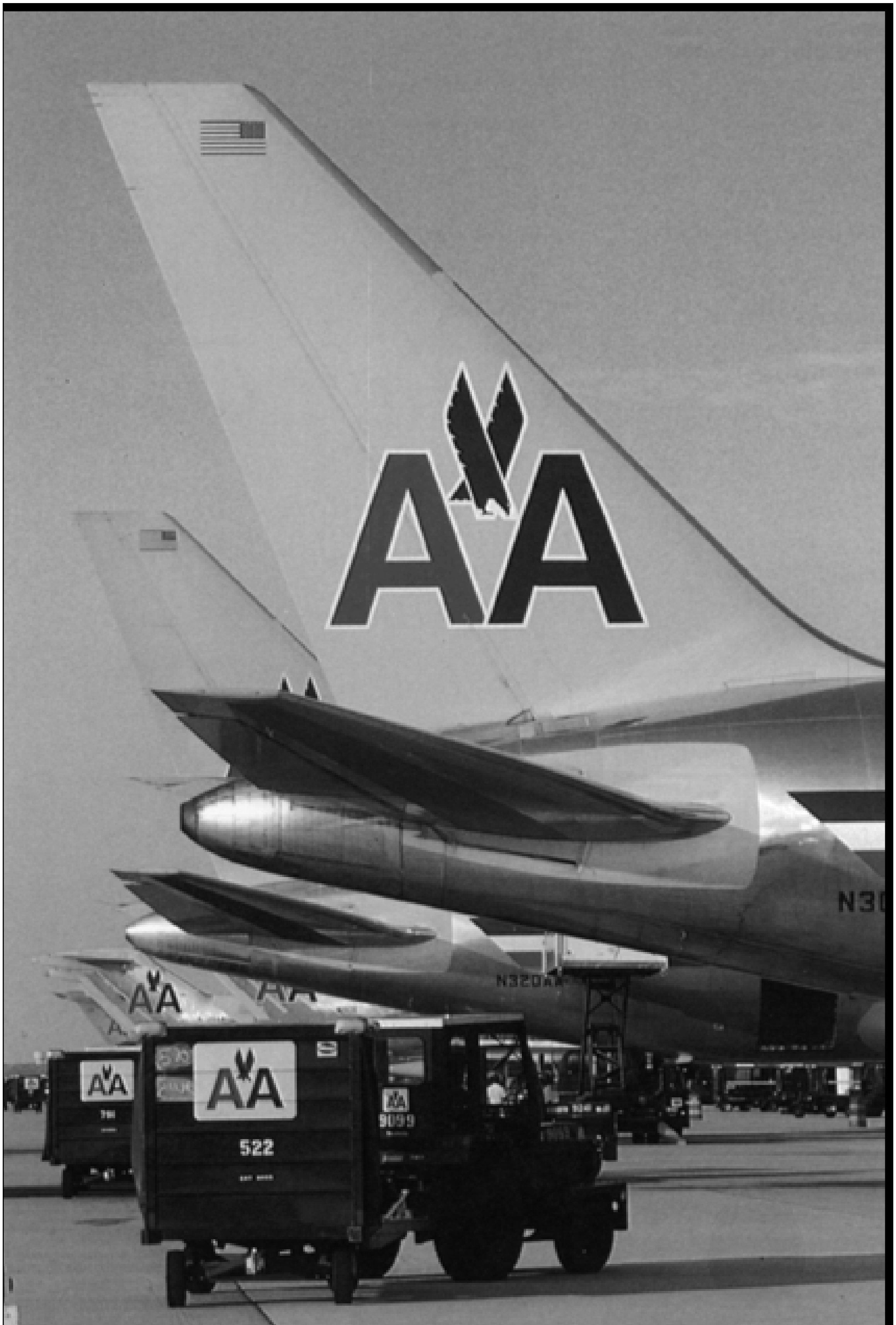


Figure 16 Operations Costs — Average Delay Per Operation (No Airspace Improvements)



Appendix A

Capacity Team Participants



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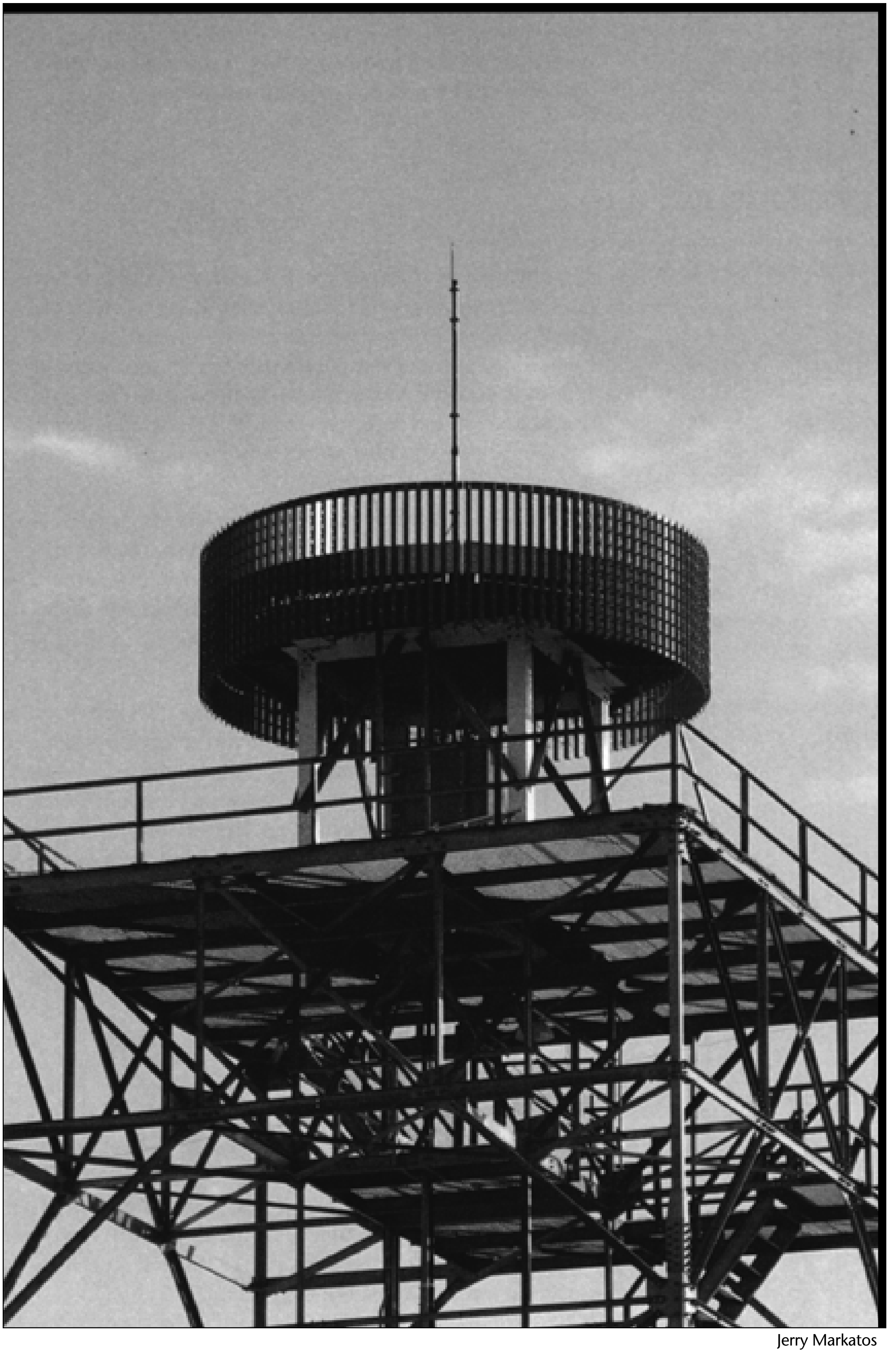
Air Transport Association of America	Bill Drew Walt Ferrari
Aircraft Owners and Pilots Association	Ken Medley

Appendix B

Computer Models and Methodology



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The RDU Capacity Team studied the effects of various improvements proposed to reduce delay and enhance capacity. The options were evaluated considering the anticipated increase in demand. The analysis was performed using several computer modeling techniques. A brief description of the models and the methodology employed follows.

Computer Models

Runway Delay Simulation Model (RDSIM)

There are two forms of the RDSIM model. The first simulates only the runways and runway exits. This version ignores the taxiway and gate complexes for a user-specified daily traffic demand. The second version, also simulates the runway and runway exits, but it creates its own demand using randomly assigned arrival and departure times. The demand created is based upon user-specified parameters. This form of the model is suitable for capacity analysis.

For a given demand, the model calculates the hourly flow rate and average delay per aircraft during the full period of airport operations. Using the same aircraft mix, computer specialists simulated different demand levels for each run to generate demand versus delay relationships.

Airport and Airspace Simulation Model (SIMMOD)

SIMMOD is a fast-time, event-step model that simulates the real-world processes by which aircraft fly through air-traffic-controlled en route and terminal airspace and arrive and depart at airports. SIMMOD traces the movement of individual aircraft as they travel through the gate, taxiway, runway, and airspace system and detects potential violations of separations and operating procedures. It simulates the air-traffic-control actions required to resolve potential conflicts to insure that aircraft operate within procedural rules. Aircraft travel time, delay, and traffic statistics are computed and provided as model outputs.

Methodology

Model simulations included present and future air traffic control procedures, various airfield improvements, and traffic demands for different times. To assess the benefits of proposed airfield improvements, the FAA used different airfield configurations derived from present and projected airport layouts. The projected implementation time for air traffic control procedures and system improvements determined the aircraft separations used for IFR and VFR weather simulations.

For the delay analysis, agency specialists developed traffic demands based on the *Official Airline Guide*, historical data, and various forecasts. Aircraft volume, mix and peaking characteristics were developed for three demand periods (Baseline, Future 1, and Future 2). The estimated annual delays for the proposed improvement options were calculated from the experimental results. These estimates took into account the yearly variations in runway configurations, weather, and demand based on historical data.

The potential delay reductions for each improvement were assessed by comparing the annual delay estimates.

The RDSIM model, in its capacity mode, was used to perform the capacity analysis for RDU.

Appendix C

Glossary

AOPA	Aircraft Owners and Pilots Association
ASDE	Airport Surface Detection Equipment
ATA	Air Transport Association of America
ATC	Air Traffic Control
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
MALSR	Medium intensity approach light system with runway alignment indicator lights
NM	nautical miles
PRM	Precision Runway Monitor
RDSIM	Runway Delay Simulation Model
RDU	Raleigh-Durham International Airport
RVR	Runway Visual Range
SIMMOD	Airport and Airspace Simulation Model
SM	statute miles
TCA	Terminal Control Area
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

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